FRUIT SET OF HAND-POLLINATED FLOWERS OF PEACH (PRUNUS PERSICA) AND APRICOT (PRUNUS ARMENIACA) IN DIFFERENT MICRO-ENVIRONMENTS

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

Fenton E. Larsen

1959

This is to certify that the

thesis entitled

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presented by

FENTON E. LARSEN

has been accepted towards fulfillment of the requirements for

Ph. D. degree in Horticulture

Major professor

Date June 22, 1959

O-169

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AN ABSTRACT

Submitted to the School for Advanced Graduate Studies of Michigan
State University of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Horticulture

1959

Approved ______________________

ABSTRACT

A series of studies was conducted in 1957 and 1958 to determine the value of several types of materials as protectors against adverse weather conditions. These materials were made into two- by four-foot bags and placed over large peach and apricot branches with emasculated and hand-pollinated blossoms. The object of these studies was to increase fruit set in the peach and apricot breeding program at the Michigan State University South Haven Experiment Station. This was desirable since the weather at bloom has often been poor, and, as a result, the fruit set in the breeding program has usually been ten percent or less.

In 1957 and 1958 three types of protectors -- polyethylene, waxed parchment, and unwaxed parchment -- were used immediately after pollination for varying periods. At one location in 1957, fruit set of Perfection apricots was reduced by all protectors which were applied for three weeks. The reduction observed was mostly due to frost while the protectors were on, although high day temperatures may have been partially responsible. The set on branches protected for a one-week period was comparable to the control. At another location, the fruit set of Henderson apricots in the waxed and unwaxed protectors was significantly better than the control after a three-week treatment. However, the set was significantly reduced in the polyethylene protectors. During the same year, fruit set of Redhaven peach on branches covered by

unwaxed protectors was significantly increased compared to the control and other treatments. Again, the set was significantly reduced by the polyethylene protectors.

In 1958 the length of treatment was reduced to five days. At one location, fruit set of Perfection apricots was not significantly increased by the protectors. Many fruits were lost due to frost damage. At another location, however, the set of Henderson apricots was significantly increased in the waxed protectors, compared to the control and all other treatments. In the unwaxed parchment protectors, the set of Henderson apricots was also significantly better than the control. The polyethylene protectors significantly reduced the set of Henderson apricots. Fruit set of Redhaven peaches was significantly increased by the unwaxed protectors.

Temperatures taken inside these protectors by the use of thermocouples were found to be, always, from one to two degrees F. lower at night than outside and from five to as much as 28 degrees F. higher than outside during the day.

In 1958 supplementary frost protectors were made of fiberglass and aluminum foil, black polyethylene and aluminum foil, multilayered brown paper bags, and blanket type insulated materials. The latter were made of sides of double layers of brown paper with shredded paper in between. After the five-day treatment with the waxed and unwaxed parchments and the polyethylene protectors, the frost protectors were placed over one lot of the treated branches during nights when frosts occurred. No significant benefit was

obtained from the supplementary frost protectors, and all but the fiber glass - aluminum foil protectors usually reduced fruit set because of low inside temperatures.

In 1959 attempts were made to determine the approximate time between pollination and fertilization of Henderson apricots under controlled conditions in the laboratory. This was done by crushing the pistils and using the Lacmoid-Martius yellow staining technique. Fertilization did not occur normally on excised branches, but studies in the field using the same staining technique indicated this period to be about four days. An approximate period of four days from pollination to fertilization was also indicated for Perfection and South Haven apricots 6 and 7 by studying pollen tube growth from full bloom. Limited observations indicated that the time between pollination and fertilization of Redhaven peaches was also four days.

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ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Professor Stanley Johnston and Dr. J. E. Moulton for their help, guidance, and suggestions throughout the investigation.

Appreciation is expressed to the members of the committee, Drs. L. W. Mericle, C. E. Peterson, A. L. Kenworthy, and F. C. Elliott for their suggestions during this study; also to Drs. D. H. Dewey and J. A. Cook of the Horticulture Department, Dr. C. M. Hansen of the Agricultural Engineering Department, and Dr. C. L. Bedford and Professor W. F. Robertson of the Food Science Department for their suggestions and willingness to make available the necessary equipment to carry on the investigation.

Gratitude is also expressed to Dr. William Baten of the Statistics Department for guidance in the statistical analysis of the data.

The utmost gratitude is also expressed to my wife, ReNae, and to my parents, Mr. and Mrs. Fenton A. Larsen, for their help and encouragement throughout the period of graduate study.

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INTRODUCTION

For many years the peach and apricot breeding program at the Michigan State University South Haven Experiment Station has been seriously hampered by the fact that the weather is frequently rainy, cold, windy, and in general quite unfavorable for obtaining an adequate set of fruit from hand-pollinated blossoms. In some years forty to fifty percent of the emasculated and hand-pollinated blossoms set fruit. However, this is higher than average, and a ten percent fruit set is more typical. Sometimes no fruit at all is obtained.

In a given year, the period of time during which cross-pollinations can be made is usually only about one day. It is usually impossible to repeat the crosses in the same year if for any reason they cannot be completed successfully in the very short period when the flowers are at the proper stage of development for emasculation and pollination.

To the plant breeder, failure to obtain fruit involves the loss, not only of invaluable breeding material, but it also means the loss of a year's time in procuring the desired crosses. Every precaution possible needs to be taken to prevent these serious losses.

Elsewhere entire plants have been covered for protection against the weather, and in more severe climates, trees are sometimes moved into the greenhouse where the crosses are made. Since

neither of these systems seemed practical for Michigan, the possibility of covering branches to provide a micro-environment favorable for fruit set was investigated.

The main objectives of this study were as follows:

1. To determine the length of the critical periods between pollination and the time the pollen tubes start to grow within the style and the length of time between pollination and fertilization in apricots and peaches.

2. To compare the characteristics of the micro-environments produced where different materials were used to cover branches.

3. To evaluate the effectiveness of several materials in protecting hand-pollinated peach and apricot blossoms from adverse environmental conditions.

4. To determine, from the standpoint of fruit set, the length of time the branches should be subjected to an artificial micro-environment following pollination.

LITERATURE REVIEW

In breeding many crops, entire plants or plant parts are often covered, following the hand-pollination of flowers, to protect them from contamination with foreign pollen. This practice was found to be unnecessary for sweet cherries by Schuster (42) for apricots by Schultz (41) and for peaches by Johnston (27).

Manipulation of the micro-environment in the field by bagging or using tents has been used as a method of studying fruitfulness in tree fruits. Among others, this method has been used to study cross- and/or self-fruitfulness in peaches by Detjen (13) and Kerr (29), in apples by Knowlton (31) and Murneek (36), in apricots by Schultz (41), and in apples, pears, cherries, and plums by Wellington (47). However, there seems to be no evidence in the literature relating to the control of the micro-environment about branches of fruit trees to improve the set of fruit from hand-pollinated blossoms.

Plant and Plant Protector Temperatures

It is well known that many types of materials are used to protect low-growing plants, especially vegetables, during early spring periods when frosts are threatening and that the protection given is a result of the retention of heat inside the protector from that given off by the soil. Waggoner (46) recently has published a report concerning the use of various plastic films for

this purpose and states that three to seven degrees of protection can be expected near the center of most types of protectors. However, this is not true for protectors that have no open contact with the soil, such as those used to cover only certain branches or plant parts in breeding work or pollination studies. The temperature in these protectors has been found by Geiger (20) to be lower at night than outside air temperature.

It is also well known that many plant parts and other objects are often warmer than air temperature during the day and cooler during the night. This has been reported by Grainger and Allen (23) for apple buds. They also found that black currant and raspberry buds were nearly always cooler than the air.

Gardner, et al. (18) have reported records of plants being frozen stiff even though the thermometer indicated one to two degrees above freezing. Occasionally plants were cooled to a temperature 12 to 15 degrees F. below that of the surrounding air. They observed that the above effects were caused by the fact that all substances constantly receive and emanate heat. Radiant heat strikes an object and may be partly reflected and partly absorbed depending on the composition of the substance. During a clear day, the heat received by any substance through radiation from the sun and from other substances will be in excess of that emitted. During a clear night, the heat lost by radiation will exceed that gained. Cloudy days reduce the sunlight, and the substance will be warmed less than on a clear day; and during a cloudy night much

of the heat lost by radiation may be reflected by the clouds, and the substance will be cooled less than on a clear night.

Effect of Weather at Bloom on Fruit Set

In 1908, U. P. Hedrick (25) observed that rain, and the cold and wind that accompany it, at blossoming time were responsible for the loss of more fruit than any other climatical agency, and that no condition of spring time weather was as harmful to blossoms, aside from a killing frost, as a prolonged rain. He further indicated that the damage was done in several ways. The most obvious injury was the washing of pollen from the anthers. In addition, the secretion on the stigmas was often washed away or became so diluted that the pollen did not germinate. The chill of rainy weather probably decreased the vitality of pollen, and an excess of moisture often caused pollen grains to swell and burst. A low temperature, even though it did not touch the freezing point nor accompany rain, often could be disastrous to fruit setting. The injurious effect was probably due to the prevention of growth of the pollen tubes. Hedrick also observed that continued dry winds injured blossoms by evaporating the secretion from the stigma, thereby preventing the retention and germination of pollen. Damp, warm winds, if long continued, were unfavorable to pollination. A cold, dry, north wind at blossoming time would chill vegetation and stop the normal functions of flowers and leaves. Finally, Hedrick reported that hot weather at blossoming time might also be injurious by preventing pollen germination and tube growth or

by drying up the stigma. An abundance of sunshine and a low percentage of humidity were the most favorable conditions for the setting of fruit.

In 1929 Wellington, et al. (47) reaffirmed the statements above made by Hedrick in 1908 in their report of studies concerning self- and cross-incompatibilities in apples, pears, cherries, and plums.

Effect of Temperature on Fruit Set

After working with apples, Knowlton and Sevy (32) indicated that a temperature constantly below fifty degrees F. may considerably decrease fruit set because of slow pollen tube growth, and that a high temperature at bloom (75 to 85 degrees F.) may reduce fruit set by a permanently injurious effect on pollen tubes and their growth.

From his work with plums, Dorsey (14) stated that the greatest damage from low temperature was due to a retarding of pollen tube growth. The stigma of the plum will remain receptive for four to six days, and the style will absciss 8 to 12 days after bloom. Since pollen tube growth will be slow in the plum, even under favorable conditions, a delay in pollination or slow pollen tube growth during a period of low temperature will render fertilization uncertain.

While working with apples, Murneek, et al. (37) found that low temperature during pollination time may prevent the growth of pollen tubes if it does not outright kill the essential flower

parts, and that extremely high temperature, especially accompanied by wind, may reduce fruit set by causing stigmas to dry up and to be receptive to pollen for only a short time.

Semeniuk (43) has shown that no fruits of Matthiola incana were formed following pollination of flowers in 85-degree F. chambers. He presumed that this temperature caused the abortion of the ovules as well as the pollen.

Cochran (8) studied some factors affecting fruit setting in peppers and found that no fruit was set at ninety to one hundred degrees F. and that reducing the temperature by ten-degree increments from ninety to sixty degrees F. resulted in increased fruit set. The best temperature was between sixty and seventy degrees F.

After studying white pea beans, Davis (12) reported that when the maximum daily temperature exceeded 75 degrees F., the pod set rapidly decreased.

Lambeth (33) observed that when the mean temperature for the 24-hour period following anthesis of lima beans was above 78 degrees F., the pod set was materially reduced. A mean temperature of 78 degrees F. usually represented several daylight hours in which the air temperature was greater than ninety degrees F.

From their work with peas, Karr, et al. (28) reported that peas were particularly sensitive to high temperature during a period from six to ten days from full bloom. During this period, high night temperatures (87 degrees F.) were particularly effective in reducing yields while high day temperatures (ninety degrees F.) were only moderately effective. High day and night temperatures

combined were essentially additive in their effect on reducing yield.

<u>Effect of Rain on Fruit Set</u>

Gardner, Bradford, and Hooker (17) indicated that the well known effects of rain during blossoming time in preventing pollination, in washing away and destroying pollen, and in diluting the stigmatic secretions should be mentioned in regard to fruit setting.

The pollen of certain tree fruits has been reported by Overly and Bullock (39) to be apparently injured after thirty minutes in water.

Goff (21) reported that prolonged rain was not likely to injure the vitality of pollen if the weather remained cool (near fifty degrees F.) but it might destroy its vitality if it was as warm as 65 to 70 degrees F.

According to Dorsey (14) rain will not burst plum pollen nor kill it. On account of the adhesive action between stigma and pollen, rain will not completely wash pollen from the stigma.

Boyd and Latimer (4) have found evidence that indicated heavy rain did not wash pollen from the stigmas of McIntosh apples since they obtained the best fruit set when pollinations were made between two heavy, prolonged showers.

<u>Effect of Humidity on Fruit Set</u>

From his work with apples, Heinicke (26) reported that very high humidity caused abscission of partly developed fruits.

Murneek, et al. (37) and Gardner, et al. (16) have indicated that high humidity during periods of low temperature may greatly increase the susceptibility of flowers and young fruits to freezing injury.

The best fruit set of McIntosh apples was obtained by Boyd and Latimer (4) during humid,cloudy, or rainy weather with a mild temperature.

Cochran (8) and Davis (12) reported that high humidity was favorable to fruit setting in peppers and white pea beans, respectively.

Effect of Reduced Light on Fruit Set

Gray (24), Dorsey (14), and Boyd and Latimer (4) have shown that cloudiness or slightly reduced light does not limit fruit set.

Detailed studies with cherries by Gray (24) showed that shading trees with muslin and wire screen did not reduce fruit set. He did, however, reduce it by heavy reduction of light intensity by shading with burlap. He attributed this to an indirect effect of a reduction in photosynthesis.

Adams (1) found that the pollen of apple, pear, strawberry, loganberry, raspberry, and black currant germinated alike in light or dark.

Effect of Wind on Fruit Set

Dorsey (14) and Gardner, et al. (19) reported that wind may cause stigmatic fluids to dry permanently and thus prevent the germination of pollen grains.

The Relation of Temperature to Pollen, Pollen Germination, and Pollen Tube Growth

Pollen growth may be greatly influenced by temperature, as indicated by the findings of many investigators.

Using *Datura stramonium*, Bucholz and Blakeslee (6) found that pollen tube growth was most rapid in the pistil at ninety degrees F.

Smith and Cochran (44) found that temperature had a great effect on the germination percentage of pollen as well as on pollen tube growth in tomato styles. The best germination of pollen was obtained at 85 degrees F., while the maximum rate of pollen tube growth occurred at seventy degrees F. Pollen germination was almost as good at seventy degrees F. as at 85 degrees F. but decreased rapidly below this temperature and was very poor at one hundred degrees F. Pollen tube growth also decreased rapidly as the temperature was reduced below seventy degrees F. and was very poor at one hundred degrees F. They also found that pollen tubes were short at fifty degrees F. and very short and distorted at one hundred degrees F.

After studying the germination of pollen of several fruits in sucrose solutions, Goff (21) found that the pollen of two varieties of plums and one variety of cherry, strawberry, and apple germinated slightly at forty degrees F. One pear variety failed to germinate at this temperature. All germinated better at fifty degrees F.

Childers (7) reported that there will be some germination of the pollen of various fruits at forty to fifty degrees F. but that it will not be satisfactory until the temperature has reached sixty to seventy degrees F. Optimum conditions for pollen germination and tube growth will be between seventy and eighty degrees F. above which there will be a decrease.

Adams (1) found that the pollen of apple, pear, strawberry, loganberry, raspberry, and black currant in sugar solution germinated best between seventy and 73 degrees F.

While working with certain species and interspecific hybrids of Prunus, Becker (3) found that pollen on agar-sucrose media germinated faster at 85 degrees F., but the rate of pollen tube growth was faster at seventy degrees F. He noticed no consistent differences in germination percentages at the various temperatures.

According to Sandsten (40), 75 degrees F. will be optimum for the growth of apple, pear, and plum pollen growing in various sugar solutions.

Time Interval Between Pollination and Fertilization

The time interval between pollination and fertilization for many plants has been reported by Meyer and Anderson (35) to be from 12 to 48 hours. In a few plants, such as barley, this time interval will be less than one hour, and in some plants, as certain oaks and pines, it may be many months. They further indicated that the absolute rate of pollen tube elongation may range up to 34 millimeters per hour.

The time between pollination and fertilization of oak has been reported by Conrad (11) to be about one year.

According to Coit (9), there may be a great variation in the time elapsed from pollination to fertilization between closely related plants, as indicated by thirty hours required for the Satsuma orange and four weeks required for the trifoliate orange.

Knight (30) has shown that fertilization of a Rome Beauty x Wagener cross occurred 24 hours after pollination.

After working with several fruits, Sandsten (40) found that, under favorable conditions, 19 to 32 hours will be required for pollen tubes of apples, plums, and cherries to reach the ovary.

Connors (10) claimed that if weather and other conditions permit, fertilization of the peach will occur within 24 hours after pollination, and the ovary will begin at once to swell.

Harrold (22) has shown evidence of fertilization in the Carman peach four days after full bloom.

From his work with sweet cherries Tukey (45) indicated that fertilization occurred in one to two days after full bloom.

Fertilization in Redhaven peaches, according to Lombard (34), did not occur until one to two weeks after full bloom.

MATERIALS AND METHODS

1957 Season

Laboratory Experiments

Laboratory experiments were conducted to determine if a polyethylene bag, two by four feet, would hold enough heat to provide some frost protection when the temperature was lowered below freezing.

A polyethylene bag was suspended two feet above the floor in a room in which the temperature could be varied over a wide range from several degrees below freezing to 75 or 80 degrees F. After checking thermocouples for accuracy in an ice bath, the leads were extended through the wall of the room, and the thermocouples were placed at various locations inside the bag and at the same levels outside of the bag. The bag was inflated and tied tightly to prevent air from escaping.

The temperature in the room was maintained at 75 degrees F. for 24 hours then lowered gradually from 75 degrees F. to 27 degrees F. over a 24-hour period. Temperature readings were taken at thirty-minute intervals for the first eight hours and again at the end of the period. The temperature was then raised to fifty degrees F. over a nine-hour period and held for 16 hours. During the time that the temperature was rising, readings were taken at thirty-minute intervals.

After the 16-hour holding period, the temperature was again lowered to 26 degrees F. over a 19-hour period. Temperature readings were taken at ten-minute intervals during the first four hours of the lowering period and again after three hours and 12 hours.

Field Experiments

The experiments described below, as well as the field experiments during the 1958 and 1959 seasons, were conducted at the Merkle and Station farms of the South Haven Experiment Station of Michigan State University.

Bag Preparation

Polyethylene (.003), waxed parchment, and unwaxed parchment (Figures 1, 2, and 3) were used as test materials from which to prepare bags for the first season's experiment. Polyethylene bags were prepared by cutting four-foot lengths of two-foot tubing. One end was closed by doubling over one-half inch and machine sewing. Waxed and unwaxed parchment bags were prepared from four- by four-foot sheets of paper by machine sewing along two sides to make a two- by four-foot bag. Since the bags described were designed to serve a protective function, they will be referred to throughout the text as protectors.

Thermocouple Preparation

Thermocouples were prepared by using 12-foot lengths of number 24 copper-constantan wire. Insulation was removed from the tips of the wire, and the leads on one end were twisted tightly together and secured with a thin film of solder. All thermocouple

Waxed parchment protector (Figure 1), unwaxed parchment protector (Figure 2), and polyethylene protector (Figure 3) which were placed on peach and apricot branches following pollination to improve fruit set.

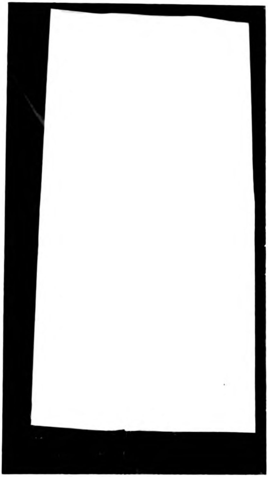

Figure 1

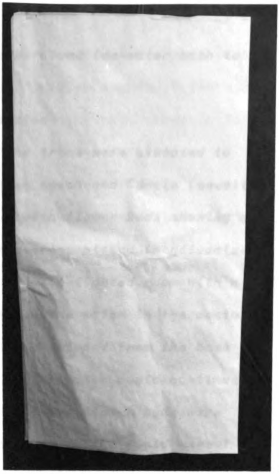

Figure 2

Figure 3

junctions were tested in a uniform temperature ice-water bath to determine accuracy.

Pollen Collection

About three to four days before the trees were expected to bloom in the field, branches of Kalhaven peach and Curtis (seedling name) and South Haven apricot number 6 with flower buds showing a slight amount of pink were cut from the tree, placed in galvanized containers of water, and brought into a well-lighted room with a temperature range of 70 to 75 degrees F. The water in the containers was changed daily, and about one inch was snipped from the base of each branch at the same time so that the branches could continue to receive ample water. Under these conditions, flower buds were forced open one to two days before the buds in the field were in the balloon stage. Once the blossoms were open, they were snapped from the branches and collected.

To facilitate anther collections, a six- by six-inch copper coated wire screen with mesh slightly larger than window screen was placed over a petri dish. Each blossom was grasped between thumb and forefinger, and the anthers were rubbed over the screen in such a way that they were broken off, allowing them to fall through the screen into the dish below. With the proper pressure, very few filaments or other floral parts were broken from the blossom, and the dish contained a large quantity of pollen.

The blossoms from each variety were collected in a clean box. After the pollen was extracted from each variety, the hands were

cleansed, either with isopropyl alcohol or washed thoroughly with soap and water to avoid contamination of pollen samples. The wire screens were also cleansed with a clean cotton swab soaked in isopropyl alcohol.

The anther-pollen mixture was allowed to air dry for about 24 hours during which time the dishes were agitated to promote better drying. During the drying process, most of the anthers dehisced providing an abundance of viable pollen.

Pollen germination was observed in a ten percent sugar solution to determine the viability of pollen.

Apricot Pollination and Bagging at the Merkle Farm

Pollen was collected for Merkle Farm apricot pollinations on April 23. Dry pollen was placed in a four-ounce narrow necked open bottle for transport to the field. On the morning of April 24, apricot pollination work was begun. Curtis was selected as the pollen parent and two trees of Perfection were used for the seed parent.

Branches which were comparable, well distributed over the tree, of a suitable size for bagging, in good condition, and which had a sufficient number of blossoms were selected for the treatments and controls. Side branches which were too long to fit properly under the protectors were headed back.

Only blossoms which were in an expanded balloon stage, but not yet open at the tips, were selected for emasculation and pollination. All other blossoms were removed from the branches.

Emasculation was accomplished by nipping the corolla just below the point of attachment of the stamens with a special pair of clippers made for this purpose. This portion of the corolla along with the stamens was pulled off, leaving the pistil exposed.

Pollination was accomplished by transferring pollen from the pollen container to the stigma with a clean, soft camels hair brush. To prevent injury to the stigma, pollen was applied with a light brushing or daubing action.

Counts were made of all pollinated pistils on the branch, and this information along with the date, branch number, and nature of the cross was placed on two 3-inch by 6-inch red tags which were tied to the branch. The position of the tags was used as an indicator to show that all fruit formed beyond the tags was a result of hand-pollination.

After pollination was completed, any side branches which were still too long after heading back were tied closer to the main branch by wrapping a single cord around several side branches and drawing them in toward the main branch. By this technique a branch too large to normally fit inside a protector could be successfully covered.

A thermocouple was secured in a central position on the branch, and the branch was covered with a protector which was tied securely just above the red tags. The thermocouple leads were secured at the base of the tree at a convenient position for taking temperature readings (Figure 4). Thermocouples were placed in three protectors of each treatment and on two control branches.

Figure 4

Thermocouple leads centrally located beneath a Redhaven peach tree for convenient temperature readings.

Figure 4

The number of branches used for each treatment varied from four to six depending on the number of suitable flowers on each branch. Control branches were not bagged. A total of twenty branches was used. The treatments were applied at random within the selected trees as well as being randomized on a given tree.

After two protectors of each type had been applied and one control branch was finished, the pollination work was interrupted by showers which lasted for four hours and delivered about .70 inches of precipitation. The remainder of the treatments was then completed between 2:30 and 4:30 P.M. About four hundred blossoms were pollinated for each treatment and control. Exact figures are shown in Table 1.

During the course of this and subsequent experiments, it was discovered that if a cord was tied around the outside of the protector about midway between both ends, so that it fit snuggly against the branches inside, the wind would cause less damage to both the protectors and the pistils and young developing fruits inside. Consequently this procedure was followed in all subsequent bagging tests.

Temperature Records

Temperatures inside the protectors containing thermocouples were recorded between 7:30 and 8:00 each morning and between 3:00 and 3:30 each afternoon with the use of a portable potentiometer. In addition to the scheduled readings, the temperature was recorded at frequent intervals during the coldest periods of nights during which a temperature of 32 degrees F. or lower was expected.

TABLE 1

NUMBER OF APRICOT POLLINATIONS (MERKLE FARM - 1957)

Type of Protector Polyethylene	Waxed Parchment	Unwaxed Parchment	Control
407	436	404	423

TABLE 2

NUMBER OF APRICOT POLLINATIONS (STATION - 1957)

Type of Protector Polyethylene	Waxed Parchment	Unwaxed Parchment	Control
290	253	245	246

TABLE 3

NUMBER OF PEACH POLLINATIONS (MERKLE FARM - 1957)

Type of Protector Polyethylene	Polyethylene with Slits	Waxed Parchment	Unwaxed Parchment	Control
569	581	560	604	549

Predictions were based on United States Weather Bureau forecasts for southwestern Michigan. Temperature readings were also taken, at the time the other readings were taken, from a thermometer which was four feet above the ground and located within a few feet of the trees.

Apricot Pollination and Bagging at the Station

Since the South Haven Experiment Station headquarters are located only a few hundred feet from the eastern shore of Lake Michigan, which has a retarding effect on bud development, it was possible to repeat the apricot experiments at this location two days after the experiment was begun at the Markle Farm.

Pollen was collected on April 25 for pollinations at the Station. On the afternoon of April 26, pollination work was started at this location using South Haven Apricot Seedling number 6 (SHA #6) as the pollen parent and five Henderson trees as the seed parent.

The same general procedure as used at the Merkle Farm was used here except that no thermocouples were placed in the bags for temperature readings, since it was not possible to get readings at both locations during the same periods. Furthermore, weather records indicated that frosts do not generally occur at this season so close to Lake Michigan.

It was necessary to use more trees since the trees were younger and a large number of suitable branches was not available on one tree. Fewer blossoms were also used because they were more

difficult to emasculate without damage to the pistil since it was reflexed inside the blossom and might be broken off when the corolla was removed. A total of 23 branches was used.

Just as the pollination and bagging were completed, moderate showers began which lasted over a 16-hour period and delivered about .70 inches of precipitation. The total number of flowers pollinated is indicated in Table 2.

To obtain a continuous temperature record for a short period of time inside the various protectors used, it was necessary to apply bags to a South Haven apricot number 6 tree that was close to a source of electrical power and shelter for use of a continuous recording potentiometer (Figure 5). The thermocouples and protectors were applied to the branches in the same manner as in the regular experiments except that no emasculations and pollinations were performed. On April 27 two of each kind of protector were placed on the tree, and the recorder was operated for three days.

During the course of the experiments, both at the Station and at the Merkle Farm, night temperatures in the protectors were observed to be lower than outside temperatures. As a result of this, one of each kind of protector was placed on a pole, with cross pieces to spread the bags, at the same level as the protectors in the tree (Figure 5). Thermocouples were placed in the protectors, and the recorder was operated for two more days to determine the influence of plant material on the temperature within the protector.

Figure 5

Protectors placed on a South Haven apricot number 6 tree and on poles. Thermocouple leads connected to a continuous recording potentiometer.

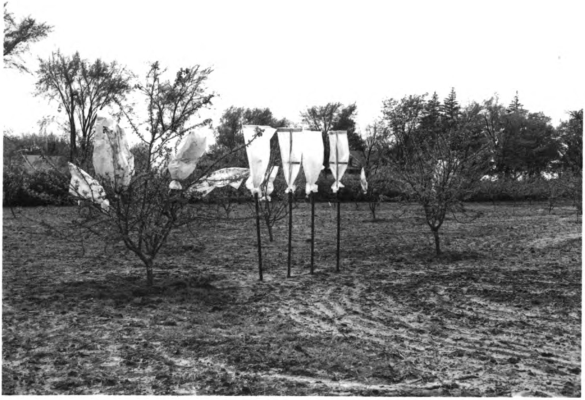

Figure 5

Peach Pollen Collection, Pollination, and Bagging (Merkle Farm)

The pollen for the peach crosses was collected on April 30 as previously described. Kalhaven was used as the pollen parent and two trees of Redhaven were used as the seed parent. Pollinations and bagging were begun and completed at the Merkle Farm on April 30 between 9:00 A.M. and 3:00 P.M. A total of 25 branches was used.

The same procedure as was followed for the apricots at this farm was used for the peaches (Figures 6 and 7) except that an additional treatment was applied. In addition to the regular polyethylene protectors, polyethylene protectors with two slits in them were also used. The slits were approximately three inches long, six inches apart, and near the base of the bag. The purpose of the slits was to provide for increased aeration within the polyethylene protectors. The total number of flowers pollinated is indicated in Table 3.

Protector Removal Dates

After the protectors had been on a few days, it seemed apparent that damage to the enclosed branches might occur if the protectors were left on for an extended period of time because of the high temperature prevailing in some of them.

To determine the influence of the duration of protection, two protectors of each kind used on apricot trees at the Merkle Farm were removed at the end of one week, and the foliage and floral parts were observed for possible damage. The remaining protectors were left in place for an additional two weeks.

Figures 6 and 7

Protectors on Redhaven peach trees.

Figure 6

Figure 7

The dates for the removal of the bags for each location are given below:

Apricots	Merkle Farm	April 1 and April 14
Apricots	Station	April 15
Peaches	Merkle Farm	April 14

Treatment Period Weather Data

During the period that protectors were on the peaches and apricots, detailed weather notes were kept, which are presented in Table 4.

Fruit Set Counts

Preliminary fruit set counts were made before the normal fruit drop was completed to insure against data loss in the event that certain branches or the whole tree might be lost.

After the normal fruit drop was completed, final counts were made and the percentage of fruit set was calculated from these data. Final counts for all experiments were made on June 18.

Harvest

The fruit was harvested while still firm in order to be sure that none would drop and be lost. It was held in baskets until ripe, pitted, and the pits were planted along with those secured from the regular breeding work of the South Haven Experiment Station. The pits were not discarded since the crosses made were those which should provide valuable progeny for subsequent breeding work.

The harvests were made on the following dates:

Apricots	Merkle Farm	July 20
Apricots	Station	July 22
Peaches	Merkle Farm	August 5

TABLE 4

1957 WEATHER DATA FOR THE PERIOD OF APRICOT AND PEACH TREATMENT (APRIL 24 - MAY 15). RECORDED AT THE SOUTH HAVEN EXPERIMENT STATION*

Date	Max.	Min.	Cloudy	Windy	Rain (inches)
April 24	76	52	partly	yes	.70
25	74	50	partly	yes	.40
26	71	53	partly	slight	trace
27	69	43	yes	slight	.67
28	62	45	partly	slight	.03
29	64	38	no	yes	
30	74	44	no	yes	
May 1	68	46	no	yes	
2	62	44	partly	yes	
3	60	33	no	yes	
4	47	37	partly	yes	
5	46	37	no	slight	
6	56	39	no	slight	
7	72	50	no	yes	
8	70	57	no	yes	
9	68	46	yes	slight	
10	56	41	yes	slight	1.34
11	64	50	yes	slight	.97
12	67	46	yes	slight	.02
13	73	54	yes	slight	.02
14	78	60	yes	slight	.07
15	77	42	yes	slight	.07

*Maximum and minimum temperatures at the Merkle Farm are usually ± four to five degrees F. of those at the Station.

1958 Season

Laboratory Experiments

Since the protectors used in the 1957 season failed to provide any frost protection and were detrimental in some cases if left on too long, it was necessary to test new materials which might give some degree of frost protection.

One frost protector was constructed with sides of blanket type insulation material made of shredded paper between two layers of heavy brown paper. Another frost protector was made of nursery paper, and another of two multi-layered heavy brown paper bags of different sizes which fit inside each other with about one-half inch of air space in between the sides of the bags.

These protectors were suspended in a controlled temperature room, as in the 1957 laboratory experiments, with one thermocouple centrally located inside the protector and one thermocouple located at the same level on the outside of the protector. The protectors were tied securely at the top to prevent air from escaping.

The temperature in the room was maintained at 75 degrees F. for 18 hours and then lowered to 34 degrees F. over a twenty-hour period. Temperature readings were taken at ten-minute intervals for the first hour, at thirty-minute intervals for the next three hours, and at various longer intervals for the remainder of the period since the temperature could be reduced only very slowly.

The temperature in the room was raised again to 75 degrees F. and nine pounds of apples to serve as a heat source were suspended in a mesh bag in the center of both the blanket type insulated protector and the nursery paper protector. The temperature was maintained at 75 degrees F. for two days and then lowered to 35 degrees F. over a 16-hour period. Temperature readings were taken at ten-minute intervals for the first hour, at sixty-minute intervals for the next three hours, at two-hour intervals for six hours, and again at the end of the period.

<u>Field Experiments</u>

The same procedure was followed as in the previous season for collecting pollen. Pollen was collected on April 18 for apricots at the Merkle Farm, on April 21 for apricots at the Station, and on April 28 for peaches at the Merkle Farm.

Apricot Pollination and Bagging at the Merkle Farm

The procedure followed was the same as the previous season, using the same types of protectors (polyethylene, waxed, and unwaxed parchment), the same parents, and the same trees.

Pollination and bagging were started at 1:00 P.M. on April 19 and completed at 4:30 P.M. when work was stopped by rain. About .66 inches of rain fell over a 19-hour period. A total of 25 branches was used in the experiment. The total number of flowers pollinated is indicated in Table 5.

No temperatures were taken in these protectors during this season since they were on only five days and the weather was cool during this period of time. The protectors were removed on April 23.

Frost Protector Application

The blanket type and the multi-layered double paper bags, as described in the laboratory experiments, were prepared for use as frost protectors. Two other types of bags were prepared in addition to these (Figures 8, 9, 10, 11). One was made of 1.5 mil. black polyethylene with aluminum foil on the upper side. The other was made of one inch fiber-glass with a heavy paper liner on the inside and aluminum foil on the outside. A variation in construction of the latter was also tried with an additional layer of aluminum foil on the inside under the paper liner.

After removal of the three types of bags used for protection in the five-day period immediately following pollination, the treated branches were divided into two equal groups. One group was covered with the four types of frost protectors (Figure 12) on nights, during which a temperature of 32 degrees F. or lower was expected, and the other group was left uncovered.

The frost protectors were put on early in the afternoon before the night of a frost warning as predicted by the United States Weather Bureau Forecasting Service in southwestern Michigan (Table 6). They were removed again the next morning and replaced the next time a frost was predicted. Inside temperature, outside temperature, and thermometer readings were taken at frequent intervals during these nights as was done during the previous season.

Fruit Set Counts

Many young fruits were frozen as a result of the heavy frost on the morning of May 7, even under some of the frost protectors.

Frost protectors of blanket type insulation (Figure 8), fiber-glass and aluminum foil (Figure 9), multi-layered brown paper bags (Figure 10), and black polyethylene and aluminum foil (Figure 11). When frosts were predicted, these protectors were placed over peach and apricot branches.

Figure 8

Figure 9

Figure 10

Figure 11

Figure 12

Frost protectors on a Perfection apricot tree.

Figure 12

TABLE 5

NUMBER OF APRICOT POLLINATIONS (MERKLE FARM - 1958)

Type of Protector			
Polyethylene	Waxed Parchment	Unwaxed Parchment	Control
492	505	436	259

TABLE 6

DATES OF FROST PROTECTOR APPLICATION AND THE LOW AIR TEMPERATURE RECORDED THAT NIGHT - 1958

Dates of Frost Protector Application		Low Night Temperature °F.
April	25	29
	26	35
	29	34
May	1	40
	5	35
	6	25
	7	35
	9	40
	23	32

Preliminary fruit set counts were made even though it was extremely difficult to distinguish fertilized ovaries from the non-fertilized ones. Determinations could only be made on the basis of size.

Final counts were made on May 23, and percentage set was calculated.

Apricot Pollination and Bagging at the Station

The procedure at this location was the same as described for the Merkle Farm except no frost protectors were used. The same parents and trees as used the previous season were used in 1958.

One series of pollinations was begun on April 22 at 1:00 P.M. and completed at 3:30 P.M. including a total of 20 branches. The weather at this time was very cold (46 degrees F. at 3:30 P.M.), cloudy, and windy. A good set of fruit would not be expected under these conditions.

The following day, April 23, another series of pollinations was completed between 7:30 and 9:30 A.M. A total of 12 branches was used. The weather was again cold (45 degrees F. at 3:30 P.M.), cloudy, and windy as the day before. At about 1:00 P.M. showers began which lasted over a period of about 15 hours and delivered .77 inches of rain.

Table 7 gives the total number of flowers pollinated for the treatments and controls.

The bags were all removed early on the morning of April 27. Fruit set counts were made on April 30.

Peach Pollination and Bagging at the Merkle Farm

Pollen was collected on April 28. Pollinations were completed between 8:00 A.M. and 2:30 P.M. on May 1, using a total of 28 branches. Table 8 shows the total number of flowers pollinated.

The same parents and trees were used as in the previous season. After removal of the protectors (May 9), which were on for five days immediately following pollination, the same procedure as was used for the Merkle Farm apricots was used for the peaches except no temperatures were taken in the frost protectors. Table 9 gives the dates of frost protector application. Fruit set counts were made on June 7.

Treatment Period Weather Data

Detailed weather data, shown in Table 10, were taken from the time of apricot pollination until the time the protectors were removed from the peaches.

Fruit Harvest

Apricots	Merkle Farm	July 28
Apricots	Station	July 21
Peaches	Merkle Farm	August 15

As in the previous season, the fruit was harvested before completely ripe, and the pits were planted with pits from the regular breeding work of the Experiment Station.

TABLE 7

NUMBER OF APRICOT POLLINATIONS (STATION - 1958)

Polyethylene	Type of Protector Waxed Parchment	Unwaxed Parchment	Control
647	642	632	590

TABLE 8

NUMBER OF PEACH POLLINATIONS (MERKLE FARM - 1958)

Polyethylene	Type of Protector Waxed Parchment	Unwaxed Parchment	Control
599	588	609	309

TABLE 9

DATES OF FROST PROTECTOR APPLICATION AND THE LOW AIR TEMPERATURE RECORDED THAT NIGHT - 1958

Dates of Frost Protector Application	Low Night Temperature °F.
May 5	36
6	27
7	36
9	40

TABLE 10

1958 WEATHER DATA FOR THE PERIOD OF APRICOT AND PEACH TREATMENT (APRIL 19 - MAY 9), RECORDED AT THE SOUTH HAVEN EXPERIMENT STATION

Date		Air Temperature (degrees F.)* Max.	Min.	Cloudy	Windy	Rain (inches)
April	19	66	52	yes	slight	.02
	20	63	45	yes	no	.64
	21	63	41	partly	yes	
	22	65	42	yes	yes	.06
	23	53	35	yes	yes	.05
	24	63	37	yes	yes	.77
	25	47	30	partly	yes	
	26	55	29	yes	yes	
	27	55	35	yes	yes	.02
	28	55	45	yes	yes	.02
	29	54	32	partly	yes	.01
	30	55	34	no	yes	
May	1	55	46	no	yes	
	2	65	40	no	yes	
	3	65	52	yes	yes	.25
	4	67	42	yes	yes	
	5	65	33	partly	yes	
	6	52	36	partly	yes	
	7	49	34	no	yes	
	8	54	36	partly	slight	
	9	58	36	no	yes	

*Maximum and minimum temperatures at the Merkle Farm are usually ± four or five degrees of those at the Station.

1959 Season

Laboratory Experiments

In 1959 laboratory experiments were designed to investigate the effects of temperature and humidity on pollen tube growth and the interval of time between pollination and fertilization.

On March 21, Redhaven peach and Henderson apricot branches were brought from South Haven and placed in water in gallon porcelain containers. Five branches of each were placed in the greenhouse at day temperatures ranging between 70 and 75 degrees F. and night temperatures between 60 and 65 degrees F. The remainder of the branches were placed in the cooler at 35 degrees F. until March 23 when they were also placed in the greenhouse.

On March 29, the blossoms on the apricot branches placed in the greenhouse on March 21 began to open. On March 31, the pollen was collected from these branches. On April 1, the blossoms on the branches placed in the greenhouse on March 23 were ready for emasculation and pollination. These branches were cut in 12- to 18-inch sections, and three or four sections were placed in water in pint glass jars. The blossoms were emasculated and all pollinated at the same time with the pollen collected on March 31.

Two jars of branches were placed in each of six controlled temperature peach ripening cabinets measuring seven by three x three feet. One jar in each chamber was placed in a two-by four-foot polyethylene bag in which a number 2 can of water and a hygrothermograph were placed. The other jar was placed outside of the bag along with another hygrothermograph. The polyethylene bag and can of water were used to provide high humidity.

The cabinets were maintained at 45, 50, 60, 70, 80, and 90 degrees F. Temperature and humidity were recorded by hygrothermograph.

At the same time the branches were placed in the cabinets, pollen was placed in each cabinet in a series of three petri dishes. One dish contained two percent Agar mixed in 15-percent sucrose solution, another contained 15-percent sucrose solution, and the third contained distilled water. These dishes were placed in the cabinets five hours prior to placement of pollen to allow them to reach cabinet temperature.

Pollen tube measurements (ten tubes per dish) in micrometer units were taken at 1, 2, 3, 4, 12, 24, and 48-hour intervals in each of the dishes with a binocular microscope equipped with an ocular micrometer.

Random samples of four blossoms were taken from each treatment in each chamber at 4, 12, and 24-hour intervals and at daily intervals for five more days. The pistil of each blossom was crushed between two microscope slides, stained with Lacmoid-Martius yellow for two to five minutes as recommended by Nebel (38), mounted under a cover glass, and observed under a microscope for pollen tube growth in the style.

These branches were discarded after ten days as were the Redhaven branches on which the blossoms did not open properly.

On April 10, branches of Henderson and South Haven number 6 apricots were brought from South Haven and placed in containers of water. The South Haven apricot number 6 branches were placed in the greenhouse as described above. The Henderson branches were placed in a 35-degree F. cooler until April 13 when they too were placed in the greenhouse.

On the evening of April 16, the South Haven number 6 branches were in full bloom, and the pollen was collected in petri dishes from the flowers and allowed to air dry over-night at room temperature. The pollen was then placed in a two-ounce glass jar which was closed tightly and stored at forty degrees F.

On the morning of April 18, the blooms of the Henderson branches were in the balloon stage. They were emasculated and pollinated with South Haven number 6 pollen. The branches were cut in sections one or two feet long, and five sections were placed in each of three pint glass jars filled with water. One jar was placed in each of three peach ripening cabinets maintained at fifty, seventy, and ninety degrees F., respectively. One forty-watt fluorescent light was placed in each chamber. The lights were left on continuously because the temperature could not be maintained and properly regulated if they were turned off and on. Hygrothermographs were placed in each cabinet. The relative humidity was maintained between thirty and forty percent by placing number 10 cans of water with cloth wicks inside near the air circulation fan at the bottom of the cabinet.

Random samples of four pistils were taken from each cabinet at 12-and 24-hour intervals and daily for six more days. These pistils were crushed, stained with Lacmoid-Martius yellow, and observed under the microscope for pollen tube growth.

Pollen was placed in petri dishes on agar, in 15-percent sucrose solution, and in distilled water in each of the three chambers and in a sixty-degree F. refrigerated room. Observations of pollen behavior were made at the same time pistil collections were made.

Field Experiments at South Haven

On the morning of May 2 between 8:00 and 9:00 A.M., the blossoms on eight branches of two Henderson apricot trees at the Station were emasculated and then pollinated between 9:00 and 9:30 A.M. with South Haven number 6 pollen previously collected according to normal procedure.

At intervals of 4, 8, and 24 hours, and daily thereafter for three days, 12 to 24 pistils were collected at random from the Henderson branches. The pistils were crushed and stained with Lacmoid-Martius yellow as previously described, and the progress of pollen tube growth was observed under the microscope. Additional collections were made at unscheduled intervals when it was considered necessary to keep close watch on pollen tube growth

In addition to the above collections, pistils were also collected at one, two, three, four, and five days after full bloom from Perfection, South Haven number 6, and South Haven number 7 apricots at the Merkle Farm which were in full bloom some time on May 1. Pollen tube growth was observed in these pistils in the same manner.

On May 5 between 10:00 and 11:00 A.M. the blossoms on three Redhaven peach branches on a tree at the Merkle Farm were emasculated and then pollinated between 11:00 and 11:30 A.M. with Kalhaven pollen previously collected according to normal procedure. Pollen tube growth was observed in collected pistils for a period of 24 hours after which it was necessary to discontinue the observations. Temperature and humidity were recorded on a hygrothermograph during the observation period.

RESULTS

1957 Season

Laboratory Experiments

Laboratory experiments indicated that a polyethylene bag of the type used would usually give little or no frost protection. It was found that the temperature of the air inside the bag was quickly affected by changes in the outside air temperature. As the outside air temperature was lowered, the air temperature inside the bag changed accordingly. The same was true as the outside air temperature was raised. There was no appreciable lag in the rise or fall of the inside temperature (Figure 12).

Field Experiments

Bagging Technique

Relatively large branches with many buds could be enclosed in a two- by four-foot protector with comparative ease if done properly. The best procedure consisted of trimming off the tips of extremely long side branches and binding them closer to the main branch with cord. The protectors could then be slipped easily over the branch, closed, and tied tightly with several loops of cord around the branch at the top of the protector.

Damage to the protectors and materials inside was greatly reduced by a cord tied snugly around the outside of the protector at the center. If this was not done, the material inside, as well

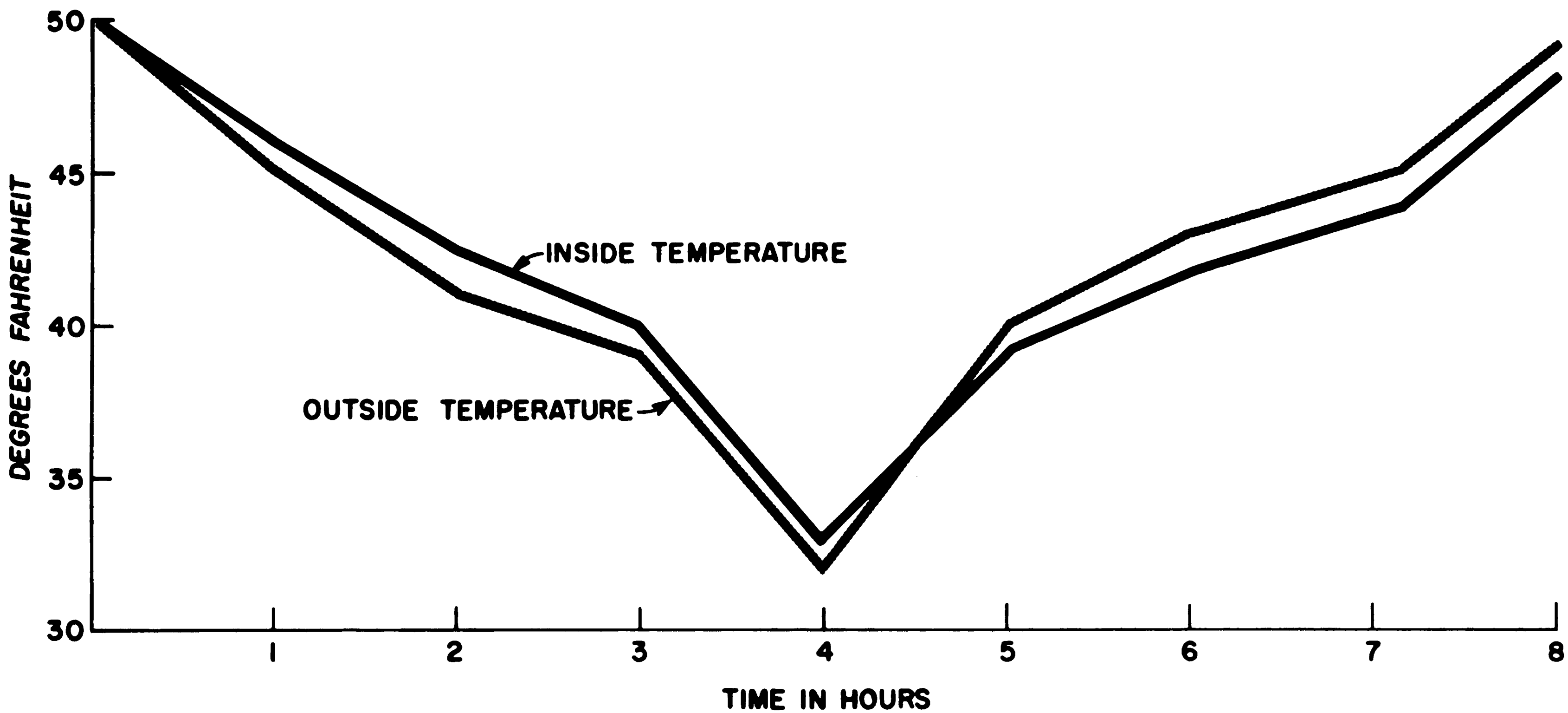

Figure 12. Fall and rise of air temperature inside a polyethylene bag as compared to outside air temperature in a controlled temperature chamber.

as the protector, was sometimes given a thorough thrashing by the action of the wind on the loose protector. This was especially damaging to the paper protectors during a rain storm.

Protector Durability

There was no damage to the polyethylene protectors during the course of any of the experiments.

The unwaxed parchment protectors were the next most durable as only three or four had to be replaced at the various locations. Rain had little effect on these protectors unless it was accompanied by strong, gusty winds, and even this damage was materially reduced if they were tied as described above.

The waxed parchment protectors were the least durable of the three and were sometimes extensively damaged by rain and an accompanying wind. This damage again was reduced if they were properly tied.

The lower durability of the waxed protectors was due to the fact that moisture seemed to soften the waxed paper so that it tore easily if buffeted by a wind. The damage was not great unless there was excessive wind along with the rain.

Humidity Inside Protectors

No satisfactory way of measuring relative humidity inside the protectors was available, but visual observations indicated that it was greatest in the polyethylene protectors followed by the waxed parchment with the unwaxed protectors having the lowest relative humidity. This is to be expected since this is the relative order of porosity.

Large amounts of condensate collected in low pockets of the polyethylene protectors. Less water collected in the polyethylene protectors in which slits had been cut for aeration. Although water did not collect in the waxed protectors, they were usually damp. No water collected in the unwaxed protectors. Since they were relatively more porous than the waxed parchment or polyethylene, they were usually dry.

Temperature in the Protectors

During the day, temperatures in all protectors were invariably higher than the outside air temperature as measured by thermocouples on control branches (Figure 13). This difference between the two temperatures was dependent on weather conditions. On one occasion when the weather was clear and warm, there was a difference of 28 degrees F. between the outside and inside temperatures of a polyethylene protector. The extremes, however, were not usually this great. On cool, cloudy days, the temperatures in the protectors were only two or three degrees F. warmer than outside temperatures. On warm, cloudy days, there was usually a difference of 10 to 15 degrees F. between the two temperatures.

The high extremes of the regular polyethylene protectors, and those with slits, were greatest and usually about the same. The high extremes of the waxed and unwaxed protectors were, on the average, about the same but usually four or five degrees F. lower than the polyethylene protectors and often a great deal more than this.

The average temperatures at the 3:00 to 3:30 P.M. readings were highest for regular polyethylene, followed by polyethylene with slits, with unwaxed parchment next, and waxed parchment coolest (Table 11). Table 12 gives a complete record of these readings.

As shown in Figure 13, all protector temperatures were lower at night than outside temperatures with the polyethylene protectors having the lowest minimum, followed by the waxed and unwaxed protectors which were about the same but about two degrees warmer than the polyethylene and still cooler than the outside temperature.

On frosty nights when air temperature dropped below 32 degrees F., the polyethylene protectors averaged about three degrees F. colder than outside temperatures; while the waxed and unwaxed protectors averaged two degrees F. colder than outside (Table 13).

In general, temperatures inside all protectors were higher than outside from about 6:00 A.M. until about 7:00 P.M. At this time the protectors cooled two or three degrees below outside temperatures and remained so until the next morning. This also occurred even though no plant materials were enclosed in the protector as indicated by the temperatures recorded in the empty protectors supported on poles at the Station where continuous temperature records were taken.

Effect of Protectors on Enclosed Branches

The weather during the first week of treatment was usually sunny and warm. The second week was sunny and cool, while the third week was cloudy and warm (Table 4).

TABLE 11

AVERAGE TEMPERATURES (DEGREES F.) 3:00 - 3:30 P.M. IN FOUR TYPES OF PROTECTORS AND RANGE OF TEMPERATURES (MERKLE FARM - 1957)

	Type of Protector				
	Polyethylene	Polyethylene with Slits	Unwaxed	Waxed	Control
Apricots	76**	--	73.3**	72.2	61.3
Range	53-100	--	52-95	53-98	48-82
(April 24-May 14)					
Peaches	75.6**	74.3	74.1	72.9	60.7
Range	61-95	61-99	61-94	63-91	44-77
(April 30-May 14)					

**Apricots -- Temperature in all protectors greater than on control branches at one percent level. Polyethylene greater than all treatments at one percent level. Unwaxed greater than waxed at one percent level.

Peaches -- Temperature in all protectors greater than on control branches at one percent level. Polyethylene greater than waxed at one percent level. Averages tested by analysis of variance and Duncan's multiple range tests.

TABLE 12

DAILY TEMPERATURES (DEGREES F. AT 3:30 P.M.) INSIDE THREE TYPES OF PROTECTORS* PLACED ON APRICOTS (APRIL 24 - MAY 13) AND PEACHES (APRIL 30 - MAY 13) AS COMPARED WITH OUTSIDE AIR TEMPERATURE 1957)

Date	Polyethylene	Polyethylene with slits	Waxed Parchment	Unwaxed Parchment	Control
			Apricots		
April					
24	75 75 74		75 74 74	73 73 76	61
25	82 90 80		84 73 84	80 75 84	65
26	-- -- --		-- -- --	-- -- --	--
27	53 55 53		54 53 53	54 53 52	48
28	77 85 77		82 72 82	81 76 81	63
29	86 93 82		92 78 88	86 78 91	68
30	93 99 87		98 83 89	93 82 94	72
May					
1	83 91 78		86 75 81	83 73 84	62
2	73 69 73		73 71 70	73 69 77	61
3	55 69 56		60 56 51	62 59 61	43
4	55 68 62		52 56 48	59 60 61	46
5	69 81 68		67 58 55	70 65 72	50
6	86 93 80		74 73 71	84 76 90	64
7	93 93 90		96 84 93	90 86 95	72
8	90 88 --		83 -- --	84 -- 94	80
9	-- -- --		-- -- --	-- -- --	--
10	67 65 66		67 65 67	63 59 68	56
11	68 72 71		68 69 68	66 68 70	62
12	-- -- --		-- -- --	-- -- --	--
13	75 76 75		76 76 75	73 72 74	70
			Peaches		
April					
30	93 88 84	86 86 96	94 83 89	89 87 90	71
May					
1	90 81 83	78 80 92	88 81 84	84 79 86	63
2	75 73 72	68 71 76	73 70 72	73 70 71	61
3	70 57 63	56 57 66	61 59 55	66 58 63	44
4	78 66 68	62 67 70	71 63 65	72 67 69	48
5	76 65 67	65 66 72	68 65 63	71 67 69	49
6	89 81 82	80 86 91	86 83 80	87 80 85	64
7	93 85 92	86 91 99	91 88 86	94 89 91	73
8	95 90 91	83 87 93	90 84 86	91 85 91	77
9	-- -- --	-- -- --	-- -- --	-- -- --	--
10	65 61 61	60 61 63	61 59 59	61 60 61	55
11	66 66 65	65 63 66	65 63 63	65 64 64	61
12	-- -- --	-- -- --	-- -- --	-- -- --	--
13	76 74 74	73 74 74	74 72 73	72 72 72	70

*Each figure represents the temperature in one protector.

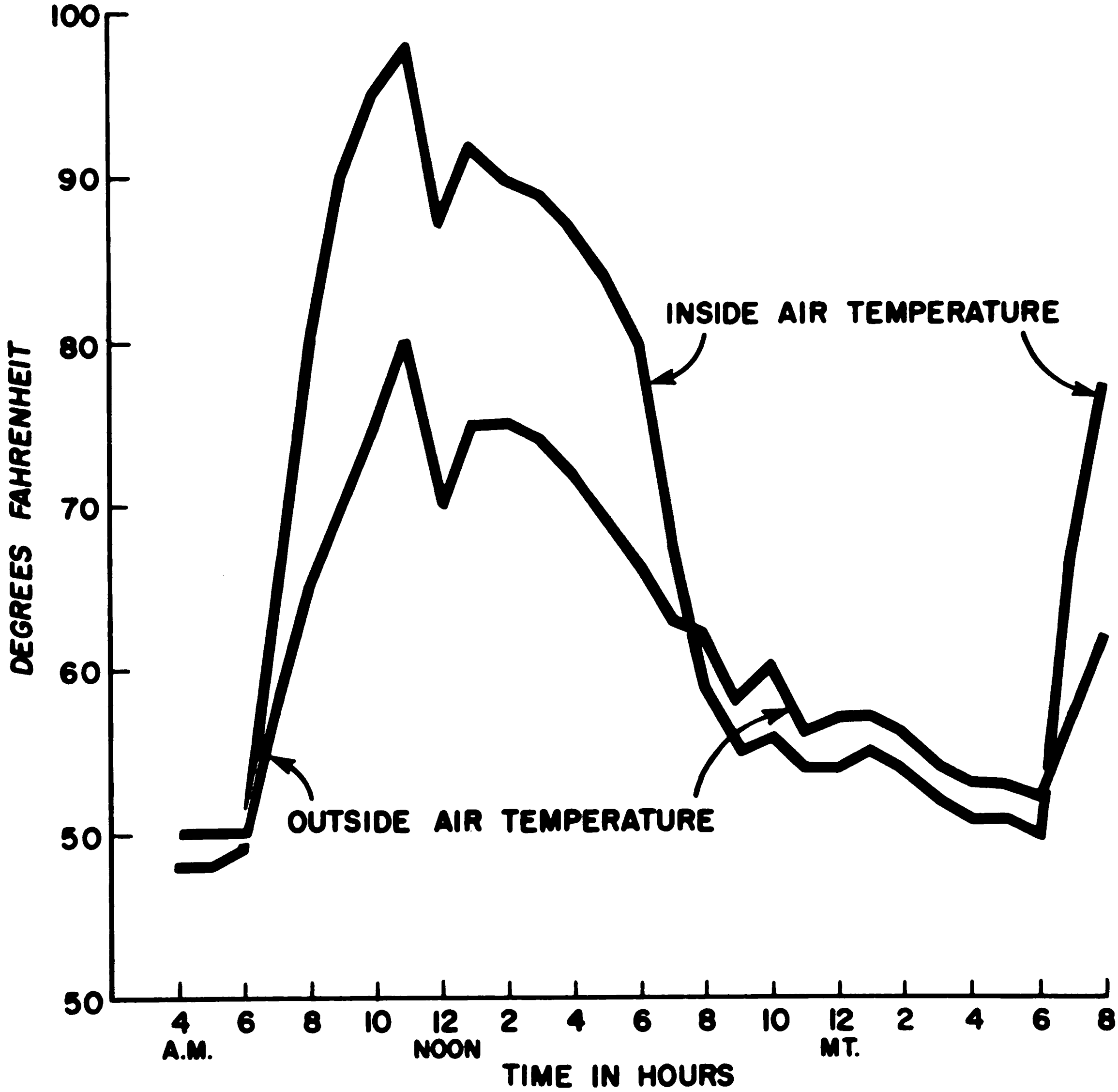

Figure 13. Average air temperature within protectors on apricot branches compared to outside air temperature over a 28 hour period (April 30, 4 A.M. to May 1, 8 A.M.). Protector air temperatures were consistently above outside air temperatures during the day and below outside air temperature during the night.

TABLE 13

AVERAGE TEMPERATURE* WITHIN THREE TYPES OF PROTECTORS ON PEACHES AND APRICOTS COMPARED WITH AIR TEMPERATURES BELOW 32 DEGREES F.

Type of Protector				
Polyethylene	Waxed Parchment	Unwaxed Parchment	Control	Thermometer Reading
28	29	29	32	31**
28	29	29	30.5	28
27	28	28	30	28
27.5	29	29	30.5	30
27.5	28.5	28.5	31	30
28.5	29	29	30.5	30
28	29	29	30	30

*Average of three protectors per treatment. Polyethylene protector temperatures were consistently lowest.

**Temperature readings in this column are usually lower than temperatures measured at approximately the same time by thermocouples on the control branches in the tree. This is because the thermometer was only four feet above the ground, at least four or five feet lower than the control branches or protectors in the tree.

Apricots

Effect on leaves. No adverse effects on the leaves were observed from any protectors except from the polyethylene left on three weeks (Figures 14, 15, 16, 17). In the case of polyethylene protectors left on for three weeks, the leaves were small, necrotic, and few in number as compared to untreated branches. This effect was noticeable for several weeks. The leaves on branches covered for only one week were normal.

The leaves produced on branches which were in the waxed and unwaxed protectors for three weeks were in excellent condition and were slightly larger and greener than those on control branches at the end of the treatment period (Figure 14) since they initially grew faster. These differences, however, disappeared in two or three weeks.

Effect on fruit. No adverse effect on the fruit itself was observed from any of the treatments. The fruit, however, generally developed faster and was initially larger than on control branches although the difference in size was not evident at the time of harvest.

Peaches

Effect on leaves. There appeared to be no damage to the leaves from any of the protection treatments. Branches were enclosed in all protectors for a period of two weeks. This period coincided with the last two weeks of the apricot treatment.

The leaves under the polyethylene appeared normal as compared to those on the control branches. The leaves under the waxed and

Figure 14

Effects of polyethylene protectors on apricot branches after three weeks (upper branch with tags) and waxed parchment after three weeks (lower branch with tags). Leaves in polyethylene protectors were necrotic, burned, and few; while those under waxed protectors (unwaxed also) were comparable to leaves on controls.

Figure 15

An apricot branch covered with polyethylene for three weeks (upper branch with tags) compared to a control branch (lower branch with tags).

Figure 14

Figure 15

Tagged apricot branches were treated with poly-ethylene (Figure 16) and waxed parchment (Figure 17) for one week. Leaves are comparable to control in Figure 15.

Figure 16

Figure 17

unwaxed protectors were larger and greener than the leaves on the control as was true for the apricots. The condition of the leaves in the unwaxed protectors even seemed to be slightly superior to those in the waxed protectors. These differences, however, were not noticeable after two or three weeks.

Effect on fruit. Peaches responded to the treatments in a manner similar to apricots. There was no apparent damage to the fruit. The fruit was initially larger on the treated branches than on control branches, but this was not evident at harvest time.

Fruit Set of Peach and Apricot Treatments and Controls

Apricots

Since preliminary observations indicated that fruit set might be improved if the protectors were not left on for an extended period of time, some of them were removed from the apricots at the Merkle Farm after one week.

Data for percentage of fruit set are presented in Table 14. There was no fruit set in the polyethylene protectors left on three weeks (Figures 18, 19) while there was a 29.9 percent set when these protectors were only left on one week as compared to a 41 percent set on unprotected control branches. The polyethylene treatment was still poorest of the three treatments, however. A 40.1 percent set of fruit was obtained in the waxed bags left on one week, and a 37.5 percent set of fruit was obtained in unwaxed bags. Almost no fruit was set in any of the bags left on the branches for three weeks.

TABLE 14

FRUIT SET OF APRICOTS (PERCENTAGE) -- MERKLE FARM 1957
(EACH FIGURE REPRESENTS FRUIT SET IN ONE PROTECTOR)

Type of Protector						
Polyethylene		Waxed Parchment		Unwaxed Parchment		Control
1 wk	3 wk	1 wk	3 wk	1 wk	3 wk	
33.0	0	44.1	1.0	39.6	7.7	13.0*
26.8	0	36.1	0.0	35.4	4.2	48.9
			10.8		5.9	45.6
			0.0			56.4
						41.2
			Average			
29.9**	0	40.1**	2.9	37.5**	5.9	41.0

*It is interesting to note this figure in the control column, as this was the only control branch in this experiment which was rained on immediately after its blossoms were pollinated (Figures 20, 21), (.70 inches of rain in four hours). This figure is only one-fourth that of most of the other figures in the column.

**Greater than three-week treatments at the one percent level but less than control although not significantly. Averages were tested by analysis of variance and Duncan's multiple range tests.

Fruit set (29.9 percent) on a branch of Perfection apricot (center foreground) which was covered with polyethylene for one week (Figure 18), and fruit set (none) on a branch which was covered with polyethylene for three weeks (Figure 19).

Figure 18

Figure 19

Fruit set (13 percent) on a control branch of Perfection apricot which was pollinated immediately prior to rain (center - Figure 20), and fruit set (46 percent) on a control branch pollinated 18 hours prior to rain (Figure 21) Merkle Farm - 1957.

Figure 20

Figure 21

At the Station all protectors were left on for three weeks. Data in Table 15 indicate that fruit set in the polyethylene protectors was extremely poor as was the case at the Merkle Farm.

In this experiment all controls received .70 inches of rain which commenced immediately after pollinations were completed and which lasted over a 16-hour period.

As at the Merkle Farm, fruit set in the waxed parchment was superior to other treatments, followed by the unwaxed parchment. Both were significantly better than the control. Fruit set in polyethylene was less than the control except in one case where it was equal to that on unprotected branches. It is difficult to explain this one case of relatively high fruit set in the polyethylene protectors (Table 15). Perhaps there was better aeration in this protector and less extreme conditions than in the other protectors of this treatment. Later experiments showed that fruit set was considerably improved in polyethylene protectors with slits in them as compared to protectors with no slits (Table 16).

Peach Fruit Set (Merkle Farm -- 1957)

The percentage of fruit set on branches covered for a period of two weeks is presented in Table 16.

Polyethylene protectors, as with the apricots, reduced fruit set. Fruit set was improved considerably in the polyethylene treatment by making two slit-holes in each protector, but it was still slightly lower than the control. Fruit set in the waxed protectors was superior to the control, but not enough to be significant.

TABLE 15

FRUIT SET OF APRICOTS (PERCENTAGE) -- STATION 1957 (EACH FIGURE REPRESENTS FRUIT SET IN ONE PROTECTOR)

Type of Protector			
Polyethylene	Waxed Parchment	Unwaxed Parchment	Control
15.5	46.3	42.8	15.5
2.3	20.9	15.0	11.7
0.0	18.0	36.6	8.0
0.0	38.1	32.6	10.0
0.0	46.6		15.4
			4.0
			9.7
			14.3
			12.5
	Average		
3.7	33.9*	31.7*	11.1

*Greater than the control at the one-percent level.

TABLE 16

FRUIT SET OF PEACHES (PERCENTAGE) -- MERKLE FARM 1957 (EACH FIGURE REPRESENTS FRUIT SET IN ONE PROTECTOR)

Type of Protector				
Polyethylene	Polyethylene with Slits	Waxed Parchment	Unwaxed Parchment	Control
0.0	11.0	20.3	24.8	10.0
0.0	3.3	16.5	32.6	5.2
0.0	8.5	7.8	30.9	7.5
4.6	5.9	9.2	11.2	8.3
3.0	5.2	10.1	25.0	9.2
		Average		
1.5	6.8	12.8	24.9*	8.4

*Significantly greater than control and all other treatments at the one percent level.

1958 Season

Laboratory Experiments

Chambers with controlled temperatures were employed again in 1958 to determine the insulating properties of three new materials not tested in 1957 (bag of blanket insulation, multi-layered double paper bag, nursery paper bag). The nursery paper was not used in field tests because it was found to be too difficult to construct.

The tests indicated that these bags might give some frost protection but that the amount of protection would be negligible unless there was a heat source inside the bag. In one experiment, nine pounds of apples were suspended in the bags to serve as a heat source. The apples would evolve from 1 to 1.5 B.T.U. per pound per 24 hours (48).

The results for two of the bags are illustrated graphically in Figures 22, 23, 24, and 25. If apples were inside the blanket type insulated bag, it retained enough heat to be six or seven degrees F. above outside temperature under these particular conditions. Under the same conditions, however, the nursery paper bag was only about two degrees F. above outside temperature. Without the heat source, inside and outside temperatures for both bags were within a degree of each other.

The graphs also illustrate that the inside temperature dropped steadily with outside temperatures, and there were no lags and sudden declines under the temperature range of this test.

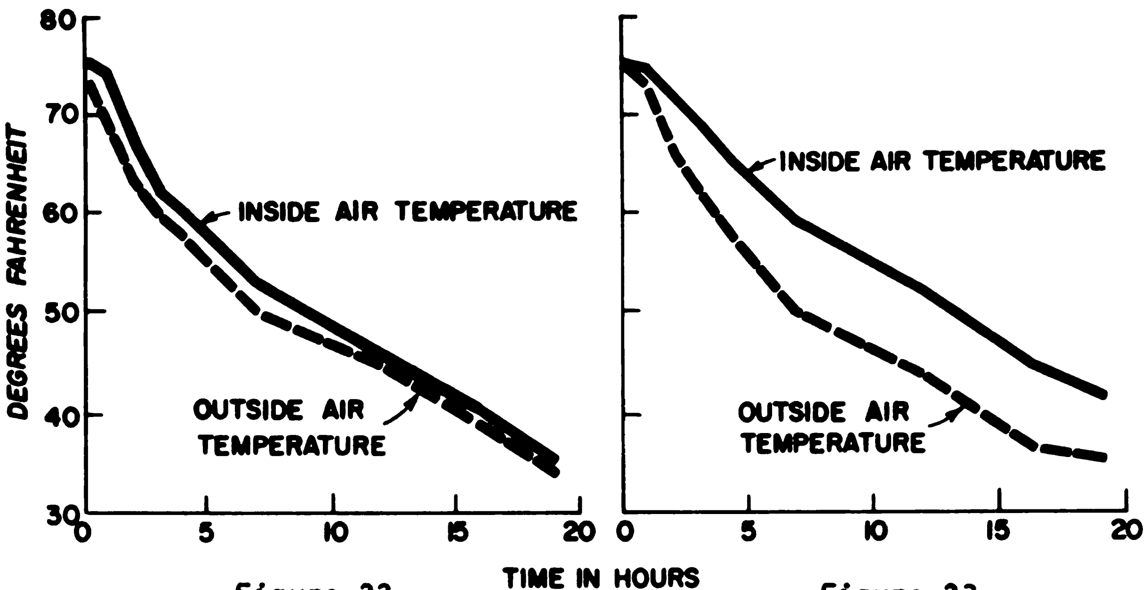

Figure 22 *Figure 23*

A comparison of air temperatures inside a blanket type insulated bag with outside air temperature. In Figure 23 apples were placed inside the bag for a heat source.

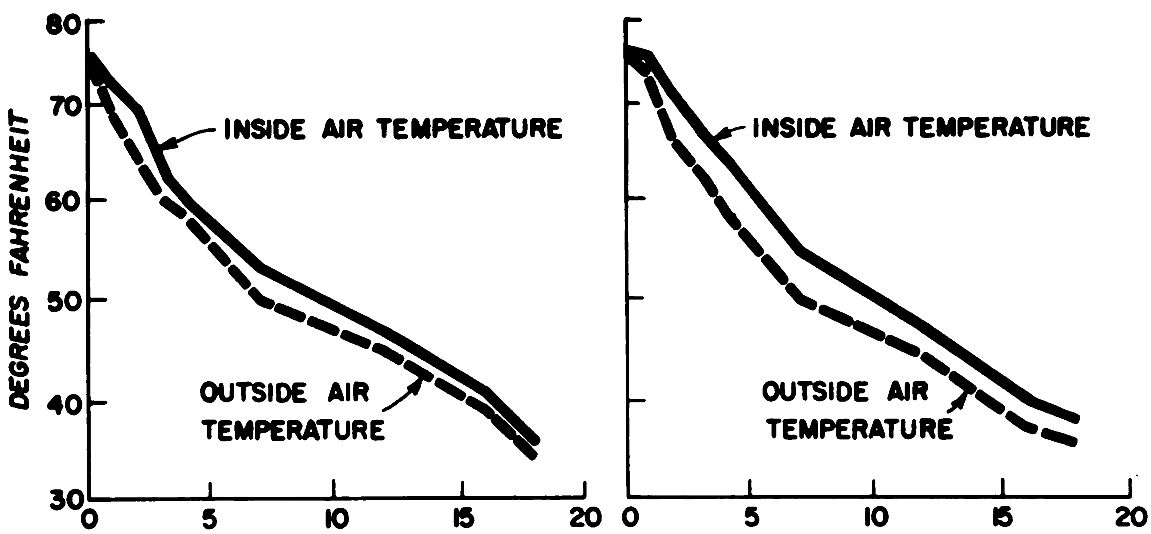

Figure 24 TIME IN HOURS *Figure 25*

A comparison of air temperature inside a nursery paper bag with outside air temperature. In Figure 25 apples were placed inside the bag as a heat source.

Field Experiments

All protectors (polyethylene, waxed, and unwaxed parchment) tested in the field in 1957 were tested again in the field in 1958. These protectors, however, were only left on for five days immediately following pollination. They were then removed, and the frost bags described above and in the procedure section were put on one group of branches when frosts were predicted. These bags will be referred to as "frost protectors".

Effect of Polyethylene, Waxed and Unwaxed Parchment Protectors on Enclosed Branches

No effect on the leaves was observed from any of the treatments. No adverse effect on the apricot fruit was observed at the Merkle Farm from any of the protectors which were removed on May 24. However, polyethylene protectors were employed on some trees of the regular breeding work next to the trees of this experiment. These protectors were left on one day longer, and all young, developing fruits were frozen on the morning of May 25 when the temperature reached a low of 27 degrees F. at the Merkle Farm. Fruit which was not covered by polyethylene protectors was not harmed.

Two frosts occurred at the Station while the protectors were still on the branches. These occurred three and four days after pollination on the mornings of April 25 (thirty degrees F.) and April 26 (29 degrees F.) When the protectors were removed on April 28, it was apparent that the young fruits had been damaged by frost since many were black and water soaked. The fruits under

the polyethylene protectors appeared to be damaged most severely while there was less damage under the paper protectors. The uncovered branches did not show signs of injury.

In the case of the peaches, the protectors left on the branches during the five days immediately following pollination did not cause any apparent damage to the fruit. No frost occurred while these protectors were on.

Influence of Frost Protectors on Temperature

Three types of frost protectors -- bag of blanket insulation, multi-layered double paper bag, and black polyethylene - aluminum foil -- were tested during two cold nights. The recorded temperatures indicated that little or no frost protection was provided by any of them. Consequently, the fiber-glass protectors described under procedure were constructed and used during subsequent cold nights along with the other protectors.

During the coldest night of the season (25 degrees F.), temperatures inside the fiber-glass protectors were two or three degrees higher than outside. The black polyethylene - aluminum foil protectors provided no protection, and temperatures inside the blanket and multi-layered paper protectors were lower than outside. After this date, there was only one cold night during which time the fiber-glass protectors were cooler than control temperature (Table 4). Because of this difference in results on only two cold nights, no definite conclusion can be drawn as to the value of this type of bag for frost protection .

Effect of Frost Protectors on Peaches and Apricots (Merkle Farm)

The heavy frost on the morning of May 7 killed many of the young fruits both inside and outside the protectors. However, fruits under many of the frost protectors were killed which would have survived if the protectors had not been on, since inside temperatures were lower than outside by two or three degrees.

Data on fruit set and temperatures within the protectors are presented in Tables 17 and 18.

Fruit Set in Polyethylene, Waxed, and Unwaxed Protectors

In 1958, fruit set of apricots in the protectors at the Merkle Farm was the same as the previous season. It was best under the waxed parchment followed by the unwaxed parchment with the polyethylene poorest as usual. These results were the same, both for preliminary counts (May 8), made because of the heavy frost, and for the final counts (May 23). Table 19 gives fruit set figures for both dates.

The greatly reduced fruit set observed on the later date was not all due to frost. The figures were higher for the first date because of difficulty in making accurate determinations so soon after pollination.

At the Station, fruit set of apricots under the polyethylene, waxed, and unwaxed protectors (Table 20) followed the same trend as found at the Merkle Farm, but the differences were more pronounced. This was also true in the 1957 season (Figure 29).

TABLE 17

A COMPARISON OF AVERAGE* TEMPERATURES (DEGREES F.) INSIDE FROST PROTECTORS RECORDED DURING SEVERAL COLD NIGHTS

Type of Protector					
Fiber-glass	Blk. Poly. Al. Foil	Double Paper Bags	Blanket Insulated	Control Temp.	Thermometer Temperature
-	30.5	30.5	30	30	30
-	29.5	29	28.5	28.5	28.5
-	29	29	28	29	29
-	35	34.5	33.5	35	35
35	34	32.5	32	35	34.5
30.5	29	26.5	25.5	28	25.5
30	28.5	26	25	28	25
32	31.5	31	31.5	33.5	32
32	32	31.5	31	33.5	32

*Extremes were only ± one degree F. from average.

TABLE 18

AVERAGE* FRUIT SET (PERCENTAGE) UNDER FROST PROTECTORS - APRICOTS AND PEACHES (MERKLE FARM - 1958)

	Fiber-glass	Blk. Al.	Poly. Foil	Double Paper Bags	Blanket Insulated	Control
Apricots	17.6	14.6		1.1	0	10.1**
Peaches	23.6	12.1		15.6	8.5	18.6**

*Three protectors.

**Average of all branches not covered with frost protectors after removal of polyethylene, waxed, and unwaxed parchment protectors. None of the values in this table are significantly greater than the control.

TABLE 19

FRUIT SET (PERCENTAGE) OF APRICOTS AT THE MERKLE FARM IN 1958 AT PRELIMINARY AND FINAL COUNT DATES (BRANCHES NOT COVERED WITH FROST PROTECTORS)

	Type of Protector			
	Polyethylene	Waxed Parchment	Unwaxed Parchment	Control
Preliminary Counts May 8	42.4	62.2	54.3	54.6
	27.7	56.3	42.8	28.6
	31.9	69.7	36.9	54.7
				38.3
Average	34.0	62.7*	51.3	44.0
Final Counts May 23	5.4	35.5	4.3	1.3
	5.5	10.9	0.0	8.6
	16.7	44.5	8.6	9.5
				8.4
Average**	9.2	16.8	4.3	6.9

*Greater than control at five-percent level.

**None significantly greater than control.

TABLE 20

FRUIT SET OF APRICOTS (PERCENTAGES) FOR TWO DIFFERENT POLLINATION DATES -- STATION, 1958

	Type of Protector			
	Polyethylene	Waxed Parchment	Unwaxed Parchment	Control
April 22	0.0	11.2	15.3	3.4
	1.4	22.3	8.2	8.1
	1.1	8.9	24.4	8.0
	0.0	12.3	3.2	0.0
	1.4	19.4	2.1	1.1
Average	.8	14.8	10.8	4.1
April 23	0.0	12.7	3.6	.0
	2.4	7.3	5.1	0.0
	2.2	16.4	7.5	0.0
Average	1.5	12.1	5.4	0
Average of both days	1.1	*13.4**	8.1**	2.1

*Greater than unwaxed at five-percent level.

**Greater than control at one-percent level.

Fruit set under the polyethylene protector was very poor, while it was best in the waxed protector. The 8.1 percent fruit set in the unwaxed protector was significantly higher than that in the polyethylene but significantly lower than in the waxed protector (Figures 26, 27, 28).

Fruit set of peaches in the polyethylene, waxed, and unwaxed protectors followed the same trend as the previous season (Figure 29). Fruit set in the unwaxed protectors was significantly better than for the other treatments, while it was very poor in the polyethylene protectors. Although fruit set in the waxed protectors was better than in the polyethylene, the difference is not significant statistically. See Figures 30, 31, 32, 33, and Table 21.

TABLE 21

FRUIT SET OF PEACHES (PERCENTAGE) -- MERKLE FARM, 1958

Type of Protector			
Polyethylene	Waxed Parchment	Unwaxed Parchment	Control
0.0	8.8	18.4	13.0
0.0	25.9	27.8	17.0
27.3	11.5	32.9	7.0
1.5	27.6	40.3	8.4
	Average		
7.2	18.7	29.8*	11.3

*Greater than control at five-percent level.

Typical fruit set in 1958 on Henderson apricot branches which were protected by waxed parchment (13.4 percent -- Figure 26) and unwaxed parchment (8.1 percent -- Figure 27). Fruit set on control (2.1 percent -- Figure 28). Fruit set on a polyethylene branch (1.1 percent) is not shown.

Figure 26

Figure 27

Figure 28

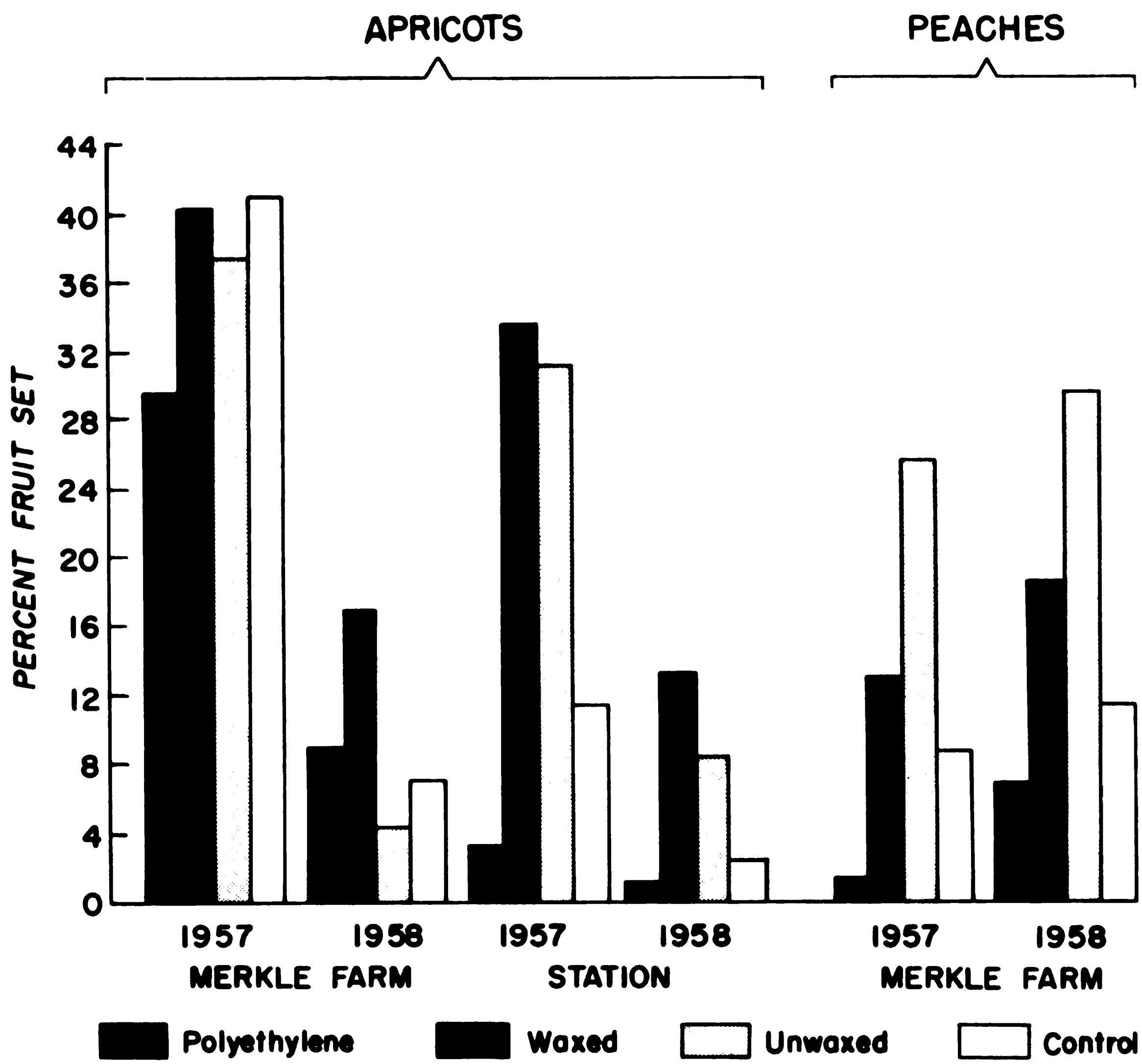

Figure 29. A comparison of average fruit set from 3 types of protectors and control.

Typical fruit set in 1958 on Redhaven peach branches covered by unwaxed parchment (29.9 percent -- Figure 30), waxed parchment (18.7 percent -- Figure 31), and polyethylene (7.2 percent -- Figure 32). Fruit set on control branch (11.3 percent -- Figure 33).

Figure 30

Figure 31

Figure 32

Figure 33

1959 Season

Laboratory Experiment -- Pollen Tube Growth

Only an occasional pollen tube could be found from Henderson pollen placed in distilled water, and these tubes protruded only slightly from the pollen grain. At eighty and ninety degrees F. pollen on agar or in sucrose solution began to germinate in less than one hour. Two, 3, 12, and 24 hours were required at 70, 60, 50, and 45 degrees F., respectively for pollen to begin germinating (Figure 34). Tube growth was initially most rapid at eighty degrees F., but after 12 hours the tubes growing at seventy degrees F. were slightly longer and after 48 hours were much longer than tubes at eighty degrees F. or any other temperature.

After 48 hours pollen tube length was greatest at seventy degrees F. and decreased in the following order: 80, 60, 50, 45, and 90 degrees F., respectively (Figure 34). Although germination was rapid at ninety degrees F., the tubes extended only a short distance from the pollen grain. Random observations indicated that germination percentages were best at seventy degrees F. and poorer at higher or lower temperatures.

Pollen grain and tube bursting on agar was greatest at ninety degrees F. and decreased as the temperature was lowered over the range of the experiment. Only an occasional grain or tube burst at 45 or 50 degrees F.

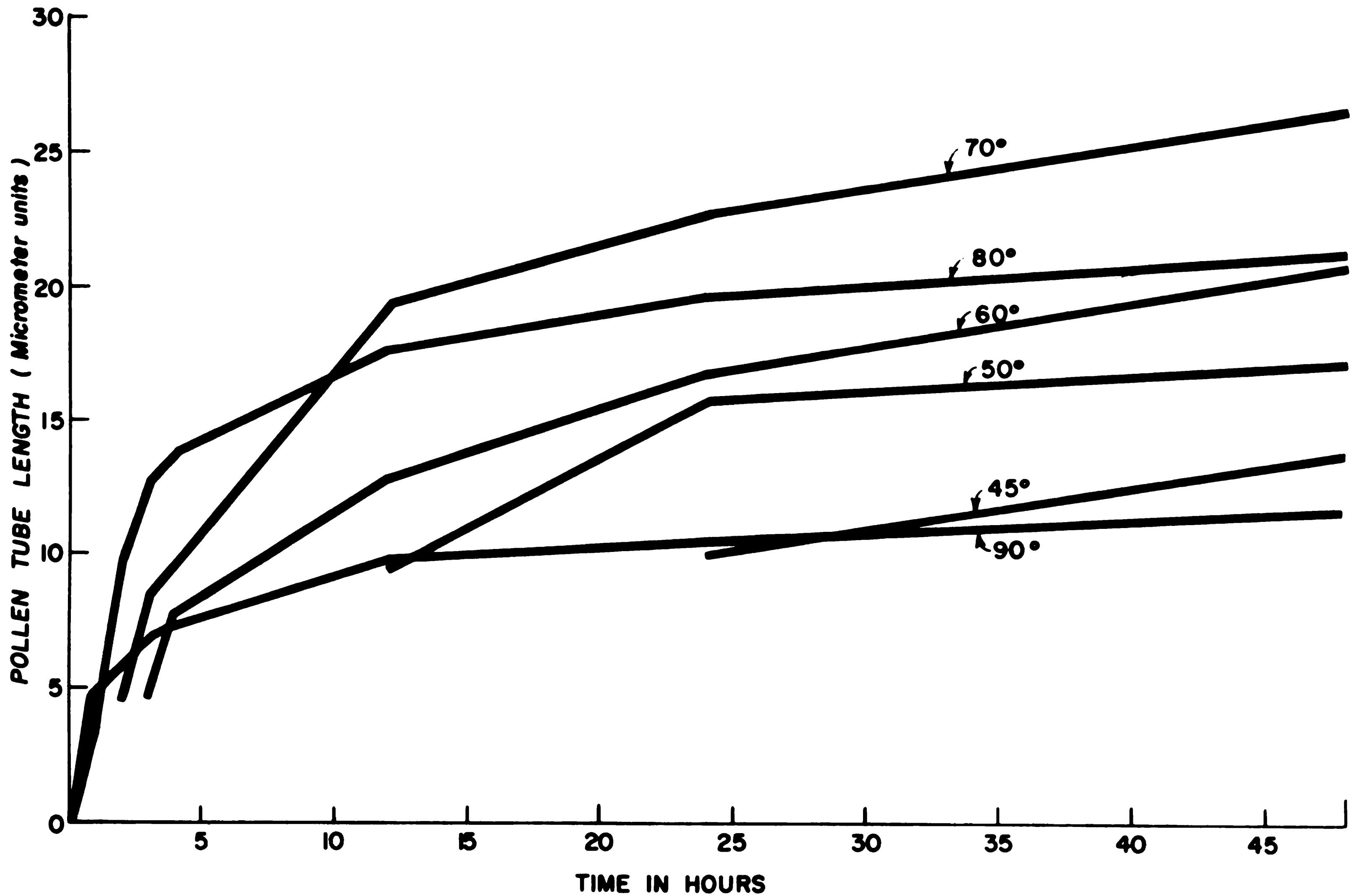

Figure 34. *Average (10 tubes) growth of pollen tubes on 2% agar in 15% sucrose solution. Growth measured in micrometer units at six temperatures over a 48 hour period.*

South Haven number 6 pollen did not germinate in distilled water and did not grow well in either of the other two media used.

Only on two occasions were pollen tubes found in any of the pistils grown at controlled temperature and humidity; consequently, it was not possible to determine the effects of these two factors on pollen tube growth in the styles of flowers on excised branches.

Field Experiments at South Haven

Apricots (Perfection, South Haven number 6 and 7): At one day after full bloom most of the pollen tubes were between one-fourth and one-third (four to six millimeters) of the distance down the style with occasional tubes slightly ahead of the others.

At two days after full bloom, most pollen tubes were one-half to three-fourth (10 to 14 millimeters) of the distance down the style; while at three days after full bloom, they had covered seven-eighth (about 18 millimeters) of the distance with occasional tubes being traced to the ovary.

At four days after full bloom, many tubes could be traced into the ovary, but it was difficult to follow them very far since all of the ovary on both sides of the style had to be cut away so as to leave only a thin section which could be crushed and observed. Large numbers of tubes could be seen in all varieties, but they seemed to be less abundant in South Haven number 6.

Apricots (Henderson): At eight hours after pollination, a few pollen grains were germinated with tubes just slightly protruding from the grain. At one, two, and three days after pollination,

the bulk of the tubes were respectively one-fourth, one-half, and three-fourth (about 4, 9, and 14 millimeters) of the distance down the style. At 4½ days, many tubes could be traced into the ovary.

Many tubes were also visible in the styles of the Henderson variety, but they were much less abundant than in the varieties which were allowed to open-pollinate.

Peaches: At eight hours after pollination, the pollen was only beginning to germinate; while at 24 hours many tubes could be found one-fourth (two or three millimeters) of the distance down the style. Observations indicated that peach pollen tubes would take about the same amount of time to reach the ovary as did the apricot pollen tubes.

The relative humidity and temperature record for the seven-day period following pollination of the apricots is shown in Figure 35.

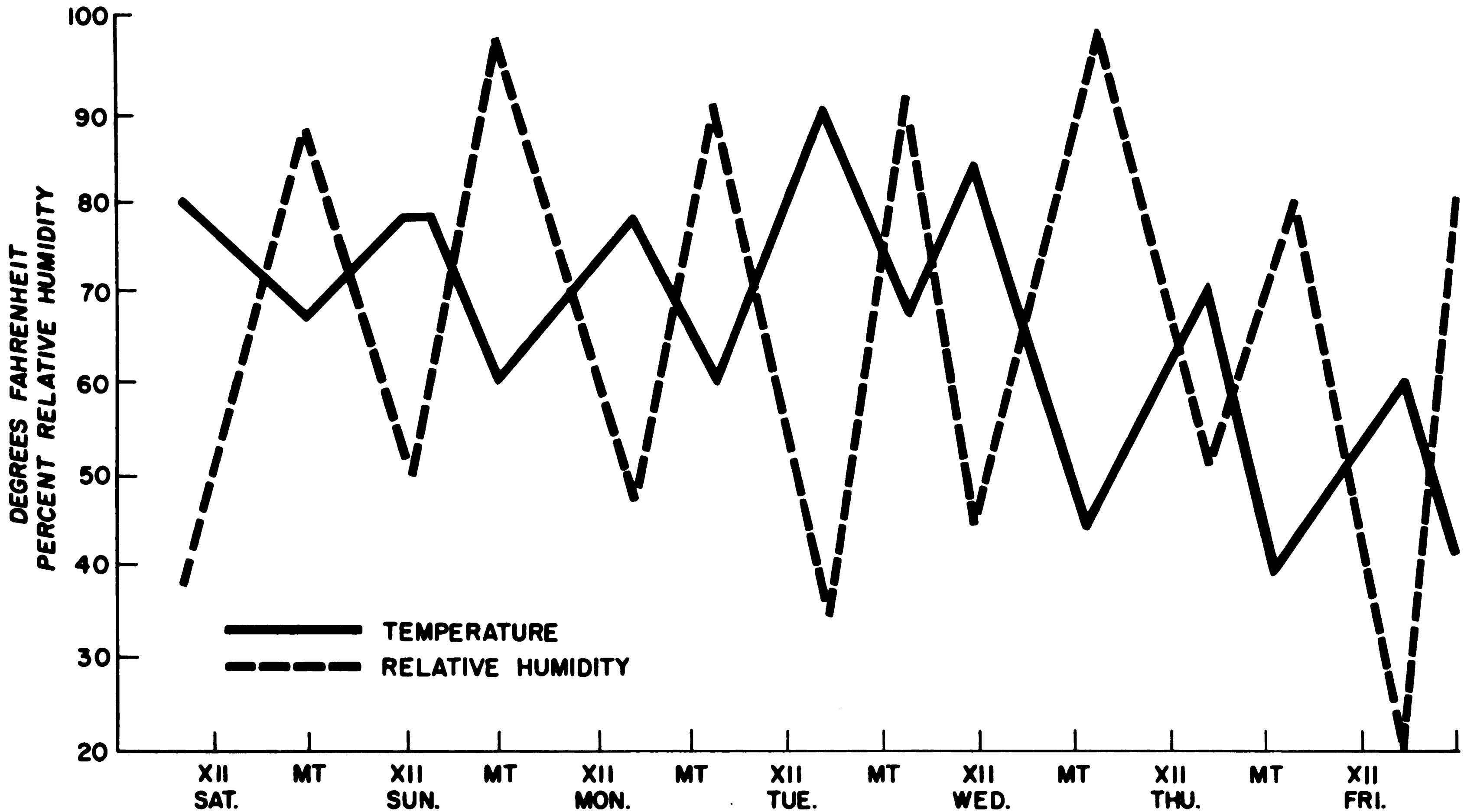

Figure 35. Relative humidity and temperature record for the period of May 2, 9:00 A.M. to midnight May 8, 1959.

DISCUSSION

Temperature within the Protectors

The 1957 and 1958 laboratory experiments indicated that the air temperature within the protectors tested would be slightly above outside air temperature as the temperature was lowered and after it had reached a minimum. However, this was not observed in the field where the inside temperature was lower at night than outside air temperature at comparable levels in the tree.

This lower-than-air-temperature phenomenon has been reported by Gardner, et al. (18) and Geiger (20) to be a common occurrence at night for plants and other objects. They indicated that objects constantly absorb and emit heat and that after the sun sets, the amount of heat emitted may be in excess of that absorbed. As a result, the temperature of certain objects may become lower than that of the surrounding air which transmits the heat lost by the object.

The results of these experiments agree with observations reported by Geiger (20). As shown in Figure 13, the inside temperature was higher during the day and lower during the night than outside temperature.

The probable reasons for differences in results in the field and in the laboratory were that, in the field, heat was radiated to the wide expanse of open sky and the atmosphere. In addition,

air movement and relative humidity were not the same under both sets of conditions.

If the source of heat inside the protectors was great enough and if the insulation properties of the materials were adequate to retain this heat, the inside temperature could be maintained above outside temperature and some frost protection would be provided. These conditions, however, were not attained in the field. Inside temperatures above those outside, during periods when night temperatures were below 32 degrees F., were not observed except on one occasion. This occasion occurred in the case of the fiberglass frost protectors the first night they were used, but not thereafter. This probably was due to moisture absorption after one night's use which increased heat conduction thereafter. The insulation properties of the other protectors were not sufficient to retain any heat.

Fruit Set

After the first year's study, the polyethylene, waxed, and unwaxed protectors were used for only five days immediately following pollination to improve fruit set. This was done because observations showed these protectors would give no frost protection and that longer use during warm weather might be detrimental. In every experiment, except in the case of the apricots at the Merkle Farm in 1957 and 1958, the fruit set in the waxed and unwaxed protectors was superior to fruit set on the control branches, while fruit set under polyethylene was inferior.

In 1957 at the Merkle Farm, some protectors were left on the apricots for only one week. During this period weather conditions were nearly ideal, from a commercial standpoint, for fruit setting. As a result there was no benefit from bagging. In addition, some protectors were left on three weeks. This was especially detrimental to fruit set which was probably, in part, due to abnormally high day temperatures (frequently ninety to one hundred degrees F., see Table 12) in the protectors during this extended period of time. A number of investigators working with various types of plants have reported detrimental effects of high temperature on fruit set (8, 28, 33, 43). In addition to high temperature, two frosts occurred during which the temperature was low enough to freeze many of the young fruits in the bags, but those on the outside were unharmed.

In 1958 at the Merkle Farm, fruit set of apricots in the unwaxed protectors was inferior to the control. Since preliminary fruit set counts indicated this treatment should have been second only to the waxed treatment, these fruits must have been more susceptible to the 25-degree F. temperature which occurred on the morning of April 30 after all protectors had been removed.

In addition to the above observations, it was found that apricot fruit set in the waxed parchment protectors was, without exception, superior to other treatments and, except as mentioned above, significantly better than the control. In contrast, peach fruit set in the unwaxed parchment was superior to other treatments and always significantly better than the control.

Fruit set for the apricots was much poorer in 1958 than in the previous year. This was due primarily to the weather which was rainy and cold for ten days following pollination. Since apricots are very sensitive to weather conditions during the time of bloom and fruit setting, poor weather may frequently mean an almost complete loss of fruit.

Fruit set of peaches was slightly better in 1958 than in the first season. The protectors were probably left on too long (two weeks) in 1957. The weather during both seasons was cool and windy following pollination and unfavorable for a high percentage fruit set.

A definite explanation for peach fruit set being better in unwaxed parchment than waxed protectors and apricot fruit set being better in waxed parchment than unwaxed cannot be offered. Possibly the higher temperature (Table 11) and lower humidity in unwaxed protectors favored fruit set of peaches. On the other hand, the apricots may have been favored by the lower temperature (Table 11) and higher humidity in the waxed protectors. However, no direct evidence has been found for these observations.

<u>Beneficial Effects of Waxed and Unwaxed Protectors</u>

These materials provide a micro-environment which is favorable for fruit set in the following ways.

1. Protection of the exposed pistils from rain. The results of the apricot experiments showed that rain shortly after pollination may be very effective in reducing fruit set (Tables 14, 15, 20). In those tables, figures are given from control branches

which were rained on immediately after pollination (Tables 14 and 15), three hours after pollination (Table 20 -- April 23), and 18 hours after pollination (Table 14). In every case where this occurred, except at 18 hours, fruit set was reduced regardless of whether the temperature was warm or cool.

About eight hours are required for apricot pollen to begin germinating. Microscopic observations indicated that pollen is easily floated off the pistils with a drop of water before the pollen has germinated. A continuous rain for a few hours or a short heavy rain would, undoubtedly, be very effective in washing off a high percentage of the pollen grains present. Even though all pollen grains were not washed off, the probability of fertilization would be materially reduced. In addition to the washing away of pollen, rain may dilute stigmatic secretions (25, 47) and delay pollen germination. Several hours delay in germination can cause a reduction in the number of pistils fertilized.

Laboratory observations indicated that rain would probably cause little pollen bursting since very few apricot pollen grains burst when placed in petri dishes with water. However, it is conceivable that germination may be reduced after extended periods of rain (21, 39).

2. Higher day temperatures during cold periods. Since many investigators have reported delayed pollen germination and slow pollen tube growth during periods of cool temperatures (14, 25, 32, 37, 44, 47), any increase in temperature will be likely to increase the probability of fruit setting. During cool, clear days, the

increase in temperature provided by the waxed and unwaxed protectors may be five to ten degrees F. Even on cloudy days, the increase in temperature may be four to five degrees F. Higher inside temperatures were probably very important in increasing fruit set in peaches and apricots during both years. During periods of warm weather, the very high temperatures created inside the protectors may have been detrimental. Several investigators have reported detrimental effects of high temperature on fruit set (8, 12, 28, 33, 43).

3. Wind protection. A number of investigators have indicated that drying winds cause stigmatic secretions to evaporate and dry prematurely, thus preventing pollen germination (14, 19, 25, 47). The protectors entirely eliminated this hazard by providing protection from the wind in addition to providing humidity. Protection from wind was probably also very important in increasing fruit set in peaches and apricots during both years.

Since most of the pistil is exposed after emasculation and subjected to the effects of adverse weather, any one or all of the above benefits may be very important in increasing fruit set, especially when the weather is unfavorable for fruit setting.

Pollen Tube Growth in Vitro

Of the temperatures tested, Henderson pollen germinated most readily, and the pollen tubes grew most rapidly during a 48-hour period at seventy degrees F. Both germination and pollen tube growth were decreased at higher or lower temperatures. The tubes became too long and entangled to measure growth over a longer period of time. Also, the cultures became contaminated with mold.

Little bursting of pollen was observed in distilled water which would indicate that rain probably is not much of a factor in reducing set from this cause.

Although seventy degrees F. was optimum for apricot pollen germination and tube growth in culture, this does not necessarily mean that seventy degrees F. would be optimum in the field. The temperature requirement in the field would, undoubtedly, be affected by conditions within the pistil. These conditions are not present in vitro. However, the optimum observed in the laboratory does show that temperature is important in governing pollen tube growth and that extremes one way or the other are unfavorable.

None of the media used seemed to favor germination and growth of South Haven number 6 pollen although it appeared to be normal. Since media requirements for pollen growth differ widely for various crops, this was not surprising.

<u>Pollen Tube Growth in the Style</u>

Temperature and humidity seemed to be important factors with respect to fruit setting in the various micro-environments obtained in the field. As a result, an attempt was made in 1959 to show the effects of certain ranges of temperature and humidity on pollen tube growth in the style. This was done by subjecting excised branches to artificial environments so as to determine the effects of temperature and humidity on the time between pollination and fertilization. It was especially desirable to determine this period of time for apricots since almost no information can be

found in the literature about these early stages of development in this crop. More information can be found for peaches, but there appears to be no general agreement about the time interval between pollination and fertilization since the conditions were obviously different with each investigator.

As described earlier these attempts with apricots failed. No definite explanation for this can be given but such factors as insufficient water supply, constant temperature, possible immaturity of male or female parts, and the extremely artificial environment to which the branches were subjected were, no doubt, important.

In addition to the laboratory tests, observations were made under field conditions to demonstrate the approximate time between pollination and fertilization. As stated earlier, the time between pollination and fertilization was determined to be about four days for apricots and approximately the same time was determined for peaches. The day temperatures during the period when the above observations were made were usually in the high seventies, and night temperatures were in the sixties. At slightly lower temperatures, the time between pollination and fertilization might have been shorter although no direct evidence of this was obtained.

The time between pollination and fertilization found for peaches agreed with that reported by Harrold (22) for Carman peach but was longer than stated by Connors (10) and shorter than that stated by Lombard (34) for Redhaven peaches but nearly intermediate between the two reports.

As stated above no reference was found in the literature concerning the period between pollination and fertilization in apricots.

Duration of Protection by Polyethylene, Waxed, and Unwaxed Protectors after Pollination

The experiments indicated that during extremely good weather bagging may not be necessary. Since unexpected rain may occur, however, the branches should probably be covered for the first 12 to 24 hours following pollination. Under average conditions, some benefit may be attained by providing a micro-environment for three or four days as this is the approximate time required for fertilization. If the weather should be cool, one or two days longer may beneficial; but it does not seem probable that more than five days (as used in 1958) would be needed.

If frosts are predicted, these protectors should be removed, because the inside temperatures may be colder at night than outside temperatures. Late spring frosts are often just on the borderline of that which will kill peach and apricot pistils. The one or two degrees F. lower temperature inside the protectors may be just sufficient to kill many of the pistils and young developing fruits.

Use of Frost Protectors

Since most of the frost protectors used were conducive to lower inside than outside temperatures and the others gave no consistent increase in temperature, no definite conclusions can be drawn as to any possible benefits which might be attained from this type of bag.

The probable reason for failure of these bags to maintain higher inside temperatures is that the source of heat inside was insufficient to provide any lasting effects. If a better material or means of construction could be found, this type of protector might be of some value. Some source of inside heat might also prove to be useful.

SUMMARY

1. Before field experiments were conducted in 1957 and 1958, laboratory studies were carried out to investigate the potential value of several types of bags as frost protectors.

a. In 1957 the experiments indicated that a two- by four-foot polyethylene bag (.003) would give little or no frost protection since the inside temperature would only be about one degree F. above outside temperature when the latter was lowered to 27 degrees F.

b. In 1958 the experiments indicated that a bag made of nursery paper would give little frost protection even with nine pounds of apples inside as a heat source. However, the results indicated that a bag made of blanket type insulated material (described under procedure) would probably give four or five degrees of frost protection if nine pounds of apples were suspended inside as heat source, but not otherwise.

2. Field experiments designed to increase fruit set of emasculated and hand-pollinated apricots and peaches were conducted in 1957 and 1958 by using two- by four-foot bags made of .003 polyethylene, waxed parchment paper, and unwaxed parchment paper. These bags were placed over large branches immediately after pollination and left on one or three weeks for the apricots and two weeks for the peaches in 1957. In 1958, these three types of bags were all on for five days.

At the Merkle Farm, temperatures were taken in these protectors by means of thermocouples during the coldest periods of nights when frosts occurred and between 3:00 and 3:30 P.M. (generally the warmest period of the day at South Haven). At the Station continuous temperature records were taken for about four days in two each of these protectors by the use of a continuous recording potentiometer.

It was discovered that inside temperatures in all protectors were colder at night and warmer during the day than outside air temperatures with the extremes being dependent on weather conditions.

a. In 1957, apricot fruit set was not increased at the Merkle Farm by the use of any of these protectors. If the protectors were left on for three weeks, fruit set was considerably reduced. This was concluded to be due to prolonged high day temperatures and to frost.

Fruit set of apricots at the Station was increased from 11.1 percent for the control to 31.7 percent and 33.9 percent for the unwaxed and waxed protectors respectively. Fruit set under polyethylene was reduced to 1.5 percent.

Peach fruit set at the Merkle Farm was increased from 8.4 percent for the control to 12.8 percent and 24.9 percent for the waxed and unwaxed protectors respectively. Fruit set was reduced to 6.8 percent and 1.5 percent for the polyethylene with slits and the regular polyethylene protectors respectively.

b. In 1958 apricot fruit set at the Merkle Farm was increased from 6.9 percent for the control to 9.2 percent and 16.8 percent for the polyethylene and waxed protectors, respectively. It was reduced to 4.3 percent in the unwaxed protectors.

Apricot fruit set at the Station was increased from 2.1 percent for the control to 8.1 percent and 13.4 percent for the unwaxed and waxed protectors, respectively. Fruit set in the polyethylene protectors was reduced to 1.1 percent.

Peach fruit set at the Merkle Farm was increased from 11.3 percent for the control to 18.7 percent and 29.8 percent for the waxed and unwaxed protectors, respectively.

3. In 1958, frost protection bags were constructed of fiber-glass and aluminum foil, black polyethylene and aluminum foil, multi-layered brown paper bags, and blanket type insulated material. These frost protectors were put in place early in the afternoon before a frost was predicted and removed early the next morning. Temperatures in the bags were taken at frequent intervals during the coldest periods of these nights. No frost protection was given by any of these protectors except the fiber-glass, and this occurred only on one occasion.

4. In 1959, laboratory experiments were conducted to study the growth of Henderson apricot pollen and the growth of pollen tubes in apricot styles.

a. Henderson pollen germinated and grew best at seventy degrees F. on sucrose-agar media. Results were poorer at higher or lower temperatures.

b. No results were obtained from studies to determine the effects of certain ranges of temperature and humidity on pollen tube growth in the style.

5. In 1959, field studies were conducted to determine the approximate time between pollination and fertilization of Henderson, Perfection, South Haven number 6, and South Haven number 7 apricots and Redhaven peaches. This was accomplished by crushing and staining the pistils with Lacmoid-Martius yellow.

Eight hours after pollination, the pollen of both peaches and apricots was just beginning to germinate. Four days were required for pollen tubes to reach the central region of the ovaries of apricots. Limited observations indicated that this would also be true for the peaches.

The results of these studies indicate that a definite benefit may be obtained from the use of the waxed and unwaxed protectors on peaches and apricots following pollination. The waxed protectors increased fruit set the most on apricots, whereas the unwaxed protectors increased fruit set the most on peaches.

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