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Peach Growing in Massachusetts

By John S. Bailey

Peaches have a limited adaptability to Massachusetts climatic conditions, and this deals with management practices essential for their successful production.

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PEACH GROWING IN MASSACHUSETTS

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The peach growers of Massachusetts are highly favored by many good local markets, a factor which has led to a considerable peach industry in the State. However, the effects of winter injury, X-disease, oriental fruit moth, and the hurricane of 1938 have greatly reduced the number of trees as shown by Table 1.

Table 1. Number of Peach Trees in Massachusetts

Year	Farms Reporting	Nonbearing Trees	Bearing Trees	Total
1909	—	162,114	154,592	316,706
1919		135,426	346,260	481,686
1924	8,601	—	—	306,408
1929	5,384	121,721	182,198	303,575
1934	5,411	58,377	167,357	225,735
1939	2,571	43,878	61,803	105,681

At the present time, peach growing in this State is not as highly specialized an industry as it is in some states. Peaches are usually grown as a secondary crop, and therefore peach orchards do not receive the thought and care they deserve. To be successful, the grower must give more attention to such important items as the choice of the best varieties, the selection of sites free from danger of winter injury, control of such pests as oriental fruit moth and X-disease, and better methods of culture.

WINTER INJURY

The killing of fruit buds and less frequently of the tree is one of the great obstacles to peach growing in Massachusetts. Fruit bud killing results from one or a combination of the following sets of conditions:

1. The fruit buds develop slowly all through the fall and during warm periods in winter. A late warm fall, especially one with a great many sunny days, causes the buds to develop past the condition in which they are most resistant to low temperature; that is, the buds fail to mature and harden off. Then during a period of extreme cold they are killed at a temperature which they might have withstood had they been in the stage of greatest hardiness.

2. Until the rest period of peach buds is over they develop very slowly, even at a high temperature. However, the rest period is short, ending in late December or early January. A period of warm weather during January or February will cause the buds to develop enough so that they are not able to withstand a temperature much below zero. It is not known how high a temperature is necessary to bring about this condition. Probably there is some development between 40° and 45° F., and undoubtedly, considerable takes place above 45°.

3. In some winters, the temperature falls so low that the buds, even in their

most resistant condition, cannot withstand the cold and all are killed. The killing of fruit buds in this way is less frequent than in the other two ways.

The temperature at which fruit buds are killed is uncertain. In some years, buds have been killed at a temperature of −10 F. In one year buds were reported to have withstood −20°. This difference is probably due partly to the internal condition of the buds, but mostly to the weather conditions preceding the killing temperature. Experience in the college and experiment station orchards indicates that in most years −14° or −15° is the danger point at which buds are killed regardless of their stage of development.

Most varieties of peaches form many more fruit buds than can be developed into mature fruits. Probably not more than five percent of the buds develop into mature peaches, so that if ten percent of the buds are uninjured and are well distributed over the tree, there are enough for a good crop.

Investigation shows that increased hardiness is associated with increased storage of reserve food material (carbohydrates) in the tree, while decreased hardiness is associated with increased storage of water and nitrogen. Therefore, the best cultural practice is to (1) fertilize early in the spring, (2) cultivate thoroughly through the early part of the season and then sow a cover crop, and (3) thin the crop adequately to prevent overbearing.

This treatment stimulates the tree to make a vigorous growth early in the season and to store up later the maximum amount of reserve food material. But the increased cold resistance gained in this way is slight. The greatest hope for success lies in the careful choice of sites, in the planting of the hardiest of our present varieties, and in the introduction of more hardy varieties.

In Massachusetts, the wood of peach trees is less likely to be killed by winter cold than are the fruit buds. However, the wood may be killed in severe winters under much the same conditions as the fruit buds. Hardiness of bud and hardiness of wood do not always go together. Elberta, which is one of the tenderest in bud, is one of the hardiest in wood.

A peach tree will recover from moderate injury to the wood if proper remedial measures are taken. It is best not to prune or fertilize the tree until the extent of the injury can be observed accurately. If the injury is not too severe, the dead parts of the tree should be removed and the remainder given a light detailed pruning to stimulate growth. Thorough cultivation and liberal fertilization also help the tree to outgrow the injury. Heavy pruning and fertilization may result in the production of too large a leaf area. Then during a dry period in the summer this excessive leaf area might demand more water than the reduced conducting system could supply, and cause the death of the tree. The winter injured tree should have very careful, and not extreme, treatment while recovering from the injury.

ESTABLISHING THE PEACH ORCHARD

Sites and Soils

The choice of a good site is a very important step in starting a peach orchard. Since winterkilling is one of the greatest obstacles to peach growing in Massachusetts, a site should be chosen where this danger is least.

The ideal site is located on a gentle slope, high enough above the surrounding land (100 to 125 feet above the general stream level is good) so that cold air and water drain off readily, and with no bare slope above, from which cold air can flow down through the orchard. Protection from the prevailing winter winds is advantageous. In Massachusetts no peach orchard should be planted more than 1200 feet above sea level.

Since an ideal site is seldom available, it is usually necessary to select the nearest to the ideal from among several fairly good sites. To help in making a choice it will pay the grower to compare the temperatures prevailing on different sites on several winter mornings when the temperature is below zero. The thermometers used should be compared so that any differences in readings can be taken into account. On a still morning, when there is no wind to keep the air thoroughly mixed, there may be a difference of 6°F. or more on two adjacent sites differing no more than fifty feet in elevation. When the temperature falls as low as −14°F., a variation of only two or three degrees may mean the difference between a good crop or a crop failure.

Peach trees succeed on a wide variety of soils from medium clays to very light, sandy loams, but they thrive best on light, sandy or gravelly loams. Since peach trees can not stand "wet feet," the soil must be well drained regardless of type. A desirable subsoil has two or three feet of light porous material to give good drainage and a more compact layer below to retain moisture. Although peaches will grow on poor soils, they thrive much better on soils more fertile than those ordinarily used for apples.

Varieties

Peach varieties are changing so rapidly that those considered of commercial importance five years ago are practically discarded today. Many new varieties are being introduced and a number of these look better than the older varieties of the same season. Therefore, the progressive peach grower should try the more promising of these new varieties so that he may have first-hand information on which to base plans for orchard replacement or expansion.

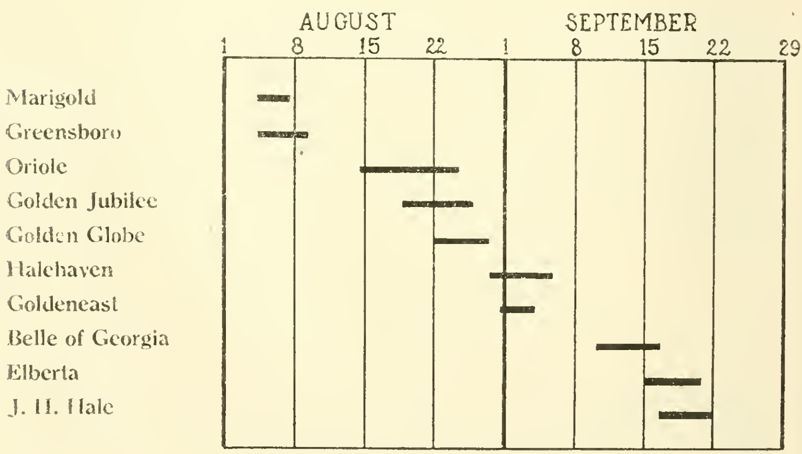


Chart I. Average Ripening Season of Peach Varieties in Massachusetts. The exact dates will vary from year to year, and in some years the order of ripening may be changed.

The chief points to be considered in the selection of varieties are cold resistance of fruit buds and wood, productivity, season of ripening, quality, color and firmness of the flesh, and freeness of the stone. The season of ripening has become of increasing importance because of the very heavy planting of Elbertas in South Carolina. In addition to the very early Elbertas shipped from Georgia, there will be an additional and probably even larger shipment from South Carolina. Shipments of Elbertas from Georgia are heavy in July and moderate in August; those from South Carolina are moderate in July and heavy in August. Anyone intending to plant peaches should consider this, for it means that any varieties ripening before Halehaven will probably have very stiff competition for a number of years.

The following varieties are listed in their approximate order of ripening. Those starred are the most reliable for commercial planting.

Marigold is an early peach ripening in Greensboro season. See Chart 1. The fruit is attractive, medium sized, yellow fleshed, semicling, and fine flavored. The fruit buds are about as cold resistant as those of Greensboro, which for years has been considered one of the most bud-hardy varieties.

*__Oriole__ is an attractive yellow-fleshed freestone of medium size with firm flesh. The tree starts to bear early and bears heavily. Unless a thorough job of thinning is done, the fruit will be small. The fruit tends to ripen on one side first. The fruit buds are as cold resistant as those of Greensboro.

*__Golden Jubilee__ is a truly fine peach. When well grown, the fruit is large, oval, yellow fleshed, and freestone. The flesh is fine textured and the flavor is excellent. The buds are as tender to cold as those of Elberta. The fruit has flesh too soft for long distance shipment, but is excellent for roadside and local markets. It ripens three to four weeks ahead of Elberta.

Golden Globe is a large, round, yellow-fleshed freestone of very good quality. It is attractive, firm fleshed and should be a good shipper. It starts to ripen about five days ahead of Halehaven. The fruit buds may not be cold resistant enough, but it merits trial.

*__Halehaven__ is a medium to large, attractive, yellow-fleshed, freestone peach of very good to excellent quality. The flesh is fine textured and firm. A fairly thick, tough skin with the firm flesh makes it a good shipper. It ripens about three weeks ahead of Elberta. Its cold resistance is not much better than that of Elberta.

Goldeneast is a very attractive, large, yellow-fleshed freestone. Flavor is good to excellent. It starts to ripen a few days after Halehaven, and finishes ripening at about the same time as that variety. It is larger but probably not quite so good in quality. It has a slight tendency to cling in some seasons. The cold resistance of the fruit buds is not much better than that of Elberta. The flesh is firm and the skin medium thick and tough, which should make it a good shipper.

*__Belle of Georgia__ is an old variety with white flesh and excellent quality, ripening about five days ahead of Elberta. The trees are productive and fairly hardy in both bud and wood. It is too soft to ship or can well. It has been replaced in some sections and will certainly be replaced in Massachusetts when a firmer peach of the same season with equal quality and hardiness is introduced.

*__Elberta__ is the most widely grown and best-known peach east of the Rocky Mountains. It is a yellow-fleshed, attractive freestone with firm flesh. It ships and cans very well. The trees are very productive and the wood is very cold resistant. However, the fruit buds are lacking in cold resistance, and the quality of the fruit is poor. These disadvantages are so slight in comparison with its advantages that Elberta stands head and shoulders above all others as a commercial variety for the East.

*J. H. Hale is another old stand-by of the eastern peach grower. It is one of the largest, handsomest, and finest flavored peaches grown. The fruit is yellow fleshed, freestone, and firm so that it ships and cans well. Unfortunately, the tree is distinctly dwarfish and unproductive, the flowers are self-sterile, and the fruit buds are no more cold resistant than Elberta. It starts to ripen with Elberta or a few days later and extends the season several days beyond Elberta.

Since the list of varieties recommended for trial and for commercial planting is revised annually by the staff of the Pomology Department, anyone planning to plant peaches should obtain the latest list to supplement the above information.

Planting

In the past, peaches were usually planted on the square system, 18 to 20 feet each way, with little regard for the contour of the land. The orchard was then cultivated both ways. Since very little land in Massachusetts is level enough to be suitable for this kind of culture, the soil in many orchards has been badly eroded and seriously impoverished by this practice.

It is now recognized that the best way to plant any orchard which is to be cultivated is on contours. See Figure 2. That is, each tree row is set along the contour line at a certain level. All cultivating is then done around the slope, never up and down the slope. In time, this will result in the building up of terraces with the peach trees at the edges.

Since the contours are seldom parallel, the rows will not be the same distance apart at all points. Also, it will usually be necessary to go to the end of the row to take cultivating equipment, spraying equipment, and harvest wagons from one row to the next. On the other hand, working around the slope conserves gasoline and saves wear and tear on equipment.

Because of the curved rows, there will be some inconvenience in spraying due to change in position in relation to the wind. On the credit side, there will be almost 100 percent retention of rainfall and consequently negligible erosion. By the retention of fertile top soil and water and increased ease of producing more cover crop, the productivity and length of life of the orchard should be increased.

Since the laying out of a contour orchard requires technical skill and training, anyone desiring to plant such an orchard should consult his county agricultural agent or the Soil Conservation Service.

Before peaches are planted, prepare the land thoroughly by plowing and discing. If possible, do this a year in advance and grow a green manure crop. While peaches can be planted successfully in the fall if obtained from a near-by nursery and put in at once, spring planting is preferable. Plant the trees as early as it is possible to get on the land. Use one-year-old, thrifty trees and set them 18 to 20 feet apart each way or, better, 18 to 20 feet apart on contours. Remove any broken or injured parts of roots before the trees are set. Dig the planting hole large enough to take the roots without crowding. Firm the soil well around the roots so that no air spaces are left. After they are planted, prune the trees as outlined under the discussion of pruning on page 8.

ORCHARD MANAGEMENT*

A successful peach orchard has seldom been grown in sod. It should be cultivated from early spring until early midsummer. For this reason, sites on steep slopes are less desirable, because they wash badly unless the orchard is laid out on contours. When cultivation is stopped, a cover crop should be planted which will give the greatest amount of organic matter to be turned under the following spring.

Because of their habit of bearing, peach trees require more fertilizer than apple trees. Barnyard or poultry manure in moderate quantities is excellent. Of the commercial fertilizers, those carrying nitrogen, particularly mineral nitrogen such as nitrate of soda, have given the best results. The amount to be applied depends on the fertility of the soil and the health and vigor of the trees. A mature tree in good condition should make a terminal growth of from twelve to sixteen inches, and the fertilizer application and pruning should be adjusted to get such a growth.

With soils of average fertility, the following amounts of nitrate of soda usually give the desired results: trees one to two years old, ½ to 1 pound to a tree; trees three to four years old, 2 pounds to a tree; trees five to seven years old, 4 pounds to a tree; and trees eight years old or older, 5 to 6 pounds to the tree. The ripening date of the crop can be delayed several days by very liberal applications of nitrogen. This delay may be desirable with some varieties to get them on the market when it is not glutted with fruit from other sections.

In the past, phosphoric acid and potash generally have proved of little benefit to peach trees. Recently, a number of orchard soils deficient in potash have been found. So there may be soils in Massachusetts where the use of these materials would be profitable. The grower can determine whether his trees will respond to phosphoric acid or potash by applying each to a part of his orchard and noting the results. They will probably be most effective if applied to the cover crop and will then become available to the trees as the crop residue decays.

Peach trees thrive better if the soil is well supplied with organic matter. Manure, if it is available, is an excellent source. The usual way of adding organic matter to the soil, however, is by the use of cover crops, planted as soon as cultivation is stopped. This has been customarily about the middle of July, but there is a growing tendency to stop cultivation much earlier — in June or even the last of May. The early cessation of cultivation and sowing of the cover crop has several advantages. It saves time in cultivating. With less cultivation, less organic matter is burned out of the soil. With more time for the cover crop to grow, more organic matter is produced to be turned under. The earlier competition of the cover crop for nutrients and moisture causes the trees to stop growing earlier and harden off more for the winter. On the other hand, there is danger of too much competition during the time the fruit is ripening. In a dry season the competition for water may be so severe that the cover crop will have to be mowed.

Good cover crops for early sowing are buckwheat (Figure 3), Japanese millet, barley, or, on rather fertile soils, a mixture of buckwheat and Japanese millet or Japanese millet and soy beans. For midsummer, buckwheat and rye are a good

*Fertilizer recommendations are based on normal time needs. Growers must keep informed and make such substitutions or alterations as war emergency conditions demand.

combination, or early sown buckwheat may be disced down in the fall and rye sown. Legumes, except soy beans, are less desirable because they are too slow in starting and make too little growth before they must be turned under.

Cover crop growth will usually be increased considerably by the application of fertilizer at the time of seeding. This is probably a much better time to apply phosphoric acid, and perhaps potash, than in the spring. These materials will be more quickly used by the cover crop. Then the trees will benefit indirectly from the increased organic matter turned under. Six to eight hundred pounds of 4-12-4 is recommended for soils of average fertility.

Mulching with hay or similar material has been found to be a good practice in apple orchards. There is reason to believe that it would be equally successful in peach orchards. Spreading low grade hay as it becomes available over the area occupied by the roots, benefits the trees in several ways. The decaying mulch furnishes the trees with nitrates and potash, conserves moisture, and probably benefits them in other ways. The amount needed varies with the size of the trees. One to four tons of air-dry material per acre should be sufficient but more will help. If enough is applied, no fertilization will be required after the mulch has started to decay.

Pruning

The peach tree is subject to many ills which shorten its life. One of these is the breaking down of the main framework of the tree. Hence pruning, particularly during the first two or three years, is very important because it determines to a large extent the form and strength of the tree's framework. There are two methods of training by which the peach tree can be formed: the modified central leader and the open center. Since the peach doesn't naturally form a central leader, this type of tree will probably be more difficult to establish and maintain. Also, a rather vigorous nursery tree is required for training in this way. Medium or small-sized trees should be trained open center.

To establish a modified leader tree, the leader should be headed 36 to 48 inches high at planting time. As many scaffold branches as possible should be left, particularly those having a wide branch angle and those well spaced both up and down and around the trunk. The lower scaffold should be 12 to 18 inches from the ground. The scaffolds should be headed back so that they will all be about the same length. The second and third year any branches which develop sharp crotch angles should be removed, and the tree thinned out lightly. Special care should be exercised to keep the scaffold branches and leader in balance, otherwise the lower scaffolds may outgrow the leader. This type of tree is probably more subject to trunk and crotch injury during the winter than lower-headed trees.

Trees to be trained by the open center method should be headed low, 18 to 24 inches, at planting time. Such low-headed trees are easier to prune, thin, and harvest and are less subject to trunk and crotch injury and wind damage during the winter. The scaffold branches should be selected as close together and as near the top of the leader as possible. Three is the best number. If these scaffolds are close enough together, they will form at the union with the trunk a very strong knot-like growth which should result in very little splitting. If the nursery tree is vigorous, the scaffolds can be left 10 to 12 inches long; if it lacks vigor, they should be cut to stubs, leaving just enough to retain the basal buds. If a

Figure 1. A Good Peach Site.
It is protected from the prevailing winds and has good air and water drainage.

Figure 2. A Promising Young Peach Orchard Planted on Contours.
This method of planting conserves moisture, fertility, and soil. Picture courtesy of Soil Conservation Service.

Figure 3.
Upper: A cover crop of buckwheat adds considerable organic matter to the soil.
Lower: A cover crop of weeds can add much organic matter to the soil, provided weed growth is good.

Figure. 4 Upper: Peach Tree Before Pruning.
This is a poorly formed tree of the two-story type. The branches in each story originate from the same height on the trunk. Such a poor distribution of branches should have been corrected early in the life of the tree.

Lower: The Same Tree After Pruning.
It has been thinned out and the top branches cut back to keep the head low. The lower branches, which interfere with cultivation and bear inferior fruit, have been removed.

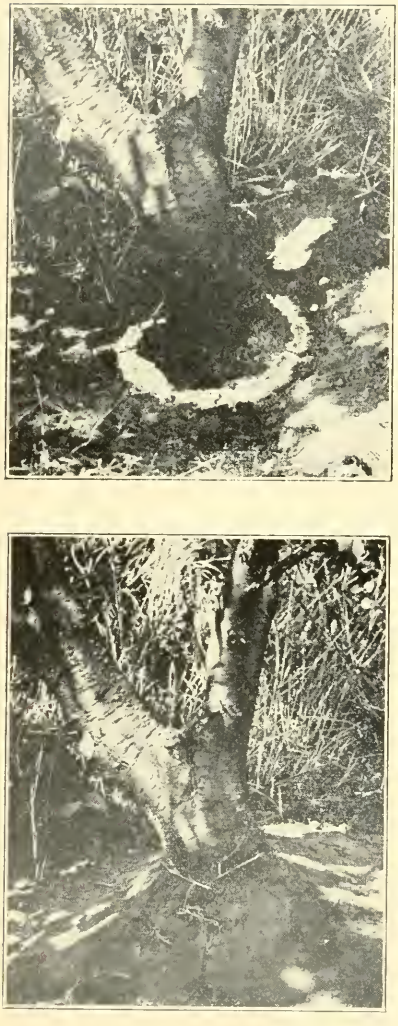


Figure 5.
Paradichlorobenzene Treatment for Peach Tree Borers.
Upper: Apply the crystals in a complete, compact ring around the tree, 1 or 2 inches from the trunk.
Lower: Cover with a small mound of earth 12 to 18 inches high.

Figure 6. X-Disease.
In late summer the peach leaves show curling and tattering. In severe cases most leaves drop from infected shoots leaving only a few at the tip.

light corrective pruning is given two or three weeks after planting, removing any other branches which start to form, and a second corrective pruning two weeks later, only a light corrective pruning will be necessary the second year. After the second year, a light thinning out and just enough heading back to keep the scaffolds in balance is all that should be necessary.

In Michigan a variation in the training of an open-center type tree has been developed called the "side-leader" method. It is said to give an especially strong head. When this method is used, a single branch, as nearly horizontal as possible, should be selected at the height at which it is desired to form the head. This "side-leader" should be shortened to 10 or 12 inches and the leader cut off above it. During the first year the scaffold branches are developed from this side leader. The second year and thereafter the pruning is the same as for the regular open-center type of training. The main problem in this type of training is to maintain the terminal scaffold as a sort of leader; otherwise, the other two scaffold branches will pinch it off.

No matter what the type of training, only light corrective pruning should be given the second and third years. It should also be remembered that the first fruit is borne on the small inside branches. These should be left until they have borne and have been shaded out by the more vigorous outside branches. They can be removed the fourth or fifth year.

The peach pruning should be left until as late in the spring as possible. This gives a chance for injury to buds or wood to become evident so that pruning can be done accordingly. Dormant sprays should be applied in the fall where possible, and other farm operations should be planned so that pruning can be left till last and then rushed through.

The amount of pruning to be given the bearing tree should be determined by the number of fruit buds left on March 1 and by the growth stimulation desired. The examination for live buds should be very thorough. Buds in all parts of the tree and trees in all parts of the orchard should be examined. Unless this is done, what might have been a partial crop following winter injury may be pruned off. In a year when there are many live buds, the trees should be thinned out to reduce the fruit thinning operation, to help prevent overbearing with consequent breakage of branches, and to stimulate the production of more shoots with fruit buds for the next year's crop. Also any branches which are getting too long should be cut back. The cut should be to a side branch in two- or three-year-old wood. This reduces any tendency to sucker. If the number of live fruit buds is small, only dead, injured, or very weak wood should be removed. Thus, most of the few remaining live buds will be left and a partial crop obtained.

The very severe pruning or dehorning of peach trees following severe bud killing is not recommended, for the dehorned trees might have borne a partial crop if properly pruned. Trees are apt to grow too vigorously following dehorning, resulting in tenderness and severe injury the following winter. Dehorning results in large pruning wounds which are very hard to heal. Trees with wood damaged by cold should not be dehorned. These trees will recover better if they are left unpruned.

Thinning

Thinning the fruit is as essential to good orchard management as spraying or cultivating. Too often this operation is neglected or poorly performed, to the disadvantage of both the grower and his orchard. In a good crop year, most peach varieties need thinning, since the trees set more fruit than they can carry to maturity and still develop good size.

The principal reason for thinning is to obtain large peaches. A three-inch peach has about three times the volume of a two-inch peach. With the increase in size of the fruit there is a comparatively small increase in the size of the pit. Therefore, one three-inch peach is worth more than three two-inch peaches because there is more flesh to eat and fewer pits for the tree to develop.

The thinning should be done as soon as possible after the June drop. Early thinning is essential, for it helps to preserve, but not to increase, the vigor of the tree. It requires as much reserve material to develop the growing pit as to develop the rest of the fruit. Early thinning decreases this heavy withdrawal of food reserves by the developing fruits, leaving a larger portion for growth and fruit-bud formation.

This preservation of vigor by thinning helps to increase cold resistance, because, as has already been pointed out, cold resistance is correlated with the presence of a large supply of reserve material within the tree. Experience shows that where a tree has been exhausted by bearing a heavy crop, it is more susceptible to injury by winter cold.

Thin the fruit to a distance of six to eight inches, depending on the size of the mature fruit of the variety. During the thinning operation, twist off the fruit; never pull it off, because pulling results in many injured branches.

In addition to increasing the size of the fruit and helping to preserve the vigor of the tree, thinning improves the grade, quality, and color of the fruit, decreases labor in harvesting the crop, and lessens the danger of broken limbs.

Spraying

The spray program to be followed for the peach, as for any other fruit, depends on the insects and diseases present. Therefore, a knowledge of these troubles is essential in order to follow a spray program intelligently.

Insect Pests

The following are the most important insect pests of the peach:

The Peach Tree Borer is one of the worst pests of the peach. As a small white larva it bores into the base of the tree trunk and eats the cambium and sapwood. Its presence can be detected by the gummy exudate from its burrows. As it seldom burrows very deep, it can be dug out with a sharp knife in the early fall or spring. The soil should be dug away from the base of the tree to a depth of five or six inches to get any borers below the surface.

In a large orchard, an easier way to dispose of borers is by using paradichlorobenzene (Figure 5). This is a white crystalline solid which vaporizes slowly at ordinary temperatures. It may be obtained under various trade names. The gas is not poisonous to man but will kill insects on sufficient exposure. To apply paradichlorobenzene:

First — scrape away all sod, loose soil, sticks, large stones, or other debris from around the trunk to a distance of about one foot, without disturbing the firm soil beneath. Remove masses of gum present on the base of the tree.

Second — apply the crystals in a complete, compact ring around the tree one to two inches from the trunk. Do not allow the crystals to come in contact with the bark, as injury may result. Be sure also not to place the crystals more than two inches from the trunk or their effectiveness is decreased. It is dangerous to use paradichlorobenzene on trees less than three years of age. Trees three to five years old require one-half to three-quarters of an ounce for each tree. Trees six years old or older require one ounce. Exceptionally large trees may require 1¼ to 1½ ounces. Never use more than 1½ ounces.

Third — place three to five shovelfuls of fine earth, from which all weeds and other debris have been removed, over the crystals around the tree, making a small mound 12 to 18 inches high. Place the first shovelful or two carefully over the crystals, so as not to knock them against the bark. Pack the mounds down well with the back of a shovel or some similar tool.

Fourth — after four to six weeks remove the mound. See Figure 8.

Paradichlorobenzene treatment should be applied in late August or early September, and repeated each year, as the gas kills only the borers present in the tree at the time of treatment.

Recently ethylene dichloride emulsion has been tried as a control for peach tree borers, and is reported to be more effective than paradichlorobenzene. It has been used in the college and experiment station orchards in Amherst on a fairly large scale for the last three years. Borer control has been excellent. Injury to trees has occurred only where the emulsion was poured on the trunks of young trees or where the amount applied was increased considerably over recommended dosage. However, reports of severe injury to trees following its use have come from several states outside Massachusetts. Until the reasons for the injury are more fully understood and ways of preventing it are worked out in detail, ethylene dichloride emulsion should be used cautiously. Stock emulsion of ethylene dichloride is available commercially. Directions for its application and proper dosage are usually on the container and should be followed carefully. Broken stock emulsion should not be used until it has been reemulsified by pumping through a spray pump and nozzle. The emulsion should be kept off the trunks of the trees and overdosing should be avoided. In spite of some adverse reports, this treatment looks very promising, but it cannot be recommended unconditionally without further experimental work.

The Plum Curculio is often very troublesome on peaches. It injures the fruit by puncturing the skin and laying its eggs underneath, and by feeding on the surface. These injuries may cause immature peaches to drop, disfigure and reduce the market value of mature fruits, and offer an opportunity for the spores of the brown rot fungus to enter.

The plum curculio winters in stone walls, hedge rows, or any trash in or about the orchard. The destruction of such hibernating quarters aids greatly in its control.

Since it is a chewing insect, curculio can be controlled by spraying with lead arsenate in the "shuck" spray. See Spray Program.

The Oriental Fruit Moth probably is the most serious insect pest of peaches at the present time. It has spread along the Atlantic seaboard and is now generally distributed through all the peach growing sections of Massachusetts. In the form of a small larva, it enters new tender shoots and bores into developing fruits. Its presence in the fruit is very difficult to detect without cutting the fruit open. Infested shoots are detected readily, because the terminal leaves and often the tips of the shoots wilt and die. In a severe infestation, the tips of infested shoots are covered with a gummy exudate.

The control of oriental fruit moth is aided by burying all infested or dropped fruit at least six inches below ground. Since the larvae pupate in cracks or crevices, this pest has been brought into some orchards by the introduction of old, infested containers. Therefore, it is important to destroy all old containers, especially any which have been used for infested fruit. As the larvae seem to prefer succulent, rapidly growing shoots, the stimulation of excessive growth by heavy pruning and fertilization should be avoided where this pest is present. Up to the present time, the best control has been furnished by egg and larval parasites of the oriental fruit moth. These have been bred and liberated by the Massachusetts Agricultural Experiment Station, the experiment stations of several other near-by states, and by the Federal Government. In the last few years, sulfur-oil-talc dusts or fixed-nicotine sprays have shown promise. A schedule of four applications at 5-day intervals, beginning three weeks before the harvest time of each variety is recommended.

The European Red Mite is not so common on peaches as on apples, but it may be a serious pest in some years. It is a tiny, red mite which sucks the juice from the leaves, giving them a bronzed, yellowish, unhealthy appearance. The best time to look for the European red mite is in the winter or early spring before growth starts. If they are present, the tiny red eggs will be found around the base of small twigs and spurlike growths. The eggs can be killed by applying an oil spray early in the spring. See Spray Program.

Diseases

The following are the most common diseases of the peach:

Peach Leaf Curl is a fungus disease which curls and distorts the young leaves early in the spring. It is easily controlled by spraying, but if spraying is omitted, it may become serious in both young and bearing orchards during seasons when long cold periods occur after growth has started. Spraying with Bordeaux mixture or lime sulfur late in the fall or early spring will control it. See Spray Program.

Brown Rot is a serious fungus disease of the peach in Massachusetts. The principal source of infection is the mummied fruits on the ground and clinging to the trees. The fungus may enter through the flowers in the spring causing blossom blight. Following this, it is likely to advance into the fruit spurs and twigs, causing cankers which sometimes occur even on large branches. From these cankers and from the overwintered mummies, the spores spread to the fruit, but can enter the fruit only through breaks in the skin, chiefly those made by the curculio and the scab fungus. As brown rot develops, the peaches become brown and mushy, and most of them drop from the tree. In the fall these rotton fruits dry up and mummify. The brown rot fungus winters over in these mummied fruits. The collection and destruction of mummies in the fall or early spring aids in the control of this disease.

The most important control measure is spraying or dusting with sulfur. Since brown rot is apt to develop late in the season, particularly during periods of high temperature and rain or high humidity, late sprays or dusts may be needed. Sulfur dust applied just before harvest is very helpful in preventing the development of rot in the harvested fruit. See Spray Program.

Peach Scab is another fungus disease which attacks fruit, twigs, and leaves. It is most noticeable as small olive-black specks on the fruit. However, it often causes circular brown spots on the leaves and twigs as well. The fruit spots may enlarge and coalesce, forming large, irregular, sooty-looking areas which usually develop large cracks. It is through these cracks that much of the brown rot of the fruit develops. Peach scab can be controlled easily by timely spraying or dusting with sulfur. See Spray Program.

X-Disease or **Yellow-Red Virosis** of the peach is a virus disease which can be transmitted by budding, but is also spread by other means which are not known. X-disease is always associated with diseased chokecherries located near by.

The leaves of chokecherries infected with X-disease are intensely colored, light green, greenish yellow, or reddish yellow to flaming red. The tissues along the midrib and veins are the last to lose their green color so the leaves may have a mottled appearance. Leaves may be normal in size or small and "mouse-eared." The tip leaves usually lose their color last, leaving rosettes of green among the bright reds and yellows.

Diseased peach trees appear nearly normal during the spring and early summer. About mid-June small, yellowish or yellowish-brown spots appear on the leaves on one or more branches. The leaves turn yellowish and the spots fall out giving a tattered appearance (Figure 6). Diseased leaves become twisted and curled toward the midrib. Finally, the leaves may drop. On badly diseased branches all leaves may fall off except a few at the tips of the shoots (Figure 6). The fruits usually drop from such badly diseased trees around midseason or earlier. If they remain on the tree, they are small and bitter.

X-disease spreads rapidly from chokecherry to peach, but much less extensively or not at all from peach to peach. It can be controlled by killing all chokecherries around the site before a new orchard is planted, by securing nursery stock from areas free from the disease, by avoiding buds from diseased orchards when propagating, and by killing all chokecherries in the vicinity of established orchards. Removing diseased peach trees from young orchards probably helps, but removing them from bearing orchards is of doubtful value.

Chokecherries should be eliminated for a distance of at least 200 feet from the orchard, but 500 feet is better. It is especially important to kill all choke cherries around the site before planting a new peach orchard.

Chokecherries can be killed by spraying with a weed killer, such as ammonium sulfamate or a proprietary mixture of sodium chlorate and a deflagration agent. These are used dissolved in water at the rate of ¾ pound per gallon. Spraying may be done at any time when the trees are in leaf, but probably is most effective in early July. The leaves should be thoroughly wetted with the spray. High pressure is not necessary. Since these materials kill by penetrating the leaves and then being carried down to the roots, the trees should not be cut till the year after spraying. Trying to kill chokecherries by cutting, pulling, or digging is a waste of time for any pieces of root left will sprout.

SPRAY PROGRAM

Fall Dormant — If European red mite eggs are absent, this spray may be used to control leaf curl. Apply in late fall, after leaves drop, lime sulfur, liquid 7 gallons or dry 18 pounds, water to make 100 gallons; or Bordeaux mixture 8-8-100. For a few trees it may be more convenient to use dry lime sulfur 12 level tablespoonfuls, water to make 1 gallon, or dry Bordeaux mixture. Where this spray can be used, it saves valuable time in the spring.

Late fall or early spring, before the buds start to swell.

Proper stage for dormant spray.

Spring Dormant — If the Fall Dormant was omitted, apply early in spring before buds start to swell. If European red mite eggs or San Jose scale are absent, use lime sulfur or Bordeaux mixture as in the Fall Dormant for the control of leaf curl. If European red mite eggs or San Jose are present, apply Bordeaux mixture 8-8-100 for leaf curl and add a miscible oil or oil emulsion, according to directions on the container, to control these insects. For a few trees it may be more convenient to spray with dry Bordeaux mixture, adding oil emulsion or miscible oil. Dilute each material according to recommendations on the container.

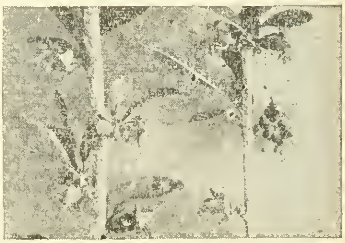
When blossoms show pink.

Proper stage for pink spray.

Pink — Apply when the blossom buds show pink to control brown rot. Use a wettable sulfur as recommended by the manufacturer. Dusting sulfur, 300-mesh or finer, may be used instead of a spray. Unless exceedingly moist conditions prevail, this application may be omitted in orchards where brown rot was kept under control the previous season.

Wettable sulfur is a sulfur which has been treated with a wetting agent so that it will mix with water. It is a mild form of sulfur which is much less likely to cause injury than either liquid or dry lime sulfur. The manufacturer's recommendations as to dilution should be followed carefully.

Just as the shucks start to fall.



Proper stage for "shucks" spray

Shuck — Apply when the shucks are splitting. This spray (wettable sulfur as recommended by the manufacturer, lead arsenate 2 pounds, zinc sulfate 4 pounds, freshly hydrated lime 4 pounds) is primarily for curculio control, but also helps in the control of brown rot and scab. For a few trees it may be more convenient to use wettable sulfur 3 level tablespoonfuls, zinc sulfate 1 level tablespoonful, freshly hydrated lime 2 level tablespoonfuls, lead arsenate $1\frac{1}{2}$ level tablespoonfuls, water to make 1 gallon. Under certain conditions, especially high humidity, this spray will cause arsenical injury in the form of excessive leaf drop, "burned" spots in the leaves, and wounds with gummosis on the twigs. The dust formula (sulfur 70 parts, lead arsenate 10 parts, and hydrated lime 20 parts) is much safer, but it may cause similar injury in some seasons. Where curculio is not a serious pest, and on nonbearing trees, sulfur alone either as spray or dust should be used. Even where curculio is a pest, arsenical injury from the Shuck spray or dust may be more destructive than the curculio damage. Conditions under which this spray may be used safely are high elevation, a cool season, and dry weather during and following the spraying operation. Sulfur alone either as spray or dust has some repellent action against curculio.

When mixing a spray containing lead arsenate, the lead arsenate should always be added last and preferably just before beginning to spray.

By freshly hydrated lime is meant 300-mesh lime, less than one year old, containing at least 70 percent calcium oxide. Never use lime of high magnesium content for orchard pest control.

First Cover — Apply 7 to 10 days after the Shuck to control brown rot, scab, and curculio. Use the same materials as for the Shuck.

Second Cover — Apply two weeks after the First Cover to control brown rot. Use the same materials as in the Pink.

In years of excessive rainfall or if brown rot is present at the time of the Second Cover, additional cover sprays or dusts will be needed at intervals of 10 to 14 days, using sulfur as in the Pink spray. Dusting may be continued right up to harvest, but spraying should be discontinued two weeks earlier to avoid an objectionable residue. If brown rot is present and the weather is wet, an application of sulfur dust is advisable just before harvest to prevent brown rot decay in the harvested fruit.

If aphids become numerous at any time, add $\frac{3}{4}$ pint of 40 percent nicotine sulfate to 100 gallons of spray solution, or use a 2 percent nicotine dust.

This spray program is available in brief form as the "Spray and Dust Chart —Peaches," Extension Leaflet No. 100B, which is revised annually. For the latest information obtain this chart from your county agricultural agent or from Massachusetts State College.

HARVESTING AND MARKETING

The successful harvesting and marketing of peaches depend to a considerable extent on the care used in handling during the harvesting operations. A little extra time spent in careful handling to prevent bruising pays good dividends.

The stage of maturity at which the peaches should be picked depends on the way in which they are to be marketed. To attain the best quality, they should be left on the tree as long as possible. For the roadside stand they can usually be left on the tree until one side begins to soften. For shipment to local markets they should be picked before they begin to soften. For long-distance shipment they should be picked when they are hard ripe; that is, when the flesh has lost its hard character and has become springy to the touch.

Picking at the hard ripe stage is absolutely necessary if the fruit is to be run over a sizing machine. In order to get all of the fruit at the proper stage of maturity, it is often necessary to make more than one picking, the number depending on the variety, the season, and the size of the crop.

The stage of maturity at which to pick should be determined by the orchard manager, because pickers should never be allowed to press or squeeze the fruit. A good manager can tell by the eye when the fruit is ready to pick. In white-fleshed peaches the ground color changes from green to greenish-white to white. In yellow-fleshed peaches the change is from green to greenish-yellow to yellow or orange-yellow.

The picking container most commonly used is the 16-quart peach basket. It is slung over the shoulder by means of a strap or sling made especially for the purpose.

Careful grading is one of the most important operations in the successful marketing of peaches. Nothing builds up a grower's reputation and sells his fruit more readily than a uniformly high quality pack. Most growers grade their fruit to some extent. Some merely throw out culls and small fruit, while others grade more carefully to get uniformity of size and quality. This grading is usually done by hand on sorting tables in a shed or packing house.

Since peaches soften very rapidly even at moderate temperatures, it is desirable to handle the fruit as rapidly as is consistent with careful handling, and to get it into a cool cellar or storage house as soon after picking as possible. This speed in handling is very necessary where peaches are to be shipped to distant markets.

The successful marketing of peaches depends on having fruit of high quality (preferably yellow fleshed), putting up a uniformly good pack, and exhibiting it in an attractive manner. Because of the availability of good local markets and the relatively small size of the peach industry in Massachusetts, very few peaches are shipped out of the State. Most of the crop is sold at roadside stands or in local markets. A few of the larger growers sell part of their crop through commission men in the large markets such as Boston, Worcester, and Springfield.

Most of the crop is marketed in 16-quart peach baskets, although some of the high quality fruit, especially where sold at roadside stands, is marketed in 4-quart till baskets.

From the standpoint of both the handling and marketing of the crop, it is highly desirable to have several carefully selected varieties to insure a continuous supply of fruit throughout the season. This is especially true for the roadside stand, for nothing pleases a customer more than to be able to get high quality fruit, whenever wanted, throughout the season.

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Breeding Snapdragons for Resistance to Rust

By Harold E. White

Rust is a disease destructive to the ornamental value and seed productive capacity of snapdragons, and the results of attempts to produce resistant strains for greenhouse and garden use are here presented.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

BREEDING SNAPDRAGONS FOR RESISTANCE TO RUST

By Harold E. White,
Assistant Research Professor of Floriculture

Geographical Distribution and Economic Importance of Rust Disease

Rust disease, *Puccinia antirrhini* Diet. & Holw., of snapdragons, *Antirrhinum majus*, was localized in its distribution to the West Coast area of the United States prior to 1913 but eventually spread eastward across the country. Specimens of the disease, according to Peltier (10), were recorded by Dr. J. C. Arthur of Purdue University as early as 1879; and Blasdale (1) in 1895 reported it as being common on snapdragons in gardens around San Francisco, California. In 1913, a severe epidemic of the disease was reported in greenhouses in Illinois by Peltier (10); and by 1915 the occurrence of rust was noted throughout most of the Middle Western States and as far east as Massachusetts. By 1931 the disease was reported in France (7); in 1933 in England; 1934, in Germany and Denmark; 1935, in Italy, Switzerland, Hungary, Austria, and Sweden; 1936, in Poland, Latvia, Rumania, Egypt, and Morocco; and finally, by 1937 it was reported from Soviet Russia at Leningrad, Odessa, Veronezh, and the Caucasus.

The rust disease of snapdragons, presumably, was introduced into Europe from North America; at least, the British reports credit the disease as having come from the United States. What basis the English have for their contention is not known, but since the disease is not transmitted by seeds the probable mode of introduction may have been on imported plant materials.

Snapdragons were not widely cultivated under glass as a cut-flower crop in the early 1900's nor were they as popular in gardens as they are at present. At that time, varieties were limited, and wider distribution to the trade was restricted because they were propagated vegetatively by cuttings. The passing on of varieties of snapdragons in the form of rooted plant material by interstate shipments probably was one means of rapidly disseminating the rust disease. However, it is also quite possible that the disease may have been present for many years in the Middle Western and Eastern States but was brought to the attention of pathologists only when it became definitely destructive. In those days, and occasionally even now, the loss of a crop was ascribed by growers to an all-inclusive cause such as "blight," which frequently included fungus diseases and poor cultural practices.

The destructiveness of snapdragon rust in the greenhouse resulted in a change from the customary method of propagation by cuttings to the present practice of using seed. The latter method permitted the grower to get a start with rust-free plants provided he gave careful attention to cultural conditions such as temperature and humidity, and applied fungicides to protect the young plants. Introduction of seed propagation methods made for a more rapid and wider distribution of snapdragons as well as encouraging the production of a better choice of varieties. In the greenhouse, rust disease can be very destructive, particularly if careful cleanup and control practices are not followed. However, under garden and field conditions of culture, snapdragon rust is also destructive, not only to the decorative value of the flowers but to the seed production capacity of the plants as well. All the snapdragon seed used for production of ornamental garden material is grown on a large acreage basis in California. According to Emsweller and Jones (4), because of rust disease the production of seed is more often a matter of a few pounds per acre than the possible 75 pounds per acre, which is rarely attained.

Snapdragon rust has been known for some sixty years; yet there are peculiarities about the epidemiology of the disease which still are not clearly understood. For example, climatic conditions appear to affect the prevalence and degree of destructiveness of the disease. Maximum infection of snapdragon plants in the field at Waltham, Massachusetts, generally occurs by early August, but some years it may be mid-July or late August. Blodgett and Mehlquist (2) note that in 1936 rust disease was extremely light on snapdragon seed field plantings at Guadalupe, California; whereas at Lompoc, some thirty miles south, the disease situation was serious. In 1937, however, rust disease conditions in the plantings were entirely reversed, being serious at Guadalupe but much less so at Lompoc.

Materials and Methods

Breeding work with snapdragons was initiated at Waltham, Massachusetts, to develop strains which would be less susceptible to rust than commercial varieties. The approach to the problem has been along two lines: interbreeding susceptible varieties with rust-resistant strains developed by Dr. E. B. Mains (9); and intercrossing highly susceptible commercial varieties with one another to produce resistant types of snapdragons different from those obtained by use of Mains' material. The rust-resistant strains obtained from Mains were not suitable for commercial use but were considered important because of their potential value for breeding. Some eleven different resistant lines of these snapdragons were planted in the field to determine their degree of rust resistance under climatic conditions in Massachusetts. A number of these strains had been released some years earlier by Dr. Mains to experiment station workers in Virginia, Arkansas, Michigan, and California for testing and further use in breeding work. The following susceptible garden varieties of snapdragons were used as comparative test material: Ruby, Copper King, Old Gold, Canary Bird, Golden Dawn, Apple Blossom, Cattleya, and Gotelind.

Mains' rust-resistant strains all produced plants in which the flowers were predominantly magenta colored, with the exception of strain GW1-G1-F1-GB1 which was white flowered. Individual florets on the plants were narrow and pointed. The foliage as well as habit of growth was characteristic of the wild species of *Antirrhinum*. These plant-growth habits in the hybrids are noted by Mains (9) as being typical of *A. glutinosum*, one of the parents from which the rust resistant strains were derived. Strains 7-13-8-1-G1-F1-F1, 7-13-8-1-G1-F1-G1, and GW1-G1-F1-GB1 were highly susceptible to rust at Waltham; whereas 2-1-1-1-G1-F1-G1, 7-13-8-1-G6-F2-F1-G1, 292, 293, and 294 strains showed some resistance. The number of progeny obtained from the different strains was not sufficient to permit an analysis as to the hereditary ratio of segregation for rust resistance. Garden varieties of snapdragons used in the field for comparison with the rust-resistant strains were completely destroyed by the disease. Mains (9), working with some of the same garden varieties, reported that the variety Canary Bird showed considerable tolerance to rust in his tests; but at Waltham, Canary Bird was severely rusted.

Plants selected from the most resistant line, No. 294 (Table 1), were crossed with the following susceptible commercial varieties: Ceylon Court, White Rock, Cheviot Maid, Afterglow, W. W. Thompson, Jennie Schneider, Helen, Weld Pink, Penn's Orange, Emily, Giant White, and Giant Yellow. Reciprocal crosses were made between the No. 294 and Ceylon Court and White Rock. There were 7,000 to 8,000 plants of the F_1 generation crosses tested for rust resistance in the field. Check rows of susceptible varieties were interplanted with the hybrid material to insure adequate inoculation with rust.

TABLE 1. RUST REACTION OF THE MAINS' STRAINS OF SNAPDRAGONS AT WALTHAM, MASSACHUSETTS.

Strain Number	Flower Color of Progeny	Total Number of Plants	Number of Resistant Plants
2-1-1-1-G1-F1-G1	Magenta	15	4
7-13-8-1-G1-F1-F1	Magenta	2	0
7-13-8-1-G1-F1-G1	Magenta	10	0
7-13-8-1-G6-F2-F1-G1	Magenta	6	3
GW1-G1-F1-GB1	White	5	0
293 (293 x 7-13-8-1-G6-F2-F2)	Magenta	4	2
292 (292 x GW1-G4-F2)	Magenta	9	4
294	Magenta	14	6
294	Magenta	17	6
294	Magenta	8	5
27 x F1 (*A. glutinosum* x GWD 1)	Magenta	4	4

Rust Reaction of Progeny from Crosses Between Mains' No. 294 Resistant Strain and Susceptible Commercial Varieties

Selected plants of the No. 294 resistant strain crossed with the susceptible variety White Rock produced an F_1 population of which approximately half were resistant and half were susceptible to rust. Counts made as to segregation of progeny from nine crosses between the No. 294 strain and White Rock yielded 364 rust-resistant plants to 365 susceptible plants. In Table 2, the pqn statistical method for determination of goodness of fit has been applied to the data and shows that essential conditions for a good Mendelian segregation ratio of 1:1 are present.

TABLE 2. PROGENY SEGREGATION FOR RESISTANCE TO RUST IN CROSSES BETWEEN RESISTANT STRAIN NO. 294 AND SUSCEPTIBLE VARIETIES. F_1 GENERATION

No. 294 X White Rock (Susceptible)					No. 294 X Ceylon Court (Susceptible)				
Parent Plant No.	Number of Plants: Resistant	Number of Plants: Susceptible	Deviation	Dev./P.E.	Parent Plant No.	Number of Plants: Resistant	Number of Plants: Susceptible	Deviation	Dev./P.E.
31-2	17	17	...	...	31-1	54	53	0.50	0.14
31-3	19	28	4.50	1.95	31-3	70	58	6.00	1.83
31-5	16	13	1.50	0.83	31-5	17	19	1.00	0.52
31-7	32	27	2.50	0.76	31-7	52	43	4.50	1.37
31-9	32	26	3.00	1.17	31-9	10	14	2.00	1.21
31-11	51	35	8.00	2.56	31-12	28	39	5.50	2.00
31-13	88	95	3.50	0.76	31-13	53	57	2.00	0.56
31-14	20	28	4.00	1.71	31-15	49	45	2.00	0.61
31-15	89	96	3.50	0.76					
Ratios					Ratios				
Observed	364	365	0.50	0.55	Observed	333	328	2.50	0.23
Expected	364.50	364.50			Expected	330.50	330.50		

Progeny resulting from reciprocal crosses between the No. 294 strain and White Rock and Ceylon Court, in the F_1 generation, segregated in a ratio of 50 percent rusted to 50 percent resistant plants.

Selections of the most resistant plants in the F_2 generation from the cross between No. 294 and White Rock were inbred, and from a population of 557 plants 417 were resistant to rust and 140 were rusted. The F_2 generation from crosses between No. 294 and Ceylon Court produced 509 individuals of which 382 were rust-resistant and 127 were rusted. Data on progeny segregation for resistance, when subjected to statistical analysis for goodness of fit, show that calculated and actual segregation ratios closely approached a ratio of 3 rust-resistant plants to 1 rust-susceptible (Table 3). On the basis of such data, it is concluded that resistance to rust disease is inherited as a dominant factor, as previously noted by White (13) and Mains (9).

TABLE 3. PROGENY SEGREGATION FOR RESISTANCE TO RUST IN CROSSES BETWEEN RESISTANT STRAIN NO. 294 AND SUSCEPTIBLE VARIETIES. F_2 GENERATION

No. 294 × White Rock (Susceptible)					No. 294 × Ceylon Court (Susceptible)				
Parent Plant No.	Number of Plants: Resistant	Number of Plants: Susceptible	Deviation	Dev./P.E.	Parent Plant No.	Number of Plants: Resistant	Number of Plants: Susceptible	Deviation	Dev./P.E.
32-7	121	41	0.50	0.13	32-1	30	14	3.00	1.55
32-9	136	42	2.50	0.64	32-3	105	46	8.25	2.25
32-11	27	7	1.50	0.88	32-5	118	34	4.00	1.11
32-13	115	41	2.00	0.54	32-7	93	20	8.25	2.66
32-15	18	9	2.25	1.48	32-13	36	13	0.75	0.36
Ratios					Ratios				
Observed	417 :	140	0.75	0.108	Observed	382 :	127	0.25	0.37
Expected	417.75:139.25				Expected	381.75:127.25			

In the F_3 generation, selected rust-resistant progeny varied in degree of resistance depending upon the individual heredity of the lines inbred: a few continued to breed true for rust resistance, being 80 to 90 percent resistant; others were highly susceptible to rust; and many segregated again in a ratio of 75 percent resistant to 25 percent susceptible plants. Determinations of the degree of rust resistance of the hybrids by exact progeny counts were impossible, since many of the individuals in selected lines were killed by wilt disease (*Verticillium albo-atrum*) before infection by rust occurred or the rust disease reached its peak in the field. In the early phases of the work, restricted greenhouse area prevented the use of pot culture and artificial inoculation methods which have been found to be one means of limiting these other disease factors encountered in the field. However, as in many cases of adversity, the introduction of the wilt disease factor has not been without value, as it provided conditions for observing the reactions of rust-susceptible varieties and resistant strains to the wilt disease.

Rust symptoms on individual plants within susceptible and resistant strains were variable, as evidenced by the number and size of spore pustules formed on the plants. No attempt was made to classify very finely the degree of susceptibility of the individuals into distinct groups even though there were marked differences in the distribution of spore pustules (uredinia) on the leaves, stems, and seed pods of the plants. The progeny from the hybrids was grouped either as resistant or susceptible, with the term resistant used in the sense that no spore pustules were observed on any portion of the plants. Frequently in resistant selections an inhibited or modified type of rust infection occurred on plants, evidenced by flecking or chlorotic pattern on the leaves. What apparently occurs in this type of resistance to rust is that invasion of the leaf cells takes place, resulting in a partial breakdown of the chloroplasts or cells and producing a mild type of chlorosis; but further destruction of the cell tissues is prevented by some physiological reaction between the host cells and the rust fungus. Mains and Jackson (8) in their studies of physiologic forms of leaf rust in wheat noted a fleck type of resistance to wheat rust which appears to be similar to that observed in snapdragons.

The Waltham Field Station hybrids, developed by interbreeding the Mains' strains of snapdragons with commercial varieties, have proved highly resistant to rust and are a definite improvement over the original resistant parent plants from which they were bred. Flower colors in this group have been limited to white, yellow, and various shades of pink. Bronze-colored flowers of a good shade have been difficult to obtain in these hybrids. Selection and inbreeding of the resistant lines have been continued to develop pure-breeding seed stock lines, in the course of which process it has been observed that certain characteristics of the wild species of *Antirrhinum* are frequently inherited, such as smaller flowers than those of commercial varieties and a variability in seeding capacity of the plants. Backcrossing the resistant strains to the original susceptible parents and reselection have lessened these traits to a considerable degree. Lines selfed for four to five or more generations are generally lower in hybrid vigor than material frequently crossbred.

Three of the Waltham Field Station resistant strains of snapdragons were included in trials in California by Blodgett and Mehlquist (2), who tested the reaction to rust of some 37 strains in 11 different localities within the seed-growing area of that State. Performance of the three Waltham strains was on the average as good as that of the other strains, based on the scale of rust resistance used by the California workers. One interesting feature brought out in the California tests is the variability of rust resistance in the same lines under similar climatic conditions. At Guadalupe all the strains of snapdragons tested were highly susceptible to rust disease; but in the other ten localities where the tests were conducted, these same strains, with few exceptions, showed definite resistance.

Development of Rust-Resistant Strains by Interbreeding Susceptible Commercial Varieties

A number of workers have investigated and reported on the reaction of commercial varieties of snapdragon to rust disease. Peltier (10) studied the resistance to rust of some 40 varieties of snapdragon and concluded that all of them were equally susceptible. Doran (3), who tested 46 varieties of snapdragon for their rust reaction, reported that no variety was completely resistant but that some were relatively resistant. Mains (9), using some of the same varieties that Doran tested, found them all very susceptible, with no pronounced differences between commercial varieties; but he did note individual plant differences in reaction to rust within a variety. He self-pollinated those plants showing greater resistance to rust for several generations and was able to obtain highly rust-resistant types, but as inbreeding continued he encountered self-sterility that interfered with selection of homozygous lines. Emsweller and Jones (4) report that their attempts to find rust-resistant snapdragon plants in commercial plantings in the seed production areas of California were unsuccessful.

At Waltham 32 varieties of snapdragon were tested for their susceptibility to rust under greenhouse and field cultural conditions. The basis used for designation of the degree of susceptibility was the general quantity of spore pustules present on the infected plants in relation to the destructiveness of the disease. Plants were considered *resistant* when no spore pustules were visible; *lightly rusted* when spore pustules present on the foliage were few in number; *moderately rusted* when pustules were abundant but confined to foliage; *heavily rusted* when pustules occurred on both foliage and stems, causing wilting of the plants; and *severely rusted* when pustules were abundant on foliage and stems and resulted in destruction of the plants.

In the greenhouse, 16 of these varieties were classified as moderately rusted, 7 as heavily rusted, and 9 as severely rusted. In the field tests, all the varieties were severely rusted to such an extent that only a very few of the infected plants survived long enough to permit seed to be harvested.

To determine whether commercial varieties of snapdragon carried a hereditary factor for resistance to rust, nine of the varieties found to be very susceptible were interbred with one another. Crosses were made in the greenhouse between Cheviot Maid and Rose Orange, Cheviot Maid and Laura, Lucky Strike and Afterglow, Bronze Queen and Afterglow, Cincinnati and Laura, Lucky Strike and Laura, Rose Queen and Rose Orange, and Afterglow and Cornwallis.

Progeny from these crosses in the F_1 generation were tested under field conditions for susceptibility to rust. The population within all these crosses was generally so very susceptible to rust that classification as to degree of susceptibility was not attempted, since possible results were anything but encouraging. However, self-pollinations were made of plants which showed some promise of being capable of surviving the rust sufficiently to produce seed. An F_2 progeny from such selections in all the crosses was tested in the field with the result that out of eight crosses, three produced sufficient seed for an F_3 generation. These were crosses between Lucky Strike and Afterglow, New Cincinnati and Laura, and Cheviot Maid and Laura, from plants which showed some partial resistance to rust.

In the F_3 progeny tests, two selections out of ten lines from a cross of Lucky Strike and Afterglow yielded plants which showed definite differences in reaction to rust, sufficient to allow classification into resistant and susceptible groups. One selected line had a population count of 104 individuals, of which 33 were susceptible and 71 resistant; the other had a progeny count of 102 plants, of which 67 were susceptible and 35 resistant. Progeny from the other two crosses between commercial varieties were all highly susceptible to rust. Further selections of resistant plants from these two resistant lines of Lucky Strike by Afterglow were made for an F_4 generation progeny test. A total population of 1171 plants was tested for rust reaction in the field, and 290 individuals proved to be susceptible and 881 resistant. From the data in Table 4 it will be noted that the expected Mendelian ratio of segregation was 878.25 resistant plants to 292.75 susceptible, and the observed ratio showed a deviation of only 2.75 plants from the expected. The inheritance of the resistance factor here gives a very good fit for a ratio of 3 resistant plants to 1 susceptible.

Progeny selections which were 75 percent or more resistant to rust were retained for further breeding work. From 51 resistant plants selfed for an F_5 generation, 6 yielded progeny all of which were susceptible to rust; 25 produced progeny that segregated in the ratio of 3 resistant to 1 susceptible individual; 8 gave progeny which were all resistant; and 12 produced progeny that were less than 75 percent resistant to rust.

From data presented, it is evident that commercial varieties of snapdragons do carry a hereditary factor for resistance to rust; and in this study, where 10 varieties were interbred, only 2 produced progeny carrying a relatively high degree of resistance. The nature of the resistance to rust in the commercial hybrids is different in its mode of expression from that of hybrids obtained from Mains' strains. The inheritance of resistance to rust in the Mains' strains was observed to be governed by a simple dominant Mendelian factor. While the resistant lines selected from the progeny of commercial varieties have not been interbred sufficiently to determine their degree of heterozygous or homozygous condition, the data available indicate that the hereditary factor for resistance to rust is either a recessive or a modified dominant type. Some evidence which would indicate presence of modifying factors was the occurrence of *Antirrhinum* species characters in progeny of resistant selections. Plants showing species characters were relatively more resistant to rust than those bearing less of these characteristics. Emsweller and Jones (4) observed the presence of plants susceptible to rust in presumably homozygous lines of snapdragon, and intimate that modifying factors for resistance to rust may be present in commercial varieties. The possibility of disease escape and environmental conditions having some influence on variation in susceptibility of resistant plants has been considered; but the fact that plants produced by cuttings from resistant mother plants have remained free from rust for three years in field tests is considered conclusive evidence that differences in rust reaction, noted in the resistant hybrids developed from susceptible commercial varieties, are due to hereditary factors. The resistance and susceptibility of different hybrid strains of snapdragon to rust were most effectively demonstrated under field tests as illustrated in Figures 1 and 2.

Table 4. Rust Reaction of Progeny from Selected Resistant Lines Obtained by Intercrossing Susceptible Varieties of Snapdragons (Lucky Strike × Afterglow). F_4 Generation.

	Number of Plants				$\frac{\text{Dev.}}{\text{P.E.}}$
	Resistant		Susceptible	Deviation	
	85		33	3.50	1.103
	91		32	1.25	0.394
	89		26	2.75	0.867
	87		24	3.75	1.182
	82		29	1.25	0.394
	87		32	2.25	0.709
	92		27	2.75	0.867
	91		28	1.75	0.555
	89		29	0.50	0.157
	88		30	0.50	0.157
Observed Ratio	881	:	290	2.79	0.867
Expected Ratio	878.25	:	292.75		

Progress in Combining Rust Resistance with a Desirable Plant Type

A good selection of flower colors in light and dark pinks, yellows, bronzes, and white has been developed in the Field Station rust-resistant strains of snapdragon. Some strains are 80 to 90 percent resistant to rust, and in form of flower and habit of plant growth are comparable to commercial strains. They are good seed producers and bloom well in the winter under greenhouse conditions. The most promising strains are those developed from intercrossing susceptible commercial greenhouse forcing varieties. Resistance to other diseases, such as verticillium wilt and powdery mildew, has not been conclusively ascertained although in some seasons the strains have appeared somewhat more resistant to wilt than commercial varieties. Some roguing and selection is still necessary where 100 percent pure-breeding color lines are wanted. However, the few color mixtures have not been objectionable to date. The response of these strains to rust under all climatic conditions is not known or guaranteed. The strains can be propagated from cuttings, and so far have withstood rust tests in the field for three seasons.

Figure 1.

Upper: Showing plant vigor, free flowering habit, and rust resistance of Waltham Field Station hybrids.

Lower: Right, plant selections showing hereditary susceptibility to rust. Only a very few plants have not been destroyed by the disease. Left, plants showing inheritance of resistance to rust.

Figure 2.
Upper: Plant in center is resistant to rust, while those on both sides have succumbed to the disease
Lower: A severely rusted plant bearing numerous spore pustules on leaves and stems.

Physiologic Races of Snapdragon Rust

The recurrence of rust disease on rust-resistant strains of snapdragon in the coastal regions of California in 1936 has been attributed to the appearance of a second strain or form of the rust fungus. Yarwood (14) reports that a second race of rust was isolated from infected rust-susceptible snapdragon plants and designated it as physiologic race 2 to distinguish it from the more virulent form which he calls physiologic race 1. The differentiation of the physiologic forms of rust reported was by use of excised leaves and apparently with unpurified rust cultures. At Waltham no physiologic strains of the rust fungus have been observed although tests were made for the presence of mutant forms by the use of excised leaves and direct inoculation of resistant plants with spores from plants showing partial and severe infection. No rust has appeared on plants grown from cuttings taken from rust-free plants over a period of three years. Presumably such plants should be ideal material for differentiation of any mutant forms of the rust that might occur.

Resistance of Field Station Snapdragons to Other Diseases

Snapdragon plants for breeding work have been planted in a field where plants infected with rust and wilt fungus (*Verticillium albo-atrum*) were plowed into the soil each year for a period of four or five years. The wilt disease has been quite destructive to the plantings each year, its virulence varying with seasonal conditions.

In some seasons rust-resistant strains appeared to be less affected by the wilt disease than were rust-susceptible varieties of snapdragons. Plant counts for susceptibility to wilt have been made each year but the results were variable. Certain strains were much more severely affected by the disease in some seasons than in others. Wilting caused by severe infestation of rust made differentiation between plants killed by rust and those killed by *Verticillium* rather difficult—especially since both were frequently present on the same plants — even though inspection for distinctive vascular discoloration was resorted to as a means of identification of wilt infection.

In the greenhouse, powdery mildew attacks the leaves and stems of snapdragon plants each spring and frequently is virulent enough to be very destructive. Mild infections of powdery mildew have been present on Field Station rust-resistant strains in the greenhouse, but usually the plantings are removed in the spring before the disease becomes sufficiently distributed through the different strains to permit complete observations to be made. Commercial varieties of snapdragon have not been observed to show any differences in susceptibility to mildew under natural conditions for infection.

Stem and leaf blight caused by anthracnose (*Colletotrichum Antirrhini* Stew.) is generally prevalent under field conditions. This disease is even more destructive to snapdragons than rust in some seasons and, while it usually occurs in the late fall, frequently affects seed production. So far, no differences in susceptibility to the disease have been observed in any of the commercial varieties or the rust-resistant strains.

Rust Reaction of Commercial Resistant Garden Varieties of Snapdragon

In 1934 seedsmen of California introduced and gave considerable publicity to a number of rust-resistant garden snapdragons. These new strains originated from some of Mains' strains which had been sent to the California Agricultural Experiment Station. From such material, Emsweller and Jones (4) successfully bred acceptable, improved types that were later released to seedsmen for further development and distribution to the trade. For three consecutive years a number of these commercial rust-resistant varieties were tested at Waltham for reaction to rust under field conditions.

Results of these observations are shown in Table 5. Most of the varieties showed a rather high degree of resistance to rust, but a few had a rather low degree of resistance. The degree of susceptibility to rust varied from year to year, which may be explained in part by the difference in hereditary constitution of the varieties themselves, and in part by variable climatic conditions that may have affected the development or distribution of the rust through the plantings. In several instances where held-over seed of certain varieties was available for planting the following two years for comparison with current seed stock, reaction to rust apparently was influenced in some way by climatic conditions. Plant vigor in almost all the varieties was good, but considerable variation in the type of foliage was noted with the individual varieties. The following varieties were acceptable garden types under conditions at Waltham: Alaska, Fair Lady, Buttercup, Salmon Pink,. Daffodil, Maximum White, Yellow, and Crimson.

Table 5. Rust Reaction on Introduced Resistant Garden Varieties of Snapdragon Tested at Waltham.

Variety	Percent of Plants Resistant			Variety	Percent of Plants Resistant		
	1937	1938	1939		1937	1938	1939
Alaska	83	98	87	Orange Pink	98	98	..
1937 Seed	66	93	66	Opal Queen	..	96	98
Buttercup	97	93	..	Pinkie	..	..	79
Canary Bird	..	92	..	Rose Sensation	..	..	78
California (University) Mixture	66	97	52	Salmon Pink	97	95	98
1935 Seed	97	..	..	1937 Seed	..	95	..
1937 Seed	..	91	..	Silver Pink	89	79	..
Campfire	89	97	98	Swing Time	..	..	40
Daffodil	78	97	79	Maximum White	95	98	90
Defiance	79	98	..	1937 Seed	..	97	..
1937 Seed	..	97	..	Maximum Yellow	97	98	..
Fair Lady	84	95	..	Maximum Crimson	..	..	77
1937 Seed	..	97	..	Wild Fire	98	98	97
Golden Orange	87	98	97				
1937 Seed	..	98	..				
Indian Girl	67	97	..				
1937 Seed	..	97	..				

The Susceptibility of Other Species of Antirrhinum to Rust

Where a fungus disease becomes of economic importance to crop production, the inquiry as to plant resistance may be directed to individual crop plants or to related genera and species. Blasdale (1) has reported the susceptibility of species of *Antirrhinum* native to California and some success in inoculating related genera. The reports of Dr. J. C. Arthur confirmed the observations of Blasdale (1) who has suggested that rust (*Puccinia antirrhinum* Diet. & Holw.) was indigenous on species of *Antirrhinum* in California. Peltier (10) reported successful inoculation of a number of commercial varieties of snapdragons (*A. majus* Linn.) but was not successful in obtaining infection of a number of species of *Antirrhinum* or varieties of *Linaria vulgaris* Mill. (common butter-and-eggs) which is a genus related to the snapdragon.

At Waltham, 56 different wild species and strains of *Antirrhinum* were tested in the field for reaction to rust disease. In several instances, because of low germination and lack of seed, the number of plants was not adequate for analysis as to rust resistance of some of the species.

Susceptibility to rust was found to be variable in many of the species of *Antirrhinum* studied. This was particularly noticeable where a sufficient number of plants within a species was available for testing. Seven out of twelve strains of *A. majus* Linn. were highly susceptible and five showed a moderate degree of resistance. *A. glutinosum* Boiss. contained strains that were rather variable, with four forms highly resistant to rust and others in which individuals exhibited a wide range of susceptibility. The species most outstanding in uniformity of rust resistance was *A. calycinum*, a white-flowered, low-growing type of snapdragon. The majority of species and forms tested for rust resistance produced plants which were predominantly low or prostrate in habit of growth.

Species of *Antirrhinum* found most outstanding in resistance to rust at Waltham were:

A. glutinosum Alhama (Behaart)	*A. Charidemi* Lge.
A. glutinosum Alhama (Kahl)	*A. calycinum*
A. glutinosum Geniltal	*A. Ibanjezii* Pau.
A. glutinosum Baryacas	*A. siculum* NCZ

The data on reaction of wild species and strains of *Antirrhinum* to rust diseases are not entirely in accord with observations reported by other investigators. Emsweller and Jones (4) noted resistance in *A. glutinosum*, *A. hispanicum*, *A. Ibanjezii*, *A. molle*, and *A. siculum*. Their results were substantiated by Mains (9), who records *A. asarnia*, *A. Ibanjezii*, *A. maurandioides*, *A. virgo*, and strains of *A. glutinosum* as highly resistant to rust, but *A. Orontium* as only moderately resistant. At Waltham *A. Orontium* and *A. chrysothales* were highly susceptible to rust (Table 6); whereas Blodgett and Mehlquist (2) reported these same species as among the most outstanding species resistant to rust in California.

Although the response of all the *Antirrhinum* species to rust, as reported by investigators, is not consistent, there is agreement as to the reaction of *A. siculum* and *A. Ibanjezii*, but some reservations with respect to *A. glutinosum*. Critical inspection of data presented on the response of *Antirrhinum* species and strains to rust disease indicates that species received by the several workers under the same specific name may not be identical. Blodgett and Mehlquist (2) state that several of their strains of *A. glutinosum*, *A. Ibanjezii*, and *A. Barrelieri* were of doubtful identity. Definite determinations of the identity or relationship of a number of species, and disseminations of these from one standard sample to workers in several geographical areas for testing, would eliminate much uncertainty as to whether the same strains were being tested. Apparently the intercrossing of species of *Antirrhinum* with commercial varieties has not proved entirely satisfactory, as many of the species do not interbreed readily because of sterility.

TABLE 6. SPECIES OF ANTIRRHINUM AND THEIR REACTION TO RUST DISEASE IN THE FIELD AT WALTHAM, MASSACHUSETTS

Species*	Locality Names	Number of Plants		Flower Colors
		Resistant	Susceptible	
A. Majus L.	Coimbra.........	22	68	Magenta
	Algier...........	73	99	Magenta
	Xauen..........	2	108	Pink
	Marokko........	39	66	Magenta
	Ragusa..........	—	41	White
	Split............	—	49	Pink
	Mancha I.......	—	7	Pink
	Estremadura.....	—	7	Yellow
	Trier............	—	45	Magenta
	Troia............	15	22	Magenta
A. glutinosum Boiss.	Orgiva..........	38	32	Pink
	Alhama (behaart)	20	—	Magenta
	Alhama (kahl)...	26	—	Magenta
	Alhambra........	14	21	Magenta
	Silla del Moro....	12	—	White
	Geniltal.........	74	24	Pink
	Pampaneira......	1	8	Pink
	Baryacas........	25	3	Pink
A. molle L.	Monsec..........	13	9	Ivory
	Lerida...........	11	5	Ivory
	Braganza........	4	9	Ivory
A. hispanicum Char.	Segovia..........	1	40	Pink
	Celorico.........	1	47	White
	Segovia..........	—	20	Pink
A. Barrelieri Bor.	Zaragoza........	59	69	Magenta
	Tetuan..........	24	82	Magenta
A. latifolium D. I.	Mentone.........	—	41	Yellow
	Villefranche......	—	33	Yellow
A. meonanthum	Pancorbo........	—	39	Yellow
A. orontium	....	3	30	Yellow
A. Siculum Ncz.	....	26	12	White
A. tortuosum Bosc.	....	—	35	Magenta
A. Charidemi Lge.	....	26	4	Pink
A. Chrysothales	....	3	14	Pink
A. calycinum	....	146	4	White
A. linkianum	Cintra..........	—	50	Magenta
A. litigiosum	Chorro..........	11	8	Magenta
A. species	Kerynia.........	3	9	Magenta
A. species	Lapithos.........	—	34	Magenta
A. Ibanjezii Pau.	Cartagena.......	8	—	Pink

*These species were not determined by the author and are published according to the identity of Dr. F. Gruber, Kaiser Wilhelm Institute, Muncheberg I Mark, Germany, who kindly furnished seeds of these Antirrhinums for testing.

The Nature of Disease Resistance

The nature of disease resistance in plants still remains one of the most interesting phases of biological science. Much has been published on reactions of host plants to disease organisms, but knowledge concerning the fundamental nature of disease resistance in plants is still meager. Walker (12), in his comprehensive review on disease resistance in vegetable crops, considers the subject with respect to such biological factors as disease escape, which pertains to the earliness or lateness of maturity of the crop in relation to infection as affected by environmental influences, by exclusion of an insect vector, by mechanical exclusion where the host develops tissues which are resistant to penetration by the fungus, by chemical exclusion where certain plant cell substances such as phenolic and protocatechuic acids are formed as inhibiting agents, by physiological exclusion which covers many of the phenomena that have not been explained, and lastly by strain reassortment along with physiologic races of the fungous organisms.

References which deal specifically with morphological and physiological aspects of rust resistance in snapdragon are few and not conclusive. Doran (3) presents data on stomata counts for leaves taken from snapdragon plants which he reports were resistant and susceptible to rust, and concludes that since the stomata count per unit area of leaf surface was greater on susceptible varieties and less on resistant, susceptibility to rust is directly proportional to the number of stomata. However, he does not state what varieties were used for the stomata counts, nor is his comparative scale of determining resistance or susceptibility of plants to rust, between the varieties, very explicit. Peltier (10) noted all degrees of morphological variations in the varieties of snapdragon he tested, but concludes that all varieties were equally susceptible to rust disease.

Most of the available data on rust resistance in plants as related to morphological and physiological relationships between host and fungus are on cereals. Extensive investigations with cereals by Hurd (5), Hursch (6), and Peterson (11) show that specific morphological and physiological conditions could not be readily correlated with the observed degree of resistance of wheat plants to rust disease.

At Waltham plants of rust-resistant and susceptible strains were not subjected to anatomical studies to determine relationships between fungus and host, but no correlation could be observed between degree of resistance or susceptibility and readily visible external morphological characters of the plants. The resistance of snapdragons to rust disease has been demonstrated and accepted as being regulated by hereditary factors. However, the manner in which this resistance is biologically manifest by perceptible, measurable differences in physiological, chemical, or morphological responses is not as yet clearly understood.

Summary

Snapdragon rust attracted public attention because of an epidemic of the disease in greenhouses in 1913. Since that time the disease has spread throughout the United States and has become widely disseminated through England and most of Europe.

The economic aspects of this disease are concerned with its destructiveness to the ornamental value of snapdragon plants, and reduction of seed productiveness of commercial seed crops on the west coast.

By interbreeding greenhouse forcing strains of snapdragons with rust-resistant strains of Dr. E. B. Mains, improved strains have been obtained which are highly resistant to rust.

Resistance to rust in snapdragons has been determined to be inherited as a simple dominant hereditary factor.

A modified dominant type of resistance was produced in progeny from crosses made between susceptible commercial varieties.

Rust-resistant strains have been developed that have an inherited resistance of 80 to 90 percent. Flower colors range from white to pink, yellow, and orange yellow. These Field Station rust-resistant hybrids have a vigorous habit of growth, are free flowering and suitable for winter bloom under glass.

No inheritable differences in resistance to verticillium wilt, mildew, or anthracnose were observed in the hybrids.

Fifty-six wild species and strains of *Antirrhinum* were tested for their reaction to rust. Species noted to be most resistant were: *A. Charidemi* Lge., *A. calycinum*, *A. Ibanjezii* Pau., *A. siculum* NCZ, and four strains of *A. glutinosum*.

Definite progress has been made with the Field Station strains in combining rust resistance with a desirable plant type and a winter flowering habit. Plants propagated from cuttings have been resistant to rust for three seasons in field and greenhouse tests.

No physiologic races of the rust fungus were observed on the rust-resistant hybrids tested.

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MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

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Plant Characters of Cherry Varieties

By A. P. French

Considerable economic loss has resulted from planting cherry trees untrue to name. As an aid in the elimination of such a hazard, this bulletin directs attention to the characteristics by which nursery cherry trees may be identified and records the important differences between the principal varieties.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.

PLANT CHARACTERS OF CHERRY VARIETIES

By A. P. French,[1] Professor of Pomology

INTRODUCTION

Since the publication by Shaw (4) in 1922 of descriptions of the leaves of apple varieties and the start of systematic examination of nursery fruit trees for trueness-to-name, there has been an ever-increasing interest in methods for the identification of fruit plants in the nursery row.

Because of their economic importance and the long interval between planting and fruiting, more attention has been given to differences between apple varieties than between the varieties of other fruits. Yet mixtures are as frequent and as extensive among some of the other tree fruits as with the apple. While cherries, particularly sweet, are by no means the most difficult fruit to identify in the nursery, mixtures frequently are found in some of the leading varieties. The writer has observed as many as four different varieties of sweet cherries mixed in the same row, and occasionally a solid block of a worthless Mazzard has been found being grown for a named variety. Thus the need for information which may help to eliminate mixtures in the nursery would seem to be apparent. It should be understood that the characteristics of nursery trees cannot be learned from printed descriptions alone. Much time must be spent in the nursery examining and studying stock known to be true to name before it will be possible to identify and separate mixtures accurately. Furthermore, many of the differences found in vigorous nursery trees become obscure or difficult of detection in slower growing orchard trees.

Literature

The literature concerning the plant characters of cherry varieties is quite meager. To be sure, Hedrick (2) has described the tree and flower, as well as the fruit of a large number of varieties. However, his descriptions are made from bearing trees and his pictures are those of spur leaves, neither of which can be relied upon to portray accurately or reveal completely the various character differences which are found in vigorous growing nursery trees. Bunyard (1) has called attention to the bud differences on dormant trees. These differences are worthy of note, but are relatively less important during active growth than after the tree is dormant. The only previous publications which deal with varietal differences of cherry trees from the standpoint of nursery trees are those of Upshall (6) and Shoemaker (5). The former has published rather brief descriptions of some of the more important varieties, while the latter has supplemented that study with some additional notes and comparisons.

The Present Study

This study does not pretend to be exhaustive. However, the writer has aimed to include first, those varieties which are found most commonly in commercial nurseries; secondly, several less important or uncommon varieties which may resemble or have been found in place of the above; and lastly, a few of the newer varieties. The characters herein described are those of one- and two-year-old

[1]The writer wishes to acknowledge his indebtedness to Doctor J. K. Shaw for making this study possible and for his counsel and advice during the preparation of the manuscript. Thanks also are due Mr. Lawrence Southwick, who has done most of the propagation in connection with this study.

nursery trees budded on Mahaleb stock and growing side by side in the station nursery at Amherst.

The sources of bud-wood for the several varieties include the New York Agricultural Experiment Station at Geneva, the Ohio Agricultural Experiment Station at Wooster, and the Ontario Horticultural Experiment Station at Vineland, in addition to our own bearing orchards. Every effort has been made to establish the identity of the varieties used in this study.

The Constancy of Characters

It is to be expected that at least some of the characteristics by which one variety differs from another will be affected by the environment in which the trees are growing. Consequently, some differences will be found between trees growing in Massachusetts and those of the same variety growing in Maryland, Michigan, or some other region, as well as between trees growing in soils of different levels of fertility. The effect of environment, however, is one of degree rather than kind. Thus, the actual amount of pubescence on the petiole of a variety might be somewhat less under one set of growing conditions than under another; but, since the presence or absence of pubescence is doubtless a genetic character, it would not be expected that a variety would have pubescence in one section of the country and be completely devoid of it some place else. Furthermore, even when a character is affected somewhat by environment, *the several varieties maintain their relative order for that character regardless of where grown.* While the characters as herein described are those of trees grown at one place, the writer has examined nursery cherry trees in widely separated regions over a period of about fifteen years and has found these characters to be sufficiently constant to permit their use in the identification of varieties.

When to Examine Cherry Trees

Not all of the distinguishing characteristics of a variety can be observed at any one time. For example, color of the young tip leaves and amount of pubescence on the leaf petiole can be observed most readily fairly early in the season while length growth is still active. On the other hand, bud, bark, and lenticel characters become more distinctive near the end of the growing season as the wood approaches maturity. Yet leaf spot, insect injury, spray material, and dust may obliterate some of the most valuable characteristics of the leaves in late summer. Two-year trees show certain characters which cannot be found in one-year whips; and conversely, some characters are more evident on one-year whips than on two-year trees.

It has been the experience of the writer and his colleagues that sweet cherries can be examined best while the tips are still making active growth. With most varieties the one-year whip is as easily identified as the two-year tree. However, with the sour cherry varieties, Early Richmond and Montmorency, there are important lenticel differences which seldom are found on one-year trees.

How Varieties Differ

In the accompanying illustrations, specimens have been chosen which emphasize or even exaggerate the character in question, because it is recognized that cuts in a publication seldom do justice to the object. Furthermore, it should be realized, since living plants are to be considered, that not all individuals or all parts of a single tree may possess the character in question to the degree illustrated. Yet these are the characters by which one variety of cherry may be distinguished from another.

Since the plant characters as well as the fruit characters of sweet cherries differ materially from those of the sour and duke varieties, these groups will be considered separately.

PART I. SWEET CHERRIES

TREE CHARACTERS

Habit of growth of a two-year tree depends upon the direction and length of the individual shoots. In form a variety may be upright as Black Tartarian, upright-spreading as Napoleon, spreading as Windsor, or even have drooping branches as Lyons[2] (Figure 1). Some varieties as Black Tartarian have few branches while others have more. Most sweet cherry varieties are tall, Seneca, Genesee, and Black Tartarian being among the tallest, while Schmidt and Yellow Spanish are usually the shortest. *Buds* on sweet cherries seem to be of relatively little value for identification purposes until after the season's growth is quite mature. Then they vary in size and shape: on Lambert they tend to be small and blunt (not sharp pointed); on Bing, small and pointed; on Rockport, rather large and blunt; while on Ida they are large and pointed.

Mature *bark color* may be of considerable value in comparing varieties grown on the same soil. Two-year trunk bark color varies from light yellowish brown on Napoleon and Bing through medium bright brown on Genesee and medium dull brown on Elkhorn and Emperor Francis, to dark brown on Lambert and dark reddish brown on Gov. Wood. Usually the bark color on the one-year shoot is similar to that of the two-year trunk. The shoot bark is characterized also by the amount and type of *scarf-skin* present. A good contrast in this character is found between Bing, with a rather smooth bark, and Republican or Schmidt, with rather large areas of medium to heavy scarf-skin (Figure 2).

Lenticel size, *number*, and *position* are of considerable value in identifying varieties. While both Bing and Republican have few lenticels, those on the former are small while those on the latter are rather large. The lenticels on Lyons are rather numerous and small, while on Schmidt they are numerous and rather large. Some varieties such as Seneca and False Tartarian have mixed small and large, elongated lenticels. On well-matured shoots the elevation of the lenticels is useful: on Schmidt and Emperor Francis they are distinctly raised and can be easily felt; while on Bing and Napoleon they are practically flush with the surface of the bark and hence less evident to the touch (Figure 2).

LEAF CHARACTERS

When observing leaf characters, attention should be centered, for the most part, on the fully developed leaves on the upper half of the growing shoot, as these are generally the most typical leaves for the variety. On one-year whips the leaves are usually larger than on two-year trees, and some characters will be emphasized while others may be less distinctive than on the two-year tree.

The Blade

Size of the blade is influenced materially by the vigor of growth of the tree, yet under equal growing conditions Giant will have about the largest leaves of any variety, while Seneca will have the smallest. In observing *shape*, a broad but strongly folded leaf may be mistaken for a narrow leaf unless care is taken to flatten out the edges. The *base* of the blade may be cordate as in Windsor, full

[2]The leaf position in this cut is abnormal due to a slight wilting of the trees before the picture was taken.

as in Giant, or narrow as in Gold; while the *apex* may be full as in Lambert, narrow as in Napoleon, or acuminate with a fairly long tip as in Ida (Figure 3).

Amount and type of *folding* of the blade are valuable distinctive characters. Some varieties are flat or nearly so as Giant, others are rather broadly folded (saucer-fold) as Windsor, "U"-folded as Napoleon, "V"-folded as Seneca, or almost rolled as Gov. Wood. The waviness of the *margin* is an important character. The margin may be even or unwaved as in Windsor, finely waved as in Black Tartarian, or coarsely waved as in Seneca (Figure 3). On the margin will be found *serrations* or teeth of several types. They may be double crenate and regular as in Giant, dull serrate and rather fine as in Napoleon, coarsely serrate and irregular as in Gov. Wood, or sharply serrate as in Gold (Figure 4). In general, serrations are less valuable as an aid in identifying sweet cherries than they are for recognizing apple varieties.

On the upper surface of the leaf blade will be found three characters worthy of note. *Color* may be influenced greatly by the conditions under which the variety is growing; yet some varieties such as Lyons have dark green leaves, while others such as Ida have light green ones. There is also a difference in the amount of yellow evident in the leaf color. As compared with Lyons, Bing leaves show less yellow giving them a dark clear green color. On the other hand, Ida and Emperor Francis both have light green leaves, but the former shows materially more yellow in its color than does the latter. The amount of *light reflection* from the surface depends upon its nature. It may be glossy as in Bing, semi-glossy as in Black Tartarian, or dull as in Napoleon (Figure 4).

The *texture* of the upper surface of the leaf will vary with the vigor of the tree and size and age of the leaf, but comparable leaves will show varietal differences in texture. Napoleon has a fine texture; i. e., the areas between the net veins are small, and the surface is quite smooth with the veins being little depressed. In Schmidt the lateral veins, in addition to being somewhat depressed, are rather numerous, parallel, uniform in prominence, and fairly straight. Hence, the term "veiny" is applied to that variety. Windsor shows considerable puckering along the midrib, and the cross veins are rather depressed giving a pebbled or bullate surface. With some varieties such as Genesee the tissue between the lateral veins is distinctly raised or puffed up, producing a rough or rugose surface. Occasionally a variety will show rather sizable roundish sunken areas in the leaf tissue between the lateral veins, spoken of as "pockmarks." Victor is an example of this character in sweet cherries (Figure 5).

The Petiole

Petiole *length* and *thickness* are worth observing. Republican has a short thick petiole, Gov. Wood a long thick one, and Gold a long slender one (Figure 6). The nearest to a short slender petiole among sweet cherries probably is found in Yellow Spanish. On an upright shoot the angle between the shoot and petiole determines the *position* of the petiole. It may be only moderately wide as in Black Tartarian and Napoleon or practically a right angle as in Rockport. Furthermore, the petiole and midrib may be nearly straight as in Bing, or either one or both may be reflexed. Sometimes the reflexion comes at the base of the blade as in Seneca, sometimes at the base and at the tip as in Rockport.

The *color* of the petiole is a fairly valuable character. It varies from light colored as in Napoleon, Ida, and Gil Peck to dark red as in Gov. Wood, Seneca, and Rockport. The presence or absence and amount of *pubescence* on the petiole are extremely valuable characters in identifying some varieties. Two varieties, Bing and Republican, have glabrous petioles entirely without pubescence; many others have a light to moderate amount of pubescence as Yellow Spanish and

Windsor; while a few varieties such as Gov. Wood, Seneca, Gil Peck, and Early Rivers have heavy pubescence (Figure 7). Upshall (6) lists Black Tartarian, Lambert, Napoleon, and Windsor along with Gov. Wood as having heavy pubescence; but the writer has found these four varieties to have consistently less pubescence than Gov. Wood and has frequently made use of that difference in separating Gov. Wood and Windsor. Pubescence should be determined only on young leaves as it tends to decrease in amount as the leaves become old.

On the petiole will be found *glands* which are also very valuable characters of identification. They may vary in size, shape, color, number, and position. Glands also should be observed on the fairly young leaves as they tend to become shrunken and discolored when the leaves are old. *Size* and *shape* vary from small and almost globose as in Yellow Spanish to large and reniform as in Gov. Wood. Gold has an irregular-shaped gland, frequently with a "tail" on the lower end of it. In *color* the glands may be greenish yellow as in Gold, light as in Yellow Spanish, pink to reddish as in Schmidt, or red as in Gov. Wood. Glands on the very small young leaves may have somewhat different color than they will have after the leaves have grown to approximately full size.

The *number of glands* and *their location* on the petiole are other characteristics of the variety. Several varieties typically have 2-3 glands; in Schmidt and Victor they are on the petiole near the base of the blade, in Napoleon they are somewhat farther away from the base of the blade, while in Yellow Spanish and Gold they are well below the blade on the petiole. Gov. Wood has a moderate number, 3-4 somewhat scattered, while Seneca has 4-5 or more, scattered along the petiole (Figure 8). Furthermore, a variety having several glands will frequently show both large and small glands on the same petiole. The writer has not found the character of gland position, i.e., opposite or alternate, to be constant enough to merit its use in identification work.

Color of the Young Tip Leaves

If observed while the shoot is making active length growth, especially in the first half of the growing season, the color of the very small young leaves at the tip of the shoot is a valuable character for recognition. During active growth the tip leaves of Gold and Lambert will be light green with only a tinge of red color at the most; Yellow Spanish will be yellowish green; Napoleon will be dull reddish; while Bing will be distinctly red. On Rockport the light red color is usually confined to the margin of the folded young leaves. This one character alone is sufficient for accurate separation of Bing, Napoleon, and Lambert, which are frequently found mixed; but it cannot be emphasized too strongly that this character is of value only during active shoot growth. As the tip slackens growth preparatory to the formation of the terminal bud, these color differences disappear. Varieties differ also in the type of green color found in their expanding leaves back of the very tip. Immature leaves of Gov. Wood are light yellowish green, while those of Windsor are darker green in color.

Leaf Pose

Leaf pose or the general position taken by the leaves on the upper part of the shoot is characteristic of the variety. Leaf pose involves the amount and type of folding of the blade, the angle of the petiole, and the amount and type of reflexion of the petiole and midrib. In Giant and Napoleon the petiole angle is only moderately wide and yet the leaves stand out fairly straight because of a reflexion at the junction of the petiole and midrib. Giant leaves are essentially flat while those of Napoleon are quite folded so that the lower surface of the leaf is in evidence. With Windsor and Gov. Wood the petiole starts out at a moderate angle but curves so as to put the leaf in a spreading position in Windsor and a somewhat drooping position in Gov. Wood. Windsor leaves are saucer-folded, while those of Gov. Wood are rolled. A third comparison as to leaf pose which seems worth while is that of Black Tartarian and Rockport. Unfortunately, the Black Tartarian shoot in Figure 9 does not show leaf size and pose so well as does the tree in Figure 1. In this variety, since the petiole angle is only moderate, the leaf position of spreading to drooping is due chiefly to reflexion at the point of junction between the petiole and midrib. The tip of the midrib is also somewhat reflexed. The leaf itself is saucer-folded. Rockport represents the extreme in drooping leaves, many of them hanging almost straight down. Its petiole angle is wide, while the petiole itself is curved and the midrib is reflexed somewhat at the base and noticeably at the tip. Its leaf is rather broadly folded and coarsely waved (Figure 9).

In the foregoing pages, an effort has been made to list as many as possible of the ways in which varieties differ. Some of these differences are readily seen while others are not so evident. Furthermore, under one set of growing conditions certain differences will be found to be the most valuable ones for separating a mixture; while under other conditions or at a different period in the growing season, differences which were less evident in the first instance may become the most important ones.

VARIETY COMPARISONS

From the standpoint of separating possible mixtures in a nursery row, it is most important to know the particular differences between varieties which are similar or likely to be mixed. In some instances these differences are so pronounced that one wonders why such a mixture should persist at all, while in a few cases the characters which may be used to differentiate two varieties are very few and the differences small. Many of the following comparisons are between varieties which actually have been found mixed in commercial nurseries, some of them quite frequently.

A. Standard or Older Varieties

1.	Gov. Wood	Windsor
Habit of growth	Upright-spreading, taller	Spreading
Bark (2 year)	Dark reddish brown	Light pinkish brown
(1 year)	Reddish brown with abundant scarf-skin	Light pinkish brown with little scarf-skin
Lenticels	Fairly numerous, elongated, more raised	Rather few, small, round
Petiole	Longer, redder, heavy pubescence	Moderate pubescence
Glands	More numerous, larger, darker red	
Leaf	Long, narrow	Rather short, broad
Base	Rather narrow, slightly cordate	Distinctly cordate and full
Margin	Waved	Even
Folding	U-folded, rolled, and drooping	Saucer-folded
Surface	Fairly smooth	Pebbled and puckered along midrib
Serrations	Coarse, rather pointed	Finer, more rounded
Mildew	Very little, if any	Susceptible

Young leaves up to half-grown are lighter green on Gov. Wood

2. Bing, Lambert, and Napoleon.

As compared with the two others, Bing is short, has a glossy leaf surface, no pubescence on the petioles, dark red young tip leaves, and pointed buds.

3.	Lambert	Napoleon
Habit of growth	Fairly upright	Upright-spreading
Bark (2 year)	Rather dark dull brown	Lighter, yellowish brown
(1 year)	Greenish brown with abundant scarf-skin	Yellowish brown with less scarf-skin
Lenticels	More numerous	
Young tip leaves	Light greenish	Dull reddish
Petiole	Medium in length	Rather short
Glands	Somewhat more numerous	
Leaf	Somewhat larger and broader	
Folding	Flat to saucer-folded	U-folded
Color	Rather light clear green	Medium yellowish green
Surface	Rather semi-glossy and somewhat rugose	Dull and rather smooth

4.	Bing	Republican
Bark (1 year)	Little scarf-skin	Fairly abundant scarf-skin
Lenticels	Small, round, flush	Larger, irregular, slightly raised
Buds	Pointed	Blunt
Young tip leaves	Dark red	Red
Leaf		
Margin	Even	Coarsely waved
Folding		Somewhat more folded
Surface	Glossy	Semi-glossy

5.	Napoleon	Yellow Spanish
Habit of growth	Upright-spreading	Spreading and shorter
Bark (1 year)	Light yellowish brown	Yellowish brown
Lenticels	Medium in number, flush	More numerous, raised
Petiole	Medium thick, pale	More slender, redder
Glands	Medium in size, fairly near blade	Small, well below the blade
Young tip leaves	Dull reddish, stand out	Light yellowish green, drooping
Leaf		Longer and more narrow
Base	Full	Narrower
Apex	Not twisted	Twisted
Margin	Even	Rather coarsely waved
Folding	U-folded	Less folded
Color	Medium yellowish green	Medium clear green
Surface	Rather smooth, dull	Smoother, finer, not so dull
Thickness	Medium	Thin

6.	YELLOW SPANISH	BLACK EAGLE
Habit of growth	Spreading, rather short	Spreading, somewhat taller
Bark (1 year)	Yellowish brown	Light reddish brown
Scarf-skin	Medium and broken	Thin and uniform
Lenticels	Rather numerous, medium sized, raised	Fewer, small, flush
Petiole	Medium in length, redder	Longer
Glands	Small, light	More colored, larger on matured leaves
Young tip leaves	Light yellowish green	Tinged with red
Leaf	Rather long	Longer
Base	Rather full	Rather narrow
Apex	Twisted	Not twisted, shorter tip
Folding	Medium folded	Less folded
Surface	Rather dull, fine, smooth	Semi-glossy, slightly pebbled
Thickness	Thin	Medium
Serrations	Regular	Irregular

7.	BLACK TARTARIAN	ROCKPORT
Bark (1 year)	Light brown	Brown
Lenticels	Raised	Somewhat raised
Buds	Medium in size, rather pointed	Large, blunt
Young tip leaves	Reddish	Tinged with red on outer margin
Petiole	Medium in length and thickness, pubescence moderate	Long, rather slender, redder, pubescence light
Glands	Large, rather light colored	Medium, redder
Leaf	Rather large	Smaller, more narrow
Margin	Finely waved	Coarsely waved
Position	Petiole angle moderately wide, leaf somewhat drooping	Petiole angle wide, leaf distinctly drooping
Surface	Slightly rugose, rather dark green, semi-glossy	Fairly smooth, dark green, more glossy

8.	BLACK TARTARIAN	FALSE TARTARIAN
Habit of growth	Tall, upright, few branches	Medium, upright-spreading, numerous branches
Bark (2 year)	Rather dark brown	Dark reddish brown
(1 year)	Light brown	Reddish brown
Lenticels	Raised, rather large and rather few	Somewhat raised, numerous, large and small, elongate
Young tip leaves	Reddish	Red
Petiole	Moderate pubescence	Light pubescence
Leaf	Rather large	Small
Margin	Finely waved	Coarsely waved
Tip	Reflexed	Not reflexed
Surface	Slightly rugose, semi-glossy	Smooth, fine, dull
Thickness	Medium thick	Rather thin
Serrations	Rather coarse, serrate	Medium, dull serrate

9.	Schmidt	Elkhorn
Habit of growth	Upright-spreading, short, stout	Upright, tall, rather slender
Bark (2 year)	Light brown	Dull medium brown
Buds	Medium sized, quite blunt	Large, pointed
Lenticels	Rather large, raised	Rather small, less raised
Petiole	Medium in length and thickness	Longer and more slender
Leaf	Large, broad	Smaller and more narrow
Base	Cordate	Not cordate
Folding	Saucer-folded	Flat
Surface	Veiny, dull	Slightly rugose, not veiny, semi-glossy
Color	Light yellowish green	Medium clear green

It is apparent from the above comparison that trees of Schmidt and Elkhorn have very little in common, yet according to Upshall (6) these two varieties are sometimes confused. Other mixtures or substitutions mentioned by him include Ida for Gov. Wood and Black Eagle for Black Tartarian. In neither of these last two pairs of varieties are there enough similarities in the nursery trees to warrant a comparison. They may be similar in fruit, but certainly they are distinct in tree characters.

B. Newer or Less Common Varieties

Several of the newer or less well-known varieties have more or less similarity to some of the standard sorts. In the following comparisons the standard variety which has the most in common with the new sort has been chosen to compare with it. In some cases these similarities are rather few in number.

1.	Lambert	Giant
Habit of growth	Tall	Medium tall, stocky
Bark (1 year)	Abundant scarf-skin	Less scarf-skin
Lenticels	Numerous	Fewer, less distinct
Petiole	Medium thick	Rather thick
Glands	Medium to large, reddish	Large, rather light colored
Leaf	Large	Larger and somewhat longer
Apex	Full	Narrow with longer tip
Folding	Flat to saucer-folded	Flat
Color	Rather light clear green	Darker clear green
Surface	Somewhat rugose	More rugose

These two varieties are as nearly alike as any two varieties of sweet cherries considered in this publication.

2.	Schmidt	Emperor Francis
Habit of growth	Upright-spreading, short	More spreading but tall
Lenticels	Raised	More raised
Young tip leaves	Tinged with red, light yellowish green	Redder, darker green
Glands	Large, reddish, near base of blade	Medium, lighter, well below the blade

Leaf	Large, broad	Medium, rather long
Base	Cordate	Not cordate, medium in width
Apex	Medium	Narrow
Folding	Saucer-folded	Flatter
Surface	Veiny	Smooth, finer
Color	Light yellowish green	Rather light green

3.	SCHMIDT	VICTOR
Habit of growth	Short, upright-spreading	Rather short, spreading
Bark (2 year)	Light brown	Medium dull brown
Buds	Fairly blunt	Pointed
Young tip leaves	Tinged with red, light green	Reddish, darker
Glands	Large	Rather small
Leaf	Medium in length	Rather long
Base	Cordate	Very definitely cordate
Folding	Saucer-folded	More folded
Surface	Veiny, no pockmarks	Somewhat veiny, pockmarks
Color	Light yellowish green	Rather dark green

Younger leaves on the upper half of growing shoots of Victor frequently show a chlorotic-like mottling not found in Schmidt.

4.	GOV. WOOD	GIL PECK
Habit of growth	Upright-spreading	Somewhat more spreading
Bark	Reddish brown	Brown
Lenticels	Fairly numerous, large, raised	Rather few, small, flush
Young tip leaves	Reddish	Light, only tinged with pink
Petiole	Long, red	Medium in length, light
Glands	Red	Light, fewer
Leaf	Rather large, narrow	Large, broader
Color	Rather dark green	Darker green
Serrations	Coarse, rather pointed	Finer, less distinct

5.	GOV. WOOD	LYONS
Habit of growth	Upright-spreading, tall	Spreading to drooping, yet taller
Bark	Reddish brown with abundant scarf-skin	Brown with little scarf-skin
Lenticels	Fairly numerous, large	Numerous, small
Petiole	Heavy pubescence	Moderate pubescence
Leaf		
Base	Slightly cordate	Not cordate
Margin	Waved	Slightly waved
Folding	U-folded, rolled, and drooping	U-folded, less rolled, less drooping
Surface	Fairly smooth	Somewhat pebbled, with small pockmarks along midrib
Serrations	Coarse, rather pointed	Finer, duller

6. SCHMIDT and VERNON are similar in many respects. However, the one-year whip of Vernon is taller and somewhat more slender with longer internodes. Vernon has heavier petiole pubescence. Its leaves are somewhat longer, with more rugose, semi-glossy surface and somewhat duller serrations than those of Schmidt. Other differences may be present in the two-year trees, but because of lack of material, these have not been compared.

7. SODUS resembles NAPOLEON in general habit of growth, bark color, lenticel characters, and general leaf appearance; but it differs noticeably from that variety by having heavy pubescence on the petiole and rather large yellow glands. Its leaves are somewhat less folded also.

The following three of these less well-known varieties have so little in common with any standard sort that a detailed comparison hardly seems justified; yet it may be worth while to point out such similarities as are evident. GEANT DE' HEDELFINGEN resembles NAPOLEON somewhat in size of leaf and in its smooth, fine texture and dull leaf surface. GENESEE and NAPOLEON are similar in leaf size and shape, color of the young tip leaves, and amount of pubescence on the petiole. EARLY RIVERS is suggestive of WINDSOR in general habit of growth and color of the one-year bark.

The variety SCHMIDT has several so-called improved forms which are indistinguishable from it as far as nursery characters are concerned; these include NELSON and EUREKA. However, PAUL ROSE, a light colored bud-sport, differs from SCHMIDT in color of the young tip leaves, by showing practically no sign of a reddish tinge at any time.

DIFFERENCES BETWEEN SWEET AND SOUR CHERRY TREES

Hedrick (3) in his key to cultivated species of cherries separates sweet and sour cherries on the basis of leaf size, shape, and firmness. As a group, the leaves of Sours are smaller, shorter, thicker, less folded, less drooping, darker green, with more glossy surface, shorter tips, shorter and more slender petioles, smaller and fewer glands, and finer serrations than those of Sweets. In addition to the above leaf differences, nursery trees of sour varieties are generally shorter, with more slender branches, smaller buds, and darker brown one-year bark. One-year trees of Sours are also more commonly branched than are those of the sweet varieties. No experienced nurseryman would have any difficulty separating these two types.

Figure 1. Habit of Growth.
1, BLACK TARTARIAN – upright; 2, NAPOLEON – upright-spreading; 3, WINDSOR – spreading; 4, LYONS – drooping.

Figure 2. Scarf-Skin and Lenticels.

Left to Right: FALSE TARTARIAN - large and small, elongated, raised lenticels; SCHMIDT - heavy broken scarf-skin, numerous raised lenticels; LYONS – light scarf-skin, numerous small lenticels; BING – light scarf-skin, few small, flush lenticels; REPUBLICAN – medium scarf-skin, few large lenticels.

Figure 3. Leaf Shape and Margin.
Leaf Apex: 1, LAMBERT – full; 2, NAPOLEON – narrow; 3, IDA – acuminate.
Leaf Base: 1, WINDSOR – cordate; 2, GIANT – full; 3, GOLD – narrow.
Leaf Margin: 4, WINDSOR – even; 5, BLACK TARTARIAN – finely waved; 6, SENECA – coarsely waved.

Figure 4. Serrations and Light Reflection.

1, GIANT – double crenate; 2, NAPOLEON – fine, dull serrate; 3, GOV. WOOD – coarsely serrate-irregular; 4, GOLD – sharply serrate.
5, BING – glossy; 6, BLACK TARTARIAN – semi-glossy; 7, NAPOLEON – dull.

Figure 5. Leaf Texture.
1, NAPOLEON – fine; 2, SCHMIDT – veiny; 3, WINDSOR – bullate; 4, VICTOR – "pock-marked"; 5, GENESEE – rugose.

Figure 6. Petiole Size.
Left to Right: REPUBLICAN – short, thick; GOV. WOOD – long, thick; GOLD – long, slender.

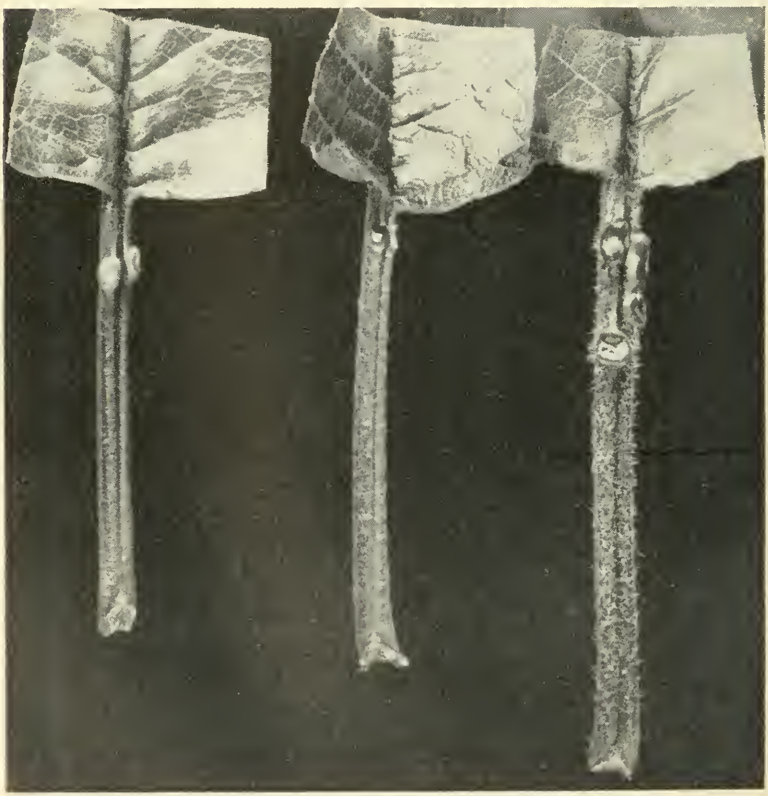

Figure 7. Petiole Pubescence.
Left to Right: BING – none or glabrous; WINDSOR – moderate; GOV. WOOD – heavy.

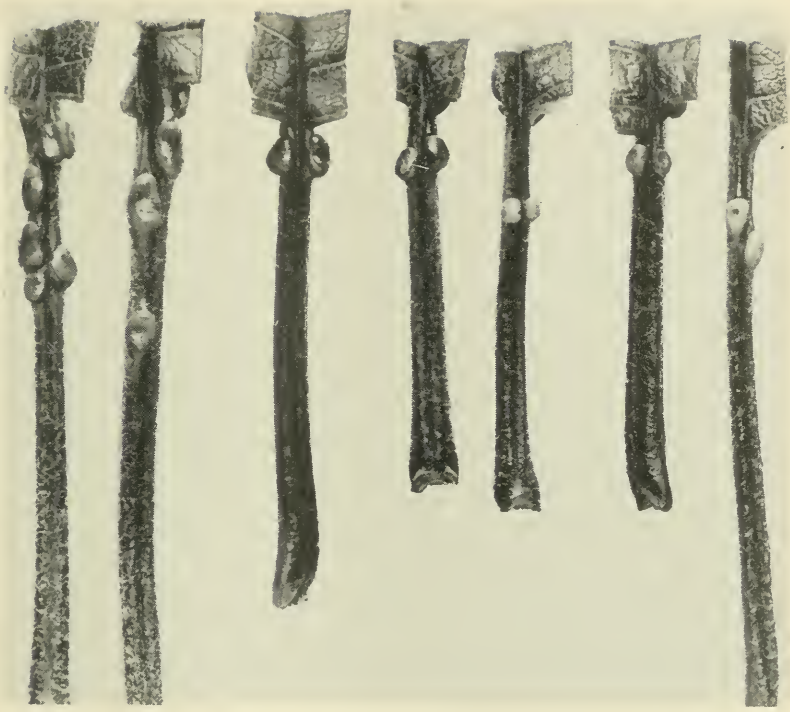

Figure 8. Gland Number, Size, and Position.

Left to Right: SENECA – numerous, large, scattered; GOV. WOOD – moderate in number, large reniform; SCHMIDT – few, near the blade; NAPOLEON – few, medium in size, fairly near the blade; YELLOW SPANISH – two, small, globose, well below the blade; VICTOR – few, small, near the blade; GOLD – two, irregular, tailed, well below the blade.

Figure 9. Leaf Pose.

1, GIANT – leaves flat, spreading; 2, NAPOLEON – leaves U-folded, somewhat upstanding to spreading; 3, WINDSOR – leaves saucer-folded, spreading; 4, GOV. WOOD – leaves U-folded to rolled, somewhat drooping; 5, BLACK TARTARIAN – leaves saucer-folded, somewhat drooping with reflexed tips; 6, ROCKPORT – leaves broadly U-folded, distinctly drooping with reflexed tips.

Figure 10. Habit of Growth.
Left: EARLY RICHMOND – spreading. Right: MONTMORENCY – upright.

Figure 11. Buds and Lenticels.

1, ENGLISH MORELLO – buds small, blunt; 2, MONTMORENCY – buds medium, rather pointed; 3, REINE HORTENSE – buds large, sharp pointed.
4, EARLY RICHMOND – lenticels at base of branch numerous, small; 5, MONTMORENCY – lenticels at base of branch few, larger.

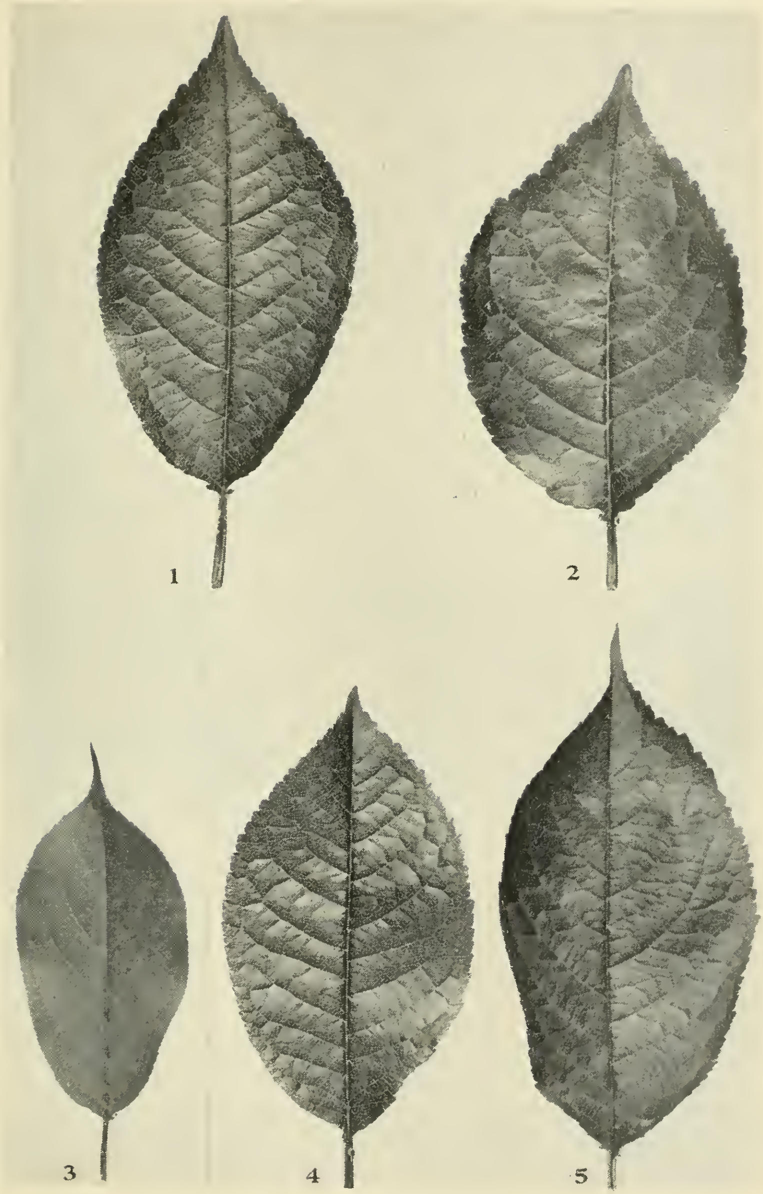

Figure 12. Leaf Shape, Size, and Surface.

1, MONTMORENCY – elliptic; 2, ENGLISH MORELLO – oval; 3, OSTHEIM – small, elliptic, fairly long lip, fine, dull surface; 4, ROYAL DUKE – medium oval or obovate, short tip, somewhat bullate, rather glossy surface; 5, REINE HORTENSE – large, obovate, long tip, somewhat rugose, semi-glossy surface.

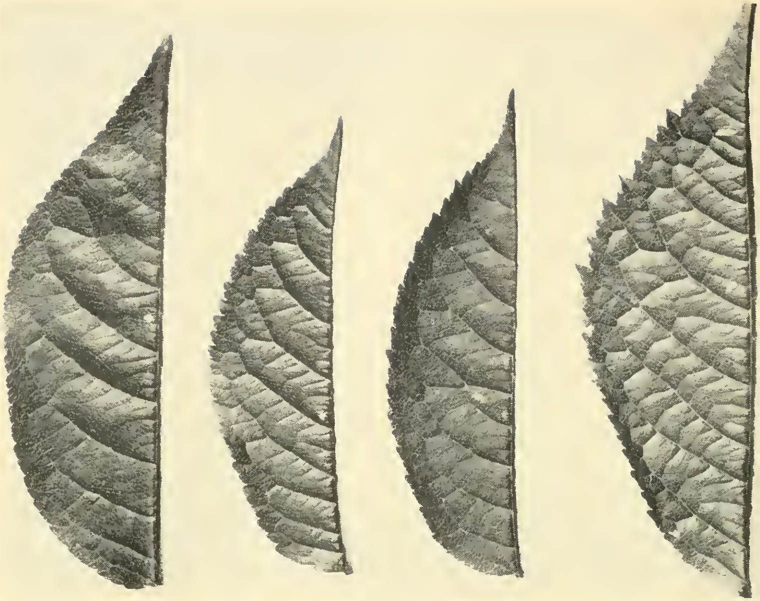

Figure 13. Serrations.
Left to Right: MONTMORENCY – fine, double crenate; LATE DUKE – fine, double, dull serrate; OLIVET – fine, double serrate; REINE HORTENSE – coarse, double serrate, and irregular.

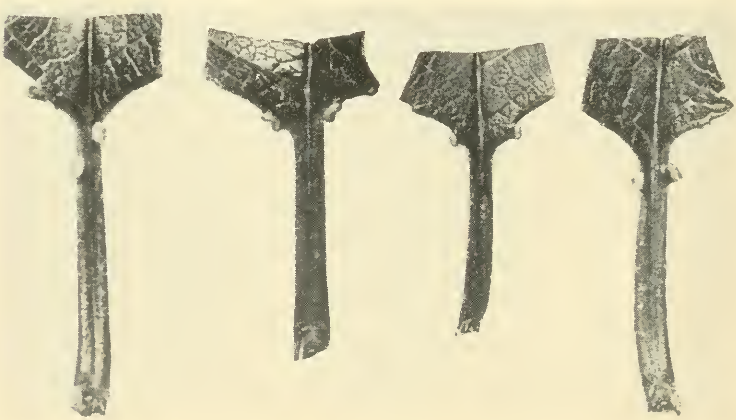

Figure 14. Glands.
Left to Right: MONTMORENCY – medium sized, on petiole; LATE DUKE – reniform, on base of blade; OSTHEIM – small, globose, on base of blade; REINE HORTENSE – medium sized, stalked, on petiole.

PART II. DUKE AND SOUR CHERRIES

While it is true that the Dukes range from nearly sweet to almost sour in fruit type, in the experience of the writer there is little danger of confusing Dukes with sweet varieties in the nursery. In leaf characters and size of tree at least, they seem to have greater similarity to the Sours than to the Sweets. For that reason and because of their smaller number, the Dukes and Sours are considered together in this section.

The number of characters which have been found useful for identification and the range of variability within these characters are in general considerably less in Sours and Dukes than in Sweets.

TREE CHARACTERS

Habit of growth. Several of the Dukes are fairly upright, yet well-grown two-year trees of Montmorency should be nearly as upright, while Early Richmond should be spreading (Figure 10). Chase tends to be somewhat drooping. A few varieties, such as Reine Hortense, have distinctly crooked shoots.

Buds. Differences in size and form of bud are more pronounced than with sweet cherries. Buds vary from small and blunt as in English Morello, medium sized and rather pointed as in Montmorency, to large and sharp pointed as in Reine Hortense (Figure 11).

Bark Color. In most varieties, the bark color is a medium brown, yet Early Richmond one-year bark is rather light brown and English Morello bark is tinged with red, especially the younger bark on a growing shoot. There are few differences in color of the two-year trunk bark.

Lenticels. The most useful difference in number and size of lenticels is found between Early Richmond and Montmorency. At the base of the branch on a two-year Early Richmond tree there are numerous rather small lenticels, while in the same position those of Montmorency are few and rather large (Figure 11). The lenticels of most Sours and Dukes are more or less raised; however, those of Suda are practically flush.

LEAF CHARACTERS

Leaf *size* varies from small as in Ostheim to fairly large as in Reine Hortense. The *shape* of the blade may be oval as in English Morello, elliptic as in Montmorency, or obovate as in Reine Hortense and Royal Duke frequently (Figure 12). The leaf *apex* may have a short tip as in Royal Duke or a long acuminate one as in Reine Hortense (Figure 12). There is no common variety of Duke or Sour cherry with a cordate leaf *base.* The leaf *surface* ranges from fine, smooth, and dull as in Ostheim, to pebbled or bullate and almost glossy as in Royal Duke, or somewhat rugose as in Reine Hortense (Figure 12). Leaf *color* may be grayish green as in English Morello, light yellowish green as in Ostheim, medium yellowish green as in Early Richmond, or dark yellowish green as in Reine Hortense. There is relatively little evidence of *margin waving* among the Dukes and practically none among the Sours. While the variation in leaf *folding* is much less with these types than with sweet varieties, V-folding in some degree occurs more frequently than it does among the Sweets, perhaps because of the stiffer nature of the leaves of Sours especially. *Serrations* may be fine, double crenate as in Montmorency; fine, double, dull serrate as in Late Duke; fine, double serrate as in Olivet; or rather coarse, double serrate, and irregular as in Reine Hortense (Figure 13). *Petioles* vary from short and slender as in Ostheim to rather long and medium thick as in Reine Hortense. The *glands* are usually two in number, although a few varieties tend to have somewhat more. They may be on the base of the blade, very small round as in Ostheim or somewhat larger reniform as in Late Duke; or usually near the base of the blade on the petiole as in Montmorency and Reine Hortense, the latter being somewhat stalked (Figure 14). *Pubescence* varies from light on Montmorency to moderate on Early Richmond. There is little evidence of petiole or midrib *reflexion* among Sours and Dukes. Hence, with most varieties the leaves tend to be somewhat upright to spreading. *Young tip leaves* are mostly green to tinged with red, although those of May Duke are quite reddish in color.

VARIETY COMPARISONS

1. Early Richmond — Montmorency

Early Richmond is the stronger grower with spreading or sprawling habit of growth, while Montmorency is fairly upright with shorter and straighter branches. Early Richmond buds are smaller and less pointed than those of Montmorency. The one-year bark color of Early Richmond is lighter and the lenticels are smaller, less raised, and more numerous, especially near the base of the branch. Petiole pubescence on Early Richmond is somewhat heavier, while the leaves are a bit lighter green in color and somewhat more folded than those of Montmorency. The differences in glands, mentioned by Upshall (6), have not been found constant enough to be of particular value. These two varieties are very difficult to tell apart as one-year trees, unless they have made unusually good growth.

2. Early Richmond — Dyehouse

It is impossible positively to separate these two varieties as seen so far. Yet as a row, Dyehouse seems to be a somewhat stronger, slightly more upright grower with more secondary shoots than an equally good row of Early Richmond.

3. English Morello

As compared with Early Richmond and Montmorency, the other two most common varieties of sour cherries found in nurseries, English Morello is usually smaller, nearly as spreading as Early Richmond with fairly numerous lenticels. The color of the shoot bark is more reddish brown throughout its length, and the buds are smaller and more blunt than on either of the other two varieties. English Morello leaves are usually smaller, more oval, and less folded, with duller surface and grayish green instead of yellowish green color. The petiole is shorter, duller red in color, and has even less pubescence than Montmorency.

4. Chase — English Morello

Chase is more dwarf, spreading or almost drooping, with lighter bark color than English Morello. It lacks the characteristic reddish shoot bark color of English Morello. Chase leaves are somewhat longer, with a narrower base and longer apex, medium green leaf color, and less red in the petiole than English Morello.

5. Suda — English Morello

Suda has a distinctly Morello-type tree, but is shorter, with brown instead of reddish brown bark, and lenticels which are practically flush instead of being raised like those of English Morello. The young growing tips of Suda are green, while those of English Morello are tinged with red. Suda leaf is narrower at base and apex and the serrations are somewhat coarser than those of English Morello.

6. Ostheim

This variety is easily distinguished from others of the Morello type by its rather short slender growth, yellowish brown bark, slender pointed buds, small elliptic leaves, with very dull, fine texture, light yellowish green color, and fine single serrations. Its glands are also distinctive, being very small, round, and usually on the base of the blade.

7. Olivet — Early Richmond

Olivet more closely resembles Early Richmond than any other common variety. It is a somewhat stronger grower, slightly more upright, with a little darker bark and fewer, larger, and more raised lenticels than Early Richmond. Olivet leaves are larger, more pointed, with a tendency toward twisted tips, less folding, more spreading position, duller surface, and sharper serrations.

8. May Duke, Reine Hortense, and Abbesse d'Oignies

These three varieties are distinctly sweet-type Dukes. All have upright-spreading trees with rather long slender branches, fairly large pointed buds, and rather large leaves with fairly coarse serrations. As distinguished from the two others, the young tip leaves of May Duke are reddish; there is less pubescence on its petioles; its leaf glands are smaller, fewer, and redder; and its leaf color shows less yellow in the green. May Duke shows less of the crooked branch character than does Reine Hortense; also its leaves are somewhat smaller and less folded and have shorter petioles and somewhat more glossy surface than that variety. May Duke bark is darker brown than that of Abbesse.

9. Reine Hortense — Abbesse d'Oignies

Reine Hortense has darker colored bark, more crooked branches, more pointed buds, and fewer lenticels than Abbesse. Its leaves are darker green, with more acuminate apex, and coarser, more prominent serrations than those of Abbesse. Reine Hortense petioles are longer, with less pubescence and the glands are more apt to be stalked.

10. Royal Duke — Brassington

In many respects these two varieties are similar. However, Royal Duke is taller and has somewhat more lenticels. Its leaves are somewhat larger and longer, with narrower leaf base, somewhat longer apex, and coarser serrations than Brassington. Royal Duke petioles are longer. The leaves on the upper half of Royal Duke shoots are more folded and more erect in position. Royal Duke is also more leafy in the head of the tree than is Brassington.

11. Late Duke

Two-year trees of this variety are similar to Reine Hortense in habit of growth and like that variety have crooked shoots, but their bark color is darker brown. Also they have somewhat more lenticels, which are both large and small with the bark split above and below each. One-year trees of Late Duke most nearly resemble those of Royal Duke. However, the side shoots on Late Duke curve upward while those of Royal Duke are straight. Furthermore, Late Duke leaves have somewhat longer tips, somewhat smoother surface, somewhat finer serrations, and rather small reniform greenish glands, often on the base of the blade, while those on Royal Duke are larger, rounder, yellow, and usually on the petiole. Late Duke loses most of its lower leaves with leaf spot, while those of Royal Duke are little affected by that disease. The color of the young tip leaves is darker on Late Duke than on any other variety in this group except May Duke.

KEY TO SWEET CHERRY VARIETIES

A Petiole not pubescent
  B Lenticels small, flush..*2 Bing
  BB Lenticels large, somewhat raised.............................31 Republican
AA Petiole pubescence heavy
  B Leaves flat to saucer-folded
    C Young tip leaves light green...............................36 Sodus
    CC Young tip leaves reddish...................................38 Sweet September
  BB Leaves U- or V-folded
    C Lenticels small, flush......................................18 Gil Peck
    CC Lenticels larger, raised
      D Leaves rather large and long..............................20 Gov. Wood
      DD Leaves rather small
        E Petiole thick...10 Early Rivers
        EE Petiole slender..35 Seneca
AAA Petiole pubescence light to moderate
  B Lenticels practically flush
    C Young tip leaves light green to tinged with red
      D Glands small, especially on young leaves..................3 Black Eagle
      DD Glands medium to large
        E Lenticels numerous......................................22 Lambert
        EE Lenticels quite few....................................17 Giant
    CC Young tip leaves reddish
      D Leaf base cordate...41 Windsor
      DD Leaf base not cordate
        E Leaf surface dull
          F Leaves U-Folded.......................................27 Napoleon
          FF Leaves saucer-folded.................................15 Geant d'Hedelfingen
        EE Leaf surface semi-glossy
          F Petiole long, slender, leaves drooping................4 Black Heart
          FF Petiole medium, leaves spreading.....................8 Downer
  BB Lenticels raised
    C Young tip leaves usually light green to tinged with red
      D Glands small..42 Yellow Spanish
      DD Glands medium to large
        E Glands greenish yellow..................................19 Gold
        EE Glands pink or reddish
          F Leaf base not cordate.................................11 Elkhorn
          FF Leaf base cordate
            G Petiole long, leaf drooping.........................32 Rockport
            GG Petiole medium, leaf spreading
              H Petiole pubescence light..........................34 Schmidt
              HH Petiole pubescence moderate......................39 Vernon
    CC Young tip leaves reddish
      D Leaf base not cordate
        E Leaves U-folded...24 Lyons
        EE Leaves saucer-folded or less
          F Leaf surface rugose, semi-glossy......................16 Genesee
          FF Leaf surface smooth, dull............................12 Emperor Francis
      DD Leaf base at least somewhat cordate
        E Leaf surface semi-glossy................................5 Black Tartarian
        EE Leaf surface dull
          F Leaves large, rather dark green.......................40 Victor
          FF Leaves rather small, lighter green
            G Lenticels few.......................................21 Ida
            GG Lenticels numerous.................................14 False Tartarian

*See Variety Descriptions, pages 18-22.

KEY TO DUKE AND SOUR CHERRY VARIETIES

A Leaves rather large, apex acuminate, serrations rather coarse
  B Young tip leaves reddish, glands small .... *25 May Duke
  BB Young tip leaves green to tinged with red, glands medium sized
    C Petiole rather long, glands on base of blade or stalked .... 30 Reine Hortense
    CC Petiole medium in length, rather slender, glands scattered on petiole .... 1 Abbesse d'Oignies
AA Leaves usually small to medium, serrations rather fine serrate to crenate
  B Leaf surface bullate, semi-glossy to glossy
    C Glands reniform, greenish, usually on base of blade .... 23 Late Duke
    CC Glands roundish, yellow, usually on petiole
      D Leaf oval with full base .... 6 Brassington
      DD Leaf oval to obovate with narrow base .... 33 Royal Duke
  BB Leaf surface essentially smooth, dull to semi-glossy
    C Glands very small, on base of blade .... 29 Ostheim
    CC Glands medium, usually on petiole
      D Leaf oval, young shoot bark reddish throughout its length
        E Lenticels raised .... 13 English Morello
        EE Lenticels flush .... 37 Suda
      DD Leaf elliptic, young shoot bark only tinged with red near tip of shoot
        E Serrations serrate .... 28 Olivet
        EE Serrations crenate
          F Lenticels at base of shoot few .... 26 Montmorency
          FF Lenticels at base of shoot many
            G Fairly large spreading tree, leaf surface semi-glossy .... 9 Early Richmond
            GG Dwarfish tree, spreading to drooping, leaf surface dull .... 7 Chase

*See Variety Descriptions, pages 18-22.

VARIETY DESCRIPTIONS

1. **Abbesse d'Oignies.** Habit upright-spreading, medium in height with slender branches. Bark yellowish brown; lenticels rather few, medium sized, raised; buds medium in size, rather pointed. Young tip leaves green. Petiole wide-angled, straight, medium in length, rather slender; pubescence moderate; glands 2 – 4, medium in size, scattered on petiole. Leaf blade fairly large, rather narrow, long; base narrow; apex narrow and acuminate; margin slightly waved; surface bullate, semi-glossy, medium yellowish green; broadly V-folded; serrations coarse, serrate, irregular.

2. **Bing.** Habit upright-spreading, rather short. Bark yellowish brown; lenticels few, small, flush; buds rather small, pointed. Young tip leaves dark red. Petiole wide-angled and straight, short, medium thick; glabrous; glands 2 – 3, rather large, reddish, near the blade. Leaf blade medium in size, broad, short; base slightly cordate, full; apex full; margin even; surface slightly rugose, glossy, rather dark clear green; saucer-folded; serrations medium in size, dull serrate.

3. **Black Eagle.** Habit spreading, medium in height. Bark light reddish brown, little scarf-skin, 2-year trunk bark medium yellowish brown; lenticels medium in number, small, flush; buds blunt. Young tip leaves tinged with red. Petiole wide-angled, slightly reflexed, long, slender, light colored; pubescence light to moderate; glands 2 – 4, scattered, small to medium, rather light colored. Leaf blade medium in size, long; base rather narrow; apex narrow; margin moderately waved; surface slightly bullate, semi-glossy, medium yellowish green; moderately saucer-folded; serrations medium, dull serrate, irregular.

4. **Black Heart.** Habit upright-spreading, tall with rather slender branches. Bark brown to reddish brown; lenticels medium in number, small, nearly flush; buds medium in size and sharpness. Young tip leaves red. Petiole rather wide-angled, strongly reflexed, long, rather slender; pubescence moderate; glands 2 – 4, scattered, large, reddish. Leaf blade medium, rather long and narrow; base narrow; apex narrow; margin coarsely waved; surface nearly smooth, semi-glossy, medium green; moderately folded; serrations medium, dull serrate.

5. **Black Tartarian.** Habit very upright, tall with few branches. Bark light brown, 2-year bark rather dark brown; lenticels rather few, large, raised; buds medium in size, rather pointed. Young tip leaves reddish. Petiole moderately wide-angled, somewhat reflexed, (leaf with reflexed tip); pubescence moderate; glands 2 – 3, fairly near the blade, large, rather light colored. Leaf blade large, rather long; base somewhat cordate; apex narrow; margin finely waved; surface slightly rugose, semi-glossy, rather dark green; saucer-folded; serrations coarse, serrate, irregular.

6. **Brassington.** Habit upright, medium in height with rather few branches; internodes short. Bark brown; lenticels few, large, raised; buds small, blunt. Young tip leaves tinged with red. Petiole moderately wide-angled, straight, rather short; pubescence light; glands 2 – 3, fairly near the blade, rather small, light colored. Leaf blade medium in size, rather broad and short, oval; base rather full; apex rather full; margin even; surface bullate, semi-glossy, medium green; very broadly V-folded; serrations fine, double, dull serrate to crenate.

7. **Chase.** Habit spreading to drooping with rather short, slender branches; internodes short. Bark brown; lenticels numerous, medium in size, raised; buds medium in size and sharpness. Young tip leaves green. Petiole wide-angled, straight, short, slender; pubescence light; glands 2, near the blade, medium in size, green. Leaf blade medium in size, rather long, elliptic; base medium in width; apex rather narrow, fairly acuminate; margin even; surface smooth, fine, dull, medium green; moderately U-folded; serrations fine, double crenate.

8. **Downer.** Habit upright-spreading, medium in height with rather few branches. Bark yellowish brown to dull brown; lenticels medium in number, rather small, flush; buds small, pointed. Young tip leaves reddish. Petiole rather wide-angled, somewhat reflexed, medium in size; pubescence light to moderate; glands 3 – 5, scattered, medium in size, reddish. Leaf blade rather large and broad; base full; apex medium in width; margin somewhat coarsely waved; surface slightly rugose, semi-glossy, medium green; somewhat folded; serrations fine, dull serrate, irregular.

9. **Early Richmond.** Habit spreading with rather long, slender branches. Bark light brown; lenticels numerous, especially at base of branch, small, slightly raised; buds medium in size, blunt. Young tip leaves greenish. Petiole moderately wide-angled, straight, rather short and slender; pubescence moderate; glands 2, near the blade, medium in size, light colored. Leaf blade rather small, elliptic; base rather narrow; apex narrow; margin even; surface smooth, fine, semi-glossy, medium yellowish green; somewhat U-folded; serrations fine, double crenate.

10. **Early Rivers.** Habit spreading, rather poor grower with fairly numerous branches. Bark light brown to dull brown; lenticels both large and small, irregular, raised; buds medium in size, rather pointed. Young tip leaves reddish. Petiole wide-angled and somewhat reflexed, rather

long, thick; pubescence heavy; glands 3 – 4, large, reddish, scattered. Leaf blade small, rather long; base slightly cordate, rather narrow; apex narrow; margin coarsely waved; surface smooth, fine in texture, dull, light green; somewhat U-folded; serrations fine, dull serrate to crenate, irregular.

11. **Elkhorn.** Habit upright, tall with rather slender and few branches; internodes long. Bark dull brown; lenticels numerous, small, moderately raised; buds rather large, pointed. Young tip leaves light green to tinged with red. Petiole wide-angled, straight; pubescence light; glands 2 – 3, medium in size, fairly near the blade, rather light pink. Leaf blade rather small; base full; apex narrow; margin even to finely waved; surface slightly rugose, semi-glossy, medium clear green; flat to slightly folded; serrations medium in size, dull serrate.

12. **Emperor Francis.** Habit upright-spreading, rather tall. Bark greenish brown with much broken scarf-skin, 2-year bark medium dull brown; lenticels numerous, medium in size, distinctly raised; buds rather large. Young tip leaves reddish. Petiole wide-angled, straight; pubescence light; glands 2 – 3, well below the blade, medium in size, rather light colored. Leaf blade medium in size, rather long; base medium in width; apex narrow; margin even to slightly coarsely waved; surface smooth, fine, dull, rather light green; nearly flat; serrations rather fine, serrate, regular.

13. **English Morello.** Habit spreading, rather short with numerous, slender branches; internodes short. Mature bark reddish brown, bark on young shoot reddish throughout most of its length; lenticels medium in number, small, raised; buds small, blunt. Young tip leaves tinged with red. Petiole wide-angled, straight, short, slender; pubescence light; glands 2, near the blade, medium in size, light colored. Leaf blade medium in size, rather broad and short, oval; base moderately full; apex moderately full; margin even; surface mostly smooth, fine, dull, grayish green; broadly V-folded; serrations fine, double, dull serrate to crenate.

14. ***False Tartarian.** Habit upright-spreading, medium in height with rather numerous branches. Bark reddish brown to dark reddish brown; lenticels numerous, large and small, elongated, somewhat raised. Young tip leaves red. Petiole wide-angled, somewhat reflexed, medium in length; pubescence light; glands 2 – 3, near the blade, large, rather light colored. Leaf blade small, rather long; base somewhat cordate, rather narrow; apex narrow; margin coarsely waved; surface smooth, fine, dull, rather light green; rather thin; slightly folded; serrations medium, dull serrate, irregular, rather shallow.

15. **Geant d'Hedelfingen.** Habit spreading, but tall with numerous branches. Bark light brown, 2-year bark dark chocolate brown; lenticels rather few, small, practically flush; buds rather large, pointed. Young tip leaves reddish. Petiole rather wide-angled, slightly reflexed; pubescence moderate; glands 2 – 3, fairly near the blade, rather small, rather light reddish. Leaf blade medium in size, broad, rather short; base rather full; apex medium in width; margin coarsely waved; surface smooth, fine, rather dull, medium yellowish green; saucer-folded; serrations medium, dull serrate, irregular.

16. **Genesee.** Habit rather upright, tall with rather numerous branches; internodes rather long. Bark reddish brown, 2-year bark medium bright brown; lenticels medium in number, rather large, raised; buds rather large, medium pointed. Young tip leaves reddish. Petiole fairly wide-angled, somewhat reflexed, rather long; pubescence light to moderate; glands 2 – 3, well below the blade, medium in size, red. Leaf blade medium in size, length, and width; base rather full; apex narrow; margin somewhat finely waved; surface rugose, semi-glossy, medium green; saucer-folded; serrations coarse, dull serrate, irregular.

17. **Giant.** Habit fairly upright, medium in height with stout branches; internodes short. Bark dull brown, moderate scarf-skin; lenticels few, small, flush; buds small, blunt. Young tip leaves light green. Petiole moderately wide-angled, medium in length, thick; pubescence moderate; glands 2–3, fairly near the blade, large, light colored. Leaf blade large, broad, rather long; base full; apex rather narrow; margin even; surface rugose, semi-glossy, rather dark clear green; flat; serrations shallow, broad, double crenate, regular.

18. **Gil Peck.** Habit spreading, medium in height with stout branches. Bark 1-year greenish brown, 2-year light dull brown; lenticels rather few, very small, flush; buds rather small. Young tip leaves tinged with red. Petiole wide-angled and straight except on young leaves where it is reflexed causing leaves to droop, medium in length, rather thick, light colored; pubescence heavy; glands 2–3, fairly near the blade, large, light colored. Leaf blade large and long; base slightly cordate, full; apex rather full; margin coarsely and finely waved; surface slightly rugose, fine in texture, semi-glossy to glossy, dark clear green; considerably U-folded; serrations medium in size, dull serrate, regular.

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*The name "False Tartarian" refers to an unknown sweet cherry which has been found substituted for Black Tartarian in a few nurseries. It is reputed to bear a small, worthless, black cherry.

19. **Gold.** Habit spreading, but rather tall with numerous branches; internodes rather long. Bark yellowish brown, 2-year bark dark brown; lenticels fairly numerous, small, raised; buds small, blunt. Young tip leaves light green. Petiole rather wide-angled, somewhat reflexed, long, slender, light green; pubescence light; glands 2, medium in size, tailed, well below the blade, greenish yellow. Leaf blade rather small; base narrow; apex narrow to acuminate; margin coarsely and finely waved; surface smooth, fine, semi-glossy, rather light yellowish green; broadly folded; serrations fine, sharp serrate, irregular.

20. **Gov. Wood.** Habit upright-spreading, rather tall with rather few slender branches. Bark reddish brown with abundant scarf-skin; lenticels fairly numerous, rather large, elongated and raised; buds medium in size, somewhat pointed. Young tip leaves reddish. Petiole moderately wide-angled and reflexed, long, thick, red; pubescence heavy; glands 3–4, scattered, large, reniform, reddish. Leaf blade rather large, long, rather narrow; base slightly cordate, but rather narrow; apex narrow to acuminate; margin coarsely and finely waved; surface fairly smooth, semi-glossy, rather dark green; U-folded and rolled; serrations coarse, serrate, irregular.

21. **Ida.** Habit upright-spreading, rather tall with numerous branches. Bark light to medium brown; lenticels few, rather large, raised; buds large, pointed. Young tip leaves reddish to red. Petiole rather wide-angled, slightly reflexed, long, rather slender, light colored; moderate pubescence; glands 2–3, fairly near the blade, medium in size, reddish. Leaf blade rather small, fairly narrow, long; base cordate, but narrow; apex distinctly acuminate; margin coarsely and finely waved; surface smooth, fine, dull, light yellowish green; broadly V-folded; serrations rather coarse, serrate, irregular.

22. **Lambert.** Habit rather upright, tall with rather few stout branches; internodes rather short. Bark greenish brown with abundant coarse broken scarf-skin, 2-year trunk bark dull, dark brown; lenticels numerous, small, flush; buds small, blunt. Young tip leaves light green. Petiole rather wide-angled, somewhat reflexed, medium in length and thickness; pubescence moderate; glands 2–4, fairly near the blade, medium to large, reddish. Leaf blade rather large, broad, short; base slightly cordate, full; apex full; margin mostly even; surface somewhat rugose, semi-glossy, rather light clear green; flat to saucer-folded; serrations medium in size, slightly double crenate.

23. **Late Duke.** Habit upright-spreading with rather slender crooked branches; internodes medium in length. Bark dark brown; lenticels rather few, large and small, raised; buds medium in size and sharpness. Young tip leaves tinged with red to reddish. Petiole moderately wide-angled and straight, short; pubescence light; glands 2, reniform, rather small, usually on base of blade, light greenish. Leaf blade medium in size, somewhat obovate; base rather narrow; apex rather narrow; margin even; surface somewhat bullate, semi-glossy to glossy, rather dark green; broadly U-folded; serrations fine, double, dull serrate, regular.

24. **Lyons.** Habit spreading to drooping, but tall with few rather slender branches; internodes long. Bark brown with light scarf-skin, 2-year bark dark brown; lenticels numerous, rather small, raised; buds medium in size and sharpness. Young tip leaves reddish. Petiole wide-angled, somewhat reflexed, long, thick, red; pubescence moderate; glands 2–3, scattered, variable in size, red. Leaf blade medium in size, long; base full to narrow; apex acuminate; margin slightly coarsely waved; surface bullate with small pockmarks along midrib, semi-glossy, dark green; U-folded; serrations medium, dull serrate.

25. **May Duke.** Habit upright-spreading, fairly tall with rather slender branches. Bark brown; lenticels very few, rather large, raised; buds rather large, pointed. Young tip leaves reddish. Petiole moderately wide-angled, reflexed at base of blade, rather short and stout; pubescence rather light; glands 2, near the blade, small, light reddish. Leaf blade rather large, rather narrow, long, obovate; base rather narrow; apex acuminate; margin even; surface somewhat rugose and bullate, semi-glossy, medium clear green; broadly V-folded; serrations rather coarse, double serrate, regular.

26. ***Montmorency.** Habit upright, rather short with stout branches. Bark brown; lenticels few, especially at base of branch, rather large, raised; buds medium in size, rather pointed. Young tip leaves greenish. Petiole moderately wide-angled, straight, medium in length and thickness; pubescence light; glands 2, near the blade, medium in size, light. Leaf blade medium in size, elliptic; base moderately narrow; apex narrow; margin even; surface rather smooth, fine, dull to semi-glossy, medium green; moderately V-folded; serrations fine, double crenate.

27. **Napoleon.** Habit upright-spreading, medium in height. Bark light yellowish brown with rather little scarf-skin; lenticels medium in number, small, flush; buds medium in size, rather blunt.

*The Montmorency herein referred to is the common type. Several attempts have been made to locate propagating wood of the "Large Montmorency" and the "Short-stemmed Montmorency" of Hedrick (2), but without success. Hence, it has not been possible to include those types in this study.

Young tip leaves dull reddish. Petiole moderately wide-angled, somewhat reflexed, rather short, light colored; pubescence moderate; glands 2–3, fairly near the blade, light colored. Leaf blade medium in size, width, and length; base full; apex rather narrow; margin even; surface smooth, fine texture, dull, medium yellowish green; rather strongly U-folded; serrations fine, double, dull serrate, regular.

28. **Olivet.** Habit rather spreading, but fairly tall with numerous branches; internodes long. Bark brown; lenticels medium in number, large, raised; buds medium in size, moderately blunt. Young tip leaves tinged with red. Petiole wide-angled, midrib somewhat reflexed; pubescence moderate; glands 2, near the blade, medium in size, light colored. Leaf blade rather large, fairly long, elliptic; base moderately narrow; apex narrow, fairly acuminate; margin even: surface rather smooth, fine, dull, medium green; broadly U-folded with somewhat twisted tips; serrations fine, double serrate.

29. **Ostheim.** Habit spreading with numerous, short, slender branches. Bark yellowish brown; lenticels medium in number, small, somewhat raised; buds rather slender, pointed. Young tip leaves tinged with red. Petiole wide-angled, straight, short, slender; pubescence light; glands 2, very small, globose, usually on base of blade, light colored. Leaf blade small, elliptic; base narrow; apex rather narrow, but acuminate; margin even; surface smooth, fine, always dull, light yellowish green; V-folded; serrations very fine, dull serrate.

30. **Reine Hortense.** Habit upright-spreading, rather tall with rather slender crooked branches; internodes rather long. Bark brown; lenticels few, medium in size, raised; buds rather large, pointed. Young tip leaves green to tinged with red. Petiole wide-angled, slightly reflexed, rather long, medium thick; pubescence light to moderate; glands 2–4, medium in size, on base of blade or near blade and stalked. Leaf blade rather large, medium in width, rather long, obovate; base rather narrow; apex rather full, acuminate; margin even to somewhat coarsely waved; surface slightly rugose, somewhat semi-glossy, dark yellowish green; broadly U- to saucer-folded with twisted apex; serrations coarse, double serrate, irregular.

31. **Republican.** Habit upright-spreading, rather tall. Bark yellowish brown with broken scarf-skin; lenticels few, large, slightly raised; buds small, blunt. Young tip leaves red. Petiole wide-angled and straight, short, thick; glabrous; glands 2–3, rather large, reddish, fairly near the blade. Leaf blade medium in size, rather broad and short; base slightly cordate, full; apex full; margin coarsely waved; surface slightly rugose, semi-glossy, rather dark clear green; rather strongly saucer-folded; serrations medium in size, dull serrate.

32. **Rockport.** Habit upright, tall with rather few branches. Bark brown to reddish brown; lenticels rather numerous, medium in size, somewhat raised; buds large, blunt. Young tip leaves light, tinged with red on outer margins of folded leaves. Petiole wide-angled, reflexed, long, slender, (leaf distinctly drooping with reflexed tip), red; pubescence light; glands 2–3, near the blade, medium in size, reddish. Leaf blade rather small, long, narrow; base cordate, rather narrow; apex narrow; margin coarsely waved; surface rather smooth, glossy, dark green; broadly U-folded; serrations medium in size, double serrate, irregular.

33. **Royal Duke.** Habit upright, rather tall with rather numerous stout branches; internodes short. Bark brown; lenticels medium in number, large, raised; buds small, blunt. Young tip leaves light green, tinged with red on outer margins of folded leaves. Petiole wide-angled, except on upper third of shoot where it is apt to be narrow, nearly straight, rather long; pubescence moderate; glands 2, near the blade, medium in size, yellow. Leaf blade medium in size, fairly broad and long, oval to obovate; base narrow; apex rather full; margin even; surface somewhat bullate, semi-glossy to glossy chiefly on younger leaves, dark green; saucer-folded; serrations shallow, double, dull serrate to crenate.

34. **Schmidt.** Habit upright-spreading, usually short and stout; internodes short. Bark brown to light brown with broken scarf-skin; lenticels numerous, rather large, raised; buds medium in size, rather blunt. Young tip leaves light yellowish green, tinged with red. Petiole fairly wide-angled, reflexed at base of blade, (leaf with reflexed tip); pubescence light; glands 2–3, near the blade, rather large, reddish. Leaf blade large, broad; base cordate, full; apex rather full; margin even to somewhat coarsely waved; surface somewhat rugose, very veiny, dull, light yellowish green; somewhat saucer-folded; serrations fine, serrate, regular.

35. **Seneca.** Habit spreading, but very tall, rather slender branches. Bark reddish brown; lenticels rather numerous, large and small, elongated, raised; buds medium in size, pointed. Young tip leaves reddish. Petiole wide-angled, somewhat reflexed, long, slender, red; pubescence heavy; glands 4–5, scattered, large and small, red. Leaf blade small, rather narrow and long; base slightly cordate, rather narrow; apex narrow; margin coarsely waved; surface smooth, fine texture, dull, medium green; rather strongly V-folded; serrations fine, dull serrate, regular.

36. **Sodus.** Habit upright-spreading, rather stocky; internodes short. Bark yellowish brown; lenticels few; buds small, blunt. Young tip leaves light green. Petiole moderately wide-angled, reflexed at base of blade, short, light colored; pubescence heavy; glands 3–4, large, yellow, scattered on petiole. Leaf blade small, short, broad; base slightly cordate, full; apex narrow; margin coarsely waved; surface somewhat rugose, semi-glossy to dull, medium green; flat to saucer-folded; serrations rather fine, double, dull serrate.

37. **Suda.** Habit spreading, rather short with slender branches; internodes short. Mature bark brown, bark on young shoot reddish throughout most of its length; lenticels numerous, small, flush; buds small, blunt. Young tip leaves green. Petiole moderately wide-angled, short, straight; pubescence light; glands 2, near the blade, medium in size, yellow. Leaf blade small, oval; base rather narrow; apex narrow; margin even; surface mostly smooth, fine, dull, medium green; broadly V-folded; serrations rather fine, double, dull serrate to crenate.

38. **Sweet September.** Habit upright, tall with rather few branches. Bark yellowish brown to brown; lenticels medium in number, small, somewhat raised; buds rather small, fairly blunt. Young tip leaves reddish. Petiole rather wide-angled and reflexed, medium in length and thickness; pubescence rather heavy; glands 2–4, scattered, medium in size, light reddish. Leaf blade rather small and long; base slightly cordate, but rather narrow; apex narrow; margin even to slightly coarsely waved; surface rather smooth to slightly bullate, dull, medium to light green; almost flat to saucer-folded; serrations double crenate, quite regular, shallow.

39. ***Vernon.** Habit spreading; internodes long. Bark brown with considerable broken scarf-skin; lenticels numerous, large, raised; buds small, blunt. Young tip leaves light green tinged with red. Petiole fairly wide-angled, reflexed at base of blade, (leaf with reflexed tip), medium in length, thick, red; pubescence moderate; glands 2–3, near the blade, large, reddish. Leaf blade large, long; base cordate, full; apex narrow; margin finely waved; surface very rugose, semi-glossy, medium yellowish green; saucer-folded; serrations fine, double, dull serrate, regular.

40. **Victor.** Habit spreading, short with few branches. Bark brown, 2-year bark medium dull brown; lenticels rather numerous, fairly small, raised; buds rather small, pointed. Young tip leaves reddish. Petiole rather wide-angled, reflexed at base of blade, (leaf with reflexed tip) reddish; pubescence moderate; glands 2–3, near the blade, small, reddish. Leaf blade large, rather long; base distinctly cordate; apex narrow; margin even to slightly coarsely waved; surface somewhat veiny with pockmarks, dull, rather dark green, (tip leaves mottled); moderate folding; serrations fine, double serrate, regular.

41. **Windsor.** Habit spreading, medium in height with rather slender branches; internodes fairly long. Bark light rather pinkish brown with little scarf-skin; lenticels rather few, small round, practically flush. Young tip leaves reddish. Petiole moderately wide-angled, somewhat reflexed, reddish; pubescence moderate; glands 2–3, scattered, medium in size, reddish. Leaf blade medium in size, rather broad and short; base cordate; apex rather full; margin even; surface somewhat rugose and bullate, semi-glossy, medium green; saucer-folded; serrations medium in size double crenate, regular.

42. **Yellow Spanish.** Habit spreading, rather short; internodes rather short. Bark yellowish brown with medium broken scarf-skin; lenticels rather numerous, medium in size, raised; buds small, rather pointed. Young tip leaves light yellowish green, drooping. Petiole wide-angled rather strongly reflexed, medium in length, rather slender, reddish; pubescence light; glands [illegible] small, globose, well below the blade, light colored. Leaf blade medium in size, rather long; base rather full; apex narrow to acuminate, twisted; margin rather coarsely waved; surface smooth fine texture, thin, semi-glossy to dull, medium clear green; medium folded; serrations medium in size, dull serrate, regular.

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*This variety is described from young orchard trees and one-year nursery whips, but no two-year nursery trees are available at this writing.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

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Weather In Cranberry Culture

By Henry J. Franklin, H. F. Bergman,
and Neil E. Stevens

Weather plays an important role in cranberry culture. This is an attempt to interpret the influence of various weather conditions on this crop.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

WEATHER IN CRANBERRY CULTURE

THE RELATION OF ICE AND SNOW COVER ON WINTER-FLOODED CRANBERRY BOGS TO VINE INJURY FROM OXYGEN DEFICIENCY

By H. F. Bergman[1]

CONTENTS

The practice of flooding cranberry bogs during the winter is well established, and cranberry growers believe that in most years little or no harm results from it. However, growers both in Massachusetts and in Wisconsin have long known that cranberry vines may lose many or all of their leaves, and that sometimes many terminal buds and considerable portions of the stems are dead after the winter flood is taken off in the spring. The first record of injury of this kind is a report by Franklin[2] of severe injury on two bogs in 1916, following late holding of a deep winter flood.

Winter-flooding injury has occurred much more frequently and has been more severe in Wisconsin than in Massachusetts. In Wisconsin it often has caused great reductions in yield and sometimes even the loss of an entire crop. When winter-flooding injury began to be noticed in Wisconsin is not known, but by 1928 or 1929 its seriousness was recognized and it was considered to be one of the most important problems confronting Wisconsin growers. For this reason it was decided to study the conditions under which the injury occurs and to find a means of preventing it.

The possibility that winter-flooding injury might be due to a lack of oxygen in the water was suggested by the fact that this had been shown to be the cause of injury to flower buds, flowers, and growing tips of vines in June flooding.[3] Determinations of the dissolved oxygen in the water on a few winter-flooded bogs in Massachusetts from 1929 to 1932, and on various marshes in Wisconsin in 1930, showed on some of them very little or no oxygen in the water over a period varying from a few days to two or three months in Massachusetts, and up to four or five months in Wisconsin. Observations from 1930 to 1932 on the bogs in Massachusetts, showed that winter-flooding injury occurred only on bogs where there had been very little or no dissolved oxygen in the water over a considerable length of time during the preceding winter-flooding period.

The data obtained up to 1932, however, failed to show definitely the conditions under which injury occurs. For this reason, and also because changes in the winter-flooding practice in Wisconsin seemed to have reduced very greatly the

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[2]Franklin, H. J. Mass. Agr. Expt. Sta. Bul. 180, p. 232, 1917.

[3]Bergman, H. F. 32nd Ann. Rpt. Cape Cod Cranberry Growers' Assoc. for 1919-20. 1920.

occurrence of leaf-drop, no further study of the problem was made for several years. However, in the spring of 1939, winter-flooding injury severe enough to cause leaf-drop and a marked reduction in yield was observed on a considerable number of bogs in Massachusetts, and work on the problem was resumed.

Determinations of the dissolved oxygen in the water on a few bogs were made weekly from late in January 1940 until the ice melted in March. The severity of injury to the vines on these bogs was ascertained the following summer. Again during the winter of 1940–41, the dissolved oxygen content of the water on the State Bog near East Wareham, Massachusetts, was determined weekly from January 15 to March 20, and at the same time an experiment was carried out to determine the effect on vines of depriving them of oxygen for known lengths of time during the winter. The degree of injury caused by this treatment was determined the following summer by comparing these vines with others which had been deprived of oxygen for only a very short time, if at all.

The results obtained during 1940 and 1941 yielded much information as to the conditions under which oxygen deficiency occurs and the relation between known degrees of injury and the dissolved oxygen content of the water during the winter. Moreover, it was found that forms of injury which are known to have occurred frequently and generally on bogs in Massachusetts, and which previously had not been recognized as winter-flooding injury, are caused by a lack of oxygen in the water during the winter-flooding period. Since these forms of injury always reduce the yield, sometimes very greatly, the problem of winter-flooding injury is now known to be important to cranberry growers in Massachusetts as well as in Wisconsin. The significance of various factors in bringing about an oxygen deficiency, and the relation of these and other factors to injury to cranberry vines as a result of oxygen deficiency, are discussed in this paper.

FORMS OF INJURY

Injury resulting from a lack of oxygen in the water during the winter-flooding period varies greatly in its severity. Such injury, in order of decreasing severity as observed on bogs in Massachusetts, causes death of a variable portion of the stems with their leaves and buds; loss of leaves of the preceding season (leaf-drop); death of the terminal (fruit) buds; death of small areas of leaf tissue in embryonic leaves within the terminal bud which later causes deformation of the leaves as they develop; retardation in the development of the new growth of uprights from the terminal buds; death of all or some of the flower buds; failure of the flowers to set fruit; failure of the fruits to grow to mature size; and reduction in the size of mature fruits. Some of these forms of injury are shown in Figure 1. The only important deviation from this order is on Wisconsin bogs flooded with alkaline water where leaf-drop may occur without the flower buds being killed.

The death of stems or terminal buds and any considerable loss of leaves are very obvious and, therefore, were the first forms of injury to be noticed and for many years were the only ones attributed to winter flooding. The additional forms of injury listed above were thought to be due to other causes. This probably is the reason that winter flooding is so generally believed to have no harmful effect, except possibly when the water is held late.

Terminal buds may be killed without injury to the stems, which then develop one or more branches (side shoots) on each upright from buds lower down on the stem. If part of the stem is killed, the side shoots develop from buds farther down on the stem. As a rule, terminal buds are more susceptible to injury than the old leaves; but in some cases the terminal buds are not harmed and may develop in the usual manner and produce one or two fruits even though the old leaves are killed and drop from the stems.

Figure 1. Uprights from a Low Area on the State Bog Showing Various Forms of Injury Caused by a Lack of Dissolved Oxygen in the Water During the Preceding Winter-Flooding Period.

UPPER: Howes Variety — (1) a normal upright; (2, 3) uprights with retarded flowers; (4) an upright with three flowers killed at a very early stage, the uppermost one visible at the left at the base of the leafy portion of the new growth: (5) an upright with the new growth very much retarded: (6) an upright with the new growth almost entirely suppressed; (7) an upright with a dead terminal bud, new shoot from a lateral bud. Uprights collected June 9, 1941. × 1 1/8.

LOWER: Early Black Variety — (1) a normal upright (from higher ground); (2) one of the best uprights in the low area; (3, 4 5) uprights on which most of the flower buds died immediately after flowering; (6) an upright on which the buds died at different stages of development, the uppermost flower blossomed but failed to set fruit. Collected July 28, 1941. × 1.

All the flower buds within a terminal bud may be killed without injury to the embryonic leaves or to the apex of the stem axis within the terminal bud. In this case, the new growth of the uprights develops as usual except that there are no flower buds although vestiges of them may be found by examination with a hand lens. Sometimes evidence that flower buds had been formed is shown by the presence of the pedicels, each bearing two small leaves (bracts) at its summit with a very small dead structure between them representing a flower bud killed very early in its development.

Injury which does not kill all or most of the embryonic leaves within a terminal bud may kill small areas of tissue within individual leaves varying from a few cells up to half a leaf. Portions of leaves remaining uninjured continue their development when the terminal bud begins active growth in the spring, but the leaves developed therefrom are then more or less deformed (Fig. 2). Apparently all or most of the flower buds are killed when embryonic leaves are injured in this way.

Figure 2. Uprights from Vines of the Howes Variety from a Bog near Waquoit Massachusetts showing severe injury to the new leaves caused by a lack of dissolved oxygen in the water during the preceding winter-flooding period. Water was held late. Most of the flower buds were killed at a very early stage of their development; two buds on the upright at the extreme right made some growth but died before blossoming. Collected June 29, 1937. × 1.

Incompletely differentiated flower buds may be injured but not killed immediately. These buds continue their development for some time but die sooner or later; the more severely injured ones die at early stages of growth, those less severely injured die later, very often developing into flowers which fail to set fruit. This delayed effect of injury shown by the death of flower buds at various stages of development before they reach the mature blossom stage is referred to in Wisconsin as "flower bud absorption."

Some berries also die before they are one-fourth grown; others continue to grow but never become large enough to be picked and the average size of the berries that mature is often reduced.

CONDITIONS UNDER WHICH INJURY OCCURS

The conditions under which injury from oxygen deficiency occurs may be considered with reference to: (1) the dissolved oxygen content of the water; (2) the oxygen requirements of cranberry vines under winter-flooding conditions; and (3) the ability of cranberry vines to withstand a lack of oxygen. Each of these has a part in determining the severity of injury and must be known if the conditions under which injury occurs are to be fully understood.

Factors Affecting the Dissolved Oxygen Content of Water

The factors which determine the dissolved oxygen content of the water on a flooded bog (or of a natural body of water) may be placed in two groups according to their nature and the effect of their action. Those of one group are physical; those of the other are biological since their effect is due to the activities of living organisms. Physical factors tend to bring the water to a definite, uniform dissolved oxygen content and to keep it in that condition; biological factors tend to prevent this. Physical factors are fundamentally the controlling ones.

Physical Factors

Water in contact with the air normally contains oxygen in solution. The amount depends upon its solubility in water and upon the proportion of oxygen in the air. Since the latter does not change appreciably, the amount of dissolved oxygen in water in contact with the air depends only on the solubility of oxygen in water. This varies with the temperature of the water; it is greatest at 32° F. and decreases as the temperature rises. If the water does not contain all the oxygen that it is able to absorb at a given temperature, more is taken up from the air; if it has more than it can hold in solution, some is given off until an equilibrium with the oxygen of the air is reached. The greatest amount of oxygen that water exposed to the air, and at a given temperature, can hold in solution is known as its saturation capacity. At 32° F. this is about 10 cc., at 40° about 8.7 cc. and at 50° about 7.8 cc. per liter (61 cu. in.).

The temperature of the water of a flooded bog, however, usually changes from hour to hour during the day and from day to day according to weather conditions. This changes the capacity of the water to hold oxygen in solution and the equilibrium between the dissolved oxygen of the water and the oxygen of the air must be reestablished under the new conditions. Other factors also often disturb the balance between the oxygen in solution and that of the air. Whenever this happens, a transfer of oxygen from the air to the water, or from the water to the air, is necessary to restore the equilibrium. The transfer takes place by diffusion, a process of migration by the spontaneous movement of molecules, through the surface layer of water in contact with the air. Oxygen diffuses into or out of this surface layer very rapidly but, because its rate of diffusion through water is extremely slow, only a very thin layer at the surface is thus brought to an equilibrium, and if the oxygen were distributed by diffusion alone it would take a very long time to bring the water of a flooded bog to an equilibrium with the oxygen of the air. There are other methods, however, by which oxygen is distributed more rapidly. These are by convection currents and by circulation of the water by the wind.

Convection currents are those caused by changes in the temperature of the water. Water has its greatest density at 39° F. and becomes lighter as it becomes warmer or colder. Convection currents are set up if the surface water becomes denser than the underlying water. The surface water then sinks and water from below rises. This tends to equalize the distribution of oxygen in solution in the water and to keep it in equilibrium with the oxygen of the air. Convection currents, however, are usually slower and much less effective than those set up by the action of wind.

The action of wind on the water of a flooded bog sets the surface water in motion producing currents which carry small masses of surface water, saturated with oxygen, below the surface. If the dissolved oxygen content of the surface water when it is carried downward is different from that of the water below the surface, oxygen passes by diffusion from the water with the greater amount of oxygen in solution to the water with less. Water from below also is brought to the surface where the oxygen in solution quickly comes to equilibrium with the oxygen of the air. This process continues until the entire mass of water is brought to a uniform dissolved oxygen content.

The effectiveness of wind in equalizing the distribution of dissolved oxygen in the water of a flooded bog depends on its velocity. The stronger the wind, the more rapidly the mixing proceeds and the greater the depth to which it extends. When the wind stirs the water to the depth to which bogs ordinarily are flooded, any local excess or deficiency of dissolved oxygen in the water below the surface is leveled out. It is to the rapidity with which oxygen diffuses into or out of the surface layer of water that circulation of the water by action of the wind, and by convection currents, owes most of its effectiveness in bringing the dissolved oxygen of the water to an equilibrium with the oxygen of the air.

A local excess or deficiency of dissolved oxygen in the water of a flooded bog may occur in the absence of wind or with wind of low velocity. An oxygen content below the saturation capacity of the water has often been found on flooded bogs. The deficit is greater in deep water, but no evidence has been obtained to indicate that on winter-flooded bogs not covered with ice the deficit ever becomes so great as to injure the vines. The occurrence of an oxygen deficit, at a depth of only two to three feet, when there is little or no wind, shows that convection currents and diffusion are not sufficient, even in relatively shallow water, to keep the dissolved oxygen in equilibrium with the oxygen of the air. An excess of dissolved oxygen under these conditions has never been found.

Biological Factors

Biological factors are those that owe their effect to physiological processes carried on by living organisms. Two of these, respiration and photosynthesis, affect the dissolved oxygen content of the water on flooded bogs and sometimes cause great variations on it.

Respiration is the term applied to a complex oxidation process taking place in every living cell, by which chemical energy is released for the performance of the physiological processes necessary to maintain life. In nearly all plants the energy is released by the oxidation of carbohydrates and fats into carbon dioxide and water. The process requires oxygen, which normally is obtained from the air outside the plant, and carbon dioxide is given off.

Photosynthesis occurs only in plants or parts of plants that contain the green coloring matter known as chlorophyll and only when they are exposed to light. It is the process by which sugars and starch are formed. Carbon dioxide and water are used in the process, and oxygen is given off. The sugars and starch thus formed are used subsequently in respiration to supply energy to the plants.

The oxygen used in respiration by the cranberry vines and other plants on a flooded bog is taken from that in solution in the water and the oxygen given off in photosynthesis goes into solution in it. Consequently, respiration reduces the amount of dissolved oxygen and photosynthesis increases it. However, when a bog is not covered with ice, changes in the oxygen content of the water as a result of these processes are usually relatively small and of short duration since there is nearly always enough wind to cause circulation of the water and thus keep it at or near its oxygen saturation capacity. But when the water is covered with ice, circulation by the wind is prevented and, since convection currents are relatively ineffective and diffusion is extremely slow, the amount of dissolved oxygen in the water surrounding the vines is determined by the respiratory and photosynthetic activity of the vines and other plants usually present.

The most abundant plants on a cranberry bog, of course, are the cranberry vines, but other green plants, particularly mosses and algae, sometimes aid very materially in reducing or increasing the oxygen content of the water. In addition, bacteria and other microorganisms which are always present where there is organic matter act to reduce the oxygen content since they use oxygen in respiration but do not carry on photosynthesis.

The density of vine growth, the abundance of moss or algae, and the amount of organic matter in the soil on different bogs or on different parts of the same bog vary greatly. This makes little difference in the dissolved oxygen content of water under ice so long as conditions are favorable for photosynthesis, since the amount of oxygen given off equals or exceeds that used by respiration, and consequently the oxygen content of the water either remains nearly the same or increases from day to day. However, under conditions which greatly retard or prevent photosynthesis, excessive vine growth or a dense growth of moss or algae is objectionable because more oxygen is used in respiration, thus increasing the probability of injury to the vines.

Under conditions unfavorable for photosynthesis, the dissolved oxygen content of the water is reduced more rapidly on bogs on which there is a great amount of organic matter. The probable reason for this is that the greater the amount of organic matter the greater the number of bacteria and other microorganisms associated with it, and the greater the amount of oxygen used in respiration. Organic matter is found on all bogs since either peat or muck usually makes up a large part of bog soils, and dead leaves make up most of the surface litter. Less organic matter comes in direct contact with the water on sanded bogs than on those not sanded. Therefore, the probability of a complete disappearance of the dissolved oxygen in water under ice, when conditions are unfavorable for photosynthesis, is greater on a peat bog that has never been sanded, or has not been sanded for several years, than on one sanded regularly at intervals of three or four years; it is least on bogs with "hard bottom."

The rate of respiration of plants on a flooded bog is influenced by the temperature of the water. Photosynthesis, likewise, is affected by temperature but also by other factors. Both respiration and photosynthesis go on slowly at 32° F., and the rate of both increases as the temperature rises. The temperature of the water under ice on a winter-flooded bog has a definitely limited range, however, varying from 32° to 39°, and changes slowly, rarely more than one degree within 24 hours.

The rate of photosynthesis is determined not only by the temperature of the water, but also by the concentration of carbon dioxide in solution, and by the intensity of the light received by the vines. The concentration of carbon dioxide in solution in water on flooded bogs not covered by ice is about the same as in the air, but in water under ice it is always greater than in the air. Photosynthesis goes on more rapidly as the intensity of the light increases although its rate is limited also by the temperature.

The intensity of the light received by cranberry vines on a winter-flooded bog depends on the intensity of the incident light, the thickness and clearness of the ice, the presence or absence of snow on the ice, and the depth and clearness of the water under the ice. The intensity of the light received at the surface of a bog on a clear day is least about December 21 and from then increases to a maximum on June 21. Perfectly clear days, however, are infrequent; haze in the atmosphere and cloudiness cause the light intensity to vary between wide extremes, values as low as 3 or 4 per cent of the June 21 mean maximum occurring when clouds are very dense.

Some measurements of light intensity under ice on winter-flooded bogs were made by means of a photoelectric cell of the barrier layer type which was connected with a quadruple range portable microammeter having a range of 0 to 4000 microamperes. The photoelectric cell was enclosed in a watertight brass case provided with a glass window in the top. All readings of light intensity were taken with the active surface of the photoelectric cell in a horizontal position corresponding to the angle of exposure of the ice surface. The same instruments were used to measure the intensity of the incident light but these measurements were compared with those of the sun and sky radiation received on a horizontal surface made with an Eppley pyrheliometer and an Engelhard recording microammeter as described by Hand.[4] Although the latter instruments measure the heat energy received on a horizontal surface, it has been shown[5] that measurements thus made may be used to determine the intensity of daylight illumination. The percentage of incident light which was found to pass through ice or to reach the cranberry vines under stated conditions is given in Table 1.

Table 1.—The Percentage of Incident Light Reaching Cranberry Vines Submerged to Different Depths, in June and in Winter Under Ice of Different Thickness.

Date	Time of Day	Radiation Intensity as Percent of Mean Maximum Intensity on June 21	Ice Thickness (*a*)	Percentage of Incident Light Penetrating —			
				Ice Only	Ice of thickness given and water to depth of —		
					12 in.	15 in.	18 in.
		Percent	Inches	Percent	Percent	Percent	Percent
June 8, 1938...	12:45–1:15 p.m.	55–60	0		90–93		86–88
.....Ditto....	9:10–9:45 a.m.	35–38	0		85–89		79–81
Jan. 14, 1941...	11:50 a.m.–12 m.	52–55	4–4.5	86–88	70	65	
....Ditto......	2:00–2.05 p.m.	40	4	74–83		52–55	
Jan. 15, 1941...	10:00–10:15 a.m.	7–9	4.5	65–70	50–55	45–58	
....Ditto......	9:00–9:20 a.m.	5–7	5.5	57–62	45–50		
Feb. 2, 1942....	2-40–2:45 p.m.	40	5.5	65–70		53–55	
....Ditto......	2:30–2:35 p.m.	32–34	6	60–67	40–45		
....Ditto......	2:45–2:50 p.m.	28–30	6	61–64	35–40		
Feb. 11, 1942...	1:00–1:05 p.m.	11–13	7.5	40–45	33–35		
....Ditto......	2:40–2:45 p.m.	30–32	7.5	34–39	27–30		
Jan. 24, 1940...	12:10–12:25 p.m.	6–8*b*	7.5–8*c*				21–25
....Ditto......	2:45–3:00 p.m.	2–4*b*	7.5–8*c*				10–17
Apr. 30, 1941 ..	9:20–9:25 a.m..	60	9.5*a*	90–96			
Jan. 25, 1942...	9:00–9:15 a.m.		11.5	47–51			

a Snow included in the ice in all instances except on April 30, 1941.

b Densely cloudy, snowing.

c No snow on the ice where measurements of light intensity were made, but near by were patches of snow ½–1 inch deep.

[4]Hand, Irving F. Monthly Weather Review 65:415-441. 1937.

[5]Kimball, H. H. Monthly Weather Review 52:473-479. 1924.

The intensity of the light which passes through ice varies. The few measurements made indicate that as much light penetrates a given thickness of clear ice as of water. However, the ice on flooded cranberry bogs is seldom clear; snow may become included in it when the ice is formed or afterward; and this reduces the intensity of the light which passes through it, although often not in direct proportion to the thickness of the ice since the amount of included snow varies greatly and the more snow in the ice the less the penetration of light. Also, since the amount of light lost by reflection from the ice surface becomes greater as the distance of the sun from the zenith increases, the penetration of light on a clear day is greatest at midday and diminishes progressively the earlier in the forenoon or the later in the afternoon the measurements are made. More light, also, penetrates on a clear day than on a cloudy one.

Less light penetrates ice with snow on it than when the snow melts into slush and later freezes into the ice. No measurements have been made of light intensity under ice with a uniform snow cover, but a few measurements showed that only one-fourth to one-third of the incident light penetrated one inch of snow. The penetration decreased rapidly as the thickness of the snow cover increased; only about 5 per cent of the incident light penetrated 4 inches of snow.

In this connection reference should be made to the practice of sanding on the ice. A layer of sand, even a quarter of an inch thick, probably excludes all the light from the vines, at least until the sand sinks into the ice as the ice melts. Although sanding on the ice may be done a little more cheaply than by other methods, there is a possibility that the shading effect may result in serious injury to the vines. The probability of injury appears to be greater if the sanding is done during December or January, when solar radiation is lowest and cloudiness is prevalent, than if done during the latter part of February or early in March, when solar radiation is greater and the heat of the sun is absorbed by the sand causing the ice to melt rapidly.

Water colored by organic matter in solution also reduces the intensity of the light received by cranberry vines at different depths in proportion to its color. Though water used for flooding cranberry bogs is generally only slightly colored, sometimes it is quite dark. Measurements show that on a clear day in June the intensity of the light received by vines at a depth of 12 inches in "dark" water may be as little as one-fourth to one-third of that received by vines in water only slightly colored.

Cloudiness, thick ice, and snow in or on the ice have but little effect on the rate of respiration; consequently the amount of oxygen used daily in respiration varies but little. On the other hand, these conditions, particularly snow on the ice, often so greatly reduce the intensity of the light received by the vines that photosynthesis goes on very slowly, if at all, and little or no oxygen is given off. If the amount of oxygen given off in photosynthesis during the short daylight period of winter days is less than that used in respiration during an entire 24-hour period, the amount of dissolved oxygen in the water will decrease from day to day. It can increase only when less oxygen is used in respiration than is given off in photosynthesis, and the rate of increase or decrease will be proportional to the amount by which the oxygen given off is greater or less than that used.

The Oxygen Requirement of Cranberry Vines Under Winter-Flooding Conditions

Cranberry vines require oxygen for respiration at all times, even in winter. Respiration is greater in parts in which there is greater physiological activity as in the leaves and in parts of the terminal buds such as the flower buds, the undeveloped new leaves, and the growing point of the uprights. Consequently, these require the most oxygen and are the first to be injured or killed as the oxygen supply is depleted.

Nothing is known as to the relative physiological activity of the leaves as compared with that of the flower buds and other parts of the terminal buds during the winter. On bogs in Massachusetts the leaves are injured or killed only after a prolonged period of deficiency or absence of oxygen and only after the flower buds and some or all of the undeveloped new leaves within the terminal buds have been injured or killed. This may be not so much because physiological activity is less in leaves than in the flower buds and other parts of the terminal buds as it is that the leaves, under most conditions, have a greater available oxygen supply than other parts. This is because photosynthesis goes on only in the leaves. The oxygen given off in the process diffuses through the walls of the cells within the leaves into the intercellular spaces and from there through the stomata into the water in which the vines are submerged. However, because oxygen diffuses through water very slowly, and since that is the only means by which it can pass from the leaves into the surrounding water, only a small part of it escapes and, therefore, it accumulates in the intercellular spaces of the leaves. This accumulated oxygen is used by the leaves for respiration, and enables them to go without injury through short periods when there is little or no dissolved oxygen in the water. However, the leaves are injured or killed during prolonged periods of very low oxygen content resulting from the exclusion of light by snow on the ice since, at such times, there is either no accumulation of oxygen in the intercellular spaces or not enough to supply the amount needed for respiration.

Parts of cranberry vines in which there is no photosynthesis are supplied entirely by the diffusion of oxygen from that in solution in the water around them. Although diffusion is very slow, enough oxygen is transferred in this way to supply the demand of respiration of the various parts of the vines as long as the amount of dissolved oxygen in the water is not less than a certain minimum, which is now placed at 3 cc. per liter (4 p.p.m.) or about 1.5 per cent of the amount normally present in the air. When there is less than that amount, it cannot be supplied rapidly enough to meet the demand of respiration thus causing injury of varying severity. It is for this reason that the flower buds and undeveloped new leaves within the terminal buds, with their relatively high oxygen requirement, are the first to be injured or killed.

The temperature of cranberry vines in water under ice is the same as that of the water;.but when the vines are frozen into the ice their temperature becomes the same as that of the ice, which is often much lower than 32°, as the temperature of the ice soon comes to that of the air. Vines on shallowly flooded bogs or parts of bogs, in Massachusetts, are often frozen into the ice. Some growers in Wisconsin freeze the vines into the ice as a means of preventing leaf-drop.[6] Vines frozen into the ice usually are at a temperature low enough to very nearly stop their physiological activity; i. e., the vines are practically dormant and hence require only a negligible amount of oxygen. This probably is obtained by diffusion from the ice, since the ice contains oxygen in solution, and thus the vines are carried through the winter without injury.

The Ability of Cranberry Vines to Withstand Oxygen Deficiency

Cranberry vines in different locations, or in different years, are not injured to the same degree by a known low dissolved oxygen content of the water for a known time. Vines in one location are sometimes injured more by a lack of

[6]Rogers, L. M. Bog Construction and Management in Wisconsin. Wis. State Cranberry Growers' Assoc. 46th Ann. Rpt. 37–38. 1933.

oxygen for a few days than are those in another location where the oxygen content was equally low for the same length of time. Or, sometimes, vines that were for a known time in water of known low oxygen content are injured less than those that were for an equal time in water of higher oxygen content, or than those in water of equally low oxygen content for a shorter time.

The difference in the ability of cranberry vines to withstand oxygen deficiency appears to depend, at least to a considerable degree, on the amount of stored carbohydrates (sugars, starch) in the vines in the autumn preceding the winter-flooding period. Vines in which there is a large amount of stored carbohydrates are injured less than those in which, for any reason, the amount is small. The reason for this seems to be that cranberry vines are able to break down the carbohydrates stored in their leaves and stems to obtain the oxygen needed for respiration, at least for a limited time when the dissolved oxygen content of the water is too low to supply it, thus preventing injury from oxygen deficiency. However, in some plants, some of the end products formed when respiration is carried on in this way are toxic and if present in more than very minute amounts usually cause the death of the parts in which they accumulate. If this also is true of cranberry vines they probably would be able to withstand oxygen deficiency for only a comparatively short time even when there is an ample supply of stored carbohydrates.

The amount of stored carbohydrates in cranberry vines preceding a winter-flooding period depends, aside from weather conditions, on the size of the crop immediately preceding the flooding period and on the freedom of the vines from previous injury. Growers report that cranberry vines are injured more severely after a large crop than after a small one or none. This is because the carbohydrate reserves in the vines are either used up or greatly reduced in the production of a large crop. The amount of stored carbohydrates in the vines when a bog is flooded for the winter then depends on the amount stored between the time the berries are picked and the time the bog is flooded for the winter. This amount may or may not be sufficient to protect the vines against a lack of oxygen during the winter flooding period, since the amount stored depends upon autumn weather conditions, which vary greatly from year to year.

THE COURSE OF THE DISSOLVED OXYGEN CONTENT OF THE WATER ON A WINTER-FLOODED BOG

Although it has been found that the dissolved oxygen in the water under ice on a winter-flooded bog sometimes becomes greatly reduced or disappears, the exact conditions under which this occurs, or the extent to which the oxygen content varies and the relation of various factors to variations in oxygen content, were not known. Neither was it known how much the dissolved oxygen content must be reduced and how long the vines must remain in water of a given reduced oxygen content to cause injury of different degrees of severity. To obtain information on these points, determinations of the dissolved oxygen in the water at three stations on the State Bog were made weekly from January 15 to March 20, 1941. The bog had frozen over about December 8, 1940, and from that time was completely covered with ice until about March 13, 1941. Determinations of the dissolved oxygen content were made by the Winkler[7] method. The amount of dissolved oxygen in the water on days when samples were taken is shown in Figure 4.

[7]Winkler, L. W. Ber. deut. chem. Ges. 21: 2843-2854. 1888. See also U. S. Pub. Health Serv. Bul. 151. 1925.

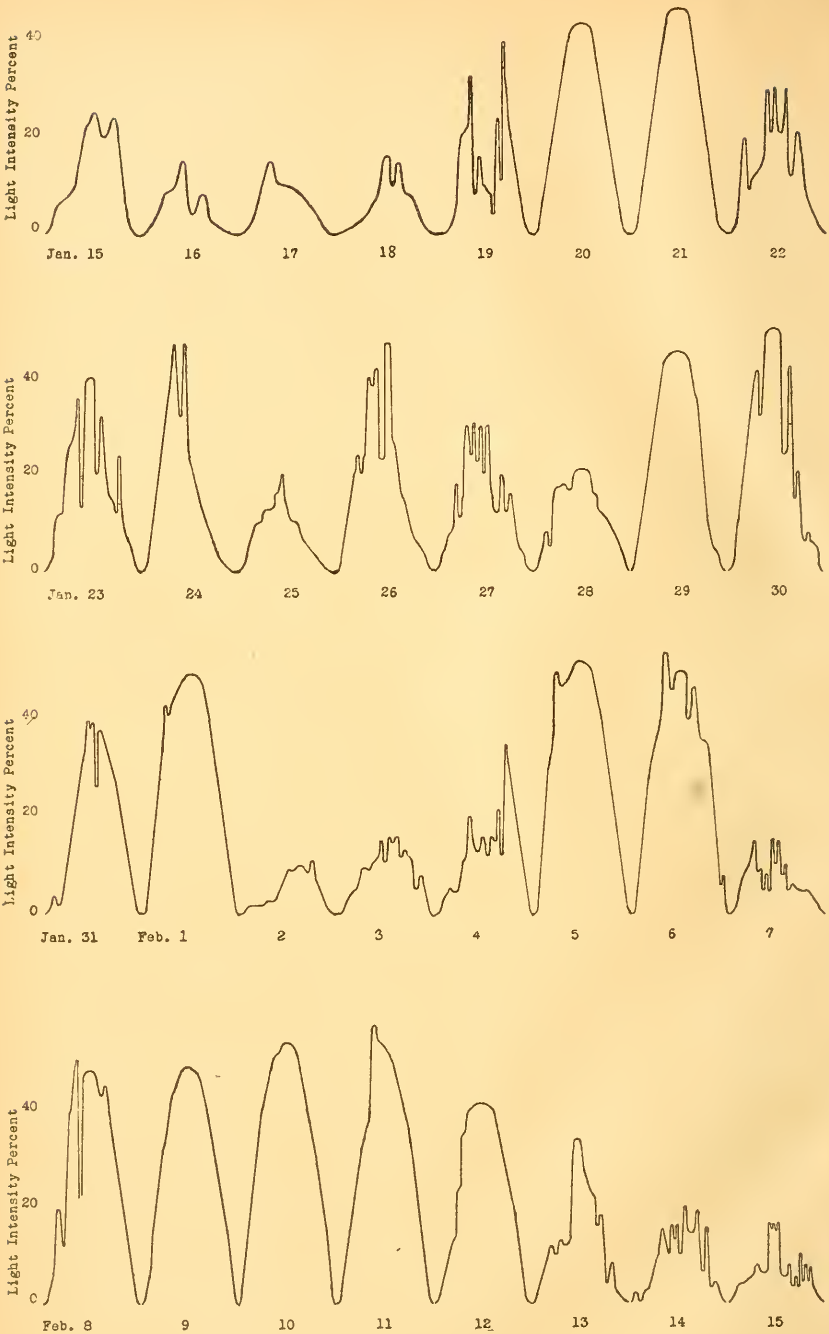
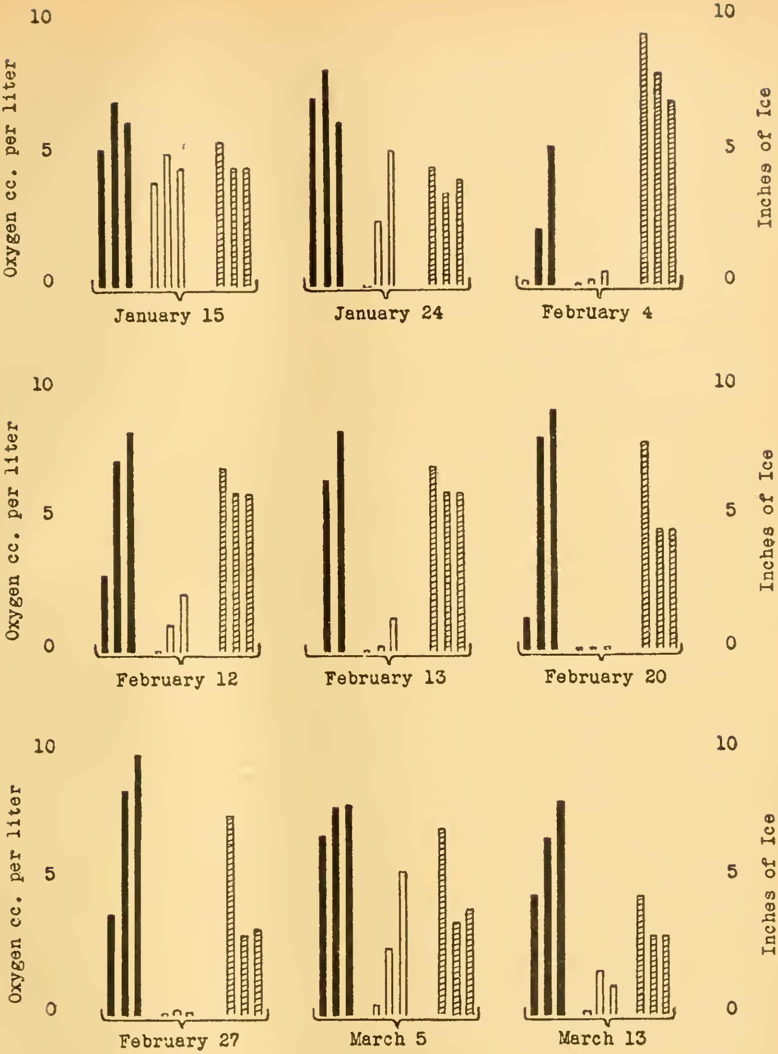


Figure 3. The Intensity and Duration of Light Daily from January 15 to February 15, 1941. The intensity in terms of percentage of the June 21 mean maximum is shown by the height of a curve as measured by the scale on the left; the horizontal extent represents the duration of light, which varies from 9 to 10 hours.



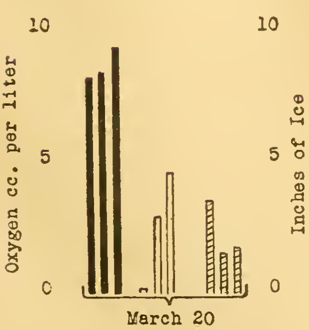


Figure 4. The Dissolved Oxygen Content of the Water Outside and Inside the Cylinders and the Thickness of the Ice on the State Bog on Various Dates from January 15 to March 20, 1941.

The bars with solid shading represent the oxygen content of the water outside the cylinders, the unshaded bars the oxygen content inside, and the diagonally hatched bars the thickness of the ice at the three stations. In each group of three, number 1 is always at the left.

It has been pointed out that changes in the oxygen content of the water under ice on a winter-flooded bog are due to a difference in the rate of photosynthesis under different conditions (p. 11). Since the intensity of the light received by the vines is the only factor among those affecting this rate which changes significantly, the great difference in the oxygen content at different times must have been due to differences in the intensity of the light received.

Among the factors upon which the intensity of the light received by the vines depends (pp. 9-11), the intensity of the incident light is of primary importance. The intensity of the incident radiation during the day, in terms of percentage of the June 21 mean maximum, from January 16 to February 15 is shown in Figure 3. This includes the periods during which the greatest changes in the oxygen content of the water occurred.

Ice and water, however, also reduce the intensity of the light received by the vines. The percentage of incident light that penetrated ice 4 to 7.5 inches thick, with snow included in it, and reached the vines at a depth of 12 to 15 inches in clear or only slightly colored water, at several intensities of incident radiation from 5 to 55 per cent of the June 21 mean maximum is shown in Table 1. The depth of the water, on January 15, was 12, 16, and 15 inches at stations 1, 2, and 3, respectively and did not change significantly between January 15 and 24. The intensity of the light received by the vines, particularly on Januray 16, 17, and 18, therefore, must have been very low—it may have been at most not more than 6 to 8 per cent of the June 21 mean maximum and then only for an hour or less; during the greater part of the daylight period it was probably less than 5 per cent of that maximum, decreasing to zero early in the forenoon and late in the afternoon. The increase in the dissolved oxygen content of the water, or most of it, between January 15 and 24, therefore, probably occurred from January 20 to 24 when the intensity and duration of the incident radiation was greatest. The oxygen content of the water at station 1 remained lower because the ice was thicker there and had more snow in it so that the vines received less light than those at the other stations.

The importance of photosynthesis in maintaining the dissolved oxygen content of the water is shown by the great decrease in the oxygen content at all three stations from January 24 to February 4 as the result of the exclusion of light by snow on the ice. Eight inches of snow fell on January 24. About half of it afterward melted, but an additional 2 inches on February 3 made about 6 inches of snow on the ice on February 4. The thickness of the ice also had increased to 9.5, 8, and 7 inches at stations 1, 2, and 3, respectively. The intensity and duration of the daily incident radiation during this period were as great as on the days between January 15 and 24 when the oxygen content of the water increased. There were only 2 days when the intensity of the incident radiation was as low throughout the day as on January 16, 17, and 18; on all other days it was greater, and on 6 days its intensity and duration were as great as on the days from January 20 to 24 when the increase in the dissolved oxygen content of the water probably occurred. However, measurements showed that only about 5 per cent of the incident light penetrated 4 inches of snow. Therefore, with 6 inches of snow, and with 7 to 9.5 inches of ice with snow included in it, it is probable that very little or no light reached the cranberry vines. Consequently, little or no oxygen was given off in photosynthesis, and the dissolved oxygen content of the water decreased. The low intensity of the incident radiation on February 2 and 3 further increased the probability that all or most of the light was excluded on those days. The dissolved oxygen content of the water at stations 2 and 3 may have been even lower from February 5 to 7 than on February 4 since most of the snow then on the ice remained for another three days.

The effect of oxygen given off in photosynthesis on the dissolved oxygen content of the water is shown also by the great increase from February 4 to 12. Whether or not the oxygen content of the water changed between February 4 and 7 is not known. The intensity of the incident radiation throughout most of the daylight period on February 5 and 6 was much greater than on February 2, 3, and 4; but since most of the snow on the ice on February 4 remained until February 7, very little, if any, of the incident light may have reached the vines. Much of the snow on the ice was melted by a rainfall of 1.49 inches on February 7 and the unmelted snow afterward froze into the ice. The ice was thinner also. The intensity and duration of the incident radiation on all days from February 8 to 11 was as great, and on February 12 nearly as great, as on January 20 and 21, the two days among those between January 15 and 24 on which it was greatest. Because of this and because of the disappearance of the snow and some reduction in the thickness of the ice, more light reached the vines, causing increased photosynthesis with a resulting increase in the oxygen content of the water.

The dissolved oxygen content at station 1 was lower than at stations 2 and 3 from February 12 to March 13 because the ice was thicker and had more snow included in it at station 1 than at the other stations. The difference in thickness was only about 1 inch on February 12 but increased to 3 to 3.5 inches on February 27 when the ice was 7.5 inches thick at station 1. The difference in thickness thereafter decreased, but on March 13 the ice was still 1.5 inches thicker at station 1 than at the other stations. Therefore, the vines at station 1 received light of lower intensity than those at the other stations with a corresponding reduction in the amount of oxygen given off in photosynthesis.

The dissolved oxygen content of the water at stations 2 and 3 was lower on February 13 than on February 12 for the following reasons. The dissolved oxygen content of the water decreased during the night of February 12 because of the oxygen used in respiration. The incident radiation during the forenoon of February 13 was of low intensity because of cloudiness; it increased from zero to 12 per cent of the June 21 mean maximum during the first two hours of the day and during the next two hours varied from 10 to 14 per cent. With light of this intensity, enough may have passed through the 4.5 inches of ice then on the bog to cause photosynthesis to go on slowly, but the amount of oxygen given off was not sufficient to make up for that used in respiration during the preceding night and part of the forenoon.

Conditions evidently were favorable for photosynthesis during at least most of the period from February 13 to 27 since the oxygen content of the water at stations 2 and 3 increased during this time. However, these conditions need not be discussed since other examples have been cited to show the relation between the amount of oxygen given off in photosynthesis and the intensity of the light received by the cranberry vines and further discussion could add nothing new.

More water was pumped onto the bog on February 28, increasing the depth by about nine inches. The pond water used for flooding had a high dissolved oxygen content and probably brought that of the water at all stations nearly, if not fully, up to its saturation capacity.

The ice went off the State Bog, except around station 1, immediately after March 13, but the bog froze over again on March 17-18. The few days during which the water was in contact with the air brought its dissolved oxygen content nearly, if not fully, up to its saturation capacity at all three stations, although 3.5 inches of ice remained over a small area around station 1.

THE REDUCTION OF THE DISSOLVED OXYGEN CONTENT OF THE WATER UNDER EXPERIMENTAL CONDITIONS

An attempt was made to provide conditions which would insure a low dissolved oxygen content indefinitely in order to determine the effect on cranberry vines of a very low oxygen content in the flooding water over a longer period than might occur under natural conditions. Three sheet-iron cylinders about five feet in diameter were placed on the State Bog, one at each of three stations[8] on sections planted with vines of the Early Black, Howes, and McFarlin varieties, respectively. The bog was flooded on December 5, 1940. It froze over within two or three days and was completely covered with ice until about the middle of March. Covers were placed on the cylinders on January 18 to exclude light and prevent any increase in the oxygen content of the water by photosynthesis. The oxygen content of the water inside the cylinders was determined first on January 15, and thereafter weekly until March 19. Its course during the winter is shown in Figure 4.

The reduction in the dissolved oxygen content of the water inside the cylinders after the covers were placed on them and the low oxygen content thereafter, at least up to February 27, shows that the initial purpose of the experiment was achieved, although not as completely in cylinders 2 and 3 as in cylinder 1. The reason for the higher oxygen content of the water inside cylinders 2 and 3 on February 12 is not known; the higher content on March 5 was because about 9 inches of water of high oxygen content had been pumped onto the bog on February 28. The increase in cylinder 1 was only slight; this cylinder was located on a high corner of the bog and, probably, very little of the water pumped onto the bog reached it.

EFFECT OF OXYGEN DEFICIENCY ON CRANBERRY VINES

The flood water was drained from the bog April 1, 1941, and the cylinders were then removed.

The detrimental effect on the cranberry vines held within the cylinders during the winter flooding period under water with a low dissolved oxygen content began to show a few days after the cylinders were removed, and the effects were evident throughout the growing season. The leaves of these vines were of a very dull reddish color and a large proportion of the leaves subsequently dropped off. Many of the terminal buds were killed also, and those not killed developed slowly. Vines of the Early Black variety were injured most. Within a month after the cylinders were removed, this variety lost nearly all the old leaves and the bare vines were dull and grayish, having the appearance of dead vines. The vines near the cylinders showed considerably less injury than those held within the cylinders. The vines that grew on slightly higher ground, consequently in shallower water, were in better condition than any of the other vines. They had no dead terminal buds, and the development of the new growth of uprights was normal.

During the summer and fall, records were taken of the number of flowers per upright, dead flower buds, flowers from which fruit matured, yield of crop, and size of berries on vines held within the cylinders, on those outside but near them, and on vines that grew on slightly higher ground. These records are shown in Table 2.

The effect of an insufficient supply or a complete absence of oxygen over periods of time varying from a few days to several weeks during the winter-

[8]The cylinders were numbered the same as the stations at which they were located.

flooding period is shown clearly by the lower yield from vines outside but near the cylinders, and particularly from those inside, as compared with yields from vines of the same variety on slightly higher ground and consequently more shallowly flooded.

TABLE 2. COMPARISON OF FLOWERS AND FRUIT ON VINES INSIDE THE CYLINDERS WITH THOSE OUTSIDE.

Variety and Location	Flowers per Upright[3] Average	Flower Buds Dead Percent	Flowers Maturing Fruit Percent	Calculated Yield Barrels per Acre	Cup-count
Early Black					
Inside cylinder	3.1	12.6	21.6	28	158
Outside cylinder, low ground[1]	3.5	12.9	28.0	55	118
Outside cylinder, high ground[2]	4.0	5.2	28.3	75	110
Howes					
Inside cylinder	3.1	16.8	33.3	50	115
Outside cylinder, low ground	3.5	17.6	34.9	72	105
Outside cylinder, high ground	3.7	4.8	49.4	110	100
McFarlin					
Inside cylinder	3.9	16.1	20.9	39	94
Outside cylinder, low ground	4.0	12.9	23.5		94
Outside cylinder, high ground	4.0	10.0	30.0	81	84

[1]Area immediately surrounding cylinders.

[2]On ground 4 to 5 inches higher and about 25 to 30 feet distant from the cylinder for McFarlin; 50 to 60 feet distant for Early Black; and 160 to 175 feet distant for Howes.

[3]This includes not only flowers that reached the blossom stage but also those killed at any stage of their development.

The yields from vines of all three varieties on higher ground were larger either because the shallow water had a higher oxygen content or because the vines were frozen into the ice part of the time. Unfortunately the dissolved oxygen content of the water on the higher ground was not determined; but it has been found repeatedly that the oxygen content is less in deep water than in shallow, even a few inches making a significant difference, particularly when there is ice over the bog.

Vines of the Howes variety on high ground were on one of the highest parts of the bog, the ground there being about 6 inches higher than that on which cylinders 2 and 3 were placed. The water was 15 to 16 inches deep near these cylinders on February 4 when the oxygen content of the water outside the cylinders was lowest; therefore, only 9 to 10 inches deep on the higher ground. Since the ice at that time was 7 to 8 inches thick, the vines on the higher ground must have been frozen into the ice and therefore, for reasons before stated (p. 12), were not injured. Vines of the McFarlin and Early Black varieties may have been frozen into the ice at the same time, but this is less certain since the high ground on which vines of these varieties were located was probably not more than 4 inches higher than that near cylinders 2 and 3.

The yield from vines just outside the cylinders was much less than that from vines of the same varieties on higher ground. Since, for two of the varieties, there was only one period during the winter when the oxygen content of the water was as low as 2 cc. per liter (3 p.p.m.), and then probably for nct more than three to five days (Fig. 4), the reduction in yield must have been the result of the low oxygen content of the water at that time. This indicates that if the dissolved oxygen content of the water falls to 2 cc. per liter even for a few days the yield is greatly reduced.[9] Oxygen deprivation over a longer period caused a further reduction in yield, but even within a variety the reduction did not appear to be in proportion to the length of time during which oxygen was lacking.

The yield of berries from the Howes vines inside the cylinder was greater than that from the comparable Early Black vines although the water on the Howes vines contained no dissolved oxygen for about 5 weeks and very little for an additional 3 weeks, while the oxygen content of the water on the Early Black vines was very low for only about a month. This probably was because the Early Black vines had been badly injured by a lack of dissolved oxygen in the water during the winter flooding period of 1939–40.

The lower yield from vines, whether inside or outside the cylinders, was the result of different degrees of injury which caused the death of uprights, the death of terminal buds and of flower buds, loss of old leaves, injury to the flower buds which caused them to fail to set, and reduction in the size of fruits.

When the water was withdrawn from the bog in April there were more dead uprights and dead terminal buds on vines of all three varieties inside the cylinders than on those just outside, and more on Early Black vines than on those of other varieties. There were only a few dead uprights or dead terminal buds on vines outside the cylinders. On the Early Black vines inside the cylinder about 12 percent of the uprights that were alive during the blossoming period died before fall; in the Howes and McFarlin varieties, about 3 per cent. Not more than 2 per cent of the uprights of vines of any of the three varieties outside but near the cylinders died during the summer.

The percentage of flower buds killed at various stages of their development ("dead buds" in table 2) was considerably greater on vines of all three varieties in the low areas just outside the cylinders than on vines of the same varieties on slightly higher ground. However, contrary to expectation, more "dead buds" were recorded outside than inside the cylinders on Early Black and Howes varieties. A probable explanation for this discrepancy is that more flower buds inside the cylinders than outside were killed at a very early stage of development and that these dead buds were not noticed when the counts were made. This is indicated by the slightly lower average number of flowers per upright on vines of the Early Black and Howes varieties inside the cylinders than just outside. Another probable reason is that, in making the counts, only uprights on which flowers or dead buds were visible were recorded, no attention being paid to sterile ones, a considerable proportion of which may have been flowering uprights on which all of the buds had been killed at a very early stage of development.

The percentage of flowers from which fruit matured, in all three varieties, was lowest on vines inside the cylinders, and was lower on vines in slightly deeper water than on those most shallowly flooded, although in some cases the difference was small. Because of the failure to observe and count flower buds killed at a very early stage of development, the percentage given for flowers from which fruit matured on vines of the Early Black and Howes varieties inside the cylinders also are higher than they otherwise might have been.

Many flowers set fruit that made more or less growth but subsequently died; other berries remained alive although they never became large enough to be picked. The percentage of such fruits could not be determined with certainty but the effect on the size of harvested fruits is shown by their cup-counts (Table 2).

The reduction in the size of fruits and the failure of berries to grow to a size large enough to be picked probably was due to an inadequate food supply during the

[9]The results of experiments completed in 1942 show that the yield is reduced if the oxygen content of the water is as low as 3 cc. per liter for two or three days.

summer caused by previous injury to the old leaves which reduced their capacity to form carbohydrates. Since the old leaves are known to carry on photosynthesis throughout the summer they probably supply a large part of the food materials for the growth of the new portion of the uprights. After the new leaves are fully grown the old leaves aid in accumulating stored food. Since the old leaves also may supply a large part of the food for the growth and ripening of the fruit, uprights which have lost all or most of their old leaves usually bear no fruit. Vines of all three varieties inside the cylinders lost more of their old leaves than did vines outside; those of the Early Black variety inside the cylinder lost nearly all their old leaves. Even when the old leaves remained on the vines, many of them were injured and accordingly were less effective in the formation of carbohydrates.

PRESENT STATUS OF THE PROBLEM

It is evident from the facts presented that some phases of the problem of injury to cranberry vines as a result of a lack of dissolved oxygen in the water during the winter-flooding period are understood much more fully than others. The conditions which determine the dissolved oxygen content of the water on winter-flooded bogs seem to be quite fully known although some details require further study. On the other hand, very little is known concerning other phases of the problem, specifically, the oxygen requirement of various parts of the cranberry plant (old leaves, flower buds, and undeveloped new leaves within the terminal bud) under winter-flooding conditions, and the relation of the amount of stored carbohydrates to the ability of the vines to withstand a lack of oxygen. The effect of the size of the preceding crop and of autumn weather conditions, particularly the amount of solar radiation, on the amount of stored carbohydrates in the vines at the beginning of the winter-flooding period should also be known. Knowledge of these relations is especially important because of its bearing on possible remedial or preventive measures.

SUGGESTIONS FOR PREVENTING WINTER-FLOODING INJURY

Some modifications of winter-flooding practices may be suggested as remedial or preventive measures. First of all, bogs should be flooded as shallowly and for as short a time as possible. Cranberries are not adapted to being under water; under natural conditions they are usually entirely out of water, or at most only partly covered during the winter. When out of water they depend upon a cover of snow for protection against winterkilling; if partly covered they become frozen into the ice with the advent of freezing weather.

Bogs in Massachusetts usually need not be flooded before the first week of December and the water should be taken off, if possible, about April 1. It would be necessary to hold the winter flood later on bogs which have a limited water supply for the protection of the vines against frost during the spring. Late holding of the water may not be particularly harmful; late-held bogs often produce a good crop. Bogs in Wisconsin usually are flooded about November 15-20, and the water is then held until the middle of April or the first of May. However the usual winter-flooding period, both in Massachusetts and in Wisconsin, might be shortened when the weather permits.

The winter flood also should be as shallow as possible; barely enough to cover the vines is all that is needed; it should not be more than 12 to 15 inches. Little or no harm will result even if occasional patches of vines are not completely covered. On the bogs that are out of grade, flooding only to this depth would leave parts of the bogs entirely without water or so shallowly flooded that most of the vines on the higher parts would be above water, but could be done, in many cases, without exposing the vines on a very large proportion of the bog to possible winterkilling. Even where a bog is badly out of grade it would be better, probably, to leave the highest parts unprotected in order to reduce the depth of the water on the lower parts. Winterkilling might cause some reduction in the size of the crop from the higher parts of a bog as a result of this practice, but usually this would be more than offset by the increase in the crop on the lower parts of the bog.

Injury to the vines from a lack of oxygen during the winter-flooding period may be prevented by two other practices: (1) by freezing the vines into the ice, and (2) by flooding the bog as usual, and after several inches of ice have formed over the bog, drawing the water out from under the ice thus allowing it to drop down onto the vines and remain there until it melts. Both of these methods have been used successfully in Wisconsin, the former more extensively than the latter.

The first method is not so well suited for Massachusetts as for Wisconsin conditions because the temperature, when the bogs are being flooded for the winter, usually is not as low in Massachusetts as in Wisconsin. The same result would be obtained in Massachusetts, however, by flooding bogs very shallowly so that the vines would be frozen into the ice if the weather should become cold enough to freeze ice several inches thick. This happens regularly on nearly all bogs in Massachusetts, but to a much greater extent on some than on others depending on the evenness of the bog and on the depth to which it is flooded.

The practice of drawing the water out from under the ice has proved very successful on those bogs in Wisconsin on which it has been used and, probably, would be equally successful in Massachusetts. It is a very satisfactory, if not ideal method of bog protection in that the vines are fully protected against winterkilling and at the same time have an abundant supply of oxygen.

The only factor that might be considered at all unfavorable for vines on bogs on which the water is drawn out from under the ice is that of light. A considerable proportion of the incident light might be cut off by the ice, the more the thicker the ice; and if the ice is covered by snow, all the light or most of it might be cut off. This, probably, would have very little adverse effect, however, since the vines would have an abundant supply of oxygen, and normally also an adequate amount of stored carbohydrates that could be used to supply the small amount of energy required for their metabolic processes at the low temperatures under which they would be. The temperature of cranberry vines under a layer of ice several inches thick generally is much lower than that of vines in water under ice. Consequently, the amount of stored carbohydrates used in respiration, even over a period of two to four months, would be very small, perhaps negligible. Moreover, with an abundant supply of oxygen available, no toxic products would be formed as they are when the oxygen for respiration is obtained by breaking down stored carbohydrates, which is done when the vines are in water containing little or no dissolved oxygen.

The objections usually expressed by growers in Massachusetts to drawing the water out from under the ice are: (1) That the ice is likely to melt during January, or February, leaving the vines unprotected; (2) the vines would be liable to be pulled out by the lifting of the remaining ice if it were necessary to reflow the bog or if a bog were flooded by a heavy rainfall; and (3) an insufficient water supply might make it impossible to reflow a bog if the winter flood were drawn off.

It is true that the ice sometimes melts during a warm period which may come at any time during the winter. It is not unusual in Massachusetts for the ice to melt in January, and this happens very commonly in February. In Wisconsin, the ice rarely goes off the marshes in January, it does sometimes in February, but usually not until March.

If the ice melts enough to expose the vines over a considerable part of a bog, after the water has been drawn out from under the ice and much before the time for the winter flood to be taken off, the bog may be reflowed at any time. If the ice remains over most of the bog until within two to three weeks of the time for the winter flood to be taken off, it would not be necessary, ordinarily, to reflow; thus, the winter flooding period would be shortened to that extent.

The risk of having the vines pulled up by the lifting of the ice when a bog is reflowed or flooded by a heavy rainfall, after the water has been drawn out from under the ice, is not nearly as great as is usually thought. Cranberry vines are sometimes pulled out in that way, but in such cases a few to several inches of vines are frozen firmly into the ice. When the water is drawn out from under the ice, allowing it to drop down onto the vines, they usually freeze onto the lower surface of the ice but do not become embedded in it to any considerable extent. When the bog is reflowed, some of the under side of the ice melts when the water comes in contact with it, since the water is warmer than the ice, thus freeing the vines again. This allows the ice to rise without pulling the vines. It is only on the more shallowly flooded parts of a bog where the vines probably would be frozen into the ice, that they might be pulled out by the lifting of the ice; but even there it would not happen if the bog were flooded to no greater depth than when the ice first formed.

Sufficient water to reflow a bog, if necessary, must be available in case the water is drawn out from under the ice and, ordinarily, would be available for most bogs. For those who do not have enough water to reflow, protection of the vines against injury due to lack of oxygen during the winter-flooding period would have to be obtained by flooding shallowly and by shortening the winter-flooding period as much as possible.

From what is now known as to the course of the dissolved oxygen content of the water on winter-flooded bogs in Massachusetts, it seems very probable that the oxygen content of the water usually does not become low enough to cause injury to the vines until sometime in January; in Wisconsin, it is known that it becomes low enough in December. Measurements have shown, too, that on winter-flooded bogs in Massachusetts, even when there is 5 to 6 inches of ice, the dissolved oxygen content of the water may increase, if there is no snow on the ice. Moreover, there have been winters in Massachusetts when the supply of dissolved oxygen in the water of winter-flooded bogs remained well above the level at which injury to the vines was apt to occur. These were the warmer winters when bogs did not become covered with ice at any time, or for only a few days at a time. The winter of 1936–37 undoubtedly was such a one; it was one of the warmest and least snowy on record.

It may not be necessary to draw the water from under the ice every winter on bogs in Massachusetts, but it should be done whenever a winter is cold enough to make 5 to 6 inches of ice, especially when there is snow on it. The water should be withdrawn as soon as possible after the snow falls, since with snow on the ice the oxygen content of the water decreases rapidly and within a few days may be low enough to cause decided injury.

SUMMARY

Injury to cranberry vines as a result of a lack of dissolved oxygen in the winter-flooding water has for many years been known to occur. It has been more frequent and more severe in Wisconsin than in Massachusetts, but often causes a very appreciable reduction in the size of the crops produced in Massachusetts.

External manifestations of injury are: Dead stems, loss of leaves, dead terminal buds, dead flower buds, failure of flowers to set fruit after pollination, and retardation in the development of flower buds.

The dissolved oxygen content of the water on a winter-flooded bog, when not covered by ice, remains at or near a maximum determined by the temperature of the water in accordance with well-known physical principles.

When ice forms on a winter-flooded bog, the dissolved oxygen content of the water depends on the relation between the amount of oxygen consumed in respiration by the cranberry vines, and by the microorganisms associated with organic matter in and on the soil, and the amount given off in photosynthesis by the cranberry vines and other green plants on the bog. Little or no oxygen is given off in photosynthesis when, because of cloudiness, increased thickness of the ice especially when snow is included in it, or snow on the ice, little or no light is received by the vines and at such times the oxygen content of the water decreases. If conditions unfavorable for photosynthesis continue, all the oxygen may disappear.

Flower buds and the undeveloped new leaves within the terminal buds are the first to be injured if oxygen is lacking, or are first to be killed if the lack of oxygen continues long enough.

Injury to the old leaves, during short periods of oxygen deficiency, probably is prevented by the accumulation, in their intercellular spaces, of oxygen given off in photosynthesis.

Cranberry vines frozen into the ice on winter-flooded bogs are not injured by a lack of oxygen during the winter-flooding period because they are at such a low temperature that they are practically dormant and the amount of oxygen required is negligible. The little oxygen needed is probably obtained from the ice.

The ability of cranberry vines to withstand oxygen deficiency appears to depend to a certain extent on the amount of stored carbohydrates. Growers state that cranberry vines are injured more severely after bearing a large crop than after a small one or none.

The dissolved oxygen content of the water on winter-flooded bogs under ice in Massachusetts varied from day to day according to the intensity and duration of the light received by the vines.

When there was snow on the ice, the intensity of the light received by the vines was reduced according to the thickness of the snow cover; only about 5 per cent of the incident light penetrated four inches of snow. When little or no light was received by the vines, the dissolved oxygen content of the water decreased very rapidly; all the dissolved oxygen was consumed within three or four days.

An insufficient supply of oxygen in the water during the winter-flooding period reduced the size of the crop the following season, but the reduction was not always proportional to the degree or the duration of oxygen deficiency. Present evidence indicates that the yield is reduced if the dissolved oxygen content of the water falls below 3 cc. per liter (4 p.p.m.) even for a few days. Oxygen deprivation over a longer period caused a further reduction in yield. The smaller yield is the result of the death of flower buds, loss of old leaves, injury to the flower buds which causes them to fail to set fruit, and reduction in the size of fruits.

Some modifications of winter-flooding practices are suggested as remedial or preventive measures. The flooding period should be made as short as possible and the water as shallow as possible. Vines may be frozen into the ice over winter; or a bog may be flooded as usual and, after several inches of ice have formed over the bog, the water may be drawn out from under the ice allowing it to drop down onto the vines and remain there until it melts. Both of the last two methods have been used successfully in Wisconsin, and the latter method probably could be used successfully in Massachusetts.

CRANBERRY ICE

By Henry J. Franklin
Research Professor in Charge of the Cranberry Station

CONTENTS

This paper tries to cover all matters in cranberry culture involving the freezing of water. Knowledge of large losses by frost, winterkilling, and hail is necessary for any proper study of other relations of weather to cranberry yields. The lists of such losses included here were compiled mainly from the records of experiment stations and individuals, the reports of meetings and conventions of cranberry growers' associations,[1] publications of the United States Weather Bureau, and old files of local newspapers.[2] They are believed to be fairly complete for Massachusetts since 1867 and for New Jersey and Wisconsin since 1874. The frequency and extent of these losses suggest that the records of selected years may lead to

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[1]Particularly the American Cranberry Growers' Association.

[2]Especially the following: The Yarmouth Register, Yarmouth, Mass., The Barnstable Patriot, Barnstable, Mass., The Wareham Courier, Wareham, Mass., The Middleboro Gazette, Middleboro, Mass., The Old Colony Memorial, Plymouth, Mass., The Berlin Courant and The Berlin Journal, Berlin, Wis., and The New Jersey Mirror, Mount Holly, N. J.

an understanding of factors in cranberry production quite as reliably as those of years seriatim with trend lines.

Important cranberry weather relations in Massachusetts, New Jersey, and Wisconsin, the states having the main cranberry growing regions of the world, are discussed here. In Massachusetts all of the industry is in the eastern part of the state and most of it in Plymouth, Barnstable, and Bristol counties[3]; in New Jersey it is nearly all in the southern half, mostly in Burlington, Ocean, and Atlantic counties[4]; in Wisconsin it is spread widely in the central and northwestern parts of the state, Wood, Jackson, Monroe, Juneau, and Washburn being the leading counties[5].

Much of the published material used in this study and some of the correspondence has been deposited in the cranberry collection of the Middleboro (Massachusetts) Public Library. A list is available.

WINTER ICE

In the Soil

New cranberry plantings with the vines still in hills should be flowed for the winter before the ground freezes much and should not be drained in the spring till the danger of considerable soil freezing is past, for heaving of the soil by freezing and thawing throws new sets out. Vines lifted in this way must be put back into place with the heel promptly in the spring.

Some bogs, usually those close to ponds, do not hold the winter flowage well because of seepage. This difficulty is sometimes best met by letting the soil and surroundings of the bog freeze considerably before flooding and then putting the water on in a cold spell that promises to continue.

Ice remaining in the bog soil after removal of the winter flood, as often happens in Wisconsin (page 31), keeps the vines above it completely dormant till after it is melted. Wisconsin growers prevent this with a shallow flood to "draw out the frost." This is effective, for the water warms fast under their brilliant sun.

On Bog Flowage

The thickness of the ice on the winter flood of cranberry bogs varies greatly in the different cranberry-growing regions and from year to year. There is not enough on Cape Cod for ice sanding in more than a third of the winters in a long term of years, but the flowage freezes down to and even into the soil somewhat on many bogs in cold winters. There is plenty of ice for sanding nearly every year in Middlesex, Norfolk, and Bristol counties, it sometimes being nearly two feet thick in Middlesex County. Only in occasional winters can ice sanding be done in New Jersey, but eleven inches of ice sometimes forms over the bogs there. Ice enough for sanding seldom fails to form in Wisconsin. In cold, open winters the flowage freezes entirely down to and into the soil, the frost going well below the root-zone of all the cranberry vines.[6] The flood on Wisconsin bogs is hardly anywhere over three feet deep and is much shallower than that on most of the acreage. The snow coverage largely governs the depth of freezing.

Cranberry vines frozen in thick ice are often pulled and injured badly when water lifts the ice considerably. For this reason the flowage must be kept near

[3]Bulletins 332 and 371, Mass. Agr. Expt. Sta.

[4]Circular 232, N. J. Dept. Agr.

[5]Bulletin 96, Wis. Dept. Agr.

[6]With a foot and a half of water over a bog, the frost goes down three to four feet in the soil in severe winters with little snow. (H. F. Bain.)

the same level throughout the winter. Outlet gates must therefore be kept clear of ice, especially in a thaw or heavy rain. A special tool (Fig. 1) is handy here. A good growth of well-anchored vines will hold two inches of ice down under the water.

Heavy ice encasing the vines sometimes breaks them off where it cracks, the injury appearing in the spring as though a cleaver had severed the vines and gashed the soil under them.

Six pounds of small copper sulfate crystals to an acre scattered on bog ice just before it breaks up in the spring prevents the development of algal scum in the water after the ice is gone. This should not be used on bogs that drain through trout ponds.

Ice Sanding

Sand is often spread on the ice of the winter flood in making new bogs in Wisconsin. This is not done elsewhere and would be a dubious practice in this State, for cranberry cuttings are more easily planted and root better in loose sand than in sand that has packed. Instead, if the bog has been made ready in the fall, the sand may be placed in piles on the frozen ground and spread in the spring.

Cranberry bogs in Massachusetts and Wisconsin are commonly resanded by spreading the sand on the ice of the winter flood. When there is ice enough to do this with trucks, the soil of the hills and sand holes from which the sand must be taken is often frozen rather deep, making the work harder. Sand holes among trees, especially evergreens, or with southern exposure give much less trouble in this way than those in the open or facing north. If the areas which are to supply sand are covered well with straw, hay, cranberry rakings, or fallen leaves late in the fall, the frost will not penetrate far into the ground. This mulch may be kept from blowing away with a few sanding planks and a little sand.

There is some danger in working in sand holes with deeply frozen surfaces, for if the frozen soil overhangs, large chunks may break away and fall on anyone below. This must be prevented by cutting down the overhang, as it forms, with chisels and sledges, or better with dynamite if it is 18 to 30 inches thick as it sometimes is in Middlesex, Norfolk, and Bristol counties. Gasoline shovels handle overhangs up to a foot or more thick very easily. They also help to do the sanding quickly and so take advantage of favorable weather.

It takes seven to eight inches of sound ice to bear surely the trucks used in bog sanding (Fig. 2). Thinner ice may let trucks through or break down under a heavy sand cover and be carried to the bottom with it. The sand is likely to come down finally onto the vines too thickly in the latter case. Sand spread on the ice of a bog through which much water flows is sometimes largely washed away downstream. Strong dry winds blowing persistently after fine sand is spread on the ice may take most of it off. Also sand that has been spread on clear, smooth ice in cloudy weather is sometimes rather badly drifted by wind. Still worse drifting of the sand is caused occasionally by the wave action of water over the ice from a heavy rain.

Inclement weather often reduces greatly the chances to sand on ice, and favorable conditions should be made the most of by doing the work rapidly Wisconsin growers try to get all the work done within ten days after the first freeze-up, often loading their sanding trucks with a dredge. Sand cannot be spread satisfactorily on ice with much snow over it. Up to three inches of light snow is sometimes scraped off before sanding, and Wisconsin growers often roll a deep snow cover down with a large roller.

If there is little snow in or on the ice or sand, a sand cover soon works down into and even through the ice because of its ready absorption of solar heat. The sand generally falls down evenly and satisfactorily among the cranberry vines from the ice before and as it melts. At times, however, when thick ice breaks up, especially where the flowage is deep, floating cakes carry the sand around a good deal, depositing it unevenly. The sand also sometimes tips the ice cakes and so gets dumped in heaps. It is better, therefore, not to sand on the ice late in the winter.

Ice sanding very often reduces the following cranberry crop as much as sanding directly on the vines. Bergman, in this bulletin, discusses the relations of the flowage ice to oxygen deficiency in the water under it, and the cranberry injuries due to the latter. The probably harmful effect of sand on or in the ice under some conditions is not the only valid objection to ice sanding as it is commonly done. Growers use much more sand on the ice than they would spread directly on the vines and so build up the sand bed of their bogs faster than they should. Bogs may be sanded about as cheaply in other ways as on the ice, except where the sand has to be trucked to them. Ice sanding is advisable under special conditions, but is valued too highly as a general practice in this State. (See pp. 11 and 88.)

HAIL DAMAGE

In frequent years hailstorms partly or wholly destroy the crop on a very few cranberry bogs in Massachusetts. They come fully as often in the New Jersey cranberry area and more than twice as often on the Wisconsin bogs.[7] They hardly ever do material harm on bogs on the Pacific coast.

Massachusetts

Because of the weak convection over the sea, summer hailstorms are much less prevalent in Barnstable, Nantucket, and Dukes counties than in Plymouth County and other parts of the cranberry district. Only one, that of June 15, 1921, seems to have occurred on Nantucket since 1886,[8] and they are rather rare on the outer Cape. As will be seen by the lists of the more destructive of these storms, given below, the town of Wareham and its vicinage (Map 1) has a much worse record of damage by hail than any other cranberry area anywhere. This is due partly to the many excellent and extensive bogs in this area and probably partly to peculiarities in the locale.[9] All the great hailstorms in this region listed here came with the same condition, a cold front that passed in the daytime and was between a warm west or southwest wind on one side and a cool northwest or north wind on the other. In every case, the center of low pressure in the morning was over or near the Maritime Provinces, the general trend of the isobars to the west of the center was from north to south, and the cold front lay from northeast to southwest or east-northeast to west-southwest across central New England. The general aspect of the weather maps was like that for cold waves in winter, only the pressure and temperature gradients were less steep. It appears, therefore, that for severe hailstorms in the main cranberry district there must be

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[7]Atlas of American Agriculture, section on precipitation and humidity, p. 44, fig. 80, 1922.

[8]The only hailstorm remembered to have done considerable harm on Nantucket came on May 18,1877, at about 10 o'clock at night. It affected nearly all parts of the island, stripped the trees of their foliage and blossoms, broke four to five thousand panes of glass, and killed large numbers of crows and blackbirds. The hailstones ranged in size from that of a walnut to that of a hen's egg.

[9]Buzzard's Bay with its converging shores heads at Wareham. As winds pass over the sea more easily than over land because of less surface friction, this bay provides an excellent channel for the delivery of strong, moist west and southwest winds into the Wareham region. Such winds are thrown upward somewhat in coming ashore and, being lighter, override the cold wind from the north under the hail conditions here considered and so may strengthen the convection and favor the occurrence of hail. Records seem to show a similar special tendency of severe hailstorms to occur around the head of Narragansett Bay.

a general weather situation favoring convergence of warm moist air over southern New England, and a definite thrust of cold air from the north; these conditions obtaining when diurnal heating produces strong local convection to combine with the favoring general conditions to produce powerful convection into cold air aloft.

Map 1. Outline Map of Southeastern Massachusetts Showing the Wareham Hail Region in Black.

The following are the more important hailstorms recorded as occurring in the history of the Massachusetts cranberry industry:

1. July 17, 1889. This was a widespread storm in eastern Massachusetts, hail falling in large quantity in many localities both north and south of Boston. It was the severest hailstorm in the history of Lynn; nothing equal to it had been seen in Milton in forty years; and at Nahant the largest hailstones were 2¼ inches in diameter. The storm came a little before 2 o'clock in the afternoon and lasted about 20 minutes. Cranberry bogs were hurt quite generally throughout Plymouth County (except in Plymouth) but mostly in Carver and Wareham, with an estimated reduction in the crop prospect of 20,000 to 26,000 barrels. The storm was destructive as far east as Sandwich where some of the hailstones weighed 3 to 4 ounces.

2. June 22, 1904. It was estimated that the hail reduced the cranberry crop prospect by from 50,000 to 75,000 barrels, and probably had an adverse effect on the 1905 crop also. The vines were so badly damaged on one bog in Wareham that it had to be replanted. Hail fell in Middleboro, Plympton, and Hanson and formed a deposit 6 inches deep in Pembroke. It skipped Carver. It was severe in Sandwich, Sagamore, Bourne, Buzzard's Bay, Wareham, and the western edge of Plymouth, accumulating to a depth of 4 inches at White Island. Ice remained on the ground the next morning at both Pembroke and White Island.

Many of the hailstones at Buzzard's Bay and Sagamore were 5 inches in circumference (measured). The hail began at 7 to 7:30 and lasted only about 10 minutes at Buzzard's Bay. A powerful wind and heavy rain came with this storm and hundreds of trees were uprooted and many buildings moved and wrecked. Window panes in great numbers were destroyed in the region of Buzzard's Bay, Bourne, and Sagamore. The hail did considerable damage as far east as West Barnstable.

3. September 6, 1905. This storm came in the afternoon and was confined to the eastern part of Wareham. The hail lasted only about 3 minutes, but hit quite a number of bogs and probably destroyed 4,000 to 5,000 barrels of cranberries.

4. June 1, 1925. Widespread hail, falling late in the afternoon from Center Carver to Cataumet, reduced the prospective cranberry crop at least 25,000 barrels, most of the loss being in Wareham, the southern part of Carver, and the western edge of Plymouth. It completely defoliated the vines and even cut off cranberry branches and drifted them in rolls on some bogs. It barked trees and scored telephone poles on the windward side. It broke window panes freely in Carver and Wareham and in parts of Plymouth and Bourne. It was driven by a wind so strong that it wrecked some buildings and moved others.

5. June 26, 1938. Hail in the eastern part of Rochester and the western part of Wareham reduced the prospective cranberry crop by probably 5,000 barrels. The bog areas affected also failed to bud well for 1939. This storm came early in the afternoon.

Injury by hail on Massachusetts cranberry bogs is almost entirely confined to June, July, and August. It occurs oftener but is less extensive and severe in August than in June and July. These differences are due to seasonal variation in the height of the freezing ceiling, strength of convection, and amount of water vapor in the atmosphere.

Destructive summer hail in southeastern Massachusetts comes usually in the afternoon or evening, rarely at night, and probably never in the morning. Unusually tall pillars of cumulus clouds in the forenoon are a fair sign of hail later in the day. Hail is always part of a violent thunderstorm, and a thunder cloud reaching unusual heights with a strongly marked spreading cirriform crown at the top is pretty sure to have it. Thunderstorms generally move easterly. This and the lay of the land and sea determine that, in all locations in most of the cranberry district, summer hailstorms must nearly always approach from a direction in the quadrant north-northwest to west-southwest.

New Jersey

Hail occurs less often toward the coast than away from it. A hailstorm on August 18, 1900, destroyed about 7,000 barrels of cranberries south of Medford. Numerous hailstorms helped reduce the 1904 crop. One of the most important of these storms occurred near Pemberton on May 22, 1923. It started at about 2 p. m. and the hail gathered to a depth of 3 or 4 inches. It defoliated cranberry vines almost completely.

Wisconsin

As the cranberry bogs of Wisconsin are much more scattered than those in the Cape Cod district, hail does less harm there in spite of its more frequent occurrence. It partially eliminated the crop of the Berlin district in 1907. It struck the bog of the Badger Cranberry Company at Beaver Brook severely on August 6, 1928, reducing the crop 2,000 barrels, impairing the quality of the rest of the fruit, and affecting the vines so that they took on their winter color and budded very poorly for the 1929 crop. The most extensive summer hail in the history of the Wisconsin industry came in the Cranmoor district on September 18, 1935. It damaged 12,000 to 15,000 barrels of berries, about 2,000 barrels being a complete loss.

WINTERKILLING

Cranberry vines sometimes are killed extensively by exposure to winter weather in all the important districts where they are cultivated except those on the Pacific coast. This injury is most widespread when streams, ponds, and reservoirs are low from restricted rainfall and large acreages cannot be flooded till well into the winter. It therefore commonly occurs fairly early in the winter when it reduces the crop total of a state seriously. In Massachusetts it may happen at any time from early December to the end of March. Dry bogs may, of course, be hurt in any winter if there is little or no snow cover and the right weather conditions prevail.

The more common form of cranberry winterkilling seems to be the same as that which sometimes affects fall-sown grains and evergreen trees and shrubs. It has been called *physiological drouth*[10] and is caused by the drying out of the vines by transpiration from the leaves while the roots are encased in frozen soil or the stems are frozen so that no water can come up through them. The injury, therefore, usually occurs in a period of strong dry winds and it generally takes several more-or-less successive days of this to do much harm. This injury always kills the winter flower buds. It may affect only the terminal parts of the upright branches or kill the vines entirely down to the ground. It may kill the more exposed vines and not harm those underneath, where the vining is heavy. It seems never to kill the cranberry roots much in Massachusetts and New Jersey, new growth coming up the following summer to produce at least a partial crop the next year. Vines sticking out of the ice of the winter flood often winterkill back to the ice, their stems being frozen and unable to carry water up to the leaves at a critical time. The leaves of winterkilled vines become reddish or light brown and fall from the stems readily when brushed. Winterkilled vines recover best when they are not disturbed or treated in any way.

Vines not picked the fall before and new plantings still in hills do not winterkill easily. Dry bogs should be picked with "snap" machines and should not be raked until early the following spring so that the vines may not be disturbed much in the fall and so made likely to winterkill.

In Wisconsin, the winter cold often freezes not only the flowage of the cranberry bogs completely down to the ground but also the soil under it to quite a depth (p. 26). If the winter water is let off early in the spring from a bog deeply frozen in this way, ice may persist in the soil till early June.[11] The occurrence of much dry weather before this melts will kill the vines if water is not put on again. This is called "springkilling" by Wisconsin cranberry men. It is due to physiological drouth and so is a form of the winterkilling already discussed. Small bog areas under some conditions of freezing are lifted higher than their dams and cause anxiety lest they fail to settle below flooding level before springkilling occurs.

A flooded bog which has the water removed in the winter and is not protected by ice or snow often winterkills easily and badly. The mechanism of this killing has not been determined.

Flooding bogs for the winter is the best protection from winterkilling. The water should go on as soon as the sand surface remains frozen all day or, at any rate, as soon as it is hard to kick it through with the heel — usually about December 1 in Massachusetts. The water should be held just deep enough to cover the vines; it is often best to let the highest parts stick out when a bog is much out

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[10]Smith, J. Warren, Agricultural Meteorology, 1920, p. 209.

[11]Ice sometimes is found in the soil of marshes in Wisconsin as late as July 4. (Cox, H. J., Frost and temperature conditions in the cranberry marshes of Wisconsin, U. S. Weather Bureau Bul. T, 1910, p. 119.)

of level. The vines are as well protected frozen into the ice as any way. A good snow cover is effective protection, and flooding may be delayed if there is one.

The winter water should usually be held till about April 1 on Cape Cod and April 8 in Middlesex County. It probably should be let off late in March in New Jersey but be held till mid-April in Wisconsin.

There is a considerable acreage of bogs on Cape Cod that cannot be flooded at all.[12] These are the bogs which have generally been most affected by the cranberry fruit worm, frost, and drouth. The recent success of sprinkling systems as protection from frost and drouth on some of these areas and the discovery of effective insecticidal controls for the fruit worm have greatly increased the need for some means of protecting such bogs from the winter. The following are possibilities:

1. Covering the vines with straw, cranberry rakings, shade cloth, or other like material. This is effective but probably too expensive.

2. Building up a covering of ice with a sprinkling system in freezing weather. This has not been tried but seems rather promising.

3. Spraying the vines with a special wax preparation. This may be effective, but the only material so far certainly available seems too expensive.

4. Use of wind breaks, such as snow fences.

5. Chemical applications. Here is an unexplored field.

A list of the more important cases of winterkilling on record as occurring in the three main cranberry states follows:

Massachusetts

1. Winterkilling was very severe on Barnstable County bogs in the winter of 1871–72, the vines being killed down to the roots in some localities. Nearly half of the strawberry plants in all New England were killed. Evergreens and Rhododendrons were killed very extensively in nurseries throughout New England. Great numbers of evergreens died everywhere over the country. Apparently the damage was done by very strong cold winds early in March.

2. There was considerable winterkilling of cranberries in the winter of 1880–81. Water supplies were low in the fall and early winter.

3. Severe winterkilling in the winter of 1894–95 reduced the 1895 cranberry crop very materially.

4. Severe winterkilling was extensive on Cape Cod bogs in the winter of 1900–1901. Water supplies were low and many growers were unable to flood their bogs. There was little snow.

5. There was considerable winterkilling on the bogs in the winter of 1903–4.

6. Very severe and widespread winterkilling occurred in the winter of 1904–5, which reduced the 1905 cranberry crop probably a third. The fact that this was also a year of maximum fruit worm injury suggests that the bogs rather generally had meager water protection, and it is recorded that such was the case.

7. Considerable winterkilling occurred on the bogs in the winter of 1910–11.

8. Winterkilling was severe and extensive in the winter of 1916–17. Many bogs winter-flowed the first days in February and some flooded late in January were badly hurt. Unprotected bogs were frozen deeper than the cranberry roots extended for some time before the killing took place, and the vines were exposed to strong, dry, northerly winds most of the three weeks ending February 5. Water supplies were low during the fall and winter.

9. Winterkilling was severe and extensive on cranberry bogs in the winter of 1917–18, one of the most severe in the history of New England. Weather conditions attending the winterkilling were much the same as in the previous winter. Ponds and streams were low during the fall and winter.

[12] Mass. Agr. Expt. Sta. Bul. 332, 1936, p. 9. (Copies in the Middleboro library.)

10. Winterkilling was severe and extensive on the bogs in the winter of 1923–24, reducing the 1924 crop fully 20 per cent. Water supplies were low during the fall and winter.

11. There was severe and widespread winterkilling on cranberry bogs in December 1934. It was estimated that this reduced the 1935 crop 20 per cent. Water supplies for flooding were very low early in the winter.

12. Very widespread and severe winterkilling in January reduced the 1940 cranberry crop probably 20 per cent. Water supplies for flooding were scanty early in the winter.

13. Dry bogs winterkilled severely everywhere in the winter of 1940–41, the 1941 crop prospect being reduced perhaps 7 per cent. Water supplies for other bogs were fairly abundant early in the winter.

14. There was extensive winterkilling in the winter of 1941–42, cutting the 1942 crop 10 per cent. Ponds and streams were very low early in the winter.

New Jersey

1. Extensive winterkilling occurred on the New Jersey bogs in the winter of 1874–75, destroying about three-fourths of the prospective crop on the exposed areas.

2. There was severe and extensive winterkilling on the New Jersey bogs in the winter of 1900–1901, though some of the injury ascribed to this may have been caused by the drouth of the previous summer. Water was scarce all winter.

3. Extensive winterkilling occurred in the winter of 1903–04, reducing the 1904 cranberry crop 25 per cent.

4. There was extensive winterkilling of cranberries in the winter of 1904–05

5. There was considerable winterkilling on the bogs in the winter of 1917–18.

6. Extensive winterkilling occurred on the bogs in the winter of 1939–40. As water supplies were low, many bogs were not flooded till February.

Wisconsin

1. Severe and widespread winterkilling occurred on the Wisconsin bogs in the winter of 1891–92. Water supplies were low in the late fall and winter.

2. Winterkilling on the bogs was severe in the winter of 1893–94. Water supplies were low during the late fall and winter.

3. There was great loss from winterkilling on the bogs in the winter of 1894–95. Water supplies were extremely low during the fall and winter and there was little snow.

4. Rather extensive winterkilling occurred in the winter of 1900–1901.

5. Serious winterkilling occurred on the bogs in the winter of 1910–11. Water supplies were low during the late fall and winter and there was little snow.

6. There was considerable winterkilling on the bogs in the winter of 1922–23. Water supplies were scanty in the fall and throughout the winter.

7. Serious and widespread winterkilling occurred in the winter of 1930–31, reducing the 1931 cranberry crop prospect 20 per cent. Water supplies were very low in the fall and early winter.

8. Very severe and extensive winterkilling occurred in late November or early December 1932, in both the Mather and the Cranmoor districts. It affected probably 60 per cent of the cranberry acreage of the State and seriously curtailed the 1933 crop. Because of drouth, many growers lacked water for winter flooding and most of those who had it failed to flood early enough.

9. There was general and very destructive winterkilling on the bogs in the Mather district in the winter of 1933–34. The vines had only partly recovered from the injury of the winter before and this second winterkilling put large areas out of production for two or three years. Part of this acreage never recovered and was abandoned. The Cranmoor district would have suffered the same fate had it not, in the fall of 1933, put through a ditch to take water from the Wisconsin River. Twenty per cent of the cranberry acreage of the State was reduced to complete nonproduction in 1934 by the winterkilling. Rainfall was light and water supplies extremely low during the fall and winter and there was little snow.

CRANBERRY FROSTS

Cultivated cranberry bogs are made from the land of marshes, swamps, swales, pond bottoms, or low meadows. They are always on the lower land in their vicinity, and in Massachusetts they usually are largely surrounded by sand hills (Fig. 3). Such locations are real frost pockets, for the air is often much colder on clear cool nights over bottom lands than it is on adjacent uplands, especially when there is little wind. This is due to the drainage by gravity of the surface air of the uplands, cooled by conduction to the ground and other exposed surfaces, especially plant leaves, which radiate heat to the cold sky, down onto the lower land.[13] Consequently frosts in May or June often kill vegetation on low land and at the same time do little or no harm on the hills, especially on their higher parts.[14] The limit of injury is sometimes conspicuous as a contour line along the uplands.

It will be seen, therefore, that protection from frost is important in cranberry culture. Most cultivated bogs are protected by flooding with water from streams, ponds, or reservoirs. This flooding is done mostly by gravity, but a third of the cranberry acreage of the State is flowed by pumping. Water supplies, however, are often scant and must be used carefully. Also, frequent flooding in the spring retards the new growth and tends to reduce productivity, and in the fall disturbs harvesting. Accurate and timely frost warnings, therefore, are much desired by cranberry growers. To provide them was one of the problems when the cranberry experiment station was established in 1910.

The frequent failure of the Weather Bureau in its former predicting was due partly to its lack of familiarity with cranberry frost problems, and the fine work of Cox[15] on bog microclimate and frost conditions on the Wisconsin marshes was a great help. General warnings of frost were inadequate, for they gave no idea of the degree of cold expected. Facts given here about the frost endurance of the vines and berries show how needful this close information is. Obviously, also, frost warnings based on noon and especially on evening observations have some advantage over morning predictions.

Recent expansion of forecast services has made good advices and warnings now available at the East Boston office of the Weather Bureau at any hour, day or night.

Spring Frosts

Figure 4 pictures the dormant fruit bud in the tip of a cranberry branch, cut open to show its center dead and dark from frost injury. The center always darkens within a day after it is killed by frost. The inside of an uninjured bud is green throughout. Except when the vines are winterkilled, these buds seldom fail to stand all the low temperatures of winter. The writer has observed one case and been told of others where they were killed by temperatures below zero in December after a very warm November, their centers turning dark as from frost injury.

Bogs vary greatly in starting new growth, and early bogs in cold locations are likely to be hurt by frost late in April. This is especially true of bogs in the

[13]For a full discussion of radiation, conduction, and air drainage in their relation to the formation of a frost hazard, see Young, Floyd D., Frost and the prevention of frost damage, U. S. Dept. Agr., Farmers' Bul. 1588, pp. 1–4, 1935. (Copies in the Middleboro library.)

[14]The temperature inversion at the Experiment Station often reaches 10° F. and sometimes 15° in the first 18 feet above the bog surface. See Brooks, Charles F., Bul. Amer. Met. Soc., 16: 93–94, 1935; and Franklin, H. J., U. S. Monthly Weather Rev., Supplement No. 16, 1920, pp. 25–26. (Copies in the Middleboro library.)

[15]Cox, Henry J., Frost and temperature conditions in the cranberry marshes of Wisconsin, U. S. Weather Bureau Bul. T, 1910. (Copy in the Middleboro library.)

northwestern part of the Massachusetts cranberry-growing region, for these bogs always lead those on the Cape in their early growth,[16] and minimum bog temperatures on cold nights in April are lowest inland.

On the night of April 28–29, 1910, from 10 to 75 per cent of the fruit buds on exposed bogs throughout the Cape cranberry section were killed by frost, much injury occurring in some cases even where the winter water had been let off within a day or two. No official records of minimum bog temperatures were made, but the Wareham Courier reported a range of from 17° to 23°F. March and April had been warm and the season was fully ten days ahead of normal when the frost came.

A severe freeze the night of April 22–23, 1919, seemed to do no harm on most exposed bogs, but it killed over half of the Early Black fruit buds on a large bog in Norton. It did not harm the Howes buds there. Minimum bog temperatures ranged down to 17° F. at the cranberry observing stations that night.

The night of April 28–29, 1934, most of the fruit buds were killed on many bogs, mainly in the northwestern part of the cranberry district (Middleboro, Lakeville, Rochester, Freetown, Assonet, and Foxboro). Minimum bog temperatures at the observing stations ranged down to 15° F. Again much loss occurred on some bogs from which the winter water had been let off within a day or two. The spring temperatures before the frost were about normal.

There was a considerable loss by frost, mostly on bogs in the northern part of the cranberry region, in the night of April 22–23, 1941, the minimum bog temperatures ranging down to 17° F. March and early April had been colder than usual, but there were several very warm days just before this frost.

These records show plainly that, when bog temperatures promise to fall below 20° F. during the last week in April, it is best to flood, especially in inland locations, unless the previous weather has been fairly cool and the spring is late.

The winter fruit buds usually will endure an air temperature of 25° F. till they grow to a cross diameter of over 2 mm. Very rarely are they killed by frost on bogs from which the winter water has been drained in late March or early April before the brown winter color of the cranberry foliage turns noticeably greenish.

From each of these buds grows out, by the stages shown in Figure 7, a considerable stem bearing the flower buds and a leafy tip. If, as often happens, a winter bud is only slightly or moderately hurt by frost, the stem grows out but usually fails to develop a leafy tip and may lack one or more flower buds also (Fig. 5). Cape Cod growers commonly call this growth an "umbrella." It is doubtful if such injury is often important, for a good set of fruit usually results even over an area where nearly all the fruiting branches are in this condition (Fig. 6). It is well to remember this when water for frost flooding must be used sparingly.

When the winter fruit bud is completely killed, new shoots start out around it and farther down the branch (Fig. 8).

New cranberry growth is never hurt by an air temperature of 30° F., but 29° often does considerable harm if it lasts long, while 28° for a short time sometimes does no injury.

Slightly harmful frosts cup the tip leaves of the new growth characteristically toward each other (Fig. 9). The leafy tips are somewhat more frost-tender than the blossom buds and blossoms, and the new growth is most easily hurt by frost before the flower buds begin to turn down (Fig. 7, D, E, F, and G).

Ferns, grape, and scrub-oak leaves have about the same frost endurance as the new cranberry growth, and much harm to any of the former around an exposed bog is good evidence that the bog is hurt.

[16]Plant growth in general is much retarded on the Cape in the spring, probably because of the influence of the sea, the water warming up much more slowly than the land.

The latest spring frost generally harmful to Cape Cod bogs came the night of June 20–21, 1918, when the temperature fell to 26¾° F. at the experiment station bog and to 23° on some bogs. It reduced the cranberry crop prospect over half (estimated) and so hurt the vines on some areas that their 1919 crop was also curtailed, all new growth being killed.

Frosts causing slight or local injury on Massachusetts bogs have occurred as late as July 3 and 4 (1927 and 1929).

Fall Frosts

Bogs in cold locations sometimes suffer from frost late in August. The earliest late-summer frost recorded as occurring on Cape Cod bogs came August 16, 1912, when the bog temperature at the observing station at South Carver fell to 28° F. The next earliest frost on record came August 22–23, 1923, the lowest bog temperature observed being 27° at Norton. Bog temperatures ranged down to 25° on August 24–25, 1940, and it was estimated that frost took 5,000 barrels of cranberries.

The earliest fall frosts to cause severe and general cranberry loss on the Cape occurred the nights of September 10–11 and 11–12, 1917. Bog temperatures ranged down to 22° F. at cranberry observing stations and to 18° in other places. Because of a backward spring and early summer, cranberries were very late in ripening and were still green or only partly colored when these frosts came. The estimated cranberry loss was 60 per cent in Massachusetts and 25 per cent in New Jersey.

Cranberries in the whitish state that precedes reddening usually endure a temperature of 28° F. without hurt, but 26° often harms such fruit greatly.

Some softening among ripe Early Black or Howes cranberries usually follows exposure to 22° F., but none results from 23°. Ripe Howes are so resistant that under bog conditions often only 10 per cent are softened by 16°, only 20 per cent by 14°, and only 55 per cent by 9°; but sometimes 25 per cent are softened by 18°. With Early Black and Centennial berries the loss at these temperatures is always much greater.[17] Ripe McFarlin, Bugle, and Smalley Howes berries endure frost as well as Howes.

Unripe, even wholly whitish, cranberries down among thick vines are hurt by frost much less than well-colored ones in the tops of the same vines, the reduction of radiation of heat from the under-berries by the vines and top berries over them and their greater exposure to conduction, convection, and radiation from below more than balancing the difference in resistance due to unequal ripeness. For this reason, crops of cranberries well hidden among the vines escape injury from more severe frosts than crops more exposed.[18] Berries of thin vines, lying on or very close to the sand, are protected by heat conducted directly from the soil and are not easily injured. With other things the same and within varieties, the smaller berries are softened by frost more readily than the large ones and single berries alone than those in clusters.

[17]These are air temperatures at the tips of the vines. The true freezing point of cranberries ranges from 24.6° to 29.4°, but they will undercool a good deal without freezing if they are not inoculated by jarring. Shaw Success (Massachusetts) and Metallic Bell (Wisconsin) have lower freezing points than the other varieties so far tested. (U. S. Dept. Agr. Circ. 447, 1937, pp. 4 and 5. Copy in the Middleboro library.)

[18]Conditions in this regard vary greatly from bog to bog and from year to year, vine coverage of the crop sometimes being complete. Chances with expected minimum bog temperatures of 20° to 21° F. may well be taken in October when this coverage is good.

Most of the cranberries that freeze in a frost in the picking season often thaw out and show no injury.[19] They may stand repeated freezing and thawing if the temperatures are not too low, but this is not beneficial.

Frost in cranberries is sensed readily with the teeth, the "bite" being distinctive. The frozen berries shaken together rattle like marbles.

Cranberries frozen on a bog when they are ripe or ripening are fair canning material, so they can be salvaged, but they sell at a lower price than the sound fruit. Berries some of which have been frozen usually become sticky and hard to sort for the fresh fruit market. Such fruit is in better condition and more easily handled when it is not picked for ten days or more after the freezing.

Harm to the terminal buds of cranberry vines from late-summer or fall frost has hardly ever been observed in Massachusetts[20] or New Jersey. Such injury on August 8, 1904, in Wisconsin reduced the 1905 crop about 25 per cent and has been important there in other years.[21] The new growth of vines on New England bogs flooded in the summer for grubs is tender in the early fall and, unless protected from frosts, is likely to lose its buds.

Cox has shown[22] that minimum air temperatures on cranberry bogs on clear, cool nights are lower 5 inches above the ground than at the surface, especially in October, the difference sometimes reaching 6 or 7 degrees. The distance above the ground of the lowest temperatures on such nights must vary with the vine growth, for they must be at the radiating surface made up of the tops of the vines.

Cranberry Observing Stations and Minimum Temperature Formulas

With the help of the late John W. Smith, then in charge of the New England Section of the Weather Bureau, and of the late Henry J. Cox, in charge of the of the Bureau's work in Chicago, three special observing stations were established in the cranberry district in April 1912. They were located at Marstons Mills (at the bog of Mr. Chester Crocker) in Barnstable County, and at East Wareham(at the Cranberry Experiment Station, elevation 18 feet) and South Carver (at the bog of the Atwood Bog Company) in Plymouth County. Similar stations at Norton in Bristol County (at the bog of the Fuller–Hammond Company) and at Halifax in Plymouth County (at the bog of the United Cape Cod Cranberry Company) were started in April 1913. Stations at South Hanson (at the packing house of the United Cape Cod Cranberry Company) and Pembroke (at the John Hill bog of the United Cape Cod Cranberry Company) in Plymouth County were added in May 1919.

Weather records of the frost seasons have been made at all these stations yearly since they were started. Study of these records, begun in the winter of 1917–18, was pursued to find formulas for predicting cranberry bog frosts and their degree of cold. Computing of minimum temperatures from relative humidity, then in favor with Prof. J. Warren Smith,[23] who had charge of the Weather Bureau work in agricultural meteorology, and with students of frost problems in the West, was tried and, with other methods that had been advanced, found unsatisfactory for cranberry frost work. Original formulas were then developed by trial, every

[19]Cox, op. cit., p. 91; Franklin, op. cit., p. 30.

[20]Many terminal buds were killed on Early Black vines on a bog in Wilmington by the frost of August 24–25, 1940.

[21]Cox, op. cit., p. 121; Lewis, C. L., Report of the thirty-seventh annual meeting of the Wisconsin Cranberry Growers' Association, 1924, p. 41; Bain, H. F., Report of the forty-second summer convention of the Wisconsin Cranberry Growers' Association, 1928, p. 11; Weather forecasting in the United States, W. B. 583, 1916, p. 180.

[22]Cox, op. cit., pp. 35, 36, 76, and 89.

[23]Smith, J. Warren, and others, Predicting minimum temperatures from hygrometric data, U. S. Monthly Weather Rev., Supplement No. 16, 1920. (Copy in the Middleboro library.)

promising weather item being tested. A frost-warning service using these formulas was started in 1920, the cranberry growers paying the telephone charges,[24] and is still maintained. The formulas have been changed from time to time to use new information and data.

Observations were made in the towers of the forest fire service at Middleboro, Bournedale, and Barnstable in 1927, 1928, and 1929, but they failed to provide data useful in frost predicting.

Observing was begun in the fall of 1924 at North Carlisle in Middlesex County, at the bog of the Lowell Cranberry Company (elevation about 150 feet). As data from this place improved the formulas for computing minimum bog temperatures for Cape Cod, other stations were established as follows:

In Worcester, Worcester County, in May 1928, at home of Mr. Clifford L. Davis, Winter Hill Observatory, 805 Grove Street (elevation 625 feet).

In Holliston, Middlesex County, in September 1929, at home of Mrs. Evelyn Weston (elevation about 240 feet).

In East Gloucester, Essex County, in May 1931, at home of Rev. Ralph M. Barker (elevation 15 feet).

In North Harwich, Barnstable County, in June 1929, at home of Mrs. Mary Soutter.

In Fitchburg, Worcester County, in May 1931, at office of city sewage plant (elevation 402 feet).

Observing in the frost seasons was continued through 1942 at all these places except the last two.

Six localities have provided data useful in the final formulas. Marked on the map (Map 2) by small circles, they are: East Wareham (5), Worcester (1), East Gloucester (4), Milton[25] (6), Paxton[26] (3), and Carlisle (2), named in the order of their value in this work.

The formulas seem to be now in their final form. They are empirical and made to show what minimum temperatures to expect under more or less ideal conditions, when temperature fall during the night is least affected by cloudiness, wind, or unusual special influences. They may be regarded as guides to experience. While they are being used in frost predicting, they are presented here merely as a study of the relations of noon and evening weather conditions to ensuing minimum temperatures near the surface of lowlands in southeastern New England in the cranberry frost seasons.

The "minimum bog temperature" is the lowest temperature during the night at the tops of cranberry vines.[27] Minimum temperatures vary on frosty nights not only on different bogs but on different parts of the same bog.[28] The formulas are made to show the minimum likely to occur over average areas of the bogs in cooler-than-average locations. Growers with bogs in warm places can allow for this. The variation in minimum bog temperatures in different parts of the cranberry district is greatest on nights following evenings with large differences in the dew point at the various observing stations, probably because of the movement and mingling of masses of air varying greatly in humidity and large variation in local winds and cloudiness.

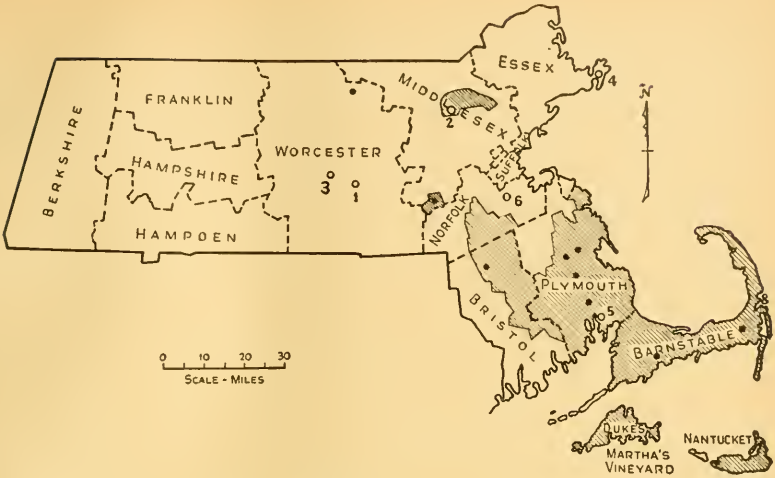
[24]The warnings were also given by radio in 1940 and 1941.

[25]Blue Hill Meteorological Observatory (elevation 640 feet).

[26]Observing station of the Yankee Network Weather Service (elevation 1395 feet).

[27]All bog temperatures mentioned in this paper are temperatures taken with unsheltered minimum registering thermometers without radiation shields. Such thermometers, covered with dew or frost as they nearly always are on frosty nights, are nearly full radiators (Schmidt, E., Refrig. Engin. 28 (3):152 and 156, 1934) and give only their own temperature. not that of the air around, them. They reflect truly, however, the temperature of plants near them, also coated with dew or frost and radiating as freely.

[28]Cox, op. cit., pp. 46–49; Franklin, op. cit., p. 28.



Map 2. Outline Map of Massachusetts showing:
(1) Shaded parts where cranberries are cultivated.
(2) Small numbered circles, the locations of the observing stations providing data for the forecasting formulas.
(3) Small black circles, the locations of other cranberry weather observing stations.

The construction of the various formulas seems to reveal the following, in the relations they cover:

1. They are all straight-line relations.[29]

2. The relations change steadily with the advance and retreat of summer and much faster in the spring than in the fall.

3. The wet-bulb temperature methods of Angström[30] and Keyser,[31] though properly rejected by Ellison[32] in the forms in which they were advanced, were evidently real approaches to fundamentals. As modified and applied here,[33] they are useful in computing minimum bog temperatures. The writer has failed to find a way to use the Young formula[34] with comparable results, but it may deserve further study.

4. The dew point is significant in the evening but not at noon.

5. The lowest of the dew points at the various stations is important in the evening in the spring and late summer. Wherever it is, it tends to command the situation before morning. As it usually is at Milton, Paxton, or Worcester, and

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[29]The addition of considerable amounts to the observed data before using a divisor in some of the formulas gives the line a more gradual slant.

[30]Angstroem, I. Anders, Studies of the frost problem, Geografiska Annaler, January 1920, pp. 20–32. Abstracted by J. Warren Smith in U. S. Monthly Weather Rev. 48:640-641, 1920 (copy in the Middleboro library).

[31]Keyser, Elgie M., Damaging temperatures and their calculation in advance by simple arithmetic, Proc. Wash. State Hort. Assoc. for 1922, Olympia, Wash., pp. 97-103.

[32]Ellison, Eckley S., A critique on the construction and use of minimum-temperature formulas, U. S. Monthly Weather Rev. 56:485–495, 1928.

[33]The wet-bulb temperature is most widely useful employed directly, but is helpful indirectly in the evening formulas that use the dry-bulb temperature with the dew point.

[34]U. S. Monthly Weather Rev., Supplement No. 16, 1920, pp. 53–58; Ellison, op. cit., pp. 493–495; Allen, Charles C., Minimum temperature forecasting in the central California citrus district, U. S. Monthly Weather Rev. 67:286–293, 1939. (Copy in the Middleboro library.)

In varied form this formula is used in frost forecasting in the West more widely than any other. It is based on the dew point and relative humidity.

as these stations are much higher than the others, its use probably is a sampling of upper-air conditions. It loses its value entirely in the fall. This suggests a shift in dominating influence from that of upper-air humidity to that of humidity near the ground.

6. The increased value in the fall of the wet-bulb temperature alone at noon and of the dew point alone in the evening seems to reflect a relation between the importance of humidity and the length of the night.

7. Dry-bulb temperatures near the coast are more closely related to ensuing minimum bog temperatures in spring to early fall than those inland.[35]

8. The evening wind velocity at Worcester, Paxton, and Pittsfield is an item of special interest. It seems to be a good measure of the general atmospheric circulation, probably because of the elevation and distance from the sea.

[35]The evening temperature at East Gloucester has a little closer relation than that at East Wareham, but the latter may be used for the former on occasion.

Formulas for Reckoning Minimum Bog Temperatures at Noon (Eastern Standard Time)

Let: T be the minimum bog temperature to be computed,
DEW the shelter dry-bulb temperature at East Wareham,
WEW the shelter wet-bulb temperature at East Wareham,
WBH the shelter wet-bulb temperature at Blue Hill Observatory,
WW the shelter wet-bulb temperature at Worcester, and
X the average between the wet-bulb temperatures at East Wareham and Worcester.

Then:

In April (last third) . . . . $T = \dfrac{DEW + WEW + 18}{6}$ or $\dfrac{X - 8}{2}$

In May (1st half) . . . . $T = \dfrac{DEW + WEW + 38}{6}$ or $\dfrac{X - 1}{2}$

In May (last half) . . . . $T = \dfrac{DEW + WEW + 54}{6}$ or $\dfrac{X + 4}{2}$

In June . . . . $T = \dfrac{DEW + WEW + 66}{6}$ or $\dfrac{WBH + 9}{2}$ or $\dfrac{WEW + 7}{2}$

In late August and September (1st half) $T = \dfrac{DEW + WEW + 52}{6}$ or $\dfrac{WBH + 5}{2}$ or $\dfrac{WEW + 3}{2}$

In September (last half) . . . . . $T = \dfrac{WBH + 3}{2}$ or $\dfrac{WEW - 1}{2}$ or $\dfrac{WW + 1}{2}$

In October (1st half) . . . . $T = \dfrac{WBH + 1}{2}$ or $\dfrac{WW - 1}{2}$

In October (last half) . . . . $T = \dfrac{WBH - 1}{2}$ or $\dfrac{WW - 3}{2}$

Formulas using East Wareham data alone are given (for both noon and evening) where they have proved satisfactory. Their forms probably may be used with local data in many places in the Cape cranberry district.

Formulas for Reckoning Minimum Bog Temperatures at 7 p. m. (Eastern Standard Time)

Let: T be the minimum bog temperature to be computed,
DG the shelter dry-bulb temperature at East Gloucester,
DW the shelter dry-bulb temperature at Worcester,
GP the dew point at East Gloucester,
EWP the dew point at East Wareham,
X the average between the wet-bulb temperatures at East Wareham and Worcester, and
M the lowest of the dew points at Carlisle, East Gloucester, East Wareham, Milton (Blue Hill Observatory), Paxton, and Worcester.

Then:

In April (last third).....$T = \frac{DG + 1.5\ M + 30}{6}$ or $\frac{X - 2}{2}$

In May (1st half).......$T = \frac{DG + 1.5\ M + 45}{6}$ or $\frac{X + 3}{2}$

In May (last half).......$T = \frac{DG + 1.5\ M + 57}{6}$ or $\frac{X + 7}{2}$

In June................$T = \frac{DG + 1.5\ M + 64}{6}$ or $\frac{X + 9}{2}$

In late August and September (1st half)............$T = \frac{DG + 1.5\ M + 54}{6}$ or $\frac{X + 7}{2}$ or $\frac{EWP + 8}{2}$

In September (last half) $T = \frac{DW + GP + 11}{4}$ or $\frac{X + 5}{2}$ or $\frac{EWP + 6}{2}$

In October (1st half)....$T = \frac{DW + GP + 7}{4}$ or $\frac{X + 3}{2}$ or $\frac{EWP + 4}{2}$

In October (last half)....$T = \frac{DW + GP + 5}{4}$ or $\frac{X + 2}{2}$ or $\frac{EWP + 3}{2}$

Add 2 degrees to the computed temperature when the 7 p.m. wind velocity at Worcester is over 7 miles an hour and the barometer does not rise more than .07 of an inch from 4 to 8 p.m.; but subtract 1 degree if the wind velocity at Worcester is not over 9 miles an hour and the barometer rises more than .08 of an inch from 4 to 8 p.m. If, as sometimes occurs in April and October, the barometer rises .15 of an inch or more from 4 to 8 p.m. with the wind velocity at Worcester not over 7 miles an hour at 7 p.m., subtract 2 degrees.

NOTE: A clear sky in the evening at all or most of the observing stations is good evidence that it will be as cold as other data indicate. A damaging frost rarely occurs when it is entirely cloudy at all inland stations and partly or entirely cloudy at East Wareham at 7 p.m., unless the barometer rises sharply from 4 to 8 p.m.

NOTE: Wind direction is generally of little value in frost predicting on Cape Cod; but, if the wind is from the north or northwest at East Wareham at both noon and 7 p.m. (E.S.T.), it is especially likely to be as cold as other conditions indicate it will be.* The barometer usually rises sharply in the evening with this wind condition. A west wind in the evening is probably safer than any other.

*Weather forecasting in the United States. W. B. No. 583, 1916, pp. 199, 201, and 208. The more severe frosts on Nantucket usually come with a dying easterly wind.

The following material, besides the formulas, has helped in the frost-warning service:

Imminence of a change to warmer at the end of a cold spell is indicated by the following:

1. *A substantial rise in the sum of the wet temperature and dew point at inland stations* (Worcester, Carlisle, and Paxton) as compared with that of the day before at the same time of day. This indicator sometimes appears with a northeast wind when there is a "Low" along the Atlantic seaboard.

2. *A shift of the wind to southerly* (i. e., southwest, south, or southeast) at inland stations (Carlisle, Worcester, and Paxton), especially if the wind is strong.

3. *Much cloudiness inland.*

4. *A definite fall of the barometer from* 4 *to* 8 *p. m.*

The imminence of the change is certain only when the last of these indicators appears. Some allowance above the reckoning may then be made safely, especially if there is much cloudiness inland.

Cox has shown[36] that there is a relation between temperature of the top soil and minimum temperature of the air over its surface. Soil temperature, however, is only one of many influences here and is itself largely determined by seasonal factors and the prevailing weather. The writer has observed soil temperatures considerably but has not found them very helpful in computing minimum bog temperatures. See more about this on pages 46, 49, 55.

On cold nights in late April, very early May, and October, minimum bog temperatures usually fall considerably lower in Middlesex County than in Plymouth and Barnstable counties. In most of May and in June, on clear, still, cool nights, minimum bog temperatures tend to be fairly uniform throughout the cranberry district; but in the fall they usually run distinctly higher on the outer Cape and the Vineyard than in Plymouth County and inland. This seasonal difference is due to the change in relationship between the temperatures of the ocean and the land, the former warming in the spring and cooling in the fall much more siowly. Fewer frosts occur on the outer Cape than inland in both spring and fall because there is usually more wind near the sea. The outer Cape is more often frosty on nights with the evening dew point lower at Harwich or East Wareham than inland. Bog temperatures in Plymouth and Bristol counties and inland tend rather considerably to fall lower than those on the outer Cape in the first night of a frosty period but to get somewhat lower on the outer Cape and Nantucket than elsewhere in the last night. The west-east lay of the cranberry region and the usually greater windiness of the Cape and the ocean around it account for this. Nantucket is surprisingly frosty, probably owing largely to the dry and loose character of most of its soil, this being mostly sand with little loam cover. The mosslike growth of *Hudsonia ericoides* over the treeless rolling uplands everywhere around the principal cranberry bogs there, by its interference with the transfer of heat to and from the soil, must also have an effect.

Occasionally in a calm and very cold night in October, after two or more successive cold nights, bog temperatures in the cranberry district fall considerably below the computed minimum[37]. This is due partly to sharp lowering of the temperature of the soil under continued cold and perhaps partly to reduced conduction of heat from the lower soil and of the heat of fusion, caused by air pocketed in the soil by freezing of the surface. Cox noticed this difference when the surface soil froze in Wisconsin.[38] Ordinary shelter temperatures at 7 p. m. are always near or below freezing when this occurs.

[36] Cox, op. cit., pp. 42–45, 56–58, and 119.

[37] Examples: October 22, 1930, and October 27, 1936.

[38] Cox, op. cit., pp. 41, 47, 79, and 80.

Frost usually forms on the vines when low temperatures harm cranberry bogs, but sometimes damage is done without it when the dew point is lower than the minimum temperature reached.[39] This is called a "dry freeze" or "black frost" by growers. Hardly one bog frost in sixty on Cape cod is a "black frost," the nights in which they occur being nearly always windy. One never occurs there from late May to the tenth of October.

CONDITIONS RELATED TO FROST OCCURRENCE ON CRANBERRY BOGS AND INJURY THEREFROM

Pressure

Damaging cranberry frosts occur more or less during the spring frost season and in October with the barometer below normal; but dangerous temperatures never come on Massachusetts or New Jersey bogs during August or the first three weeks of September, or on Wisconsin bogs in July or August or the first decade of September, unless the pressure is above normal (30.00 inches).[40]

Cloudiness

It has been said[41] that the frost danger is increased if the sky is overcast during the day, so preventing the sun from warming the ground, and then clears in the evening. Cranberry frost records fail to show that this is a considerable factor, for three fourths of the widely harmful frosts have been preceded by days that were very largely or entirely clear. Heavy low clouds in the night radiate much heat to the ground and so prevent frost. Some protective effect of this radiation continues after they are gone if they remain till late in the night. Also, much moisture often persists in place of the clouds for some time after they vanish and this radiates some heat to the ground. Persistent low cloudiness till after midnight, therefore, reduces the frost hazard.

Cloudiness in the evening can be relied on to continue till well toward morning if it is general over southern New England with rain in some places, if there is little difference everywhere between the dry-bulb and wet-bulb temperature, and especially if the barometer is not rising.

High clouds, cirrus or cirro-stratus, consist of small particles of ice and radiate heat to the ground only feebly, so the net loss of heat from the ground with a sky covered with them is almost as great as with a clear sky.[42]

Wind

A cold dry wind during the day promotes evaporation and keeps soil temperatures from rising normally, so it may materially increase the frost danger.[43] Wind at night usually curtails the accumulation of cold air near the ground by mixing

[39]Cox, op. cit., p. 95.

[40]Cox, op. cit., p. 97.

[41]Weather forecasting in the United States, W. B. 583, 1916, pp. 187, 201, and 206. (Copy in the Middleboro library.)

[42]Brunt, David, Physical and dynamical meteorology, 1939, p. 144; Young, op. cit., p. 8.

[43]Owing partly to this and partly to the usual timing of wind and pressure changes, damaging cranberry frosts occur more commonly after windy days than after calmer ones. The lowest bog temperatures in a cold spell in the spring or early fall usually follow closely the calming of the cool dry wind that blows with the inrush of the anticyclone unless a second cold front appears. The loss of heat by radiation and otherwise during the rest of the cold period, after the pressure has risen and steadied, is fully offset by the warming from insolation and other modification of the cold air mass. Here lies also the relation between north and northwest winds and most of the more positive frosts (p. 41).

TABLE 1.—RAINFALL DURING THE WEEK BEFORE THE MORE HARMFUL CRANBERRY FROSTS COMPARED WITH THE NORMAL RAINFALL FOR THE PERIOD—MASSACHUSETTS. (In Inches)

Week Preceding Frost	New Bedford		Taunton		Middleboro		Plymouth		East Wareham		Hyannis		Average	
	Rain-fall	Nor-mal	Rain-fall	Nor-mal	Rain-fall	Nor-mal	Rain-fall	Nor-mal	Rain-fall	Nor-mal	Rain-fall	Nor-mal	Rain-fall	Nor-mal
Sept. 11 to 17, incl., 1868	.48	.79	–	–	–	–	–	–	–	–		–	.48	.79
Sept. 2 to 8, incl., 1871	.00	.79	–	–	–	–	–	–	–	–	–	–	.00	.79
May 26 to June 1, incl., 1875	.00	.86	–	–	–	–	–	–	–	–	–	–	.00	.86
May 25 to 31, incl., 1876	.00	.86	–	–	–	–	–	–	–	–	–	–	.00	.86
May 6 to 12, incl., 1878	.05	.86	–	–	–	–	–	–	–	–	–	–	.05	.86
May 31 to June 6, incl., 1879	2.46	.74	–	–	–	–	–	–	–	–	–	–	2.46	.74
May 23 to 29, incl., 1884	.47	.86	.98	.77	–	–	–	–	–	–	–	–	.73	.82
June 8 to 14, incl., 1884	.50	.72	.04	.70	–	–	–	–	–	–	–	–	.27	.71
Sept. 26 to Oct. 2, incl., 1886	.29	.81	.17	.81	–	–	.14	.80	–	–	–	–	.20	.81
Aug. 31 to Sept. 6, incl., 1888	.71	.81	.53	.82	.31	.78	.39	.76	–	–	–	–	.49	.79
Sept. 24 to 30, incl., 1888	5.89	.79	4.45	.80	5.13	.77	3.72	.75	–	–	–	–	4.80	.78
June 4 to 10, incl., 1892	.43	.72	.94	.70	.12	.68	.58	.70	–	–	–	–	.52	.70
May 8 to 14, incl., 1894	.07	.86	Trace	.77	.00	.71	.07	.75	–	–	–	–	.04	.71
May 7 to 13, incl., 1895	1.07*	.86	1.12*	.77	1.13*	.71	.21	.75	–	–	–	–	.88*	.77
May 22 to 28, incl., 1900	.01	.86	Trace	.77	Trace	.71	.02	.75	–	–	.08	.79	.02	.78
May 19 to 25, incl., 1903	.26	.86	.03	.77	.00	.71	.13	.75	–	–	.03	.79	.09	.78
May 25 to 31, incl., 1903	.33	.86	.13	.77	.17	.71	.10	.75	–	–	.58	.79	.26	.78
Sept. 16 to 22, incl., 1904	.07	.79	.03	.80	.05	.77	.02	.75	–	–	.10	.67	.05	.76
May 17 to 23, incl., 1905	.40	.86	.38	.77	.27	.71	.27	.75	–	–	.15	.79	.29	.78
May 14 to 20, incl., 1906	.00	.86	.06	.77	.00	.71	.04	.75	–	–	.00	.79	.02	.78
April 22 to 28, incl., 1910	.96*	.91	.99*	.94	1.12*	.86	1.60*	.98	–	–	1.64*	.84	1.26*	.91
May 29 to June 4, incl., 1910	.23	.76	.54	.72	.40	.69	.20	.71	–	–	.30	.72	.33	.72
June 3 to 9, incl., 1912	.05	.72	.27	.70	.20	.68	.11	.70	.07	.81	.18	.69	.15	.72
Sept. 9 to 15, incl., 1913	.85	.79	.24	.80	.19	.77	.17	.75	.52	.86	.30	.67	.38	.77
May 23 to 29, incl., 1915	.16	.86	.24	.77	.08	.71	.14	.75	.30	.68	–	–	.18	.75
Sept. 4 to 10, incl., 1917	.20	.79	.18	.80	.19	.77	.18	.75	.11	.86	.00	.67	.14	.77
June 14 to 20, incl., 1918	.04	.72	.05	.70	.00	.68	.35	.70	.05	.81	.30	.69	.13	.72
May 18 to 24, incl., 1921	.16	.86	.29	.77	.13	.71	.35	.75	.13	.68	.19	.79	.21	.76
May 21 to 27, incl., 1922	.22	.86	.20	.77	.13	.71	.12	.75	.16	.68	.05	.79	.15	.76
May 17 to 23, incl., 1923	.17	.86	.40	.77	.31	.71	.70	.75	.53	.68	.31	.79	.40	.76
May 8 to 14, incl., 1936	.12	.86	.16	.77	.08	.71	.12	.75	.18	.68	.20	.79	.14	.76

*These rains broke severe drouths.

it with warmer overlying air and so tends to prevent frost as long as it continues; but it speeds transpiration and evaporation, thus drying and cooling the surface soil, and leaves relatively dry air near the ground if it dies. Moreover, a cold night wind takes heat from the soil rapidly by the apparent conductivity due to turbulence.[44] Temperatures near the ground, therefore, usually fall rapidly when the wind fails in a frosty night. No such protective effect remains from winds that fail toward morning as that continuing after low clouds clear away.

Evening winds of ten miles an hour or less, general over southern New England, when associated with a somewhat inactive area of high pressure, are likely to calm entirely before morning in spite of a large pressure gradient if the pressure rises rapidly during the evening.

With other conditions the same, fruits and foliage freeze more readily in a cold wind than in still air, because there is less undercooling of plant tissues when the air is moving, and wind forces convection, speeding the loss of heat from the plants.[45]

Rainfall

Frosts occur less easily if the surface soil of the countryside is full of water from recent rains.[46] There is not only a local effect of this water on any given small area, as that over a cranberry bog of the water in its surface sand, but probably also a mass effect from the surface-soil water of a whole region. Tables 1, 2, and 3 show the rainfall during the week before each of the more destructive frosts in the three main cranberry-growing regions, compared with the normal rainfall for those periods in the three areas.[47]

[44]Geiger, R., Handbuch der Klimatologie, Band 1, Teil D, Mikroklima und Pflanzenklima, 1930, pp. 9–10. (Partial English translation placed in the library of Massachusetts State College.)

[45]Schoonover, Brooks, and Walker, Protection of orchards against frost, Calif. Agr. Col. Ext. Circ. 111, 1939, p. 14. (Copies in the Middleboro library.)

[46]Weather forecasting in the United States, W. B. 583, 1916, pp. 187, 198.

[47]Records of daily rainfall in connection with severe frosts that came before those listed here are not available.

TABLE 2.—RAINFALL DURING THE WEEK BEFORE THE MORE HARMFUL CRANBERRY FROSTS COMPARED WITH THE NORMAL RAINFALL FOR THE PERIOD — NEW JERSEY
(In Inches)

Week Preceding Frost	Imlaystown		Indian Mills		Lakewood		Average	
	Rain-fall	Nor-mal	Rain-fall	Nor-mal	Rain-fall	Nor-mal	Rain-fall	Nor-mal
Sept. 8 to 14, incl., 1895	.95*	.80	–	–	–	–	.95*	.80
Sept. 25 to Oct. 1, incl., 1899	1.48	.80	–	–	–	–	1.48	.80
May 22 to 28, incl., 1902	.86	.74	.70	.71	.58	.75	.71	.73
Sept. 16 to 22, incl., 1904	.00	.80	.00	.90	.00	.69	.00	.80
May 14 to 20, incl., 1905	.36	.74	.90	.71	.24	.75	.50	.73
Sept. 9 to 15, incl., 1913	.20	.80	.10	.90	–	–	.15	.85
Sept. 4 to 10, incl., 1914	.00	.80	.03	.90	.00	.69	.01	.80
Sept. 4 to 10, incl., 1917	1.92	.80	1.53*	.90	1.88*	.69	1.78	.80
Sept. 13 to 19, incl., 1920	.00	.80	.00	.90	.00	.69	.00	.80
May 17 to 23, incl., 1921	.10	.74	.00	.71	.20	.75	.10	.73
May 19 to 25, incl., 1925	1.45*	.74	1.09*	.71	1.21*	.75	1.25*	.73
May 21 to 27, incl., 1927	1.39**	.74	.57	.71	1.20**	.75	1.05	.73
May 8 to 14, incl., 1936	–	–	.15	.71	.12	.75	.14	.73
May 24 to 30, incl., 1938	–	–	1.87	.71	1.27	.75	1.57†	.73
June 14 to 20, incl., 1940	–	–	.22	.95	.12	.93	.17	.94

* These rains broke considerable drouths.
** This rain broke a well-established drouth.
† May 1938 was the fourth consecutive month with the New Jersey rainfall less than normal.

TABLE 3.—RAINFALL DURING THE WEEK BEFORE THE MORE HARMFUL CRANBERRY FROSTS COMPARED WITH THE NORMAL RAINFALL FOR THE PERIOD — WISCONSIN

(In Inches)

Week Preceding Frost	Meadow Valley		Neillsville		Wisconsin Rapids		Average	
	Rain-fall	Nor-mal	Rain-fall	Nor-mal	Rain-fall	Nor-mal	Rain-fall	Nor-mal
Aug. 17 to 23, incl., 1891	1.30*	.74	1.25*	.82	1.61*	.78	1.39*	.78
Aug. 23 to 29, incl., 1893	.03	.74	.08	.82	.00	.78	.04	.78
Aug. 14 to 20, incl., 1895	.04	.74	.47	.82	.20	.78	.24	.78
June 23 to 29, incl., 1900	.15	1.00	.00	1.11	–	–	.08	1.06
June 4 to 10, incl., 1903	.02	1.00	.55	1.11	.31	.98	.29	1.03
Aug. 1 to 7, incl., 1904	.19	.74	.26	.82	.60	.78	.35	.78
Aug. 26 to Sept. 1, incl., 1909	.37	.76	.12	.83	.53	.79	.34	.79
June 2 to 8, incl., 1913	.31	1.00	.00	1.11	.30	.98	.20	1.03
July 12 to 18, incl., 1929	.20	.82	.15	.89	.40	.75	.25	.82

* This rain broke a well-established drouth.

All the widely destructive cranberry frosts in Massachusetts (Table 1) except those of June 6, 1879, September 30, 1888, May 13, 1895, and late April, 1910, were preceded by a week with rainfall much below normal for the time of year. The 1888 frost came (Table 4) after a period of extremely unseasonable cold had reduced the heat of the soil. The rains before the 1879, 1895, and 1910 frosts broke drouths and may well have failed to restore normal moisture in the soil. The Wisconsin records (Table 3) have only one instance of a very harmful frost without a marked deficiency in rainfall during the preceding week, the rain in that case breaking a drouth and probably failing to restore normal soil moisture. Some of the severe New Jersey frosts (Table 2) have come after excessive rainfall, this probably due largely to the lack of sand and the heavy vine and weed growth common on the New Jersey bogs.[48] The greater evaporation and transpiration under the higher temperatures in New Jersey were also a factor.

In the frost seasons in the Cape cranberry district since 1911, no night with dangerously low temperatures has occurred within a day or two after an inch and a half of rain at the cranberry experiment station, unless the rain broke a drouth. Three successive dangerous frost nights within five days after such a rain have never been observed in this period at any time, and two such nights in succession have not occurred from June to September, inclusive, under these conditions.

Much water in the soil tends to prevent a large fall in temperature during the night because the water vapor taken up by the air from the wet ground lessens cooling[49] and because water, a twenty times better conductor of heat than air, greatly improves the conductivity of the soil when it replaces the air in it,[50] giving a faster flow of heat into the ground when the sun is shining and a faster flow from the ground at night.[51] Also the specific heat of a wet soil is much greater than that of a dry similar soil at the same temperature. The specific heat and conductivity of the topsoil rather than its temperature alone are the important factors here, and their influence depends greatly on the water content of the soil.[52] So most soils, including sand-covered cranberry bogs, are less likely to permit frost formation when wet than when dry.

[48]Peat is a poor conductor of heat even when wet. U. S. Monthly Weather Rev. 67:440, 1939. (Copy in the Middleboro library.)

See the discussion of the relations of cranberry vine growth to the frost hazard on pages 49 and 50 of this bulletin.

[49]Young, op. cit., p. 7.

[50]Geiger, op. cit., pp. 6–8.

[51]Schoonover, Brooks, and Walker, op. cit., p. 23.

[52]Brunt, op. cit., pp. 138–141.

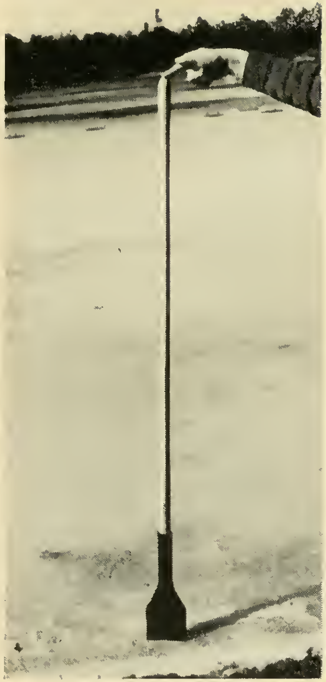

Figure 1.
Chisel for Cutting Ice Around Water Gates.

Figure 2. Ice-sanding with Trucks Equipped with Spreaders.
Spreaders are useful, but the sand is often dumped on the ice from small trucks and spread with shovels or an evener. Dry coarse sand is sometimes fed by gravity from the tail of a truck driven fast.

Figure 3. Cape Cod Cranberry Bog and Adjacent Sand Hills.

Figure 4. Winter Fruit Bud in Cranberry Tip. Cut Across to Show Frosted Center.

Figure 5. Cranberry Floral Growth ("umbrella") from Winter Buds Injured by Frost. (Compare this with Figure 7 J.)

Figure 6. Left: Cranberries from a Normal Infloresence.
Right: Berries from "umbrella" flowers.

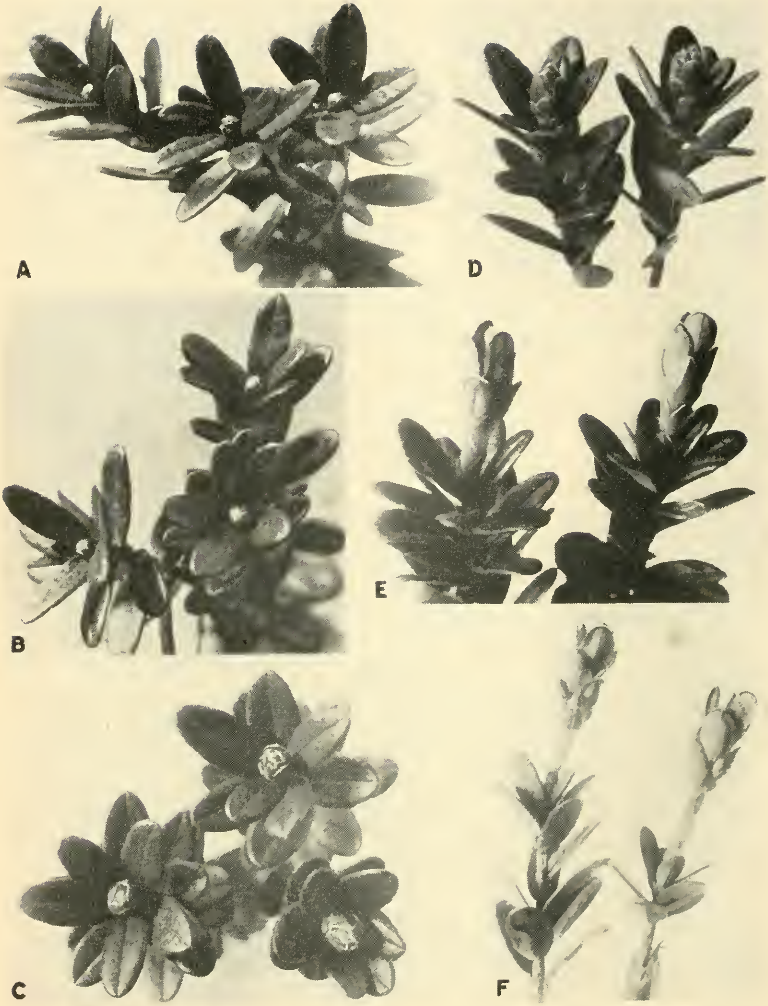

Figure 7 A to F. Stages in Normal Cranberry Inflorescence.

Figure 7 G to J. Stages in Normal Cranberry Inflorescence.

Figure 8. Cranberry Branches with New Shoots Because Frost Killed the Terminal Buds.

Figure 9. Cranberry Branches with Tip Leaves Cupped by Frost.

Figure 10. Standard Minimum-registering Thermometer Set Properly at Tops of Cranberry Vines.

Figure 11. Small Cranberry Bog with Upland Cleared Through to a Pond.

Figure 12. Upper: Skinner Pipe Sprinkling System.
Lower: Rotating-head Sprinklers at Work on a Cranberry Bog.
(Courtesy of the United Cape Cod Cranberry Company.)

Figure 13. Stop-water in Bog Ditch.
This is a small head gate, and the dike shoulders reaching out onto the bog help a lot.

TABLE 4. — AVERAGE DEPARTURE OF THE MEAN DAILY TEMPERATURES FROM NORMAL DURING THE TEN-DAY PERIODS BEFORE THE MORE HARMFUL CRANBERRY FROSTS — MASSACHUSETTS.

(Degrees Fahrenheit)

Date of Frost	New Bedford	Taunton	Middleboro	Plymouth	East Wareham	Hyannis	Average
Sept. 17, 1868	+1.60	–	–	–	–	–	+1.60
Sept. 8, 1871	−0.70	–	–	–	–	–	−0.70
June 1, 1875	+2.45	–	–	–	–	–	+2.45
May 31, 1876	0.00	–	–	–	–	–	0.00
May 12, 1878	+0.50	–	–	–	–	–	+0.50
June 6, 1879	+4.40	–	–	–	–	–	+4.40
May 29, 1884	+2.30	+5.30	–	–	–	–	+3.80
June 14, 1884	+1.35	+4.30	–	–	–	–	+2.83
Oct. 2, 1886	−2.55	−2.50	–	+1.45	–	–	−1.20
Sept. 6, 1888	−2.90	–	−2.15	+0.25	–	–	−1.60
Sept. 30, 1888	−8.15	−8.10	−7.35	−4.40	–	–	−7.00
June 10, 1892	+1.95	+5.75	+5.05	+7.75	–	–	+5.13
May 14, 1894	+4.85	+6.05	+5.45	+10.65	–	–	+6.75
May 13, 1895	+8.95	–	+12.35	+13.35	–	–	+11.55
May 28, 1900	−1.05	−2.10	−2.60	–	–	−1.10	−1.71
May 25, 1903	+10.10	+8.65	+6.80	+9.20	–	+6.95	+8.34
May 31, 1903	+4.55	+1.60	+2.45	+5.65	–	+3.70	+3.59
Sept. 22, 1904	−2.80	−1.15	+0.35	+3.25	–	−2.30	−0.53
May 23, 1905	−1.80	−0.75	−2.70	+0.90	–	−1.60	−1.19
May 20, 1906	+5.75	+6.80	+6.20	+6.65	–	+3.00	+5.68
April 28, 1910	+7.90	+8.20	+8.70	+6.75	–	+5.70	+7.45
June 4, 1910	+0.95	−1.65	−1.05	+0.65	–	−0.25	−0.27
June 9, 1912	+3.20	+0.60	+1.40	+3.65	+1.35	+2.15	+2.06
Sept. 15, 1913	−7.30	−7.25	−5.35	−5.00	−6.75	−6.40	−6.34
May 29, 1915	−0.45	−2.25	−1.00	−0.55	−0.75	–	−1.00
Sept. 10, 1917	–	−7.50	−5.70	−5.05	−4.70	–	−5.74
June 20, 1918	–	−2.40	−2.55	−2.30	−2.00	–	−2.31
May 24, 1921	+5.35	+4.40	+5.60	+4.25	+2.45	–	+4.41
May 27, 1922	+6.90	+5.80	+5.35	+4.75	+5.15	–	+5.59
May 23, 1923	+6.45	−0.95	−0.10	+0.95	−0.15	–	+1.24
May 14, 1936	–	+7.80	+6.70	+10.10	+3.80	+2.60	+6.20

Mean Temperature Before Frosts

The average departures of the mean daily temperatures from the normal means in 10-day periods, at places of observation in or near the cranberry districts of Massachusetts, New Jersey, and Wisconsin, just before the widely destructive cranberry frosts in those regions are given in tables 4, 5, and 6. They show that temperatures precedent to the more serious spring frosts have usually been above normal, only those before the June frost of 1918 in Massachusetts[53] having been substantially below.[54] Temperatures before the fall frosts, on the other hand, have tended to be below normal.[55] These considerations enter here:

1. High temperatures hasten drying of the ground by both evaporation and plant transpiration and so tend to reduce the conductivity and specific heat of the surface soil. Also much of the heat coming to the ground is consumed directly in evaporation.[56] These factors are more important in the latter and more

[53]This frost came in a well-established drouth.

[54]Widely harmful cranberry frosts closely preceded by a week or so with both supernormal rainfall and subnormal mean temperature hardly ever occur anywhere (May 27, 1927, in New Jersey) in the spring.

[55]No widely destructive cranberry frost closely preceded by a week or so with both rainfall and mean temperature above normal has ever occurred anywhere in the fall, except that in mid-September 1895 in New Jersey.

[56]Geiger, op. cit., pp. 4–6.

dangerous part of the spring season than in the fall because of the longer days and higher solar elevation.[57]

2. High spring temperatures start the new growth early and so lengthen that season of frost danger. This was the main cause of the injury from the Cape Cod frost of April 28, 1910, high temperatures having persisted through most of March and April. Such spring temperatures also sometimes create a special situation, as with the great frost on the Cape on June 20, 1918, when, because of high temperatures through April and May, many bogs were already nearing full bloom and so could not be flooded safely. High temperatures through August delay the ripening of the berries (pp. 89 and 91) and thus make them more liable to frost injury in early September. This was the situation with the destructive frost of September 10, 1917.

Table 5. — Average Departure of the Mean Daily Temperatures From Normal During the Ten-Day Periods Before the More Harmful Cranberry Frosts — New Jersey.

(Degrees Fahrenheit)

Date of Frost	Imlaystown	Indian Mills	Lakewood	Average
Sept. 14, 1895	+4.70	–	–	+4.70
Oct. 1, 1899	−2.95	–	–	−2.95
May 28, 1902	+6.70	+8.50	+6.85	+7.35
Sept. 21, 1904	+0.25	+0.25	+2.75	+1.08
May 20, 1905	+4.65	+5.85	+6.20	+5.57
Sept. 15, 1913	−2.80	−1.35	–	−2.08
Sept. 10, 1914	+0.15	+0.50	+1.15	+0.60
Sept. 10, 1917	–	−5.95	−5.35	−5.65
Sept. 19, 1920	−0.50	−0.80	+0.80	−0.17
May 23, 1921	+4.00	+3.60	+4.65	+4.08
May 25, 1925	+1.50	+3.30	+2.75	+2.52
May 27, 1927	−1.50	+1.05	−0.30	−0.25
May 14, 1936	–	+9.20	+9.70	+9.45
May 30, 1938	–	+0.95	+1.65	+1.30
June 20, 1940	–	+4.55	+4.90	+4.72

Table 6. — Average Departure of the Mean Daily Temperatures From Normal During the Ten-Day Periods Before the More Harmful Cranberry Frosts — Wisconsin.

(Degrees Fahrenheit)

Date of Frost	Meadow Valley	Neillsville	Wisconsin Rapids	Average
May 29, 1884	–	+0.60	–	+0.60
Aug. 23, 1891	0.00	−3.10	−0.50	−1.20
Aug. 29, 1893	−0.50	−1.40	–	−0.95
Aug. 20, 1895	−0.85	−2.70	+1.20	−0.78
June 29, 1900	+4.40	+4.50	–	+4.45
June 10, 1903	+1.10	+1.35	+2.40	+1.62
Aug. 7, 1904	−3.75	−3.05	−4.35	−3.72
Sept. 1, 1909*	+2.70	+5.20	+3.80	+3.90
June 8, 1913	+3.65	+5.35	+2.75	+3.92
July 18, 1929	+0.15	+0.95	+0.35	+0.48

* This frost came after a long drouth and the cranberry growers lacked water for flooding. The soil must have been dry to an unusual depth. (Cox, op. cit., pp. 10 and 117.)

3. The freezing point of plant parts generally varies with the concentration of their cell sap, so this considerably determines the temperature they will endure.[58] If conditions, like high temperatures or the free use of fertilizers, have favored

[57]Cummings, N. W., Natl. Res. Council Bul. 68, 1929, pp. 47–56, (Amer. Geophys. Union Trans.): Richardson, Burt, Evaporation as a function of insolation, Amer. Soc. Civil Engin. Trans. 95; 996–1019, 1931.

[58]Schoonover, Brooks, and Walker, op. cit., p. 14.

rapid growth before a frost, sap concentration will be low and frost may injure more and at a somewhat higher temperature than it otherwise would. If low temperatures, unfavorable for growth, have prevailed for some time, plants will stand more cold. This rule of plant frost tolerance should apply to the cranberry plant more in the spring frost season than in the fall because of the very new growth; but low temperatures in August tend to hasten the ripening of the berries, thus concentrating their juice and giving them greater frost endurance early in the picking season than they would otherwise have.[59]

4. The material in tables 1 to 6 seems to indicate that the conductivity of the soil has more influence than its temperature on frost occurrence in the spring but is the less important in the fall. Evidently ready availability of heat rather than a large reserve is necessary in the short nights of spring. Slower conduction suffices in the fall because it has more time to function, but the longer nights call for a greater supply of soil heat on which to draw. Conditions in the deeper soil must therefore enter into this more in the fall than in the spring.

Dew

Cold nights are generally less dangerous when the dew point is high than when it is low, the temperature not falling so fast or so far because of the liberation of latent heat by the condensation of water vapor in the air and the considerable return radiation to the ground. Nights with heavy dews are also generally calm (see discussion of wind, above). The heat of fusion coming from a heavy dew when frost forms is also some protection. Heavy dews therefore deserve some consideration in nights with prospective minimum temperatures at the danger line. They help till frost becomes rather general; but the wetter plants are when they really freeze, the more they are likely to be hurt.[60]

Ground Fog

The fog or mist common over cranberry bogs on frosty nights returns radiation to the ground and so has a protective influence,[61] but, as Cox indicated, this is slight.[62]

Bog Resistance

Spring growth starts more slowly on dry bogs than on bogs flowed during the winter. Partly on this account, but apparently also because of resistance gained by winter exposure, such bogs are hurt by frost rather less easily than others. Only early varieties should be grown on dry bogs so that the fruit may be gathered usually in time to escape fall frosts.

Vine Growth

A thick and deep vine growth, especially on dry bogs, much increases the frost hazard, for the following reasons:

1. The more vines the less the soil they cover is warmed by the sun and the more the heat transfer from the soil to the radiating vine surface is restricted at night.

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[59]The time of cranberry ripening also depends greatly on weather conditions in the spring (p. 89).

[60]Smith, J. Warren, Agricultural Meteorology, 1920, p. 140; Schoonover, Brooks, and Walker, op. cit., p. 14.

[61]Young, op. cit., p. 8; Allen, op. cit., pp. 288–289.

[62]Cox, op. cit., pp. 88-89.

2. Plant transpiration is the most effective mechanism returning moisture to the atmosphere from the land[63]; and the more cranberry vines, the more water they take from the surface soil.

3. Heavy vines suspend much of the water from rains so it evaporates very readily.

4. The more vines, the faster fallen cranberry leaves collect under them (pp. 61 and 63).

Watching Frosts

It is often best to watch developments when the bog temperature is likely to approach the danger point. A night usually seems fully as dangerous as it is when the first part is calm and clear, and often seems safer than it is when the evening is windy. If it is very clear and calm till after midnight and a wind then rises, it usually is a good sign that a helpful change is at hand, especially if the barometer is falling, for the wind normally falls through the night and most in clear weather.

Conditions make it necessary to begin flooding some bogs early in the day before an expected frost, and it is always well to prepare for possible trouble by filling bog ditches in the afternoon so as to be able to handle the situation promptly later if it gets too cold early in the night. More water may be put on in the evening or during the night as circumstances require. The lowest bog temperature usually occurs near sunrise.

Weather Map

Cranberry growers should subscribe for and learn to use the weather maps published week days, except holidays, by the offices of the Weather Bureau at Boston, Philadelphia, and New York. The most dangerous maps for Massachusetts, other things being the same, are those showing extensive high pressure over the Great-Lakes region with low temperatures ahead of it in southeastern Canada, New York, and New England and those with a strong high-pressure area advancing from the Hudson Bay region.[64] With the former, the general circulation around the area of high pressure is sure to sustain the flow of cold air from the north over New England and the rising pressure to slow the winds and sharpen the cold; with the latter, there is usually such a quick thrust of a cold dry air mass from the heart of Canada across New England that it is little changed by insolation.

Weather Instruments

It is risky to use cheap instruments in frost observing. All bogs to be protected should have at least two standard minimum registering thermometers, one to check the other. These are held by a metal bracket when in use, with the bulb end a little lower than the other, the bracket being attached to a sharp stick driven into the ground (Fig. 10). They are set by holding the bulb end up till the glass indicator falls to the surface of the liquid in the channel. They must be inspected frequently to make sure there is no break in the liquid column and there

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[63]Thornthwaite, C. W., and Holzman, Benjamin, The determination of evaporation from land and water surfaces, U. S. Monthly Weather Rev. 67:7, 1939 (copy in the Middleboro library); Veihmeyer, F. J., Evaporation from soils and transpiration, Natl. Res. Council, Amer. Geophys. Union Trans., 1938, 2:612–619.

[64]Smith, John W., Weather Forecasting in the United States, W. B. 583, 1916, pp. 169, 208.

Such Hudson Bay air masses, though commonly very cold, persist over New England much less often than those from farther west and rather rarely cause more than one cranberry frost.

is none of the liquid in the small enlargement of the other end of the channel from the bulb. The column must be restored if the liquid is separated in either of these ways. This is done readily by whirling the thermometer vigorously at the end of a stout string of convenient length passed through the support holes in the other end from the bulb. Care must be taken in doing this, for the instrument may be a dangerous missile if it breaks away.

Thermometer scales should be rubbed with ivory-black occasionally to condition them for easy reading.

Growers who wish to try their local weather data, where this is possible in the formulas for computing minimum bog temperatures, should have dry-bulb and wet-bulb thermometers, mounted in a shaded open-air porch or in a white-painted wooden instrument shelter, to serve as a psychrometer. These may be stationary, with a water cup and wick for the wet bulb, or be on a whirling apparatus. The instrument shelter should be at a convenient height from the ground for reading the thermometers and be 10 to 15 feet above the bog level.

A table of dew-point temperatures, as published by the Weather Bureau, likely to be useful to cranberry growers, is given here for convenience.

TABLE 7.—TEMPERATURE OF DEW POINT IN DEGREES FAHRENHEIT. (Pressure = 30.0 Inches.)

Air Temp. t	Depression of Wet-bulb Thermometer (t – t') 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0
25	24	22	20	19	17	15	13	10	8	5																				
26	25	23	22	20	18	16	14	12	9	7																				
27	26	24	23	21	19	18	16	13	11	8	5																			
28	27	25	24	22	21	19	17	15	13	10	7																			
29	28	26	25	23	22	20	18	16	14	12	9	6																		
30	29	27	26	25	23	21	20	18	16	14	11	8	5																	
31	30	28	27	26	24	23	21	19	17	15	13	10	8																	
32	31	30	28	27	25	24	22	21	19	17	15	12	10	7																
33	32	31	29	28	27	25	24	22	20	18	16	14	12	9	6															
34	33	32	30	29	28	26	25	23	22	20	18	16	13	11	8	5														
35	34	33	31	30	29	28	26	25	23	21	19	17	15	13	10	7	4													
36	35	34	32	31	30	29	27	26	24	23	21	19	17	15	12	10	7													
37	36	35	33	32	31	30	28	27	26	24	22	21	19	17	14	12	9	6												
38	37	36	34	33	32	31	29	28	27	25	24	22	20	18	16	14	11	8	5											
39	38	37	35	34	33	32	31	29	28	27	25	23	22	20	18	16	13	11	8											
40	39	38	37	35	34	33	32	30	29	28	26	25	23	21	20	18	15	13	10	7										
41	40	39	38	36	35	34	33	31	30	29	27	26	24	23	21	19	17	15	12	10	6									
42	41	40	39	38	36	35	34	33	31	30	29	27	26	24	23	21	19	17	14	12	9	6								
43	42	41	40	39	37	36	35	34	32	31	30	28	27	25	24	22	20	19	16	14	11	9	5							
44	43	42	41	40	38	37	36	35	34	32	31	30	28	27	25	24	22	20	18	16	13	11	8							
45	44	43	42	41	40	38	37	36	35	34	32	31	30	28	27	25	23	22	20	18	15	13	10	7						
46	45	44	43	42	41	40	38	37	36	35	33	32	31	29	28	27	25	23	21	20	17	15	13	10	7					
47	46	45	44	43	42	41	40	38	37	36	35	33	32	31	29	28	26	25	23	21	19	17	15	12	9	6				
48	47	46	45	44	43	42	41	40	38	37	36	35	33	32	31	29	28	26	25	23	21	19	17	14	12	9	5			
49	48	47	46	45	44	43	42	41	40	38	37	36	34	33	32	30	29	28	26	24	23	21	19	16	14	11	8	5		
50	49	48	47	46	45	44	43	42	41	40	38	37	36	34	33	32	30	29	27	26	24	22	21	18	16	13	11	8		
51	50	49	48	47	46	45	44	43	42	41	40	38	37	36	34	33	32	30	29	27	26	24	22	20	18	16	13	10	7	
52	51	50	49	48	47	46	45	44	43	42	41	40	38	37	36	34	33	32	30	29	27	26	24	22	20	18	16	13	10	7
53	52	51	50	49	48	47	46	45	44	43	42	41	40	38	37	36	34	33	32	30	29	27	26	24	22	20	18	15	13	10
54	53	52	51	50	49	48	47	46	45	44	43	42	41	40	38	37	36	34	33	32	30	29	27	25	24	22	20	18	15	12
55	54	53	52	51	50	50	49	48	47	45	44	43	42	41	40	38	37	36	34	33	32	30	29	27	25	24	22	20	17	15
56	55	54	53	53	52	51	50	49	48	47	46	44	43	42	41	40	39	37	36	34	33	32	30	29	27	25	24	22	19	17
57	56	55	54	54	53	52	51	50	49	48	47	46	45	43	42	41	40	39	37	36	34	33	32	30	29	27	25	24	21	19
58	57	56	55	55	54	53	52	51	50	49	48	47	46	45	44	42	41	40	39	37	36	35	33	32	30	29	27	25	23	21
59	58	57	56	56	55	54	53	52	51	50	49	48	47	46	45	44	43	41	40	39	37	36	35	33	32	30	29	27	25	23

60	59	58	57	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	41	40	39	38	36	35	33	32	30	29	27	25
61	60	59	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	43	42	40	39	38	36	35	33	32	30	29	27
62	61	60	60	59	58	57	56	55	54	53	53	52	51	50	48	47	46	45	44	43	42	40	39	38	36	35	33	32	30	29
63	62	61	61	60	59	58	57	56	55	55	54	53	52	51	50	49	48	47	45	44	43	42	41	39	38	36	35	34	32	30
64	63	62	62	61	60	59	58	57	57	56	55	54	53	52	51	50	49	48	47	46	44	43	42	41	39	38	37	35	34	32
65	64	63	63	62	61	60	59	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	43	42	41	40	38	37	35	34
66	65	64	64	63	62	61	60	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	44	42	41	40	38	37	35
67	66	65	65	64	63	62	62	61	60	59	58	57	56	55	54	53	53	52	50	49	48	47	46	45	44	43	41	40	38	37
68	67	67	66	65	64	63	63	62	61	60	59	58	57	57	56	55	54	53	52	51	50	49	48	46	45	44	43	42	40	39
69	68	68	67	66	65	64	64	63	62	61	60	59	59	58	57	56	55	54	53	52	51	50	49	48	46	45	44	43	42	40
70	69	69	68	67	66	65	65	64	63	62	61	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	44	43	42
71	70	70	69	68	67	67	66	65	64	63	62	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48	47	46	45	43
72	71	71	70	69	68	68	67	66	65	64	64	63	62	61	60	59	58	58	57	56	55	54	53	52	51	50	48	47	46	45
73	72	72	71	70	69	69	68	67	66	66	65	64	63	62	61	60	60	59	58	57	56	55	54	53	52	51	50	49	48	46
74	73	73	72	71	70	70	69	68	67	67	66	65	64	63	62	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48
75	74	74	73	72	71	71	70	69	68	68	67	66	65	64	64	63	62	61	60	59	58	57	56	55	55	54	52	51	50	49
76	75	75	74	73	72	72	71	70	69	69	68	67	66	66	65	64	63	62	61	60	60	59	58	57	56	55	54	53	52	51

TABLE 7. — TEMPERATURE OF DEW POINT IN DEGREES FAHRENHEIT. (Pressure = 30.0 Inches.) — Concluded.

Air Temp. t	Depression of Wet-bulb Thermometer (t — t')																						
	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5	26.0	26.5
53	7																						
54	10	6																					
55	12	9	6																				
56	15	12	9	5																			
57	17	14	12	9	5																		
58	19	17	14	11	8																		
59	21	19	17	14	11	8																	
60	23	21	19	17	14	11	8																
61	25	23	21	19	17	14	11	8															
62	27	25	23	21	19	16	14	11	7														
63	29	27	25	23	21	19	17	14	11	7													
64	31	29	27	25	23	21	19	17	14	11	7												
65	32	31	29	27	25	24	21	19	17	14	11	7											
66	34	32	31	29	27	26	24	22	19	17	14	11	7										
67	36	34	32	31	29	28	26	24	22	19	17	14	11	7									
68	37	36	34	33	31	29	28	26	24	22	19	17	14	11	7								
69	39	37	36	34	33	31	30	28	26	24	22	19	17	14	11	7							
70	40	39	38	36	34	33	31	30	28	26	24	22	20	17	14	11	7						
71	42	41	39	38	36	35	33	31	30	28	26	24	22	20	17	14	11	7					
72	44	42	41	40	38	37	35	33	32	30	28	26	24	22	20	17	14	11	7				
73	45	44	43	41	40	38	37	35	34	32	30	28	27	25	22	20	17	15	11	8			
74	47	45	44	43	41	40	39	37	35	34	32	30	29	27	25	23	20	18	15	12	8		
75	48	47	46	44	43	42	40	39	37	36	34	32	31	29	27	25	23	21	18	15	12	8	
76	49	48	47	46	45	43	42	41	39	38	36	34	33	31	29	27	25	23	21	18	15	12	8

WEATHER SEQUENCE AND FROST OCCURRENCE

Cranberry frosts have generally come later in the spring and earlier in the fall in Massachusetts and New Jersey after the months January to April as a unit have been colder than normal in the Great Lakes region, as shown by table 8. All the harmful spring frosts later than June 9, of which there have been 13 in Massachusetts and 5 in New Jersey, all 12 of the August frosts in Massachusetts except the 2 in 1925, 9 of the 12 fall frosts in New Jersey before September 20, all 8 of the frostless seasons of less than 88 days in Massachusetts, and all 4 of the frostless seasons of less than 109 days in New Jersey have followed such cold.

It may be worth noting that all the more harmful frosts in Wisconsin cranberry history (p. 58), except those of June 1903, came after February, March, and April, as a unit, had been colder than normal at LaCrosse, Wisconsin; and that all three of the summer frost-free periods of less than 30 days in that State came after the months January to April, inclusive, as a unit, had been very abnormally cold.

It should be taken as an omen of unusual frosts in southern New England if the mean annual temperature of either northern[65] or southern New England has been distinctly below normal the previous calendar year. Frosts in June and in the fall before the middle of September in southern New England have usually come after March and April as a unit have been colder than normal in northern New England.

Cranberry frosts have not only usually occurred later in the spring and earlier in the fall but also tended to come oftener and be more severe when the above correlations favored their occurrence. Material like this may perhaps be used presently as a basis for better management of bog flooding. The winter water, or late April reflow, should probably be held well into May *on bogs with water supplies for frost flooding* when frost is most likely to occur in June. This will delay blossoming and so prevent the development of a situation like that of June, 1918, when the bogs were generally nearly in full bloom and so could not be flooded safely when severe frost came. On the other hand, when June frosts are not likely and the growing season promises to be long, the winter water should be held late *on bogs that cannot be reflowed*, for this will largely insure the crop from frost injury.

All August frosts in Massachusetts cranberry history, except that of August 30, 1934, have followed a June–July unit colder than normal in northern New England; and all the widely destructive August frosts in Wisconsin, except that of 1893, have come after July has been definitely cool in that state. Soil temperature may be involved here.

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[65]Northern New England: Maine, New Hampshire, and Vermont; Southern New England: Massachusetts, Rhode Island, and Connecticut (as defined in Climatological Data). The mean annual temperatures are given in the Climatological Data Annual published yearly by the office of the U. S. Weather Bureau at Boston.

TABLE 8.—CORRELATION OF CRANBERRY FROST OCCURRENCE WITH MEAN TEMPERATURES OF THE PREVIOUS JANUARY TO APRIL, INCLUSIVE.

Year	Departure of the Mean Monthly Temperature from Normal at Lansing, Michigan, °F. *				Frosts the Following Growing Season					
					In Massachusetts			In New Jersey		
	Jan.	Feb.	March	April	Last Frost Night in Spring**	First Frost Night in Fall**	Summer Frostless Period (Days)	Last Frost Night in Spring***	First Frost Night in Fall***	Summer Frostless Period (Days)
1884	−6.9	+0.5	−2.3	−1.9	June 14	Aug. 24	70			
1885	−7.1	−14.0	−10.9	−2.0		Aug. 29				
1886	−3.6	−0.6	−0.9	+4.6						
1888	−7.0	−0.9	−5.2	−1.6	May 21	Sept. 6	107			
1889	+5.6	−4.6	+5.4	+1.0	May 26	Oct. 2	128			
1890	+9.1	+8.6	−4.0	+1.6	May 21	Sept. 24	125			
1891	+4.3	+3.8	−2.9	+1.8	June 5	Oct 1.	117			
1892	−3.2	+4.4	−2.3	−1.1	June 10	Sept. 20	101			
1893	−7.6	−1.6	−4.0	−2.1	May 8	Sept. 2	116			
1894	+4.5	−1.7	+7.9	+2.8	May 21	Sept. 11	112			
1895	−4.9	−6.5	−5.0	+3.0	May 22	Sept. 14	114		Sept. 14	
1896	+2.2	+1.4	−3.5	+7.0	May 7	Sept. 1	116			
1897	−0.1	+3.5	+0.8	−1.0	May 7	Sept. 21	136			
1898	+2.5	+0.9	+4.8	−2.0	May 20	Sept. 12	114			
1899	−0.7	−6.1	−5.9	+4.2	May 23	Sept. 14	113			
1900	+3.2	−5.5	−8.6	+1.8	May 28	Sept. 18	112			
1901	−0.2	−10.1	−1.1	+0.8	April 28	Sept. 21	145			
1902	−1.9	−4.3	+5.8	−1.0	May 20	Sept. 15	117	May 28		
1903	−1.7	−2.3	+8.8	−2.6	May 31	Sept. 8	99			
1904	−8.0	−10.9	−2.0	−6.2	June 13	Aug. 26	73		Sept. 21	
1905	−4.2	−7.1	+3.2	−1.0	June 8	Sept. 14	97			
1906	+9.4	+0.7	−6.0	+1.0	May 29	Sept. 4	97			
1907	+0.8	−3.7	+6.4	−7.8	June 12	Sept. 26	105			
1908	+1.4	−1.3	+2.6	−1.0	June 2	Sept. 20	109		Oct 2	
1909	+4.2	+5.5	−2.3	−2.8	June 8	Sept. 5	88		Sept. 5	
1910	+1.0	−1.0	+11.8	+3.6	June 4	Sept. 22	109	May 16	Oct. 2	138
1911	+2.8	+4.7	+0.5	−1.3	May 14	Sept. 13	121		Oct. 7	
1912	−13.2	−7.1	−9.8	0.0	June 14	Aug. 16	62		Sept. 29	
1913	+3.8	−2.9	−1.2	+0.3	June 9	Sept. 10	92	May 10	Sept. 15	127
1914	+4.6	−10.2	−1.1	−0.9	May 15	Sept. 10	117	May 1	Sept. 9	130
1915	−2.0	+6.5	−2.1	+6.0	May 30	Sept. 22	114	May 26		
1916	+5.2	−3.7	−6.0	+0.1	May 19	Sept. 2	105			
1917	−1.4	−7.4	+2.4	−3.2	May 30	Sept. 10	102	May 24	Sept. 10	108
1918	−12.2	−1.1	+4.9	−3.2	June 20	Sept. 11	82	June 20	Sept. 30	101
1919	+6.1	+4.1	+1.6	−0.8	May 6	Sept. 27	143	April 23	Sept. 27	156
1920	−9.2	−3.1	+3.0	−5.7	May 16	Sept. 19	125	May 16	Sept. 19	125
1921	+6.8	+5.4	+8.2	+6.0	June 1	Oct. 9	129	June 3	Oct. 9	127
1922	−1.4	+3.1	+3.2	+1.2	May 27	Sept. 18	113	May 28	Sept. 26	120
1923	+1.2	−5.2	−3.8	−1.6	May 29	Aug. 22	84	May 24	Sept. 15	113
1924	−3.7	−0.8	−1.0	−1.0	June 11	Sept. 6	86	May 23	Sept. 11	110
1925	−3.8	+4.4	+2.4	+4.6	May 27	Aug. 27	91	May 27		
1926	+1.0	+0.5	−5.9	−6.3	June 20	Sept. 14	85	June 21	Oct. 8	108
1927	−0.8	+6.4	+5.8	−0.7	June 3	Sept. 24	112	June 2	Sept. 24	113
1928	+1.7	+1.7	−1.7	−3.6	May 16	Sept. 22	128	May 24	Oct. 1	129
1929	−5.2	−3.5	+7.2	+2.2	June 2	Sept. 20	109	May 23	Oct. 5	134
1930	−4.2	+8.1	−0.4	−0.4	May 31	Sept. 28	119	June 1	Oct. 1	121
1931	+4.1	+7.5	−0.3	+1.5	May 17	Sept. 29	134	May 5	Oct. 11	158
1932	+11.4	+7.3	−5.9	−3.0	June 7	Sept. 10	94	June 8	Sept. 26	109
1933	+9.6	+0.5	−0.4	+0.2	May 17	Oct. 3	138	May 17		
1934	+6.8	−9.7	−5.1	−2.6	May 18	Aug. 30	103		Oct. 1	
1935	0.0	−0.6	+4.8	−2.0	May 24	Sept. 16	114	May 25	Sept. 24	121
1936	−3.0	−10.1	+3.7	−4.5	May 30	Sept. 25	117	May 29		
1937	+5.0	+3.0	−2.8	−1.4	May 2	Sept. 30	150	May 16	Sept. 21	127
1938	0.0	+6.6	+8.4	+1.6	May 30	Sept. 9	101	June 1	Oct. 2	122
1939	+4.4	+1.9	−0.2	−2.6	June 2	Sept. 18	107	May 17	Oct. 13	148
1940	−4.4	+1.7	−5.1	−3.5	June 21	Aug. 24	63	June 21	Sept. 26	96
1941	+2.4	+0.5	−3.7	+6.2	May 30	Sept. 12	104	May 25	Sept. 12	109
1942	+0.8	−2.3	+4.6	+5.8	May 10	Sept. 28	140	May 10	Sept. 28	140

* Climatological Data, Michigan Section, published monthly by the office of the U. S. Weather Bureau at Lansing and available to subscribers at little cost, gives the monthly mean temperature and its departure from normal there regularly.

** Nearly all the dates before 1912 are based entirely on the records of observations at Middleboro. Since 1911 they are from the experiment station records of observations made at the several cranberry observing stations (p. 37) and are therefore much more inclusive and exact. See page 59 for definitions of frost night.

*** Mostly observations made at Whitesbog.

SUNSPOTS AND VULCANISM

A list of the more destructive frosts in the history of the cranberry industry, with suggestions as to contributive causes, follows. Those wanting to learn about the relationship of sunspot abundance and volcanic activity to atmospheric temperatures are referred to Chapters 3 to 5, inclusive, of Part 5 of "Physics of the Air" by W. J. Humphreys (1940)[66]; "The Influence of Solar Variability on Weather" by C. G Abbot[67]; and "Sunspots and Their Effects" by Harlan T. Stetson (1937).[68]

Massachusetts

1. September 8–9, 1871. Frost took at least a quarter of the cranberry crop. Possible cause, sunspot abundance.
2. June 1, 1875. The frost must have reduced the crop prospect greatly. Possible cause, vulcanism (see next).
3. May 31–June 1, 1876. A severe frost reduced the crop greatly. Possible cause, vulcanism (eruption of Vatna Jökull, Iceland, March 29 and during April, 1875). Sunspots few.
4. May 12–13, 1878. Frost killed the tops of potatoes and harmed strawberries materially in Barnstable County. It must have reduced the cranberry prospect substantially. Cause, warm early spring.
5. May 29–30, 1884. The ground froze to a depth of a quarter to a half inch throughout New England. This frost and the one next listed together reduced the cranberry crop prospect of Massachusetts fully half and of New Jersey a quarter.
6. June 14–15 ,1884. This frost did great harm to garden crops over most of the Cape. Possible causes, sunspot abundance and vulcanism (eruption of Krakatoa, Dutch East Indies, August 27, 1883, one of the greatest in recorded history). This frost did much harm on the cranberry bogs on Long Island also.
7. September 30–October 1, 1888. Loss large, probably a quarter of the crop. Sunspots few.
8. June 10–11, 1892. Cranberry prospect reduced perhaps a quarter. Possible causes, sunspot abundance and vulcanism (eruption of Bogoslof, Aleutian Islands, February 1890).
9. May 14–15, 1894. Frost took half the crop. Sunspots abundant.
10. May 28–29, 1900. Cranberry loss not estimated but very substantial. Sunspots few.
11. May 24–25, 25–26, and 31–June 1, 1903. Cranberry prospect reduced probably a third. Possible cause, vulcanism (eruptions of Mount Pelée, Martinique, May 8, 1902; Santa Maria, Guatemala, October 24, 1902; and Colima, Mexico, February and March 1903).
12. September 22–23, 1904. Frost took about a quarter of the crop. Possible causes, sunspot abundance and vulcanism (eruptions of Santa Maria and Colima, cited above).
13. May 20–21 and 21–22, 1906. Widespread and substantial damage to cranberry bogs in both Plymouth and Barnstable counties. Sunspots abundant.
14. April 28–29, 1910. Thirty-five per cent of the cranberry fruit buds killed. Sunspots few. Cause, very warm early spring before a normal frost.
15. June 9–10, 1912. Cranberry prospect cut at least a quarter. The eruption of Katmai, Alaska, took place three days before, but weather sequence probably explains the occurrence of this frost. Sunspots few.
16. May 29–30, 1915. Cranberry prospect reduced 40 per cent. Sunspots fairly abundant.
17. September 10–11 and 11–12, 1917. Frost took 60 per cent of the crop. Sunspots very abundant.
18. June 20–21, 1918. Cranberry prospect reduced 55 per cent. Sunspots abundant.

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[66]Copy in the Middleboro library.

[67]Scientific Monthly, August 1936, pp. 108–121. (Copies in the Middleboro library.)

[68]This book (copy in the Middleboro library) lists the monthly numbers of sunspots from 1749 to 1937, inclusive. Those desiring to follow their abundance should subscribe for the Monthly Weather Review, published by the United States Weather Bureau. This gives their provisional daily numbers each month.

New Jersey

1. June 14, 1875. Cranberry prospect apparently reduced fully a fifth. Possible cause, vulcanism (eruption of Vatna Jökull, cited above).
2. May 12–13, 1878. Frost took nearly half of the cranberry crop prospect. See above.
3. October 5, 1881. Frost took a third of the entire crop, or two thirds of the berries remaining unpicked when it came. Sunspots abundant.
4. May and June, 1884. See above.
5. September 14–15, 1895. Cranberry crop reduced fully a half. Sunspots abundant.
6. The first two nights in October, 1899. These frosts took probably a third of the cranberry crop. Sunspots few.
7. May 28–29, 1902. Cranberry prospect reduced more than half. Possible cause, vulcanism (eruption of Pelée, cited above). Sunspots few.
8. September 21–22 and 22–23, 1904. The frost took about a quarter of the crop. Possible causes, sunspot abundance and vulcanism (see above).
9. May 20–21, 1905. Nearly a quarter of the crop was lost. Sunspots abundant.
10. September 10–11 and 11–12, 1917. Lowest bog temperature reported 22° F. Estimated cranberry loss 25 per cent. Sunspots abundant.
11. May 27–28, 1927. Lowest bog temperature reported 18° F. Crop prospect reduced half. Sunspots abundant.
12. May 30–31 and May 31–June 1, 1938. Lowest bog temperature reported 25° F. Cranberry prospect reduced a quarter. Sunspots very abundant.

Wisconsin

1. August 21–22, 1875. Probably half the crop destroyed. This frost probably affected the 1876 crop also. Possible cause, vulcanism (eruption of Vatna Jökull, cited above).
2. Spring of 1884, probably mostly on May 29. Cranberry prospect reduced fully 80 per cent. See above.
3. Frosts in August and September and probably on or about June 1, 1889, largely reduced the cranberry crop. The previous calendar year, 1888, was one of the coldest in the northeastern United States in the last seventy years. It was followed by a very remarkable frost in the Middle West and in the South Atlantic and East Gulf States (Alabama and Georgia) on June 1, 1889. A coastal disturbance or cloudiness may have saved the eastern cranberry-growing districts from this. The weather sequence here paralleled that of the great frost of June 1918, after the cold of 1917.
4. Frosts in May and especially on August 23-24, 1891, took well over half the crop. Possible cause, vulcanism (eruption of Bogoslof, cited above). This frost reduced the 1892 crop also.
5. Last four nights of August and first night of September, 1893. Over half the crop destroyed. Sunspots very abundant.
6. August 20–21, 1895. Frost took at least half the crop. Sunspots abundant. This frost probably affected the 1896 crop also.
7. June 29–30, 1900. Nearly half of the cranberry prospect destroyed. Sunspots few.
8. June 10–11 and 11–12, 1903. Cranberry prospect reduced half. Possible cause, vulcanism (eruptions of Pelée, Santa Maria, and Colima, cited above). Sunspots few.
9. August 7–8, 1904. Lowest bog temperature reported 26° F. Frost took 40 per cent of the crop. Possible causes, sunspot abundance and vulcanism (eruptions of Pelée, Santa Maria, and Colima). This frost reduced the 1905 crop also (see p. 37).
10. August 31–September 1 and September 1–2, 1909. Lowest bog temperature reported 15° F. Half the crop taken. Sunspots rather few.
11. June 7–8, 8–9, and 9–10, 1913. Lowest bog temperature reported 24° F. Cranberry prospect reduced materially. Possible cause, vulcanism (eruption of Katmai, Alaska, June 1912). Sunspots few.
12. July 18–19, 1929. Lowest bog temperature reported 24° F. Fully a quarter of the cranberry prospect taken. Sunspots abundant.

It will be seen that most of these frosts came in periods of sunspot abundance or within a year or two after severe volcanic activity.[69] All of those in June, July, and August, except those of August, 1889, and June 30, 1900, in Wisconsin, came at such times. There may be little to go by in this, however, for the world has been in a secular trend of rising temperature since the turn of the century.[70]

SOLAR CONSTANT

Solar constant values are interesting in long-range temperature forecasting. They presaged correctly the cranberry frost conditions of 1923, 1927, and 1940 and may be helpful at times. A prediction of the solar constant published recently[71] suggests that the seasons of 1945 and 1946 will be very frosty.

MOON PHASES AND FROST OCCURRENCE

Many cranberry growers think the full moon somehow favors the occurrence of frost. A study of this is given in table 9, which is self-explanatory.[72] The summations in this table show that about as many cranberry frosts came in one phase of the moon as another. It will surprise some growers to see that, on the whole, more spring frosts came in the dark half of the moon than in the bright half.

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[69]Frost did more harm on the cranberry bogs on the Pacific Coast in 1937, 1938, and 1939—all years with sunspots very abundant—than in a long time before. The frost of July 8–9, 1938, was the most unseasonable severe frost in the history of the industry there. That of April 29–30, 1939, came after a long drouth in a season that is usually rainy there.

[70]Kincer, J. B., Our changing climate, Amer. Met. Soc. Bul. 20:448–450, 1939; Relation of recent glacier recessions to prevailing temperatures, U. S. Monthly Weather Rev. 68:158–160, 1940. (Copies of both in the Middleboro library.)

[71]Abbot, Aldrich, and Hoover, Smithsonian Inst., Astrophys. Observ. Ann. Vol. 6, Fig. 14, 1942. (Copy in the Middleboro library.)

[72]"Frost night" in the Massachusetts table means a night in which the minimum bog temperature was 28° F. or below at two or more of the following observing stations: Marstons Mills, East Wareham, South Carver, Norton, Halifax, South Hanson, and Pembroke (see p. 37). In the New Jersey table it means a night in which the minimum bog temperature was 28° F. or below at either Whitesbog or Pemberton (the observing at Whitesbog began in September 1905, and that at Pemberton began in October 1921 and ended with 1935). In the Wisconsin table it means a night in which the minimum bog temperature was 28° F. or below at Cranmoor, Mather, or Beaver Brook. (The U. S. Weather Bureau established the stations at Cranmoor and Mather, Wis., in June 1906, and at Beaver Brook in August 1916.) The frost records for October are far from complete for any of the three states, especially for Wisconsin, but all available records were used in compiling the tables.

TABLE 9.—MOON PHASES AND FROST OCCURRENCE ON CRANBERRY BOGS.

Month	Number of Frost Nights During 7-day Periods Beginning with Dates of Moon Phases as Indicated						Percentage of Frost Nights in Dark Half of Moon
	Bright Half of Moon			Dark Half of Moon			
	First Quarter	Full Moon	All*	Last Quarter	New Moon	All*	
Massachusetts 1912 to 1942, inclusive							
May..........	31	33	65	44	44	88	57.5
June..........	4	1	5	4	7	11	68.8
August........	3	3	6	1	1	2	25.0
September.....	25	20	46	19	13	33	41.8
October.......	70	72	144	80	71	155	51.8
All........	133	129	266	148	136	289	52.1
New Jersey 1906 to 1942, inclusive							
May..........	17	25	44	18	22	43	49.4
June..........	3	2	5	1	4	5	50.0
September.....	5	7	12	14	9	23	65.7
October.......	30	22	58	21	32	55	48.7
All........	55	56	119	54	67	126	51.4
Wisconsin 1906 to 1941, inclusive							
May..........	65	63	139	68	60	134	49.1
June..........	10	16	29	18	26	46	61.3
July..........	1	2	4	4	2	6	60.0
August.........	16	25	42	10	13	25	37.3
September.....	74	63	142	57	60	122	46.2
October.......	34	41	76	33	41	77	50.3
All........	200	210	432	190	202	410	48.7

* These figures include not only the frost nights of the moon-phase periods, but also the few frost nights that came between the periods of the first quarter and full moon and of the last quarter and new moon, respectively.

BOG PROTECTION FROM FROST

Bog Surroundings

Bog locations close to and usually leeward from extensive shallow salt water or large fresh water ponds or reservoirs or considerable streams are generally warmer than those elsewhere because of water vapor and heat brought to them by air from the bodies of water. Locations closely girded by much higher land or tall woods, because of restricted air circulation, are more frosty than those entirely open or with considerable dingles leading to lower land or to areas of water. With other conditions the same, the central parts of large bogs which are both long and wide have more air movement on cold nights and so are less frosty than other places.

Clearing trees and brush from the uplands around a bog allows more air movement over it on cold nights. It is hard to say how much this affects minimum bog temperatures, but it seems to raise them often two to four degrees.[73] It is more helpful with small bogs than with large ones. The clearing must be extensive and reach a real opening (Fig. 11) to be effective. Clearing a little back from a small bog, half an acre or less, may do more harm than good by removing partial shelter from night sky exposure.[74]

Grass, especially when much of it is dead, strongly restricts the flow of heat into and from the ground,[75] and it radiates heat to the sky faster than bare

[73]Judging by comparisons of the minimum temperatures of different bogs in the same neighborhood before and after clearing around some of them.

[74]Schoonover, Brooks, and Walker, op. cit., p. 14.

[75]Geiger, op. cit., p. D8

earth.[76] This causes the air near the surface over a grass cover to be colder on frosty nights than it is over bare soil. It would therefore be helpful to keep the land around bogs, especially small ones, plowed and free of vegetation, for the air draining onto the bogs from the slopes of the uplands would be somewhat warmer on cold nights.[77] This would also reduce the number of cranberry girdlers and spittle insects that come onto the bogs from the uplands, by removing their food plants from around the margins. Experience alone can tell how well these advantages will pay for the trouble and expense involved.

Moss

Both hair-cap and sphagnum moss greatly restrict the warming of the ground by the sun and the transfer of heat from the soil to the air on cold nights.[78] Their removal from cranberry bogs, therefore, helps to prevent frosts. Resanding tends to smother moss, but it may form an insulating felt under the sand. Hair-cap moss may be killed with a spray of 20 pounds of copper sulfate in 100 gallons of water, applied at the rate of 600 gallons an acre, preferably early in the spring.

Fallen Leaves

Thick accumulations of fallen cranberry leaves, like moss, greatly restrict the flow of heat into and from the soil and form an insulating layer when covered with sand. The leaves cannot be removed from dry bogs very well, but flooding brings them to bog margins freely and they should always be taken from the water there.[79]

Defrosting with Water

Growers sometimes suggest spraying frosted cranberry bogs with water before sunrise to avert injury. The writer and others have tried this and the spray has always increased the injury greatly.

Chemicals

The effects of chemical applications on cranberry frosts and their results have not been studied, but they are not used with other crops and probably would have little value.

Wind Machines

As the air overhead is commonly warmer on frosty nights than that near the ground, blowers have been used extensively in the West, especially in citrus orchards, to mix it with the lower air and so prevent frost. Some cranberry growers on the Pacific coast think they are useful, over 100 acres of bog being serviced with them. Their value for bog protection has been tested at the experiment station at East Wareham.[80] In the West, small machines are not effective beyond 300 feet and large ones beyond 500 feet.[81] Observations in California and at East

[76] Brooks, F. A., Solar energy and its use for heating water in California, Calif. Agr. Expt. Sta. Bul. 602, 1936, p. 18. (Copy in the Middleboro library.)

[77] This advantage probably would often be increased if the plowed land were wet down thoroughly before frosts.

[78] Cox, op. cit., p. 44.

[79] Mass. Agr. Expt. Sta. Bul. 371, 1940, p. 22. (Copies in the Middleboro library.)

[80] Professor C. I. Gunness, head of the department of engineering, did most of this work.

[81] Schoonover, Brooks, and Walker, op. cit., p. 21.

Wareham indicate that an advantage of three to five degrees is about all that can be expected of them. Obviously, they can be helpful only on still nights with fairly large temperature inversions, and their value then is reduced by the advantage that stillness affords (p. 45). They will never be used much on bogs in the East.

Blowers with heaters have never been successful anywhere, because the heated air rises too rapidly.

Cloth Screens

Tobacco shade cloth has been tried considerably as protection from frost on cranberry bogs.[82] It is not satisfactory when there is much moss under the vines. Good secondhand cloth is so hard to get that its use is not feasible. One thickness of new cloth is not enough. Two thicknesses spread on the vines are good protection for most Massachusetts bogs, and this seems the best way to use it, for supports are too troublesome and costly. The cloth is too bulky to handle well on large areas, but it may be left spread on a bog several days without reducing the protection much. It is too expensive, but is more available for this use than other kinds of cloth, and more practicable than glass, paper, lath, or other screens. Its use requires too much tramping on the vines and is not advocated.

Smoke

The smoke from fires near bog margins is no help,[83] their heat alone giving protection and that for but a short distance.

Heaters

Oil-burning heaters, used widely to protect orchards from frost, have been well tried on cranberry bogs and fields of other low-growing crops[84] and are effective in raising temperatures there. Their use on cranberry bogs, however, is unwise because of the expense involved, the risk of firing the vines, and the injury to the vines from necessary tramping and from spilling of oil. Wood fires in ventilated 50-gallon oil drums, properly spaced over a bog, have been tried by Isaac Birch at East Taunton and seem more feasible.

Sprinkling Systems

In 1931 a bog of two acres in Carver was equipped with a Skinner pipe system (Fig. 12, upper) which has been in service ever since as protection from both frost and drouth and has been very satisfactory. Like results are reported from a bog in North Harwich, equipped more recently with a rotating-head system (Fig. 12, lower). Such installations are costly[85] but their use by cranberry growers will increase. They may perhaps be made to provide winter protection by covering the vines with ice. The recent discovery of good insecticidal controls for the cranberry fruit worm has improved the possibilities of dry bogs greatly, and this urges sprinkling to reduce their other leading hazards.

[82] Mass. Agr. Expt. Sta. Bul. 160, 1915, pp. 93–94; Bul. 168, 1916, p. 1; and Bul. 180, 1917, pp. 184–185. (Copies in the Middleboro library.)

[83] Schoonover, Brooks, and Walker, op. cit., p. 13.

[84] Mass. Agr. Expt. Sta., 25th Ann. Rept., 1913, p. 5 (copy in the Middleboro Library); Smith, J. Warren, Agricultural Meteorology, 1920, p. 26; U. S. Monthly Weather Rev. 53:351, 1925; and 55:354–357, 1927 (copies in the Middleboro library); and Young, op. cit., pp. 34–35.

[85] The cost before the war was $450 to $500 an acre where surface water could be used. It is a big gamble to try to pump the water from the ground.

Rotating-head systems are better for cranberry service than pipe-nozzle systems because they are simpler, are less expensive to install and maintain, are less in the way of bog operations, and are troubled less by a little sand in the water.

In arranging for sprinkling equipment, each bog is a special engineering problem. The shape and size of the bog, the spacing of the ditches, the source of water and the amount available, must all be considered to determine the best spacing of the sprinklers. The first cost of the installation and the cost of its operation and maintenance over a term of years must also be considered. Medium-pressure heads (say with 70 pounds pressure at the pump and 40 pounds at the heads), moderately spaced (perhaps 8 to an acre), are best on large bogs (8 acres or more), for they use less water (64 gallons a minute to the acre) and require a much less costly power plant and pump for the ground covered than do high-pressure heads. High-pressure heads (90 pounds pressure at the pump and 60 pounds at the heads), about 5 to an acre, are advisable for bogs of 3 acres or less because of a saving in pipe with little difference in the cost of the power plant and pump. These heads put about 75 gallons a minute on an acre. The lines of pipe leading to the sprinklers should be laid on cross-pieces over the ditches to be out of the way. Main pipe lines may be of galvanized or cast iron or of wood, the latter being preferred on the Pacific coast. Galvanized piping is best for the laterals. Secondhand automobile engines and centrifugal pumps are economical and satisfactory in such systems.[86]

The method of operating sprinklers for frost protection has been to start them before the temperature has fallen below 40° F. and keep them going till it is well above freezing the next morning. It probably would be helpful also to wet the ground well by sprinkling several hours in the late afternoon and evening before a severe frost. Practices will vary with the temperature of the water used.

About 225 acres of cranberry vines on the Pacific coast are protected with sprinklers. They are not used at all on the bogs of New Jersey and Wisconsin.

Resanding

As Cox has shown,[87] the temperature of the top soil and minimum temperatures of the air over it vary with the character of the soil and its covering; and a coat of sand on a cranberry bog protects the vines from frost considerably by giving up heat to the air during the night, sand being a much better conductor than peat.[88] Resanding covers moss and dilutes and buries accumulations of fallen cranberry leaves (see above) and other organic matter on the bog floor and so tends to maintain the conductivity of the surface soil. Resanding should not be delayed enough to allow large amounts of such material to collect under the vines, especially on bogs that cannot be protected with water, for a lot of it covered with sand will largely insulate that sand from the soil below. Strictly dry bogs, especially those with fairly thick vines, should be resanded moderately every year to keep this material diluted, for it accumulates rapidly where none of it is ever removed with water. Dry bogs should not be resanded in the fall, for the vines waterkill more readily after disturbance; they should be sanded very early in the spring so that the sand may pack before frosts get dangerous, for sand conducts heat better when it is packed than when it is loose.[89]

[86]Much of this information comes from Sales Agent George N. Barrie of the Skinner System of Irrigation and Manager Emile C. St. Jacques of the Hayden Cranberry Separator Manufacturing Company.

[87]Cox, op. cit., pp. 8, 9, 41, 52, 63–64, 76–77, and 80–83.

[88]Geiger, op. cit., pp. D6–D8.

[89]Geiger, op. cit., pp. D6–D8

Cox indicated that sand protects from frost better when dry than when wet[90] and gave data supporting this view. The writer questions this,[91] and the general experience of cranberry growers is that sand is a better protection when wet. Apparently Cox failed to appraise properly the relations of water to the conductivity and specific heat of soil and magnified the effect of evaporation. Resanding is practiced generally on Massachusetts and Wisconsin bogs, but less elsewhere. It has important uses besides frost protection.[92]

Flooding

Partial flooding where water is available has long been the main protection from frost used by cranberry growers everywhere.[93] Because of its high specific heat, 2 or 3 inches of water everywhere under the vines is enough, for heat passes by radiation, conduction, and convection from the water to the air and keeps the vines from freezing. Some claim the vines must be submerged under extreme conditions, and this may be necessary on rare occasions in April and October when the water is cold. Mere filling of the ditches is never any protection beyond a few feet from the water. If water supplies are limited and it remains cold, the water may be held over on a bog from one night to another for a few successive days up to about May 10 and for a day at a time after that.[94] It may also be held over for a day or two in the fall, but this tends to impair the keeping quality of the fruit. Stop-waters in bog ditches (Fig. 13) often help greatly in efficient use of limited water supplies in frost flooding. The service of reservoirs is often greatly extended by pumping the water used in flooding back into them again and again. If the winter flowage is held till May 25, new growth usually will not start enough to be hurt by frost before the end of the month, and harmful frosts come in June only occasionally. This is often a good practice if there is no water for reflooding; but it is better, if possible, to save the winter water for this purpose by pumping. If a reservoir cannot be prepared to hold this water, the bog can often be divided with a dike so that the winter water may be held late on each half in alternate years and be pumped from one to the other for frost protection.

It is better in the long run to chance moderate losses by frost than to waste water and reduce the crop by flooding too often. Most growers with bogs in warm or even average locations in southeastern Massachusetts will probably fare much better in the long run if they flood only when the difference between the wet-bulb temperature and the dew point toward the coast and inland is greater than that between the dry-bulb and wet-bulb temperatures in the same places. Frost flooding should never be done anywhere when the difference between the dry-bulb and wet-bulb readings is more than one degree greater locally than that between the wet-bulb temperature and the dew point.

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[90]Cox, op. cit., p. 61.

[91]Mass. Agr. Expt. Sta. Bul. 160, 1915, pp. 92–93.

[92]Mass. Agr. Expt. Sta. Bul. 371, 1940, p. 23.

[93]Mass. Agr. Expt. Sta. Bul. 371, 1940, pp. 7, 8, and 22.

[94]Much injury from flooding for 40 hours in the cool and clear weather that usually prevails in a period of frost danger is not likely to occur on most bogs, even with the new cranberry growth in its most tender condition. As a flood of this duration is always an effective treatment for the blackheaded fireworm and other pests commonly abundant on the bogs in the spring, it should be used against frost and insects at the same time whenever there is the chance, unless the bog has a bad record for injury by flooding.

FROST INJURY ON MASSACHUSETTS CRANBERRY BOGS

This list shows the frosts which did harm on our cranberry bogs in the years 1910–1942, inclusive, the period since the cranberry experiment station was established.

Year	Date of Frost: Spring	Date of Frost: Fall	Range of Minimum Bog Temperatures	Remarks
1910	April 28–29		17°–23° F.	Estimated loss 35 per cent.
	June 4–5			Loss considerable (no estimate).
1911		Sept. 19–20 and 20–21		Considerable loss in Carver and the northern part of Plymouth County.
1912	June 7, 9, and 14		24°–30° F.	The crop prospect reduced at least a quarter.
1913	May 14–15		20°–30° F.	Considerable damage on bogs in some localities, especially at South Hanson and Norton.
	June 9–10		26°–38° F.	Considerable injury on bogs in some localities, especially at South Hanson and Harwich.
		Sept. 15–16	20°–29° F.	Damage most severe in Carver. 40,000 barrels estimated frozen. Serious loss in New Jersey.
1914	June 5–6		26°–31° F.	Estimated loss 5,000 barrels.
		Sept. 10–16	26°–34° F.	Estimated loss 25,000 barrels. Loss on New Jersey bogs 50,000 barrels.
1915	May 27–28		27°–38° F.	Principal injury inland, especially in Rochester. Estimated loss 4 per cent.
	May 29–30		21°–28° F.	Estimated injury 40 per cent.
1916		Sept. 2–3	28°–35° F.	700 barrels frozen.
		Oct. 1–2	21°–31° F.	500 barrels frozen.
1917		Sept. 10–11	18°–26° F.	Estimated injury 50 per cent, mostly in Plymouth and Bristol counties. No frost in most of Barnstable County. Estimated injury on New Jersey bogs 25 per cent.
		Sept. 11–12	21°–26° F.	Estimated injury 10 per cent, mainly in Barnstable County.
1918	June 20–21		21°–27° F.	Estimated loss 55 per cent. This severe frost so late in the season harmed the vines of many bogs so that they failed to bud well for 1919.
1919	April 22–23		17°–25° F.	Only slight damage from frost.
	June 22–23		29°–33° F.	There was some carry-over of injury from the June frost of 1918.

Year	Date of Frost		Range of Minimum Bog Temperatures	Remarks
	Spring	Fall		
1920		Sept. 19–20		No frost damage on Massachusetts bogs. Estimated loss in New Jersey 20 per cent.
1921	May 11–12		18°–24° F.	Estimated loss 5 per cent, mostly around South Hanson. This frost killed strawberry blossoms generally and many blueberry blossoms.
	May 24–25		23°–32° F.	Estimated loss 15 per cent, mostly in Barnstable County. Estimated loss in New Jersey (May 23–24) 10 per cent.
1922	May 27–28		25°–32° F.	Estimated loss 20 per cent.
		Sept. 18–19	21°–30° F.	Estimated loss 10,000 barrels.
1923	May 23–24 May 29–30		26°–29° F. 25°–29° F.	Estimated loss 40,000 barrels.
		Sept. 17–18	20°–29° F.	10,000 barrels estimated frozen.
1924	May 31–June 1		26°–30° F.	Estimated loss 7 per cent.
1925	May 25–26*		23°–28° F.	Estimated loss 7 per cent. Estimated loss on New Jersey bogs 15 per cent.
		Aug. 27–28	24°–34° F.	3,000 barrels estimated frozen.
		Sept. 22–23	18°–27° F.	3,000 barrels estimated frozen.
		Sept. 25–26	14°–24° F.	4,000 barrels estimated frozen.
		Sept. 30–Oct. 1	12°– 20° F.	4,000 barrels estimated frozen.
1926				Very little frost injury.
1927	June 3–4		25°–32° F.	Estimated loss 2 per cent.
	July 4–5		28°–38° F.	Slight loss.
1928				Very little frost injury.
1929	May 22–23		18°–30° F.	Estimated injury 6 per cent.
	July 3–4		29°–34° F.	Estimated loss 1,500 barrels, all in Norton.
		Oct. 8–10	8°–23° F.	500 barrels frozen.
1930	May 30–31 and May 31–June 1		20°–31° F.	Estimated loss 3 per cent.
1931				No frost injury.
1932	May 23–24		24°–29° F.	Estimated injury 4 per cent.
1933	May 17–18		23°–34° F.	Little injury.
		Oct. 14–15	20°–27° F.	Little injury.

* There were heavy frosts in New Jersey on both May 25–26 and May 26–27, 1925, the latter being the more severe there.

Year	Date of Frost: Spring	Date of Frost: Fall	Range of Minimum Bog Temperatures	Remarks
1934	April 28–29		15°–19° F.	Estimated injury 8 per cent.
1935				Little frost injury.
1936	May 14–15		18°–27° F.	Estimated loss 15 per cent. Loss on New Jersey bogs 17 per cent. Cultivated blueberry crop of New Jersey reduced 40 per cent.
1937				Little frost injury.
1938	May 3–4		14°–26° F.	Estimated loss 1 per cent.
	May 30–31		23°–30° F.	Estimated loss 7 per cent. Loss on New Jersey bogs 25 per cent.
1939	June 2–3		27°–36° F.	Loss half of 1 per cent.
		Sept. 18–19	23°–29° F.	Loss half of 1 per cent.
1940	May 29–30		25°–35° F.	Estimated loss 3 per cent. Considerable loss on Nantucket and the outer Cape.
	June 20–21 and 21–22		25°–39° F.	Little injury. Loss on bogs in New Jersey 10 per cent.
		Aug. 24–25	25°–34° F.	5,000 barrels frozen.
1941	April 22–23		17°–21° F.	Estimated loss 2 per cent.
		Sept. 19–20	22°–28° F.	5,000 barrels frozen.
		Sept. 29–30	18°–25° F.	2,000 barrels frozen.
1942	May 10–11		20°–28° F.	Estimated loss 2 per cent, mostly in Carver, Duxbury, and Rochester.

This record covers thirty-three years. The estimates of loss in most cases were made from information secured from cranberry growers at the time of occurrence. Injury to cranberry bogs occurred in the spring as early as April 22 and as late as July 4, frosts doing harm 4 nights in April, 19 nights in May, 11 nights in June, and 2 nights in July, most of the loss occurring from the middle of May to the twentieth of June. The cranberry vines are usually considerably resistant to frost injury till nearly the middle of May, and frost seldom comes on Cape Cod after June 20. Damaging fall frosts occurred twice late in August, 15 times in September, and 4 times in October, most of the injury being done from September 10 to 18. Severe frost rarely comes on the Cape before September 10, and by late September the berries are ripe enough to resist frost a good deal. Also much of the crop is gathered by late September and most of what remains on the bogs can usually be protected easily.

Inspection of the above record shows that loss by frost was much greater in the first half of the period covered than in the last half. The difference is probably due to improvement in flowage facilities and to better attention of the growers to the matter of frost protection.

RELATION OF WEATHER TO THE KEEPING QUALITY OF MASSACHUSETTS CRANBERRIES[1]

By Neil E. Stevens[2]

CONTENTS

What Is Meant by "Good" Keeping Quality

"Good" and "poor" with reference to the keeping quality of cranberries are, of course, relative terms and vary with the variety under discussion and with the locality in which it is grown. The keeping quality of berries is judged inevitably in terms of commercial practice. If the fruit of a given year satisfies what is usually demanded of it, the quality is said to be "good"; otherwise, it is called "poor."

The records of the New England Cranberry Sales Company and the American Cranberry Exchange show that over a period of years the peak of the shipping season for Early Blacks is usually reached the third or fourth week in September. The shipping season for Howes is more variable and during the ten-year period, 1925–1934 inclusive, the peak came twice (1925 and 1926) the first week in November, three times (1927, 1928, and 1929) the second week in November, once (1934) the third week in November, once (1930) the first week in December, once (1931) the second week in December, and twice (1932 and 1933) the third week in December. Allowing two weeks for the berries to reach market, it is evident that in the average year most of the cranberries of the Early Black variety have reached the consuming centers by the middle of October, while the Howes cranberries are shipped during November and December.

The handling of the so-called "odd" varieties seems to be well standardized and the bulk of this type of fruit is disposed of about the time of the Thanksgiving market. Obviously, the demands actually made on the berries vary greatly with the size of the crop and with market conditions. For example, the 1921 crop of Early Black cranberries was almost all shipped by the end of the second week in October and very few berries of any kind remained in the hands of the

[1]Several progress reports and discussions of certain phases of these studies on the relation between weather and keeping quality have been presented in various earlier papers by the writer; viz., Yearbook, U. S. Dept. Agr., 1927, pp. 238–240; Proc. Fifty-Third Ann. Meeting Amer. Cranberry Growers' Assoc., 1923; Proc. Fifty-Ninth Ann. Meeting Amer. Cranberry Growers' Assoc., 1929, pp. 8–16; Phytopathology, 22:911–916, 1932. In addition, "forecasts" were published regularly during September of each year, 1923 to 1929, in the Wareham Courier, and for 1930 to 1933 in the Plant Disease Reporter.

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growers at Christmas time. On the other hand, large shipments of the 1923 crop of Early Blacks were made as late as the first two weeks in November and considerable shipments of Howes as late as the last week in February and the first week in March. In general, however, it appears that trade practices indicate October 15 and November 15 as fair approximations of "critical" dates for Early Blacks on the one hand and Howes and odd varieties on the other, and that the average condition of Early Blacks on October 15 and of Howes on November 15 would give a fairly satisfactory picture of the state of that particular crop for commercial purposes.

The Storage Period for the Different Varieties

The actual demands made by commercial practice on the different varieties are quite different. The Early Black variety generally begins to ripen by the first week in September and as a rule is picked as soon as practicable. The picking of the Howes variety usually begins about three weeks later. The picking, storage, and transit period for Early Blacks, then, extends from the first week in September to the middle of October; and for the bulk of the Howes, from September 20 to late November.

While the storage period for Early Blacks is shorter than for the late varieties, it is also much warmer and the significance of this difference in temperature is not always appreciated. In attempting to compare the temperatures to which cranberries are usually subjected in handling and storage in Massachusetts, the daily normal temperatures at Boston, as given in Bulletin R of the U. S. Weather Bureau, were used.[3] These range from a daily mean temperature of 64° F. the first week in September to 40° the third week in November. First, taking 32° as zero, a simple summation of mean daily temperatures from September 8 to October 15 was made as representing the "day degrees" to which the bulk of the crop of Early Blacks is subjected; the total is 1029. A similar summation was made from October 1 to November 20 as representing the "day degrees" to which the Howes are ordinarily subjected; this total is 861. Of course, temperatures for Boston do not exactly represent those on Cape Cod, but the results would be about the same if weather records for any other eastern Massachusetts station were used.

A simple summation of mean temperature is, of course, not a thoroughly satisfactory way of representing the amount of heat to which an organism is subjected, and various attempts have been made to develop more satisfactory indexes. It is a well-known principle that many chemical reactions double or somewhat more than double with each rise of 18° F. in temperature. Professor Morse[4] has shown, moreover, that the rate of respiration of cranberries as measured by the amount of carbon dioxide given off follows this rule very closely within climatic temperatures. The rate of growth of most of the fungi which cause cranberry rots shows a similar relation to temperature.

Using a table of temperature coefficients prepared some years ago by the Livingstons[5], in which 40° F. is considered as unity and the coefficient doubles with each rise of 18 degrees, an "index" for the normal temperatures at Boston for these same periods was computed. The index for September 8 to October 15, inclusive, is 88.54, and for the period October 1 to November 20, inclusive, is 72.53.

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[3]Bigelow, Frank H. The daily normal temperature and the daily normal precipitation of the United States. U. S. Weather Bureau Bulletin R, 1908.

[4]Morse, F. W., and Jones, C. P. Studies of cranberries during storage. Mass. Agr. Expt. Sta. Bul. 198:75-87, 1920.

[5]Livingston, B. E., and Livingston, Grace J. Temperature coefficients in plant geography and climatology. Bot. Gaz. 56 (No. 5): 1913.

In an unusually early season such as that of 1929, both varieties, of course, ripen earlier, but this makes little difference in the relative temperatures to which they are subjected. For example, a simple summation of "day degrees" from September 1 to October 15 is 1265 and from September 21 to November 20, 1137. The corresponding indexes are 97.19 and 92.10.

There is, usually, a decided difference in the rot fungi which are most active during these two periods. Temperature studies of the growth of these fungi in culture show that the early rot fungi, such as *Acanthorhynchus vaccinii*, *Glomerella rufomaculans*, and *Guignardia vaccinii*, grow very little below 50° F., the mean temperature usually reached in the Boston region about October 22. During the entire period, then, of the storage of the Early Blacks, they are subjected to the attacks of early rot fungi. The Howes, on the other hand, during the portion of the storage period after November 1, are for practical purposes exposed only to the attack of the end rot fungus, which is able to grow somewhat even at 32° and whose optimum temperature is about 68°. It is evident, then, and must be kept in mind continually in discussing keeping quality in any of its relations that even in Massachusetts the term means something very different for different varieties.

Variation in the Keeping Quality of the Cranberry Crop as a Whole

One of the observations most frequently made by those who have had long experience in growing and handling cranberries is the variation in keeping quality of the crop from year to year. This applies not only to the keeping quality of the berries from a single bog but to the crop of an entire district.

Although this variation in keeping quality from year to year is noted in all the cranberry growing regions of the United States, this quality may vary decidedly for different sections for the same year. This is well illustrated by the results of the keeping tests made in Chicago during the years 1926 to 1929 for the purpose of determining the relative prevalence of rot-producing fungi in berries from the different cranberry growing sections. Inspection of the graph[6] shows that the greatest amount of rot occurred in the storage lots from New Jersey and Massachusetts in 1927 and in the storage lots from Wisconsin in 1926.

Determining the Keeping Quality of the Crop

Securing an accurate estimate of the actual keeping quality of the crop is much more difficult than might generally be supposed, since a large part of the decay and, indeed, the most important part from the commercial standpoint, occurs after the berries are packed and shipped. Decay which occurs in storage before packing can be estimated with considerable accuracy. Estimates of decay after shipment, however, insofar as they rest on the judgment of sales agents and inspectors, are almost always influenced by market conditions. Inevitably, rejections are most frequent on falling markets and it is during such periods that the condition of the fruit is brought most definitely to the attention of the grower and his sales representative. On the other hand, during years of short crop or rising markets, much relatively inferior fruit may be bought and sold without notice or rejections and the feeling gains credence among growers and shippers that the crop has been "good."

There is no adequate means of measuring quality from the consumers' standpoint, which is probably only one of the reasons why his point of view is so rarely considered by students of plant disease problems.

[6]Shear, C. L., Stevens, N. E., and Bain, H. F. Fungous diseases of the cultivated cranberry. U. S. Dept. Agr. Tech. Bul. 258, 1931.

The Keeping Quality of Cape Cod Cranberries during the Past Twenty-three Years

The only continuous record known to the writer of the keeping quality of the cranberry crop of any area over a period of years is contained in the published

TABLE 1.—RESULTS OF CRANBERRY HOLDING TESTS AT STATE BOG, EAST WAREHAM, MASSACHUSETTS, 1926–1935.

Variety	Bog No.	Percentage of Rotten Berries									
		1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
		October 15									
Early Black	1	1	1	4	8	5	17	2	18	2	6
	2	4	3	6	1	5	12	4	16	2	3
	3	1	0.4	4	4	5	7	2	4	2	5
	4	2	2	3	6	4	24	62	10	3	8
	5	5	6	3	..	7	25	5	39	8	19
	6	2	1	1	6	7	..	3	7	16	24
	7	7	..	6	..	19	29	12	26	..	..
	8	1	..	2	..	5	13	1	3	1	2
	9	..	22	2	10	11	33	12	16	10	17
	10	..	2	2	3	6	17	15	15	10	8
	11	..	..	..	19	59	31	8	12	6	18
Mammoth	12	2	15	4	3	3	20	7	10	2	10
McFarlin	14	1	2	9	8	11	37	37	13	12	3
Wales Henry	15	2	4	7	12	8	16	..	..	..	..
Searls	16	1	1	3	4	8	6	..	15	..	..
Middleboro	17	21	15	19	10	22	27	15	22	..	..
Howes	18	..	..	3	1	2	2	4	5	2	8
	19	0.5	1	2	5	4	5	0.2	1	1	4
	20	..	..	2	4	1	..	1	2	2	2
	21	..	..	0.2	2	3	..	1	0.1	0.3	0.3
	22	..	..	0.2	2	2	..	..	5	..	..
	23	..	..	10	14	10	19	3	4	2	6
	24	..	..	2	4	4	..	7	3	3	18
	25	1	0.4	2	2	4	4	15	9	..	..
		November 15									
Early Black	1	32	4	6	10	7	25	1	22	2	9
	2	12	7	17	2	6	21	5	26	3	8
	3	4	1	7	6	8	7	6	7	3	11
	4	10	6	8	10	9	31	89	14	5	19
	5	19	15	9	..	13	46	12	47	17	46
	6	14	7	2	10	12	..	11	16	28	36
	7	18	..	15	..	27	66	17	34	..	..
	8	11	..	4	..	8	25	3	8	5	6
	9	..	32	3	13	12	49	24	20	11	26
	10	..	5	3	8	8	29	30	22	11	16
	11	..	..	..	31	65	34	17	20	6	23
Mammoth	12	11	14	8	14	6	34	9	12	5	17
McFarlin	14	5	4	7	13	16	47	72	20	18	7
Wales Henry	15	13	11	11	26	14	25	..	..	..	..
Searls	16	4	2	3	6	7	10	..	19	..	..
Middleboro	17	34	25	32	34	35	33	23	24	..	..
Howes	18	..	..	9	5	10	6	11	6	9	14
	19	4	2	3	11	5	6	1	4	1	8
	20	..	..	4	10	4	..	7	4	6	9
	21	..	..	2	3	11	..	4	1	2	1
	22	..	..	2	8	3	..	..	..	..	..
	23	..	..	26	19	14	26	7	4	4	13
	24	..	..	3	10	8	21	7	5	8	30
	25	5	5	5	6	6	10	36	13	..	..

annual reports of the New England Cranberry Sales Company. Beginning with 1912, Mr. H. S. Griffith, for many years chairman of the Board of Inspectors of that company, regularly included in his report an estimate of the keeping quality of the cranberry crop of his district. These reports are the most reliable source of information on the quality of the various crops, not only because they are in print, which obviates the necessity of trusting to memory, but also because Mr. Griffith was an unusually keen observer and because, as a result of the frequent inspectors' meetings, the reports to a certain extent represent the combined judgment of the whole group of inspectors.

These records form the chief basis of the statements in columns 3 and 4 of Table 3. When a table like this was first prepared, the crop was considered as a whole and only one column was given to keeping quality. After the experience of 1926, however, Mr. Griffith's reports were re-examined and it was found that even as early as 1915 he had sometimes distinguished between the keeping quality of Early Blacks and of Howes. In all subsequent work, therefore, they have been considered separately.

As a check on these estimates and in order to furnish a more definite basis of comparison for the crop of subsequent years, actual storage tests of samples of unscreened berries from about twenty-five selected bogs in Plymouth County have been made at East Wareham since 1926. The results of these tests are given in Table 1.

Although the records of condition were taken both on October 15 and on November 15 for all samples, for reasons already given October 15 is considered the important date for Early Blacks and November 15 the important date for Howes and odd varieties. Records in sufficient quantity to be worth averaging are available for Early Blacks for ten years and for eight years for Howes and the odd varieties. (Table 2.) So far as they go, they confirm the more general observations made by the inspectors and indicate that the Early Blacks were relatively poor in 1931 and 1933, and in 1929 and 1930 showed somewhat more loss from decay than in such years as 1926 and 1928. In such a notably poor crop as that of 1931, the Howes in the sample lots showed decidedly more loss from decay on November 15 than in the other years.

Table 2.—Average Condition of Storage Lots of Cranberries.

Variety	Number of Samples	Percentage of Rotten Berries									
		1926	1927	1928	1929	1930	1931	1932*	1933	1934	1935
						October 15					
Early Black	8 to 10	2.9	4.6	3.3	6.9	5.6	20.7	5.2	16.8	8.5	9.5
Howes	8 to 9	...	...	2.6	4.1	2.9	7.7	2.4	3.5	2.3	5.7
Odd Varieties	5 to 6	5.4	7.4	8.4	7.6	10.2	19.5	10.7	15.0	..	..
						November 15					
Early Black	8 to 10	15.0	9.6	7.4	11.0	13.1	31.0	11.9	23.9	13.1	17.0
Howes	8 to 9	...	...	6.5	9.0	6.7	14.1	6.9	5.1	4.6	11.7
Odd Varieties	5 to 6	13.4	11.2	12.2	18.0	15.6	30.5	16.0	18.6	...	...

* These figures do not include the State Bog crop. In 1932 the crop of the State Bog was, for reasons not fully understood, very poor, the percentages of rot running higher than ever before recorded on Cape Cod. The percentages including the State Bog are as follows:

	October 15	November 15
Early Black	13.2	25.2
Howes	4.5	13.6
Odd Varieties	19.3	34.0

The Margin between "Good" and "Poor" Keeping Quality

In comparing the results of actual counts of the lots held in storage (Table 2) with the general quality "appraisal" (Table 3), it should be remembered that these storage lots represent but a very small fraction of the bogs of the area. Also that the margin between "good" and "poor" crops is usually very narrow. There is always some rot. On the other hand, during even the worst years a majority of the berries are sound at marketing time.

The condition here is somewhat comparable to atmospheric or soil temperatures — a difference of 2 or 3 degrees in average daily temperature means a great difference in the weather for the year. What actually happens, of course, in years of poor keeping quality is that rot develops to a dangerous extent in some lots of fruit which in other years are usually sound. Of course, in such exceptional years as 1931 and 1933, the amount of rot is decidedly greater than in ordinary crops of poor quality. The fact remains, however, that the margin between "poor" and "good" quality is often a narrow one.

TABLE 3. — SIZE AND KEEPING QUALITY OF CRANBERRY CROP OF MASSACHUSETTS, WITH TEMPERATURE SUMMATIONS AND NUMBER OF DAYS WITH RAIN.

Year	Yield	Keeping Quality		Temperature*			Precipitation (Days)†				
	Barrels	Early Blacks	Howes	May and June	July and Aug.	Sept.	May	June	July	Aug.	Sept.
1911	298,000						—	9	8	10	16
1912	354,000	Poor	Poor	607	1,095	335	13	7	8	–	10
1913	367,000	Good	Good	522	1,152	298	12	6	8	9	10
1914	471,000	Very poor	Very poor	625	1,056	345	5	9	11	14	3
1915	257,000	Fair	Poor	512	1,094	430	—	9	14	15	5
1916	364,000	Good	Good	520	1,150	390	—	15	17	7	7
1917	137,000	Good	Good	528	1,287	246	—	13	8	10	9
1918	218,000	Good	Good	590	1,161	279	12	7	7	8	10
1919	395,000	Poor	Poor	632	1,165	364	11	6	14	12	12
1920	309,000	Very good	Very good	451	1,197	391	16	11	9	10	10
1921	208,000	Fair	Fair	595	1,132	483	14	9	10	6	7
1922	337,000	Very poor	Very poor	770	1,165	380	6	12	11	13	5
1923	451,000	Good	Good	567	973	371	5	12	8	7	8
1924	339,000	Good	Good	473	1,111	303	14	10	2	8	9
1925	447,000	Good	Good	658	1,125	361	12	10	9	5	9
1926	438,000	Good	Poor	400	1,072	275	—	11	11	8	6
1927	385,000	Good	Fair	463	1,071	358	13	14	12	14	6
1928	348,000	Very good	Good	495	1,314	342	12	15	14	7	11
1929	421,000	Poor	Poor	646	1,070	390	11	4	9	6	11
1930	395,000	Poor	Poor	722	1,054	484	12	9	8	11	4
1931	460,000	Very poor	Very poor	654	1,292	454	9	12	12	14	5
1932	415,000	Good	Good	570	1,205	354	12	10	9	7	—
1933	506,000	Very poor	Very poor	671	1,149	402	5	10	8	13	15
1934	290,000	Good	Good	679	1,209	450	15	9	5	9	15
1935	332,000	Good	Good	531	1,251	332	10	14	10	7	10

* Temperature summations above 50° F. for East Wareham, Massachusetts.
† Number of days with .01 inch or more precipitation at the Cranberry Station, East Wareham, Massachusetts.

The Trend toward Better Handling of Fruit

One other factor should be taken into consideration in connection with the estimates of keeping quality during the past years. Throughout the period under review, there has been a constant, if somewhat uneven, trend toward better handling of fruit. Among the most important changes which have occurred during this period may be mentioned the general use of trucks in hauling cranberries, both from the bog to the screenhouse and from the screenhouse to the station; the introduction of belt screens and the reconstruction of screenhouses so as to permit cold berries to pass through a warm screening room so quickly as to still remain cool; the replacement of the barrel by the ventilated half-barrel or quarter-barrel box; and some changes in bog management, notably the practice of holding the winter flowage late on bogs which have shown a tendency toward field rot.

While there is, of course, no way of measuring these factors, their existence is undoubted and it is entirely probable that a degree of unsoundness which would have caused serious trouble in 1915, for example, might be in part overcome by these methods in 1930. These changes are still going on. One of the most important recent changes is canning, which makes it possible to dispose of "tender" berries safely and profitably.

Precipitation in Relation to Keeping Quality

With reference to the growth and maturing of its fruit, the growing season for the cranberry falls naturally into three divisions. The period from the time the winter flowage water is removed up to the last of June or first of July covers the growth of the plant up to blossoming; July and August (and for the late varieties, the first three weeks in September) cover the period of growth and ripening of the fruit; harvest is confined almost exclusively to September and the early weeks of October. In any study of the weather relations of the cranberry plant, it is probable that these divisions should be considered separately — as should the winter rest period itself.

The number of rainy days in the months during which the fruit is developing, that is July and August, is apparently more closely correlated with the keeping quality than is the amount of rain. An examination of Table 3 shows that during the period under consideration, both July and August have shown more than the normal number of days with .01 inch or more precipitation in 1914, 1915, 1919, 1922, 1927, and 1931. In all these years except 1927 the keeping quality of the crop has been below the average. On the other hand, both July and August have had less than the average number of days with .01 inch or more rain in 1913, 1918, 1923, 1924, 1925, 1929, 1932, and 1934. In all these years except 1929 the keeping quality of the crops has been better than average. The exceptions are apparently explained by other factors which will be discussed below.

On the other hand, 1920 and 1928, the years of the two soundest crops in the period, were characterized by approximately the normal number of days with rain for July and August — which suggests that an abundant and well-distributed rainfall is not necessarily followed by an unusual amount of rot in the fruit, provided other factors are favorable.

One surprising feature which has developed in this connection is the lack of correlation between keeping quality and amount of rain in September. It has long been believed that storing berries wet injures keeping quality and a rainy harvest period is supposed to be dangerous to the crop. Yet three of the four poorest years on record, 1914, 1922, and 1931, have had noticeably few rainy days in September. In the fourth year, 1933, on the other hand, September had 15 days with rain and a total precipitation of 12.15 inches.

Temperature in Relation to Keeping Quality

Between climatic temperatures at certain periods and the keeping quality of the crop there is a correlation so constant as to make it appear highly probable that there is some causal connection. Temperature in Table 3 is expressed as a simple summation of "day degrees" above a minimum of 50° F.; that is, in computing the figures, 50 is subtracted from the mean temperature of each day and the remainders are added together. Fifty was chosen as a zero point because many important cranberry fungi begin active growth at about this temperature.

A study of the table shows that in 1912, 1914, 1919, 1922, 1929, 1930, 1931, and 1933, all years in which the Early Blacks showed an unusual amount of decay, the temperature for May and June was unusually high. In all cases the summation was above 600. Moreover, these were the only years in which this variety is known to have shown an unusual amount of decay. On the other hand, in those years when the temperature for May and June was lower, the keeping quality of the Early Blacks was much better.

High temperatures during September and early October are well known to favor the decay of cranberries in storage. In 1913, 1917, 1918, and 1926, all good years for Early Blacks, the September temperatures were cool; whereas in 1915 and 1921, with very high temperatures in September but favorable conditions in May and June, the condition of the Blacks was reported as only fair.

In all the years in which the keeping quality of the Early Blacks was poor, namely, 1912, 1914, 1919, 1922, 1929, 1930, 1931, and 1933, the Howes also showed poor keeping quality. In addition, the Howes were relatively inferior to the Early Blacks in 1915 and 1926 and somewhat inferior in 1927. The reason for this is not entirely clear, but it seems possible that high temperatures in July and August are usually necessary for satisfactory development of Howes cranberries. At least, in all the years except one in which the summations for July and August fell below 1100, the Howes were either poor or decidedly inferior to the Early Blacks, that is, in 1912, 1914, 1915, 1926, 1927, 1929 and 1930. It must be admitted, however, that in general the keeping quality of the Howes corresponds less definitely with temperature conditions during the growing season than does the keeping quality of the Early Blacks. This is not surprising in view of the fact that the Howes are kept much later than are the Early Blacks.

Size of Crop in Relation to Keeping Quality

One of the first correlations which appeared when the present study was undertaken was an apparent relation both in Massachusetts and in New Jersey between exceptionally large crops and unusually poor keeping quality. At the time it seemed possible that the size of the crop might influence the estimates of the keeping quality, as some part of a large crop is usually held a longer time in storage. Since 1926, however, the keeping quality of the crop has been measured with some degree of accuracy by means of test lots held in storage, and it is apparent that the keeping quality of the exceptionally large (460,000 barrel) crop of 1931 fell much below what might have been expected as compared with crops of the previous years. The only other crop of equal size, 1914, was the poorest prior to 1930. The very best crops, those of 1920 and 1928, have been relatively small—both less than 355,000 barrels.

On the basis of the observations summarized above, the worst possible combination of circumstances from the standpoint of keeping quality would be high temperature in May and June, a greater than normal number of days having .01 inch or more of rain in both July and August, and an unusually large crop. This combination of factors has occurred twice in the last twenty-five years — in 1914 and in 1931 — years which will long be remembered by those interested in cranberries in Massachusetts because of the poor keeping quality of the fruit.

The Interrelation of the Different Factors

In such a study as the present, in which accurately controlled experiment is impossible and evidence even by observation must be slowly accumulated, it is not possible to evaluate very accurately the various factors concerned. Field observation indicates that in determining the keeping quality of the general crop, the May and June temperature is the most important of the factors considered; distribution of rainfall and temperature in July and August come next; and the size of the crop third.

The charts, Figures 1 and 2, are designed to show the combined influence of temperature during May and June and frequency of rainfall during July and

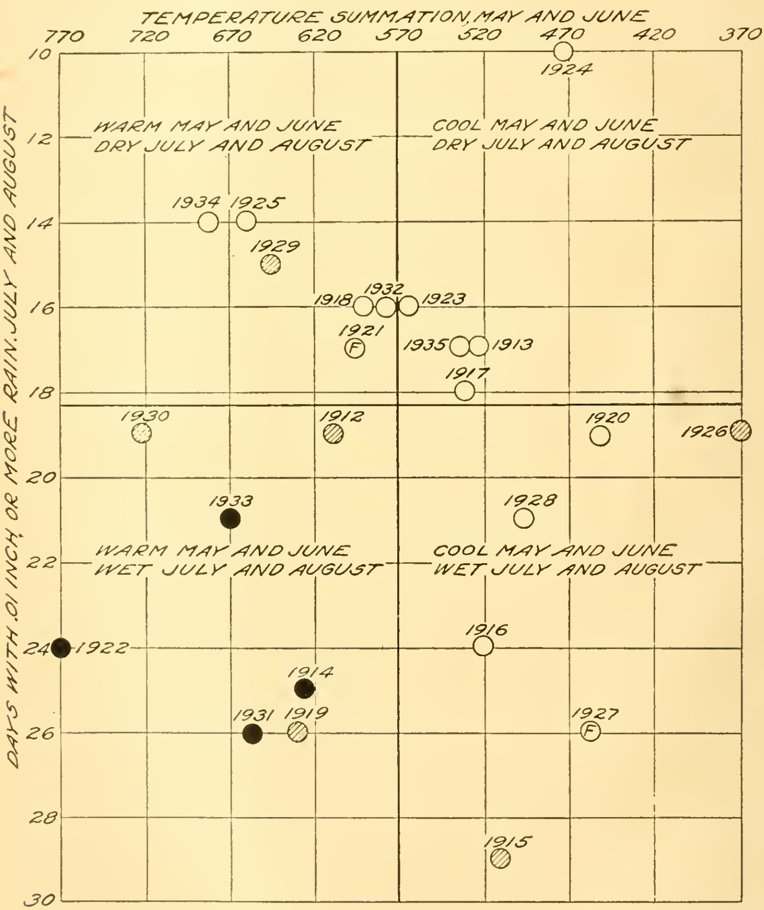

Figure 1. Temperature during May and June, Frequency of Rainfall during July and August at East Wareham, Massachusetts, and the Relative Abundance of Fruit Rots in Cranberries of the Howes Variety in the Massachusetts Crops, 1912–1935.

Black Circles — exceptionally large losses from fruit rots.
Shaded Circles — losses from fruit rots larger than normal.
Circles with F — fair keeping quality.
Unshaded Circles — slight losses from fruit rots.

August on the keeping quality of the two most important varieties, the Early Black and the Howes. The abscissas represent temperature in May and June, here computed as a summation of day degrees above 50° F.; and the ordinates, the number of days with .01 inch or more of rain during July and August. The heavy lines indicate approximately the normals. The upper right-hand portion thus includes those years having cool springs followed by summers with less than the average number of days with .01 inch or more of rain; and the lower left-hand portion, those years having unusually warm springs followed by summers with more than the average number of days with .01 inch or more of precipitation. The abundance of fruit rots or, in other words, the keeping quality of the given variety each year, is indicated by symbols.

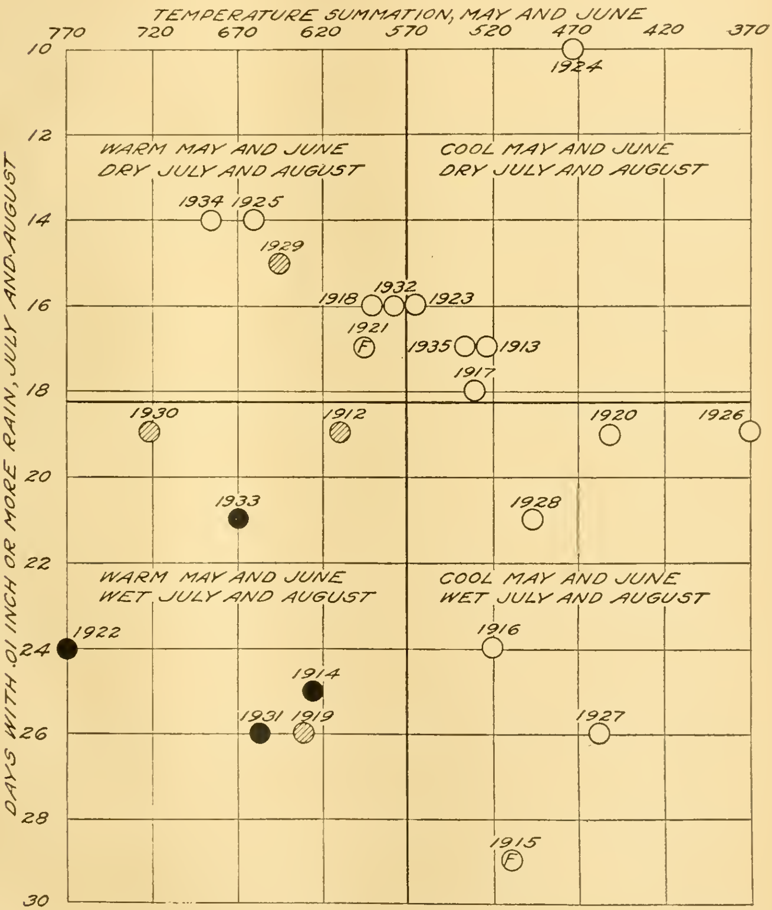

Figure 2. Temperature during May and June, Frequency of Rainfall during July and August at East Wareham, Massachusetts, and the Relative Abundance of Fruit Rots in Cranberries of the Early Black Variety in the Massachusetts Crops, 1912–1935.

Black Circles — exceptionally large losses from fruit rots.
Shaded Circles — losses from fruit rots larger than normal.
Circles with F — fair keeping quality.
Unshaded Circles — slight losses from fruit rots.

It will be noted in Figure 1, which deals with the Howes variety, that the four very bad years of record, 1914, 1922, 1931, and 1933, all fall in the group having warm May and June and more than average number of days of rain in July and August; and that the three other years in this group all had poor keeping quality. On the other hand, in the group having warm May and June but relatively dry July and August, there are one poor, one fair, and four good years; and in the group having a cool spring but frequent rain during July and August, two poor, one fair, and three good years. The fourth group, that having a cool spring and relatively dry July and August, on the other hand, contains thus far only years having crops of high keeping quality.

A similar chart, Figure 2, based on the keeping quality of the Early Black variety shows a somewhat larger number of years when quality was above average, but no other difference.

To determine how often before 1916 there had occurred weather of the type we now believe to be unfavorable to the keeping quality of the cranberry crop, a chart has been prepared (Figure 3) which shows the distribution of the various years as to the weather conditions already discussed; that is, the temperature in May and June, here expressed as the sum of the monthly mean temperature, and the number of days with .01 inch or more of rain in July and August, based on weather observations made at Middleboro, Massachusetts, during the period 1889 to 1915. This weather observation station, while not located near a cranberry bog, was considered sufficiently representative to serve the purpose. Five years, 1887, 1889, 1896, 1906, and 1914, fell within the group having weather believed to favor the increase of rot-producing fungi.

In Figure 3 has also been included such information as could be obtained regarding the keeping quality of the crop of these years. For obvious reasons unusual abundance of diseases is more likely to be made a matter of record than unusual freedom from disease. That is, a crop of poor quality is more likely to be recorded than one of high quality. Such records of epidemics of fruit rots of cranberries prior to 1912 as could be found are in an early paper by Halsted[7] and in the Proceedings of the American Cranberry Growers' Association, which, although its headquarters and most of its officers were in New Jersey, at that time numbered among its members growers from other states and maintained a lively interest in the crops of those states. From the records of this Association it is evident that the crop of 1889 was of exceptionally poor keeping quality in both New Jersey and Massachusetts, much like the crops of the more recent years of 1914 and 1931. From Halsted's paper it appears that the cranberry crop was considered of poor keeping quality in Massachusetts and Connecticut in 1883, 1887, and 1888, though apparently not so bad as in 1889.

Of the five years in this period which fall in the group having warm May and June and wet July and August, two, 1889 and 1914, are known to have had crops of very poor keeping quality, and one, 1887, a crop of poor quality. The other years known to have produced crops of poor quality, 1888, 1912, and 1915, fell in one of the groups having one unfavorable factor.

It would be of great interest if records could be obtained for the years 1896 and 1906, as well as for the two falling close to this group, 1901 and 1905. Such records are not directly available, but what is known of the crops of those years in New Jersey furnishes indirect evidence that the losses from rot for the years 1901 and 1906 at least may have been larger than normal. While the cranberry crops of Massachusetts and New Jersey vary, as regards their keeping quality,

[7]Halsted, B. D. Some fungus diseases of the cranberry. N. J. Agr. Expt. Sta. Bul. 64, 40 pp., 1889.

to some extent independently of each other, it has been observed during the last twenty years that when the crop of either State has been conspicuously poor in keeping quality, the crop of the other State has been below normal in this respect. It may then be worth while to note that the cranberry crop of New Jersey is known to have been of unusually poor keeping quality in 1901 and 1906.

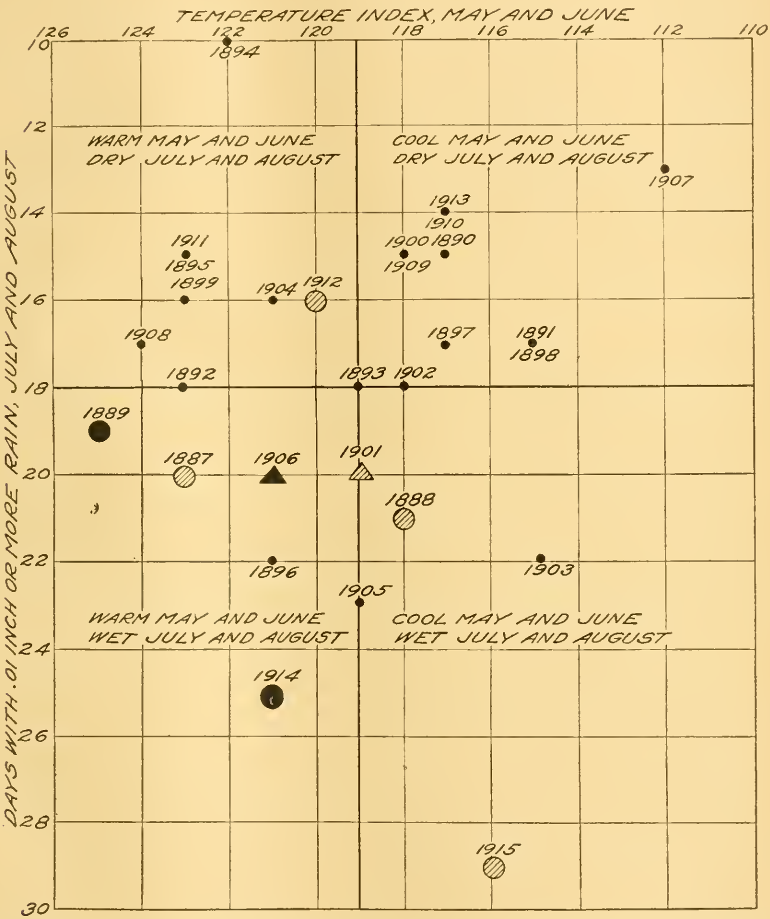

Figure 3. Temperature during May and June Frequency of Rainfall during July and August at Middleboro, Massachusetts 1887 to 1915, and Relative Abundance of Fruit Rots in Cranberries so far as Records are Available.

Black Circles — exceptionally large losses from fruit rots.
Shaded Circles — losses from fruit rots larger than normal.
Black Triangles — keeping quality very poor in New Jersey; no record for Mass.
Shaded Triangles — keeping quality poor in New Jersey; no record for Mass.
Black Dots — no records of keeping qualily available.

The Experiment in Forecasting

Beginning in 1923, following the publication of the first discussion of the apparent relation between weather and keeping quality, the writer undertook to make experimental forecasts of keeping quality in the Wareham-Carver area in Massachusetts. The reasons for choosing this region are obvious. This was the area in which Mr. Griffiths' inspections had been made and to which his estimates would most nearly apply, and the presence of the cranberry station made available weather records taken with special reference to cranberry growing.

At the outset, it was determined to publish the forecasts, not because of any practical value which they might have but because of general interest in the subject and to avoid any suggestion of partiality to special interests. From 1923 to 1928 the forecasts were published in the Wareham Courier, the official organ of the Cape Cod Cranberry Growers' Association. At first, a general forecast was made between September 10 and 15; but beginning in 1927, separate forecasts were issued for the early and late berries, the first between September 10 and 15 and the second between October 1C and 15.

With a single exception, these forecasts were substantiated by the subsequent behavior of the berries. This exception was an unusual amount of rot which occurred in the Howes of this region in the crop of 1926. The poor keeping quality of the Howes in this year was due, in the opinion of many competent observers, to the fact that in 1926 the Howes were picked unusually green and it is well recognized that this is unfavorable to best results with this variety. Even aside from any such explanation, the record is far better than could have been expected in view of the difficulty and the uncertainty involved where so many only partly understood factors are operative.

To a certain extent the publication of these "forecasts" tended to obscure the results of the experiment. Many cranberry growers, as well as inspectors and sales agents, were much interested in the work and kept in close touch with it and their actions were to some extent influenced by the published forecasts. For example, it was inevitable that, after the forecast of relatively poor keeping quality made in the fall of 1929, there should be unusual care exercised on the part of inspectors and the most interested shippers in Plymouth County. Several lots of berries known to be of poor keeping quality were sent to the cannery at once and others were handled by consignment to nearby markets. This was, of course, highly desirable but to a certain extent it obscured the accuracy of the results.

On the basis of the experience of these thirteen years, one might well conclude that it is possible to forecast with a fair degree of accuracy the keeping quality of the cranberry crop of Plymouth County from a study of the weather alone; but in practice it would no doubt always be safer to check this by actual tests of sample lots of the berries themselves: not only for the purpose of having an additional check on the crop as a whole but because this would make it possible to determine the variation in the keeping quality of berries from individual bogs. Because of the close relation of the two subjects, a discussion of incubator tests is included in the present paper.

Incubator Tests of Keeping Quality

In his annual report as chairman of the Board of Inspectors for the New England Cranberry Sales Company, 1922, in discussing the problem of distributing berries in such a way that rejections would be reduced to a minimum, Mr. Griffith said: "I believe the ultimate solution of this problem rests in the development of some method of testing berries by which we may determine their keeping qualities."

Mr. Griffith was already at work with tests designed to this end and Dr. Franklin had also made tests by storing lots of cranberries in long glass tubes. The unusually poor keeping quality of the crop in 1922 emphasized the need of such work, and following these leads, the writer began testing series of samples of cranberries gathered from different bogs in the Wareham-Carver area.

The test was modified slightly from year to year and as the work progressed a larger number of samples was included and the work carried later in the season. As at present used, the incubator test is as follows: Pint samples of sound cranberries are placed in open cartons and held in an incubator for one week. During the first two weeks in September the incubator is held at 86°–88° F. (30°–31° C.), during the last two weeks in September at 81°–83° F. (27°–28° C), and after October 1 at 75°–77° F. (24°–25° C). The only test which has been followed up consistently since the beginning of the work is that which has been made during the first and second weeks of September on samples from a series of selected bogs in Wareham and Carver. The results of this are given in Table 4. Figures in this table are, in almost all cases, an average of the two tests, one made the first and one made the second week in September. These figures show the range in percentage of decay which has actually occurred during thirteen years.

TABLE 4.—RESULTS OF INCUBATOR TESTS AT EAST WAREHAM, MASS., DURING THE FIRST TWO WEEKS OF SEPTEMBER.

Tests lasted for one week; temperature 30°–31° C. (86°–88° F.).

Variety	Bog No.	Percentage of Rotten Berries												
		1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
Early Black	1	3.5	0.1	0.1	0	3.0	0.5	2.0	0.8	1.5	0.5	2.4	0.2	0.5
	2	0	1.1	0.5	0	0.6	1.5	0.5	1.0	0	0	0.4	0	0.3
	3	0	0	0	0	0	0	0	1.0	0	0	0.6	0.2	0.2
	4	1.0	0	0.5	0	2.2	0.2	4.0	2.3	1.7	7.0	2.8	0.8	7.0
	5	..	..	..	0	1.3	0.4	1.8	2.0	4.6	2.0	2.9	1.4	4.0
	6	..	..	..	0.2	0.7	0	2.0	0.7	0.5	0.6	0.3	6.4	2.0
	8	0.4	1.1	0	0	0.4	0	0.8	0.2	9.2	1.7	1.0	0.2	0.4
	10	1.8	0.2	0.2	0	0.8	0	3.2	0.4	3.3	2.0	1.3	1.7	5.0
	A	0	0	0	0.2	4.5	0.3	5.2	9.4	5.0	0.5	0	1.5	0
	B	0.1	0.1	0	0	0.4	0	0	1.0	0.3	4.0	0.8	0.6	0
	C	0.8	0.8	1.0	2.0	1.0	2.0	4.2	3.2	4.0	0.7	5.4	0.6	0.4
	D	0	0	..	0	0	0.4	3.2	0.5	2.0	0.6	0.4	0.8	0.5
	E	0.2	0	0	0	0.4	..	..	..	0.4	2.0	1.6	0	0
	F	0	0	0	0	0	0.6	1.3	0.4	0	0.4	0.3	0	0
	G	0	0	0	0.4	0	0.4	0.7	2.8	4.6	0.7	4.9	0.4	1.0
	H	0	0	0	0	1.5	0	0	1.2	0.5	0.2	0.2	0.6	0
	I	0	0	0.3	0	0	0	0	0.8	0	0.5	1.2	0	0.5
	J	0.2	0	0	0	0.5	0	0.9	0.7	0.7	3.0	2.6	2.8	0.5
	K	..	..	..	1.5	2.2	0	2.7	1.9	2.4	2.0	9.5	0	0.2
Stanley	L	1.0	0	1.4	1.8	1.9	0.3	3.3	0.3	0	1.5	6.2	1.0	0
Mammoth	12	..	..	..	0	1.0	0	2.1	1.8	0.3	0	1.2	0.3	1.5
McFarlin	14	0.8	0	0.3	0	0.5	0.2	1.2	0.3	2.0	6.5	5.8	3.2	1.3
Searls	16	0	0	0	0.3	0	0.3	0.8	2.0	0.7	2.0	2.0	0	0
Middleboro	17	..	..	4.0	0	4.1	6.0	8.0	3.3	21.3	22.0	26.4	15.0	..
Howes	19	..	..	..	0	1.7	2.0	2.0	0.8	0	0.7	0.2	0	1.5
	25	0.2	0	0	0	1.5	0	2.4	0.4	0.3	5.0	0	0.4	1.0
	N	..	..	..	..	..	0	0	0	2.0	1.8	0	2.8	0.7
	O	0.2	0	1.0	0	0.5	0	1.0	0.5	..	6.0	1.1	0.7	1.3
	P	..	..	..	0.5	0.6	0.2	0.9	0.4	1.0	1.6	0.2	1.0	0.5

TABLE 5.—RESULTS OF INCUBATOR TESTS AT EAST WAREHAM, MASS., OCT. 1-7
Temperature 25° C. (77° F.)

Variety	Bog No.	Percentage of Rotten Berries 1926	1928	1929	1930	1931	1932	1933	1934	1935
Early Black	2	3.5	1.5	..	2.5	3.7	5.2	0	4.0	1.0
	3	2.5	1.1	1.0	2.7	4.8	3.1	4.2	1.7	1.5
	4	..	0.8	5.0	3.9	32.0	36.2	1.4	14.6	21.0
	5	4.0	0.5	..	4.7	12.9	5.4	4.8	7.4	9.5
McFarlin	14	5.0	2.0	8.0	8.4	13.4	5.0	5.1	6.5	5.0
Searles	16	4.7	0	..	1.7	4.0	19.0	0.6	..	..
Howes	18	..	0.4	4.5	24.1	10.0	9.6	0	16.1	5.0
	19	16.0	..	14.0	5.8	2.2	3.5	0.4	1.0	2.0
	20	..	0	6.0	4.0	..	0.8	1.4	4.1	20.0
	23	..	1.0	14.0	3.5	5.1	2.8	0.9	0.5	6.0
	25	14.0	0	24.0	9.5	17.7	3.3	0.5	0.8	9.5

In an endeavor to determine the most satisfactory conditions for such incubator tests, those made after September 15 were varied from year to year as to both dates and temperatures. They are, therefore, usually not strictly comparable. Table 5, however, gives the results of certain tests made the first week in October, 1926 and 1928–1935, which are comparable as to variety, bog, and temperature.

From this experience with incubator tests in the Cape Cod area, the following conclusions seem to be justified:

> In general, under Cape Cod conditions, such an incubator test serves to pick out the weak lots of cranberries with a high degree of accuracy.
>
> The nearer to time of shipment a lot can be tested, the more trustworthy are the results of the test; conversely, an incubator test made early in the season gives relatively little indication of conditions later.
>
> A wider divergence between lots is usually apparent later in the season than early in September.
>
> Incubation for one week seems to give as satisfactory results as a longer period, such as ten days or two weeks.
>
> The temperature of the incubator should be lowered as the season advances to correspond somewhat with storage temperatures and especially to make allowance for the difference in the temperature relations of the fungi which characteristically develop at that period. (See page 69, under heading "The Storage Period for the Different Varieties.")
>
> In determining keeping quality of the crop for a single bog or a single storage lot, the incubator test is apparently very useful. In attempting to forecast the crop for an entire region, it constitutes a valuable check on weather data.

These keeping tests have taken on an added significance with the growth of the preserving industry. It is obviously to the advantage of all for the cranberries which go into cans to be those which, while of very high quality at the time, are least fit for the handling and shipping they must undergo to reach the fresh fruit market.

Supplementary Note, January 1943

In the seven years which have elapsed since the foregoing manuscript was completed, the general interest in the keeping quality of cranberries has somewhat slackened. This is in large part due to the increased importance of canning, which offers an immediate outlet for cranberries which are of excellent quality at the time but might prove too weak for satisfactory shipment as fresh fruit.

In the crop just marketed, that of 1942, there was sufficient loss from decay in the Early Black variety in Massachusetts to cause comment in the November number of CRANBERRIES. The same condition was reported regarding part of the New Jersey crop. While no figures are available which make accurate comparison possible, correspondents in the Massachusetts cranberry region indicate that it is reasonably certain that there were greater losses from decay in the Massachusetts crop in 1942 than in any crop since that of 1933.

In view of this information, it seemed worth while to compile the weather data for East Wareham, Massachusetts, for the years 1936–1942. This is presented below on the same basis as in Table 3.

Comparison of the figures here given with those in Table 3 will show at once that 1942, which produced the crop of "poorest keeping quality since 1933," had fairly frequent rainfall in July and August combined with a May and June *warmer than any other except* 1922 in the period under survey.

Anyone "forecasting" the keeping quality of the Massachusetts crop in September 1942 would have unhesitatingly predicted very poor keeping quality.

ESTIMATED SIZE OF MASSACHUSETTS CRANBERRY CROP AND WEATHER DATA FOR EAST WAREHAM.

Year	Estimated Yield Barrels	Temperature*			Precipitation (Days)†				
		May and June	July and August	Sept.	May	June	July	Aug.	Sept.
1936	360,000	621	1,155	331	5	9	8	9	7
1937	475,000	631	1,378	322	13	14	3	8	9
1938	325,000	560	1,331	335	12	11	14	10	6
1939	390,000	600	1,297	368	9	7	8	9	8
1940	332,000	522	1,091	326	13	14	9	8	10
1941	510,000	642	1,173	396	11	8	13	11	3
1942	525,000	753	1,205	404	8	11	6	10	8

*Temperature summations above 50°F. for East Wareham, Massachusetts.
†Number of days with .01 inch or more precipitation at the Cranberry Station, East Wareham, Massachusetts.

MISCELLANEA

By Henry J. Franklin,
Research Professor in Charge of the Cranberry Station

The following material has interesting relations to other studies in this bulletin and is therefore presented with them.

WEATHER AND CRANBERRY SIZE

Henry Griffith Data

The late Henry S. Griffith, for many years chief inspector for the New England Cranberry Sales Company, did considerable research in connection with his duties. He made records and calculations of the size of cranberries in his inspection district, the township of Carver. In February 1930, he sent a summary of his findings up to and including 1929 to the writer, and this, together with his later calculations[1] and his letter of transmittal, follows:

Dear Dr. Franklin:

I am enclosing a complete record of the size of the cranberries for the years that I made and kept a calculation. You will notice I skipped the years 1920 and 1921 for which I am now sorry. These calculations were made only on the lots that came under my observation with the exception of one year in which Mr. Besse (S. A.)[2] gave me the results of his inspections.

In making the calculation I called the lot the unit, but nearly all of the lots were car-loads. In the case of Blacks I called lots in which the cup count[3] was below 110 as large; between 110 and 120 as average; above 120 as small. In the Howes I called lots in which the cup count was below 100 as large; between 100 and 110 as average; above 110 as small.

Sincerely yours,
HENRY S. GRIFFITH

Year	Early Black Variety			Howes Variety		
	Large Percent	Average Percent	Small Percent	Large Percent	Average Percent	Small Percent
1918	20	44	36	25	33	42
1919	8	47	45	50	47	3
1922	80	17	3	82	16	2
1923	8	30	62	23	17	60
1924	49	27	24	50	40	10
1925	48	33	19	58	40	2
1926	15	50	35	12	63	25
1927	46	35	19	62	31	7
1928	46	43	11	37	40	23
1929	40	45	15	52	41	7
1930	18	52	30	49	26	25
1931	67	22	11	64	29	7
1932	30	44	26	34	50	16
1933	52	40	8	56	42	2
1934	40	45	15	43	45	12
1935	43	53	4	30	57	13
16-year average	38	39	23	45	39	16

[1] Published in annual reports of the New England Cranberry Sales Company.
[2] The Sales Company inspector for the Wareham district.
[3] The cup used was the standard inspector's cup of the Sales Company.

For the computation of comparative indices of size, the writer has assumed that the approximate average cup counts of the different sizes in these calculations were as follows:

Size	Average Cup Counts	
	Early Black	Howes
Large	105	95
Average	115	105
Small	125	115

The annual indices were computed by multiplying these cup counts by their respective percentages in each year, adding the three products, and dividing the sum by ten. The results appear in Table 1.

Table 1 gives the following correlations between the several weather elements and cranberry size:

	Correlation Coefficients*	
	Early Black	Howes
Hours of Sunshine (December + January)	-0.671 ± 0.093	-0.393 ± 0.142
Temperature (Mean for March)	-0.368 ± 0.146	-0.606 ± 0.107
Rainfall (August)	-0.320 ± 0.151	-0.629 ± 0.102

*The coefficients of correlation are minus quantities because cup-counts are inverse measures of size.

C. D. Stevens Data

Beginning in 1926, the Boston office of the Bureau of Agricultural Economics, C. D. Stevens in charge, has tabulated data on the size of Massachusetts cranberries, all varieties together, from growers' reports made in August, October, and November. These three tabulations agree fairly well for the most part, but, all things considered, the one for October seems likely to be rather more accurate than the others. It has therefore been used here and is given in Table 2. Comparative yearly indices of size for computing correlations were obtained from this tabulation by subtracting the various percentages of "small" berries from their respective percentages of "large" berries.

Table 2 gives the following correlations between the several weather elements and cranberry size:

	Correlation Coefficients
Hours of Sunshine—December	$+0.442 \pm 0.128$
January	$+0.541 \pm 0.112$
December and January together	$+0.613 \pm 0.099$
Temperature (mean for March)	$+0.632 \pm 0.095$
Rainfall—August	$+0.384 \pm 0.135$
September	$+0.325 \pm 0.142$
August and September together	$+0.497 \pm 0.120$

TABLE 1.—RELATION OF SUNSHINE, TEMPERATURE, AND RAINFALL TO SIZE OF CRANBERRIES.

	Hours of Sunshine (Average of Boston and Providence)				Temperature (Middleboro)		Rainfall (Average of Middleboro, E. Wareham, and Plymouth)		Size of Berries (Henry Griffith Data)			
									Early Black		Howes	
	Dec.	Jan.	Sum of Dec. and Jan.	Departure from Average	Mean for March °F.	Departure from Average	Aug. Inches	Departure from Average	Index*	Departure from Average	Index*	Departure from Average
1918......	136	166	302	+13	33.9	−1.9	2.01	−2.43	1,166	+31	1,067	+46
1919......	118	134	252	−37	38.1	+2.3	7.07	+2.63	1,187	+52	1,003	−18
1922......	140	185	325	+36	37.0	+1.2	10.64	+6.20	1,073	−62	970	−51
1923......	108	130	238	−51	33.8**	−2.0	2.22	−2.22	1,204	+69	1,087	+66
1924......	125	181	306	+17	34.1	−1.7	7.89	+3.45	1,125	−10	1,010	−11
1925......	143	144	287	−2	39.4	+3.6	2.13	−2.31	1,121	−14	994	−27
1926......	140	122	262	−27	31.6	−4.2	2.79	−1.65	1,170	+35	1,063	+42
1927......	150	140	290	+1	38.6	+2.8	10.50	+6.06	1,123	−12	995	−26
1928......	153	200	353	+64	35.3	−0.5	1.50	−2.94	1,115	−20	1,036	+15
1929......	165	176	341	+52	39.5	+3.7	4.17	−0.27	1,125	−10	1,005	−16
1930......	128	120	248	−41	34.8	−1.0	2.74	−1.70	1,162	+27	1,026	+5
1931......	125	191	316	+27	36.3	+0.5	5.36	+0.92	1,094	−41	993	−28
1932......	133	113	246	−43	33.2	−2.6	4.61	+0.17	1,146	+11	1,032	+11
1933......	154	175	329	+40	34.5	−1.3	3.67	−0.77	1,106	−29	996	−25
1934......	98	132	230	−59	33.9	−1.9	2.06	−2.38	1,125	−10	1,019	−2
1935......	149	155	304	+15	38.3	+2.5	1.60	−2.84	1,111	−24	1,033	+12
Sum....			4629		572.3		70.96		18,153		16,329	
Average			289		35.8		4.44		1,135		1,021	

* See page 85.
** Average of maximum temperatures at Brockton and minimum temperatures at Middleboro.

TABLE 2.—RELATION OF SUNSHINE, TEMPERATURE, AND RAINFALL TO SIZE OF CRANBERRIES.

Year	Hours of Sunshine (Average, Boston and Providence)						Temperature (Middleboro)		Rainfall, Inches (Average, Middleboro, E. Wareham, and Hyannis)						Size of Berries (All Varieties — C. D. Stevens Data)				
	Dec.	Departure from Average	Jan.	Departure from Average	Sum of Dec. and Jan.	Departure from Average	Mean for March °F.	Departure from Average	Aug.	Departure from Average	Sept.	Departure from Average	Sum of Aug. and Sept.	Departure from Average	Percentages from Growers' Reports for October: Large	Medium	Small	Index (Large less Small)	Departure from Average
1925...	143	+10	144	−5	287	+4	39.4	+3.5	2.34	−1.33	3.86	−0.51	6.20	−1.84	48*	50*	2*	+46	+31
1926...	140	+7	122	−27	262	−21	31.6	−4.3	2.94	−0.73	1.29	−3.08	4.23	−3.81	10	59	31	−21	−36
1927...	150	+17	140	−9	290	+7	38.6	+2.7	8.62	+4.95	3.42	−0.95	12.04	+4.00	40	47	13	+27	+12
1928...	153	+20	200	+51	353	+70	35.3	−0.6	0.93	−2.74	5.58	+1.21	6.51	−1.53	33	61	6	+27	+12
1929...	165	+32	176	+27	341	+58	39.5	+3.6	5.66	+1.99	4.89	+0.52	10.55	+2.51	33	62	5	+28	+13
1930...	128	−5	120	−29	248	−35	34.8	−1.1	2.07	−1.60	0.30	−4.07	2.37	−5.67	11	69	20	−9	−24
1931...	125	−8	191	+42	316	+33	36.3	+0.4	4.33	+0.66	1.81	−2.56	6.14	−1.90	47	53	0	+47	+32
1932...	133	0	113	−36	246	−37	33.2	−2.7	3.77	+0.10	6.15	+1.78	9.92	+1.88	15*	71*	14*	+1	−14
1933...	154	+21	175	+26	329	+46	34.5	−1.4	3.56	−0.11	12.72	+8.35	16.28	+8.24	49	47	4	+45	+30
1934...	98	−35	132	−17	230	−53	33.9	−2.0	2.24	−1.43	2.14	−2.23	4.38	−3.66	17	70	13	+4	−11
1935...	149	+16	155	+6	304	+21	38.3	+2.4	1.49	−2.18	5.32	+0.95	6.81	−1.23	27	63	10	+17	+2
1936...	127	−6	171	+22	298	+15	43.2	+7.3	5.46	+1.79	7.23	+2.86	12.69	+4.65	28	64	8	+20	+5
1937...	115	−18	112	−37	227	−56	32.6	−3.3	4.67	+1.00	5.11	+0.74	9.78	+1.74	26	52	22	+4	−11
1938...	153	+20	142	−7	295	+12	38.2	+2.3	2.26	−1.41	6.38	+2.01	8.64	+0.60	23	66	11	+12	−3
1939...	134	+1	125	−24	259	−24	33.1	−2.8	3.62	−0.05	3.60	−0.77	7.22	−0.82	9	80	11	−2	−17
1940...	106	−27	175	+26	281	−2	31.6	−4.3	0.84	−2.83	5.20	+0.83	6.04	−2.00	10	53	37	−27	−42
1941...	96	−37	128	−21	224	−59	32.3	−3.6	4.02	+0.35	0.44	−3.93	4.46	−3.58	16	74	10	+6	−9
1942...	130	−3	166	+17	296	+13	39.1	+3.2	7.23	+3.56	3.14	−1.23	10.37	+2.33	45	48	7	+38	+23
Sum...	2399		2687		5086		645.5		66.05		78.58		144.63					+263	
Average	133		149		283		35.9		3.67		4.37		8.04					+15	

* August growers' reports (no October reports).

Summary and Conclusions

The only relations between weather and cranberry size that seem from this study to be important are shown in the correlations of Tables 1 and 2, and are the following.

1. *Sunshine of December and January.* A high correlation was found between this factor and size of berries, from the data of both Griffith and Stevens. It appears from this material that the chances are 7 to 1 that Massachusetts cranberries will be large when there have been over 300 hours of sunshine in December and January, and are 9 to 1 that they will be small when there have been less than 270 hours of sunshine in those months. This seems to support strongly the findings of Bergman given in this bulletin and to be especially significant as it has to do with a period when the cranberry bogs are mostly under ice-covered water and sunshine is at its yearly minimum in duration and intensity. The correlations of Table 1 suggest that this sunlight relation may be more important with the Early Black than with the Howes variety. There is a hint here that ice-sanding cranberry bogs early in the winter may tend to stunt the berries (pp. 11 and 28).

2. *Mean Temperature of March.* There was a high correlation between the temperature of March and cranberry size, the apparent chances being 7 to 1 that cranberries will be large after a March mean temperature above 38° at Middleboro, and 8 to 1 that they will be small after this temperature has been below 34°. March is normally the month in which the ice disappears from the winter flood of the cranberry bogs in southeastern Massachusetts, and the time of its leaving depends on the prevailing temperatures. It appears from these correlations that the earlier the ice is melted the larger the cranberries are likely to be.

3. *August Rainfall.* A considerable correlation was found between August rainfall and cranberry size, and Table 2 suggests that the rainfall of September may also be a factor. The results of experiments reported heretofore[4] support the evidence from these rainfall correlations.

The various correlations suggest that the winter and spring weather elements considered affect cranberry size fully as much as does rainfall, within the usual limits, during the growing season. No clear evidence was found of any relation between June or July rainfall and cranberry size. As good size is an important quality in cranberry marketing, it is probably often advisable to irrigate to obtain it; but it does not appear from these studies that material advantage is likely to be gained by doing this before the berries are set and well started in growth. This seems to fall in with the common grower experience.

CRANBERRY SIZE AND KEEPING QUALITY

The available evidence indicates that crops of cranberries of much greater than average size seldom keep well. The crops of 1922, 1925, 1931, 1933, and 1942 were of definitely larger berries than those of the other years since 1917, and all of those crops except that of 1925 were outstandingly poor in keeping quality. The summer of 1925 was very dry throughout, the mean temperature during the cranberry storage season was abnormally low, and the berries went to market promptly in response to a brisk demand.

[4]Mass. Agr. Expt. Sta. Bul. 271:250, 1931.

SIZE OF BERRIES AND SIZE OF CROPS

Some large cranberry crops (e. g., those of 1923, 1926, and 1937) are of small berries; but crops of berries much larger than normal (e. g., those of 1922, 1925, 1931, 1933, and 1942) probably are never small unless they have been much reduced by such accidents as frost or winterkilling. Size of berries is evidently related to crop size, but the factors that affect it often fail to work in unison with others equally important that determine crop totals.

WEATHER AND CRANBERRY RIPENING

The only relations between the weather and the time of cranberry ripening found interesting are set forth in Table 3. The dates of the first full-car shipments of the Early Black variety by the New England Cranberry Sales Company, kindly provided by the management, were used to index the times of ripening. No work with other varieties was attempted because of obvious difficulties and irregularities.

Table 3 gives the following correlations between temperature and time of ripening:

	Correlation Coefficients
March	+0.384 ± 0.096
April	+0.512 ± 0.083
May	+0.335 ± 0.10
June	+0.434 ± 0.091
August	−0.494 ± 0.085
The spring months (March + April + May)	+0.592 ± 0.073
The spring months + June	+0.614 ± 0.07
Balance between the spring months + June and August (March + twice April + May + June − twice August)	+0.732 ± 0.052

The mean temperatures of each of the three spring months and of June show a positive and that of August a negative relation to the time of ripening. April and August are about equal and more important than the other months in their influence, and the spring months together more important than August alone. A correlation coefficient fourteen times the probable error appears when the five months involved are roughly weighted according to their probable importance, shown by their individual correlations, and August is balanced against the other months together. This is convincing evidence that this relation is real and suggests strongly that it is the main one that determines the time of ripening of Early Black cranberries. This conclusion may seem to contradict the results of some experiments[5] which showed earlier ripening as a consequence of watering during a drouth; but other findings[6] suggest that this effect came about through the lowering of temperature by evaporation. The negative correlation of August fits in nicely with the temperature effects on cranberry coloring obtained in the storage experiments.

July temperature shows no relation to the time of ripening. Cranberry vines in that month, being in bloom and setting their fruit, probably are in a condition of transition or balance between the earlier temperature influence and that of August.

[5]Mass. Agr. Expt. Sta. Bul. 271:250, 1931.
[6]Mass. Agr. Expt. Sta. Bul. 293:23-24, 1933; 347:9, 45, 1938; 355:52, 1939.

TABLE 3.—RELATION OF SPRING AND SUMMER TEMPERATURES TO TIME OF RIPENING OF EARLY BLACK CRANBERRIES.

Year	First Full-car Shipment		Monthly Mean Temperatures, °F. (At Middleboro)										Summations of Monthly Mean Temperatures (Letters represent months)					
	Date	Departure from Average**	March (a)	Departure from Average	April (b)	Departure from Average	May (c)	Departure from Average	June (d)	Departure from Average	Aug. (e)	Departure from Average	(a) +(b) +(c)	Departure from Average	(a) +(b) +(c) +(d)	Departure from Average	(a) +2(b) +(c) +(d) −2(e)	Departure from Average
1907	9-12	−6	36.4	+0.7	42.2	−2.9	51.3	−4.2	61.2	−2.8	66.4	−1.4	129.9	−6.4	191.1	−9.2	100.5	−9.1
1908	8-28	+9	37.3	+1.6	45.5	+0.4	58.0	+2.5	65.7	+1.7	66.6	−1.2	140.8	+4.5	206.5	+6.2	118.8	+9.2
1909	9-2	+4	35.5	−0.2	45.8	+0.7	53.7	−1.8	64.6	+0.6	64.6	−3.2	135.0	−1.3	199.6	−0.7	116.2	+6.6
1910	8-29	+8	39.0	+3.3	50.0	+4.9	54.0	−1.5	62.7	−1.3	65.2	−2.6	143.0	+6.7	205.7	+5.4	125.3	+15.7
1911	9-7	−1	33.3	−2.4	42.7	−2.4	59.6	+4.1	63.7	−0.3	67.3	−0.5	135.6	−0.7	199.3	−1.0	107.4	−2.2
1912	9-2	+4	34.3	−1.4	45.7	+0.6	56.8	+1.3	63.1	−0.9	65.5	−2.3	136.8	+0.5	199.9	−0.4	114.6	+5.0
1913	9-3	+3	40.9	+5.2	46.8	+1.7	53.4	−2.1	63.6	−0.4	67.8	0.0	141.1	+4.8	204.7	+4.4	115.9	+6.3
1914	9-2	+4	34.2	−1.5	44.0	−1.1	57.5	+2.0	62.9	−1.1	68.3	+0.5	135.7	−0.6	198.6	−1.7	106.0	−3.6
1915	9-7	−1	32.8	−2.9	47.1	+2.0	53.6	−1.9	62.1	−1.9	66.8	−1.0	133.5	−2.8	195.6	−4.7	109.1	−0.5
1916	9-9	−3	27.2	−8.5	42.1	−3.0	54.4	−1.1	60.7	−3.3	67.9	+0.1	123.7	−12.6	184.4	−15.9	90.7	−18.9
1917	9-11	−5	33.6	−2.1	41.2	−3.9	48.1	−7.4	64.0	0.0	70.2	+2.4	122.9	−13.4	186.9	−13.4	87.7	−21.9
1918	9-10	−4	33.9	−1.8	44.9	−0.2	59.4	+3.9	61.4	−2.6	68.8	+1.0	138.2	+1.9	199.6	−0.7	106.9	−2.7
1919	9-6	0	38.1	+2.4	43.9	−1.2	56.3	+0.8	64.1	+0.1	65.4	−2.4	138.3	+2.0	202.4	+2.1	115.5	+5.9
1920	9-11	−5	36.1	+0.4	42.7	−2.4	51.6	−3.9	62.2	−1.8	70.1	+2.3	130.4	−5.9	192.6	−7.7	95.1	−14.5
1921	9-6	0	42.7	+7.0	49.0	+3.9	54.5	−1.0	64.2	+0.2	65.6	−2.2	146.2	+9.9	210.4	+10.1	128.2	+18.6
1922	9-11	−5	37.0	+1.3	45.2	+0.1	58.0	+2.5	68.0*	+4.0	69.2*	+1.4	140.2	+3.9	208.2	+7.9	115.0	+5.4
1923	9-6	0	33.8*	−1.9	47.7*	+2.6	56.1*	+0.6	65.4	+1.4	65.1	−2.7	137.6	+1.3	203.0	+2.7	120.5	+10.9
1924	9-12	−6	34.1	−1.6	44.5	−0.6	53.3	−2.2	61.5	−2.5	67.4	−0.4	131.9	−4.4	193.4	−6.9	103.1	−6.5
1925	9-1	+5	39.4	+3.7	46.7	+1.6	53.4	−2.1	67.9	+3.9	68.1	+0.3	139.5	+3.2	207.4	+7.1	117.9	+8.3
1926	9-11	−5	31.6	−4.1	42.4	−2.7	53.7	−1.8	60.8	−3.2	67.8	0.0	127.7	−8.6	188.5	−11.8	95.3	−14.3
1927	9-8	−2	38.6	+2.9	44.6	−0.5	52.9	−2.6	61.1	−2.9	64.8	−3.0	136.1	−0.2	197.2	−3.1	112.2	+2.6
1928	9-12	−6	35.3	−0.4	43.7	−1.4	53.4	−2.1	62.7	−1.3	71.6	+3.8	132.4	−3.9	195.1	−5.2	95.6	−14.0
1929	9-3	+3	39.5	+3.8	44.8	−0.3	56.8	+1.3	65.2	+1.2	65.9	−1.9	141.1	+4.8	206.3	+6.0	119.3	+9.7
1930	9-3	+3	34.8	−0.9	43.3	−1.8	57.3	+1.8	68.6	+4.6	67.1	−0.7	135.4	−0.9	204.0	+3.7	113.1	+3.5
1931	9-5	+1	36.3	+0.6	46.8	+1.7	57.6	+2.1	64.3	+0.3	69.5	+1.7	140.7	+4.4	205.0	+4.7	112.8	+3.2
1932	9-10	−4	33.2	−2.5	44.9	−0.2	56.6	+1.1	63.7	−0.3	69.3	+1.5	134.7	−1.6	198.4	−1.9	104.7	−4.9
1933	9-8	−2	34.5	−1.2	45.7	+0.6	58.6	+3.1	65.3	+1.3	68.8	+1.0	138.8	+2.5	204.1	+3.8	112.2	+2.6
1934	8-30	+7	33.9	−1.8	46.9	+1.8	58.5	+3.0	66.4	+2.4	66.0	−1.8	139.3	+3.0	205.7	+5.4	120.6	+11.0
1935	9-5	+1	38.3	+2.6	44.5	−0.6	54.0	−1.5	64.1	+0.1	68.2	+0.4	136.8	+0.5	200.9	+0.6	109.0	−0.6
1936	9-2	+4	43.2	+7.5	43.6	−1.5	57.8	+2.3	65.1	+1.1	68.9	+1.1	144.6	+8.3	209.7	+9.4	115.5	+5.9
1937	9-12	−6	32.6	−3.1	44.4	−0.7	57.9	+2.4	65.1	+1.1	74.0	+6.2	134.9	−1.4	200.0	−0.3	96.4	−13.2
1938	9-8	−2	38.2	+2.5	47.9	+2.8	54.3	−1.2	65.0	+1.0	71.6	+3.8	140.4	+4.1	205.4	+5.1	110.1	+0.5
1939	9-8	−2	33.1	−2.6	43.5	−1.6	55.6	+0.1	63.4	−0.6	72.5	+4.7	132.2	−4.1	195.6	−4.7	94.1	−15.5
1940	9-7	−1	31.6	−4.1	41.7	−3.4	54.9	−0.6	63.1	−0.9	65.5	−2.3	128.2	−8.1	191.3	−9.0	102.0	−7.6
1941	9-3	+3	32.3	−3.4	48.8	+3.7	56.6	+1.1	64.8	+0.8	66.9	−0.9	137.7	+1.4	202.5	+2.2	117.5	+7.9
1942	9-2	+4	39.1	+3.4	47.0	+1.9	59.4	+3.9	65.0	+1.0	67.5	−0.3	145.5	+9.2	210.5	+10.2	122.5	+12.9
Sum			1285.7		1622.2		1998.9		2302.7		2442.2		4906.8		7209.5		3947.3	
Average	9-6		35.7		45.1		55.5		64.0		67.8		136.3		200.3		109.6	

* Average of maximum temperatures at Brockton and minimum temperatures at Middleboro.
** Days.

It seems from the temperature summations in Table 3 that the chances are 5 to 1 that Early Black cranberries will ripen early when the sum of the mean temperatures of the spring months at Middleboro is more than 141, and are 8 to 1 that they will ripen late when this sum is less than 133. One may see here that the very dangerous situation that attended the occurrence of the great frosts of early September 1917 was well established by the end of May of that year; for cranberries were then bound to be late in ripening and therefore very susceptible to injury by early-fall frost, and the likelihood of such frosts was clearly indicated by previous temperatures[7] and the prevalence of sunspots (pp. 55, 56 and 57).

There are some errors hard to avoid in the material in Table 3. The date of first full-car shipment fails in some years (e. g., 1919, 1922, and 1933) to index correctly the time of ripening because unfavorable weather delayed the picking of the berries. In a few years (e. g., 1916, 1923, 1930, and 1939), the mean temperatures at Middleboro may have failed to be representative of those in the whole cranberry-growing section. The growers became frightened by the very large crop of 1914 and shipped berries earlier than they otherwise would have; but in some years, when they were sure of the market because the crop was small (e. g., 1918, 1921, 1924, 1927, and 1938), they delayed picking a little to give the berries better color and size. However, the correlations shown would be stronger if these known sources of error were removed from the table.

To sum up, then, cranberries ripen early if the spring has been warm and August is cool, and ripen late after a cold spring and warm August.

LATE RIPENING AND KEEPING QUALITY

There seems to be no certain record of a Massachusetts cranberry crop that ripened late (say, with the first full-car of Early Blacks shipped after September 9) and had poor keeping quality[8] except that of the Howes variety in 1926; and this exception was probably due largely to difficulties in marketing the largest cranberry crop the country had ever produced.

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[7]The mean temperature of the calendar year 1916 was subnormal in both northern and southern New England.

[8]As already noted, the 1922 crop was not a true exception to this.

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MASSACHUSETTS
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Descriptions of Apple Varieties

By J. K. Shaw

The identification of fruit varieties before trees leave the nursery is important if disappointments in the orchard are to be avoided. These pictures and descriptions, including most of the apples now in common cultivation in America, are intended to help others to recognize these varieties and to serve as a record for future generations.

MASSACHUSETTS STATE COLLECE

AMHERST, MASS.

DESCRIPTIONS OF APPLE VARIETIES

By J. K. Shaw, Research Professor of Pomology

This paper presents some of the results of twenty-five years' observation of the vegetative characteristics of apple varieties. It includes most varieties in common cultivation during the first third of the twentieth century, also a few new varieties which may or may not come into common cultivation. Doubtless there may be additional varieties which have just as good or better claims for consideration but various difficulties have prevented their inclusion.

The illustrations are from varieties known to be true to name and include pictures of leaves, one-year whips, and two-year trees. The leaves were taken from the current season's growth and are well developed and typical of the variety. Some attempt is made to show variations that may occur, but the main effort has been to use only typical leaves. Leaves originating from spurs or from weak, slow-growing wood are not typical and are nearly or quite valueless for variety identification.

The trees were photographed in August before they had completed the season's growth, but at about the time of our nursery identification work. Owing to inferior soil or dry weather, the two-year trees do not show as vigorous growth as may be usual with the variety.

Cuts of the flowers of most of the varieties are included, but no descriptions are given. Flower descriptions have little practical value, for when a tree blossoms, it will soon bear fruit from which identification can be made.

While the paper was prepared to present the characteristics of the varieties as they grow in the nursery; the characteristics of the trees in the orchard, as they appear up to the time of heavy production, have also been kept in mind. When trees begin to produce heavily, the form of the tree is considerably modified. Leaves on vigorous shoots of the current season on older trees maintain their varietal characteristics.

No one can learn to identify varieties from the printed page, even when supplemented by good illustrations; the trees must be studied as they grow in the nursery and orchard. However, by first comparing descriptions and illustrations with trees known to be true to name, one may gradually learn to identify varieties — or at least to determine whether trees in question are true to name — by the use of such descriptions and pictures as are presented here.

Descriptive Terms

The descriptive terms have been kept non-technical, since this paper is addressed to the nurseryman and fruit grower rather than to the technical worker with fruit plants. The characters are described in the following order:

Tree:
- Vigor
- Form

Shoots:
- Length
- Size
- Direction (straight or zigzag)
- Curvature
- Length of internodes

Bark:

- Color toward base of current season's growth
- Color on wood two years old or older

Lenticels:

- Number
- Size
- Shape
- Color
- Raised or even with surface

Leaf Blade:

- Size
- Folding of blade
- Bending of midrib (straight or reflexed)
- Waving of leaf edge
- Shape
- Color
- Angle with branch

Serrations:

- Sharpness
- Size
- Regularity
- Depth and distinctness

Surface:

- Light reflection (shining or dull)
- Texture (rough or smooth)
- Pubescence

The Tree: Vigor is an indication of the size of the tree, and, like all other characteristics, is to be interpreted in comparison with other varieties growing at the same time and under similar conditions. Form applies only to trees two years old or older and alludes to the position and appearance of the main branches growing out from the trunk. The angle of the branch with the trunk varies from spreading through diverging and ascending to upright, the last term describing the most acute angle. Rows of upright trees are very narrow. If the branches curve upward, the tree is described as upcurving. In some varieties the angle of the main branches is more or less irregular; some spreading and others more or less diverging or even ascending.

The Branches or Shoots. The shoots may be long or short, slender or stout, according to the variety. Their growth may be straight or zigzag, that is, changing direction slightly at each bud. The curvature of the shoots is correlated with the form of the tree — if the branches are much curved, the form of the tree is upcurving. The internodes, which are the spaces between buds, may be short or long, differing with the variety.

The Bark: Near the growing tip, the bark is always some shade of green; toward the base, it takes on, with increasing age, some form of reddish or olive. The bark on wood two years old or older is some shade of green or olive, sometimes with a more or less reddish tinge.

The Lenticels: These are the breathing pores, which appear as small dots on the bark. They may seem inconspicuous but are of value in identifying varieties. They vary in number, size, shape, and color in different varieties. They are often more abundant in some parts of the shoot than in others, and the tendency is to consider the numbers in the area where they are most plentiful. They are generally roundish in form, but occasionally a variety may show some elongated lenticels. The color is usually some shade of grayish, but some are more or less yellowish or even almost white. In some varieties the lenticels are even with the surface; in others, they are raised so that they can be felt distinctly with the thumb or finger or detected with a small magnifying glass.

The Leaf Blade: The blade of the leaf is of the greatest importance in identifying varieties, and the description is therefore given in detail. Size is a varietal characteristic, although it may be affected somewhat by the vigor of the tree. The blade may be flat, or the two halves may be more or less folded upward. The midrib may be straight or curved downward (reflexed). In some varieties the leaf edge shows no waving whatever; in others, it may be coarsely or finely waved. Apple leaves are usually oval; but sometimes they are more or less ovate, which means that they are narrower toward the tip than at the base of the leaf; they may be broad, or they may be narrow. The color is always some shade of green; but it may vary from light to dark green, or it may be slightly yellowish or bluish green. In some varieties the leaves are rather upright, forming a narrow angle with an upright-growing branch; in others they may be spreading; and in still others, drooping. This leaf angle is generally correlated with the branch angle, so that the form of the tree can be foretold with considerable accuracy from the leaf angles on a one-year whip.

The Serrations: The notches along the leaf edge vary with different varieties and are of great value in identification. They may be very sharp or very dull, but in most varieties they are intermediate. They may be large or small — frequently referred to as coarse or fine. Sometimes the serrations are all alike in size and are described as regular; in other varieties they vary and are called irregular. If the spaces between the serrations are pronounced, the serrations are said to be distinct.

The Surface: The light reflection from the upper surface of the leaf varies with the variety. Some leaves are more or less shining; others dull. The surface texture of the leaf may be smooth or rough. The pubescence, which varies in amount, is most apparent on the under side of the leaf, and where abundant gives a grayish color to the foliage.

Following the technical description of a variety, the prominent characteristics are given — those which have come to be relied upon for recognizing a variety.

Years of experience have shown that certain varieties are likely to be confused in the nursery and consequently mixed in the orchard. Therefore, the description is completed by a statement of how the variety differs from those with which it is most likely to become mixed.

List of Varieties

Alexander
Arkansas (Mammoth Black Twig)
Arkansas Black
Autumn Strawberry

Bailey Sweet
Baldwin
Ben Davis
Bismark

Chenango
Cortland
Cox Orange
Crimson Beauty (Red Bird)

Delicious
Duchess (of Oldenburg)

Early McIntosh
Early Strawberry
Esopus Spitzenburg

Fallawater
Fall Pippin
"False Baldwin"
"False Gravenstein"
Fameuse

Golden Delicious
Golden Russet
Golden Sweet
Gravenstein
Grimes

Hubbardston
Hyslop

Jonathan
Joyce

King David
King (of Tompkins County)

Lobo
Lodi
Lowland Raspberry

Macoun
Maiden Blush
Malinda
Martha
McIntosh
Medina
Melba
Milton
Minkler
Mother

Newtown Pippin
Northern Spy
Northwestern Greening

Ontario
Opalescent
Orleans
Ortley

Patricia
Patten Greening
Peck Pleasant
Pedro
Pewaukee
Porter
Pumpkin Sweet

Ralls
Rambo
Ranier
Red Astrachan
Red June
Rhode Island Greening
Ribston
Rome Beauty
Roxbury Russet

Smokehouse
Stark
Stayman
Summer Rambo
Sweet Bough

Tioga
Tolman
Transcendent
Twenty Ounce

Wagener
Wealthy
Westfield
White Winter Pearmain
Williams
Willowtwig
Winesap
Winter Banana
Wolf River

Yates
Yellow Belleflower
Yellow Transparent
York Imperial

ALEXANDER

Tree: moderately vigorous, diverging, moderately upcurving.

Shoots: medium or below in length, rather slender, nearly straight, little to moderately curved, with rather short internodes. **Bark:** greenish olive — dark olive. **Lenticels:** few to medium, small, roundish, yellowish gray.

Leaf Blade: medium in size, nearly flat to moderately folded, more or less reflexed, slightly waved, broad oval to ovate, rather pale green, spreading, of medium thickness. **Serrations:** rather dull, irregular, of medium depth. **Surface:** dull, rough.

Prominent Characteristics

Dull, rather irregular serrations and rumpled surface of the leaves.

Differs from —

Wolf River by its somewhat smaller stature, shorter shoots, less reddish bark and smaller, less waved leaves with less dull serrations.

ALEXANDER

ARKANSAS (Mammoth Black Twig)

Tree: vigorous, broadly ascending.

Shoots: long, medium to stout, nearly straight, little or no curvature, medium internodes. **Bark**: reddish olive — dark olive with some scarf skin. **Lenticels**: medium in number and size, roundish, grayish, slightly raised.

Leaf Blade: medium or above in size, nearly flat to somewhat folded, slightly reflexed, even, broad oval, dark clear green, spreading, of medium thickness. **Serrations**: sharp, medium sized, quite regular, rather deep and distinct. **Surface**: quite smooth, with some pubescence.

Prominent Characteristics

Vigorous, upright spreading growth; nearly flat, smooth leaves with rather sharp, distinct serrations.

Differs from —

Stayman by more spreading growth, more slender shoots, less brownish lenticels, and less, shorter, and less hairy pubescence.

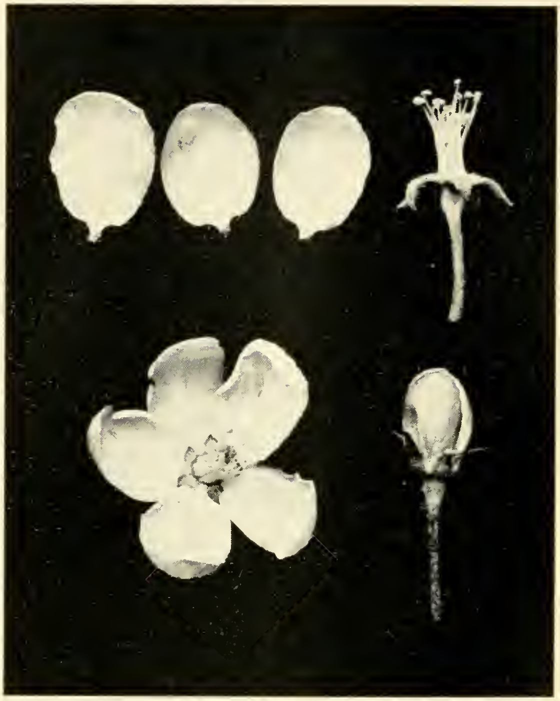
Winesap by being much more vigorous and having none of the roundish leaves with coarse, dull serrations mentioned in the description of that variety.

Arkansas Black by greater vigor and more spreading habit, straighter shoots, leaves less waved, and more distinct serrations.

Turley by more distinct serrations, less folded, smoother, more shining leaves.

No differences between Arkansas and **Paragon**, as grown in Eastern nurseries, have been found. A variety known in Nebraska under the name **Paragon** is distinct in tree and fruit.

ARKANSAS (Mammoth Black Twig)



ARKANSAS BLACK

Tree: moderately vigorous, rather broadly divergent.

Shoots: medium in length and size, nearly straight, slightly curved, with medium to rather short internodes. **Bark**: dark reddish olive — grayish olive with considerable scarf skin. **Lenticels**: medium in number and size, roundish, grayish yellow, nearly even.

Leaf Blade: medium in size, more or less folded, slightly reflexed, often moderately waved, oval, dark clear green, spreading to slightly upright. **Serrations**: moderately sharp, medium to rather coarse, moderately regular. **Surface**: moderately dull, medium smooth, with light to moderate pubescence.

Prominent Characteristics

Only moderate vigor; dark bark; dark green leaves, somewhat folded and waved.

Differs from —

Arkansas by less vigor, somewhat darker colored bark, and smaller leaves more folded and waved.

ARKANSAS BLACK

AUTUMN STRAWBERRY

Tree: quite vigorous, tall, narrowly diverging.

Shoots: rather long, medium to slender, with slight or no curvature and medium internodes. **Bark:** reddish olive — dark olive with a moderate amount of scarf skin. **Lenticels:** medium in number, small, roundish, yellowish gray, slightly raised.

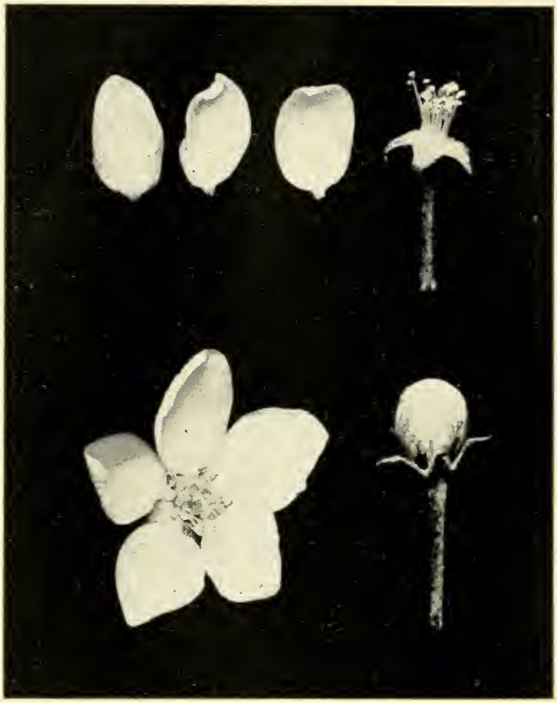
Leaf Blade: rather small, somewhat folded, nearly straight, more or less waved, roundish, rather dark green, spreading, of medium thickness. **Serrations:** sharp, medium in size, fairly regular, rather distinct. **Surface:** shining, rather smooth, with medium hairy pubescence.

Prominent Characteristics

Tall, upright spreading tree with rather small, roundish leaves with pretty sharp, distinct serrations.

Autumn Strawberry is not easily confused with other varieties. It is sometimes confused with **Early Strawberry**, but only on account of similarity of names.

AUTUMN STRAWBERRY



BAILEY SWEET

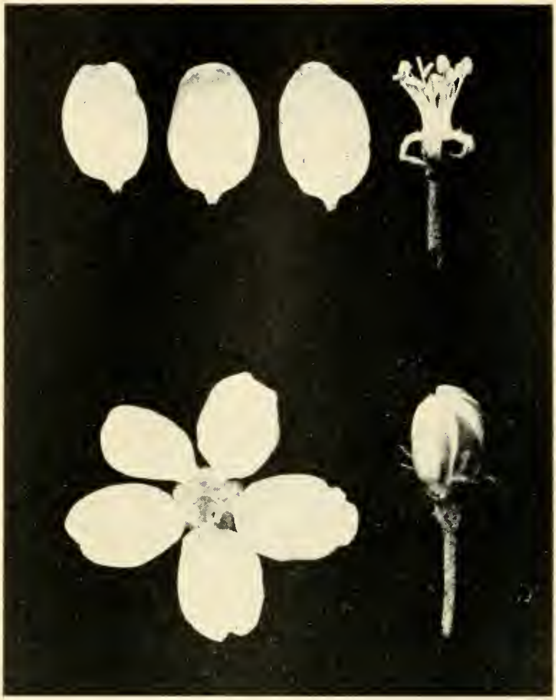
Tree: moderately vigorous, diverging, rather upcurving.

Shoots: medium in length and size, nearly straight, usually moderately curved. with medium internodes. **Bark:** dark reddish — dark olive with no scarf skin, **Lenticels:** medium in number and size, roundish or oval, yellowish gray, raised.

Leaf Blade: medium in size, somewhat folded, slightly reflexed, nearly even, ovate, medium green, spreading. **Serrations:** only fairly sharp, small, quite regular, not very distinct. **Surface:** shining, with medium coarse texture and little pubescence.

Bailey Sweet is not grown in large numbers but a few are often met with. It has not been found confused with other varieties.

BAILEY SWEET



BALDWIN

Tree: vigorous, rather broadly diverging, somewhat upcurving.

Shoots: medium to long, rather thick, nearly straight, with slight to medium curvature and medium internodes. **Bark:** reddish olive — dark olive with medium scarf skin. **Lenticels:** medium in number and size, roundish, yellowish gray, slightly raised.

Leaf Blade: rather large, broadly folded, nearly straight, even, broad oval, medium green, spreading. **Serrations:** rather sharp, regular, not very distinct. **Surface:** moderately shining, smooth, with medium pubescence.

Prominent Characteristics

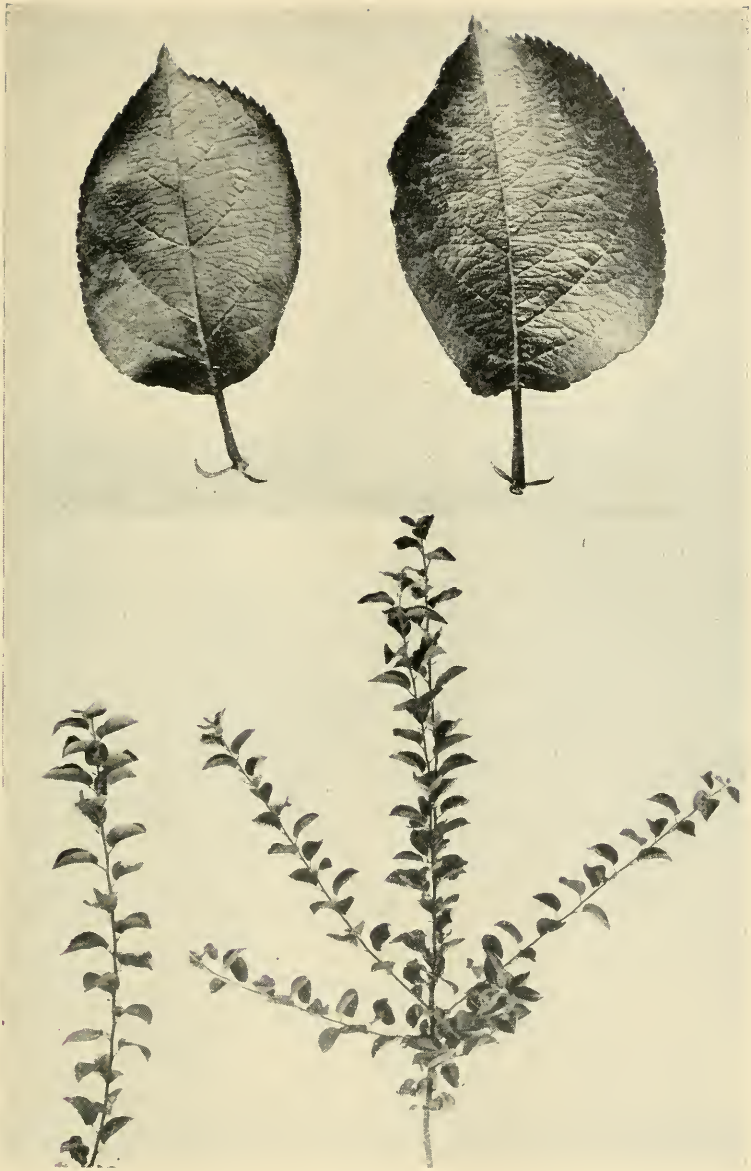
Vigorous growth, broad leaves folded near the edge rather than near the midrib, and moderately sharp, close-set serrations which are often curved toward the tip of the leaves.

Differs from —

Roxbury Russet by more reddish bark and less pubescence on the leaves, which show a more distinct "saucer" shaped folding.

"False Baldwin" by stouter, more curving shoots with more olive-colored bark; more broadly folded, less waved, stiffer leaves, which drop more readily in the fall and are less susceptible to scab; a less distinct rosette of leaves at branch tip at terminal bud formation; less dull surface and less pubescence of the leaves.

The **"False Baldwin"**, the true name of which is not known, has been found, often in considerable numbers, in nurseries. While the tree closely resembles Baldwin, the fruit is distinct; it is roundish, yellow, often with a bronzy red cheek, obscurely striped and splashed; it matures in early September but often drops prematurely.



BALDWIN

BEN DAVIS

Tree: moderately vigorous, moderately diverging, slightly upcurving.

Shoots: medium in length, rather slender, somewhat zigzag, with no to moderate curvature and rather long internodes. **Bark:** reddish yellow olive — yellow olive. **Lenticels:** few, small, roundish, yellowish gray, nearly even.

Leaf Blade: rather small, more or less folded, slightly reflexed, distinctly waved, narrow oval, medium green, generally spreading. **Serrations:** only moderately sharp, fairly regular, rather shallow. **Surface:** rather dull, moderately smooth, with considerable pubescence.

Prominent Characteristics

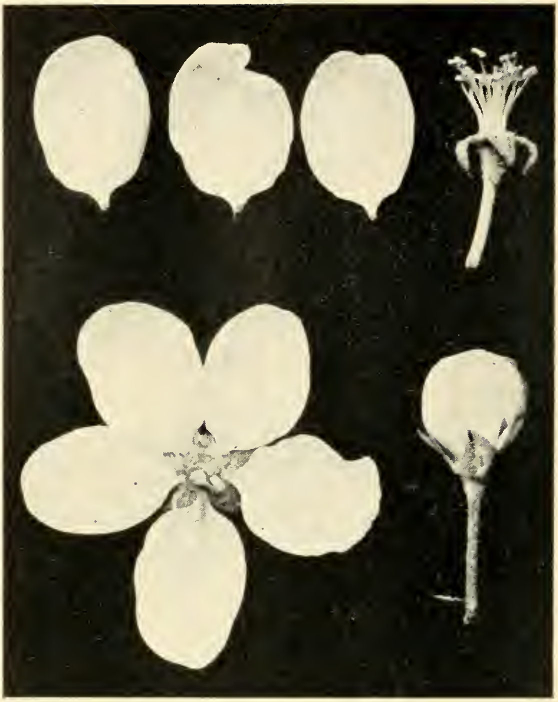
Medium-sized tree of rather upright growth, with rather narrow, waved leaves, narrowing at the base and apex. It cannot be distinguished from **Black Ben** and **Gano** except by the fruit. If these two varieties are distinct in fruit characters, they have been hopelessly confused in the nurseries.

Differs from —

Jonathan by larger, less pubescent leaves and less slender, less spreading growth.

Martha (crab) by more upright growth, slightly duller serrations, and less zigzag shoots.

BEN DAVIS



BISMARK

Tree: rather weak, rather broadly diverging.

Shoots: medium to rather short, rather slender, nearly straight, slightly curved, with medium internodes. **Bark:** dull reddish olive — yellowish olive with considerable scarf skin. **Lenticels:** very few, small, roundish, yellowish gray, even.

Leaf Blade: small to medium, more or less folded, slightly reflexed, distinctly waved, oval, often slightly yellowish, spreading. **Serrations:** dull, irregular, very shallow. **Surface:** rather dull, somewhat rough, with considerable pubescence.

Prominent Characteristics

Small trees of rather spreading growth, with rather light green leaves distinctly waved and folded near the edge. Serrations rather coarse and very shallow.

Differs from —

Alexander by weaker growth, rounder head, and smaller, more waved leaves, curled upward near the edge.

Jonathan by less slender, less spreading growth, and leaves broader at the base, with shallower, finer serrations.

BISMARK

CHENANGO

Tree: vigorous, ascending, moderately upcurving.

Shoots: rather long, medium in size, nearly straight, slightly to moderately curved with rather short internodes. **Bark:** greenish olive — dark olive. **Lenticels:** few, small, roundish, yellowish gray, raised.

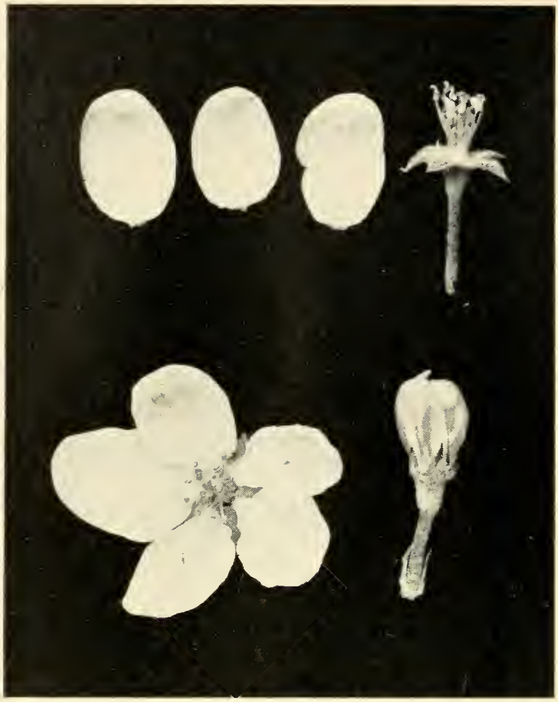
Leaf Blade: rather large, flat or slightly folded, sometimes slightly reflexed, generally even, broad oval, pale yellowish green, spreading. **Serrations:** moderately sharp, fairly regular, shallow, not very distinct. **Surface:** moderately shining, smooth, with moderate pubescence.

Prominent Characteristics

Stout, moderately vigorous tree; yellowish bark; and large, flattish, yellowish green leaves, having rather sharp, shallow serrations.

It is not likely to be confused with other common varieties.

CHENANGO



CORTLAND

Tree: vigorous, diverging, somewhat straggly.

Shoots: rather long, medium in size, nearly straight, not much curved, with medium internodes. **Bark:** dark reddish — dark reddish olive. **Lenticels:** medium in number and size, roundish, russet, slightly raised.

Leaf Blade: medium to large, flat, often down-folded, straight or slightly reflexed, nearly even, broad oval to oblong, medium green, spreading. **Serrations:** moderately dull, fairly regular, shallow. **Surface:** dull, rather rough, with moderate pubescence.

Prominent Characteristics

Quite vigorous, rather tall, upright, spreading, with dark red bark on the matured shoots. The leaves are flat, with the midrib often showing a reverse curvature. The growing tips are of a clear light green color.

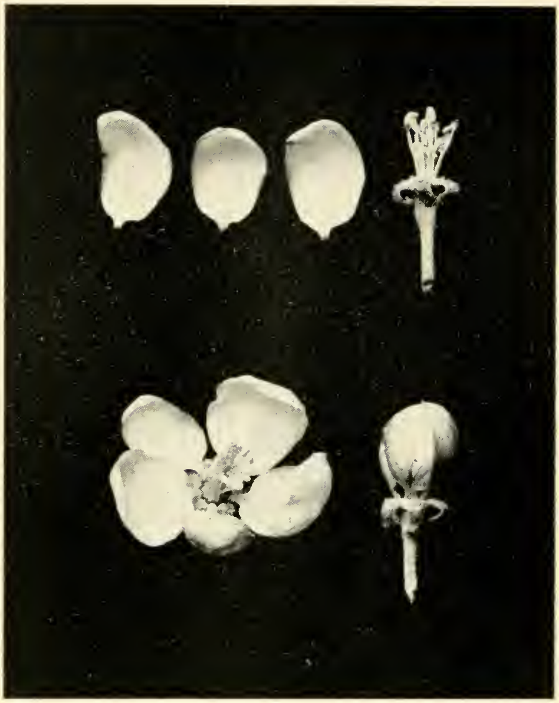
Differs from —

McIntosh by longer leaves, absence of a cordate base, more greenish growing tip, darker colored bark, and somewhat sharper leaf serrations.

Macoun by taller, less upcurving, more slender growth, and narrow, smooth, less folded leaf.

Early McIntosh by shorter, more slender shoots, more reddish bark, and flatter leaves.

CORTLAND



COX ORANGE

Tree: rather weak, moderately diverging.

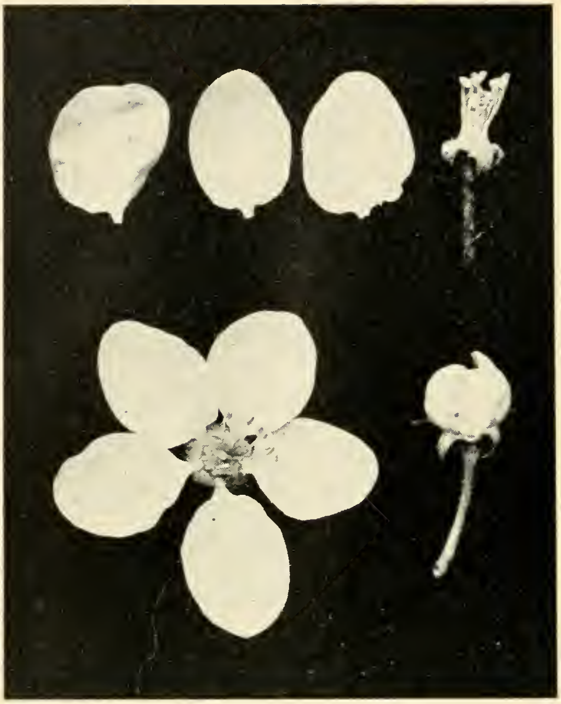
Shoots: short to medium, slender, slightly zigzag, slightly curved. **Bark:** reddish olive — yellowish olive. **Lenticels:** medium in number, medium to rather small, roundish or oblong, yellowish gray, slightly raised.

Leaf Blade: small, more or less folded, nearly straight, slightly waved, narrow oval to ovate, rather upright. **Serrations:** rather dull, regular, rather shallow. **Surface:** moderately shining, slightly rough, with medium pubescence.

Prominent Characteristics

Slender, rather upright growth; small leaves with dull, fine serrations.

COX ORANGE



CRIMSON BEAUTY (Red Bird)

Tree: vigorous, moderately ascending.

Shoots: generally long, medium in size, slightly zigzag, slightly curved, with medium internodes. **Bark:** reddish olive — dark olive. **Lenticels:** medium number, large, roundish, yellowish gray, slightly raised.

Leaf Blade: large, generally moderately folded, moderately reflexed, somewhat waved, broad oval, sometimes slightly ovate, medium dark green, spreading to slightly drooping. **Serrations:** moderately dull, rather coarse, somewhat irregular, rather shallow to medium in depth, moderately distinct. **Surface:** somewhat shining, rough, with medium to light pubescence.

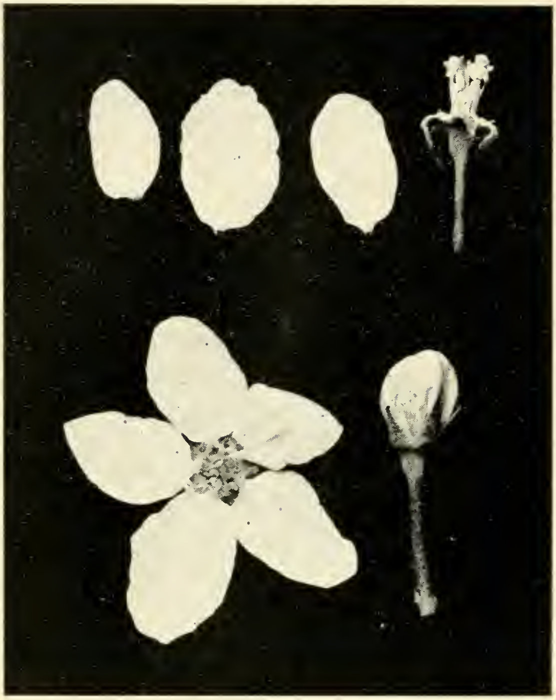
Prominent Characteristics

Vigorous growth, and rather large, coarse, rough leaves, with moderately dull, rather shallow serrations.

Differs from —

Yellow Transparent by redder bark, and broader, coarser leaves, with less pubescence.

Crimson Beauty (Red Bird)



DELICIOUS

Tree: only moderately vigorous, straggling, irregular growth, rather narrowly diverging.

Shoots: medium in length and size, often slightly zigzag, not much curved, with rather short internodes. **Bark:** very dark reddish olive — dark olive. **Lenticels:** few to medium, medium in size, roundish, yellowish gray, nearly even.

Leaf Blade: small to medium, slightly to moderately folded, straight or slightly reflexed, even, ovate, dark green, rather upright. **Serrations:** only moderately sharp, rather coarse, quite regular, moderately distinct. **Surface:** rather dull, moderately rough, with little pubescence.

Prominent Characteristics

Irregular straggly growth; dark reddish bark; dark green, stiff, upright leaves, with moderately sharp, rather coarse, characteristic serrations.

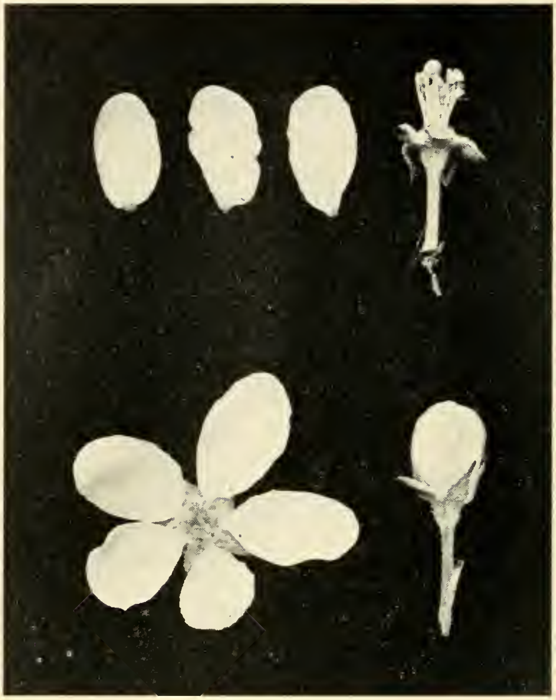
Differs from —

Winesap by more upright growth, peculiar serrations, and the absence of the small, round, coarsely serrate leaves peculiar to Winesap.

Stayman by weaker, more upright growth; darker bark, with more lenticels; and less hairy leaves.

Arkansas (Mammoth Black Twig) by weaker, more upright growth; and smaller, more upright leaves, narrower at the apex.

DELICIOUS



DUCHESS (OF OLDENBURG)

Tree: rather short, not very vigorous, moderately diverging.

Shoots: medium to rather short, rather stout, nearly straight, not much curved. **Bark:** dull reddish — greenish olive. **Lenticels:** rather few, small, roundish, grayish yellow, nearly even.

Leaf Blade: medium to rather large, flat to slightly folded, often slightly reflexed, even to moderately waved, broad oval, medium green, spreading. **Serrations:** rather dull, rather irregular, rather shallow, rather distinct. **Surface:** rather dull, often with roundish depressions, rather coarse, with medium pubescence.

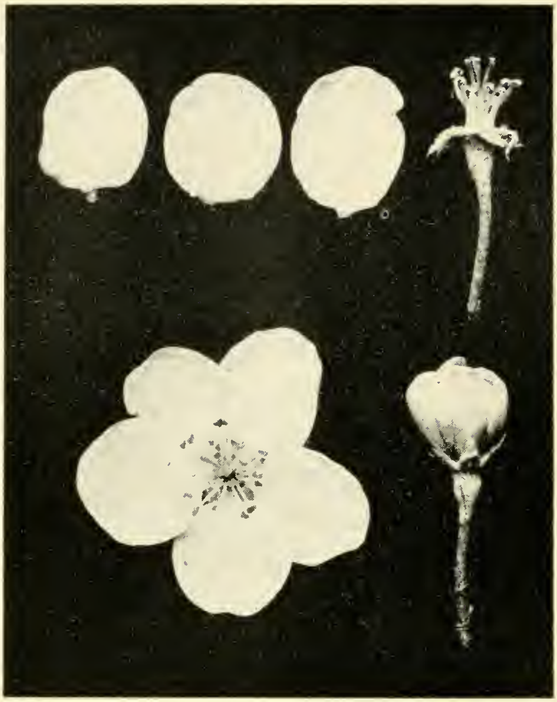
Prominent Characteristics

Rather short, stout growth; smooth satiny bark; broad leaves with rather dull, irregular serrations. Many leaves with characteristic depressions about one-half inch in diameter.

Differs from —

Wealthy by shorter, more stocky trees; leaves broader at base and apex; less "pebbly" surface and absence of cedar rust spots when that disease is prevalent; and presence of leaf depressions.

DUTCHESS (OF OLDENBURG)



EARLY McINTOSH

Tree: vigorous, ascending, moderately upcurving.

Shoots: rather long, medium in size, slightly zigzag, moderately curved, with rather long internodes. **Bark:** moderately dark reddish olive blended with yellowish olive — dark olive. **Lenticels:** medium in number and size, roundish or oval, yellowish gray, slightly raised.

Leaf Blade: medium to large, more or less folded, slightly reflexed, even or coarsely waved, broad oval, medium dark green, spreading. **Serrations:** rather dull, medium in size, fairly regular, rather shallow. **Surface:** rather shining, moderately smooth, with medium pubescence.

Prominent Characteristics

Tall, rangy growth; one-year trees often curved, with bark blended reddish and yellowish. Leaves rather large, more or less folded and waved, with medium serrations.

Differs from —

McIntosh by more yellowish color in the bark; taller; leaves more folded and waved, with slightly sharper serrations.

Milton by taller, less slender growth; lighter, more reddish bark; and larger leaves, more folded and waved.

Kendall by lighter bark with fewer and larger lenticels.

EARLY McINTOSH

EARLY STRAWBERRY

Tree: only moderately vigorous, narrowly diverging.

Shoots: medium in length, rather slender, nearly straight, very slightly curved. **Bark**: pale reddish olive — dark olive. **Lenticels**: very few, small, roundish, yellowish gray, even.

Leaf Blade: rather small, nearly flat, slightly reflexed, even, oval, spreading. **Serrations**: moderately sharp, rather small, fairly regular, rather shallow. **Surface**: rather shining, smooth, with medium pubescence.

Prominent Characteristics

Rather slender growth; few lenticels; smallish, flat, oval leaves with rather fine, moderately sharp serrations.

Differs from —

Autumn Strawberry by less vigorous growth and absence of roundish hairy leaves.

EARLY STRAWBERRY

ESOPUS SPITZENBURG

Tree: only moderately vigorous, moderately diverging.

Shoots: medium in length, rather slender, nearly straight, very slightly curved, with short to medium internodes. **Bark:** medium olive — medium olive. **Lenticels:** many, medium in size, round, light gray, even.

Leaf Blade: medium to small, more or less folded, reflexed, slightly waved, oval, spreading. **Serrations:** dull, medium in size, somewhat irregular, rather shallow. **Surface:** dull, with medium texture and considerable pubescence.

Prominent Characteristics

Rather upright growth, olive bark, conspicuous lenticels, and folded, dull, serrate leaves.

Differs from —

Jonathan by less willowy, spreading growth and larger leaves.

York Imperial by taller, less stocky growth and oval instead of ovate leaves, with more pubescence.

ESOPUS SPITZENBURG

FALLAWATER

Tree: very vigorous, broadly divergent.

Shoots: medium long, stout, nearly straight, little curved with short internodes. **Bark**: dark reddish olive — dark olive. **Lenticels**: medium in number and size, roundish, yellowish gray, raised.

Leaf Blade: medium to rather large, somewhat folded, slightly reflexed, nearly even, broad oval to slightly ovate, dark green tinged with dark red, spreading, rather thick. **Serrations**: medium in size, quite regular. **Surface**: somewhat shining, rather rough, with medium pubescence.

Prominent Characteristics

Vigorous growth; dark reddish bark; dark green, rather coarse leaves, rather sharply serrate; susceptibility to cedar rust.

Not likely to be confused with any other variety.

FALLAWATER

FALL PIPPIN

Tree: very vigorous, moderately diverging.

Shoots: medium to rather long, nearly straight, slightly curved, with medium internodes. **Bark:** dark reddish olive — dark grayish olive with considerable scarf skin. **Lenticels:** medium or below in size, roundish, grayish yellow, slightly raised.

Leaf Blade: rather large, much folded, reflexed, generally much waved, oval to oblong, dark clear green, spreading. **Serrations:** very sharp, rather large, irregular, rather deep. **Surface:** shining, with moderately coarse texture and medium pubescence.

Prominent Characteristics

Tall, vigorous growth; rather large, folded, reflexed leaves, sharply and irregularly serrate.

Differs from —

Rhode Island Greening by taller growth, more lenticels, and more folded leaves with sharper serrations.

Grimes Golden by larger, stouter growth and leaves with sharper, more irregular serrations.

FALL PIPPIN

"FALSE BALDWIN"

Tree: quite vigorous, moderately ascending.

Shoots: medium to rather long, medium in size, nearly straight, slightly curved, with medium internodes. **Bark:** reddish olive — dark olive with considerable scarf skin. **Lenticels:** medium in number and size, roundish, yellowish gray, nearly even.

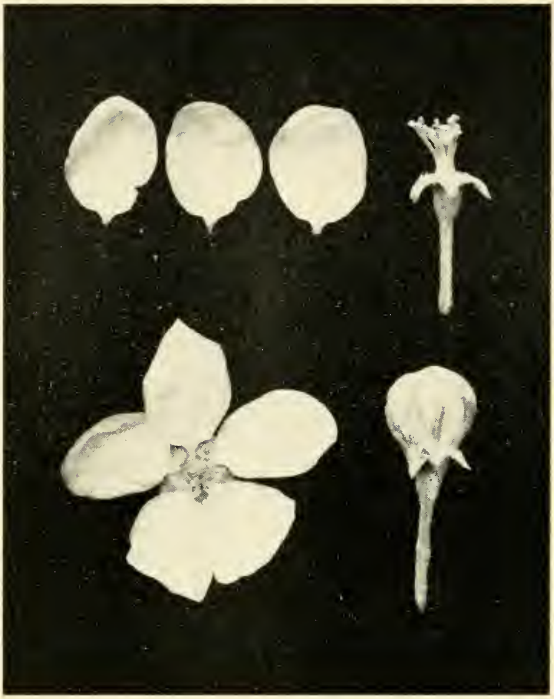
Leaf Blade: rather large, moderately folded, slightly reflexed, generally slightly waved, broad oval, medium green, spreading. **Serrations:** sharp, fairly regular, distinct. **Surface:** rather dull to somewhat shining, fairly smooth, with medium pubescence.

This is a variety that has been met with in plantings of Baldwin, which it closely resembles. Its true name is unknown. The fruit ripens in early September and drops badly just before harvest. The apple is roundish and pale yellowish when ripe, with some reddish stripes and splashes on the sunny cheek.

Differs from —

Baldwin by lighter colored, more reddish bark; more spreading growth, and longer, less curved shoots; leaves more folded and waved, and more folded and waved leaves around the base of the shoots; a more distinct "rosette" of folded leaves at the shoot tips in the early fall, with a distinctly duller surface and a bluish cast; leaves more susceptible to scab, less rigid, and not stripping so easily in the fall.

"FALSE BALDWIN"



"FALSE GRAVENSTEIN"

Tree: moderately vigorous, rather narrowly diverging.

Shoots: medium to rather long, medium in size, nearly straight, slightly curved, with medium internodes. **Bark:** reddish olive — yellowish olive. **Lenticels:** medium in number, small, elongated or roundish, yellowish gray, even.

Leaf Blade: medium in size, nearly flat, nearly straight, broad oval to roundish, medium green, generally spreading, rather thick. **Serrations:** moderately sharp, fairly regular, of medium depth. **Surface:** of coarse texture, with medium pubescence.

Prominent Characteristics

Upright, moderately vigorous growth; rather large, coarse, roundish leaves with moderately sharp serrations.

This variety has been grown as **Gravenstein** in many nurseries and may be found in many orchards. Its true name is unknown. It may be a Russian variety. The fruit ripens in August, earlier than **Gravenstein**, and is of poor quality. It is well colored, with red stripes and splashes, and is irregular, round conic in shape.

Differs from —

The true **Gravenstein** by its coarse, roundish leaves and more upright growth. The dormant tree is more like **Gravenstein**.

"FALSE GRAVENSTEIN"

FAMEUSE

Tree: rather vigorous, ascending, moderately upcurving.

Shoots: medium to long, medium in size, nearly straight, moderately curved, with medium internodes. **Bark**: dark reddish — dark olive. **Lenticels**: rather few, rather small, roundish, yellow gray, nearly even.

Leaf Blade: medium or above in size, somewhat folded, moderately reflexed, moderately or little waved, oval, medium dark green, spreading. **Serrations**: rather sharp, moderately regular. **Surface**: shining, coarsely roughened, with rather little pubescence.

Prominent Characteristics

Moderately tall; dark reddish bark; rather coarse leaves, waved, with moderately sharp serrations.

Differs from —

McIntosh by more upright, irregular growth and by leaves narrower towards apex, not cordate at base, with sharper, more irregular serrations and less pubescence.

FAMEUSE

GOLDEN DELICIOUS

Tree: moderately vigorous, moderately diverging, somewhat upcurving.

Shoots: medium to rather long, medium to slender, nearly straight, often slightly curved, with medium internodes. **Bark:** reddish olive yellow — grayish olive. **Lenticels:** many, conspicuous, medium in size, generally oval, yellowish gray, slightly raised.

Leaf Blade: medium in size, considerably folded, moderately reflexed, oval, rather light green, spreading. **Serrations:** moderately sharp, nearly regular, rather distinct. **Surface:** somewhat shining, rather smooth, with little pubescence.

Prominent Characteristics

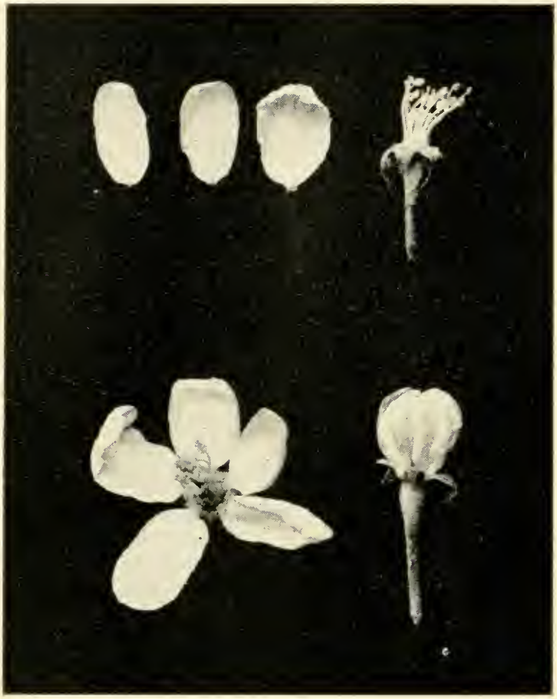
Yellowish olive bark; large, conspicuous lenticels; folded leaves, more or less waved and with rather sharp serrations.

Differs from —

Grimes by larger, more conspicuous lenticels, less shiny leaves with duller serrations, and more reddish coloration on the base of the petioles.

The variety now grown in many nurseries under the name **Yellow Delicious** cannot be distinguished from Golden Delicious.

GOLDEN DELICIOUS



GOLDEN RUSSET

Tree: only moderately vigorous, diverging, moderately upcurving.

Shoots: medium in length, rather slender, nearly straight, slightly to moderately curved, with rather short internodes. **Bark**: dark reddish olive — greenish olive. **Lenticels**: many, medium in size, roundish, light grayish, raised.

Leaf Blade: small to medium, nearly flat, more or less reflexed, oval, often narrow at base and with a distinct point, dark green, spreading to drooping. **Serrations**: sharp, nearly regular, moderately distinct. **Surface**: moderately dull rather coarse, with rather heavy pubescence.

Prominent Characteristics

Many conspicuous, raised, whitish lenticels; rather dark green leaves, finely and sharply serrated.

Differs from —

Roxbury Russet by less vigorous growth, much more conspicuous lenticels, and smaller, shorter leaves. The resemblance is only in name.

GOLDEN RUSSET

GOLDEN SWEET

Tree: tall and vigorous, ascending.

Shoots: medium in length and size, straight, very little curved. **Bark**: reddish olive — grayish olive. **Lenticels**: medium in number, small, roundish, grayish, even.

Leaf Blade: medium or above in size, generally flat, often reflexed, somewhat waved, rather broad oval or ovate, dark green, spreading to drooping. **Serrations**: sharp, irregular, quite distinct. **Surface**: dull, moderately smooth, with medium pubescence.

Prominent Characteristics

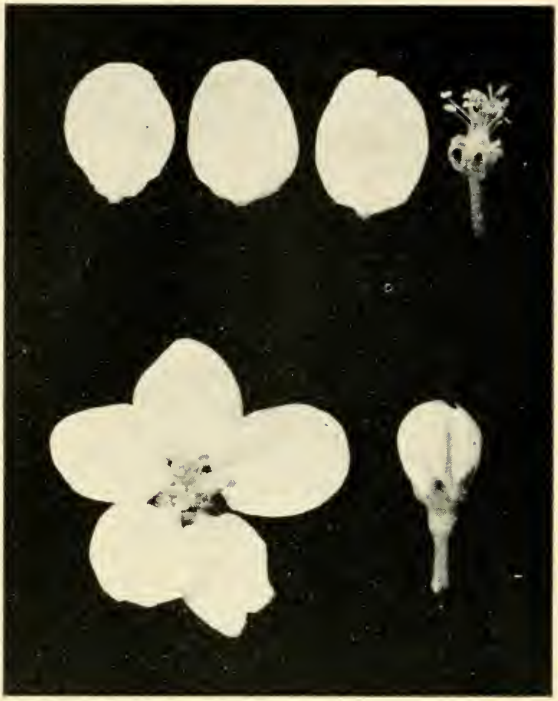
Rather tall, with reddish bark and with leaves having sharp, distinct serrations.

Differs from —

Sweet Bough by more reddish bark and much sharper serrations.

Tolman by sharper serrations and less pubescence.

GOLDEN SWEET



GRAVENSTEIN

Tree: vigorous, broadly upcurving.

Shoots: medium to rather long, rather stout, straight, distinctly curved, with medium internodes. **Bark**: reddish olive — greenish olive. **Lenticels**: very few, medium in size, roundish, yellowish gray, even.

Leaf Blade: medium to rather large, flat or slightly folded, little reflexed, not waved, oval to oblong, medium green, spreading, thick. **Serrations**: moderately dull to rather sharp, regular, shallow. **Surface**: shining, smooth and a little leathery, with little pubescence.

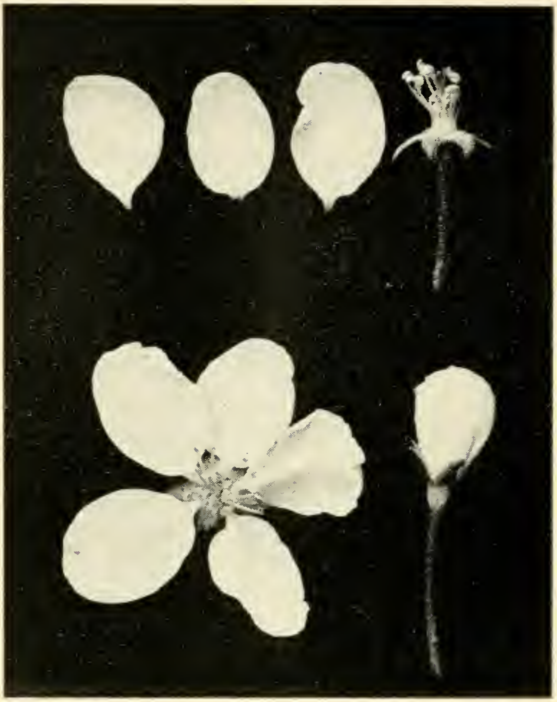
Prominent Characteristics

Vigorous stout growth; broadly upcurving form; smooth, satiny bark with very few lenticels; somewhat leathery leaves with shallow serrations.

Differs from —

Rhode Island Greening by narrower, thicker leaves with finer, more shallow serrations and less pubescence.

GRAVENSTEIN



GRIMES

Tree: rather vigorous, diverging to ascending.

Shoots: medium to rather long, medium in size, somewhat zigzag, little curved, with medium to short internodes. **Bark:** dark reddish — greenish olive. **Lenticels:** medium in number and size, roundish, medium gray, even.

Leaf Blade: medium in size, moderately to distinctly folded, considerably reflexed, distinctly waved, rather narrow oval to ovate, dark clear green. **Serrations**: sharp, shallow, fairly regular. **Surface:** medium to rather shining, rather smooth, with medium pubescence.

Prominent Characteristics

Rather upright growth; greenish bark color; clear dark green, much folded leaves, considerably reflexed and waved, with moderately sharp and rather fine serrations.

Differs from —

Golden Delicious and **Yellow Delicious** by smaller, less conspicuous lenticels; more shining leaf surface; sharper, more regular serrations; and very little or no red at the base of the petioles.

GRIMES

HUBBARDSTON

Tree: vigorous, diverging, moderately upcurving.

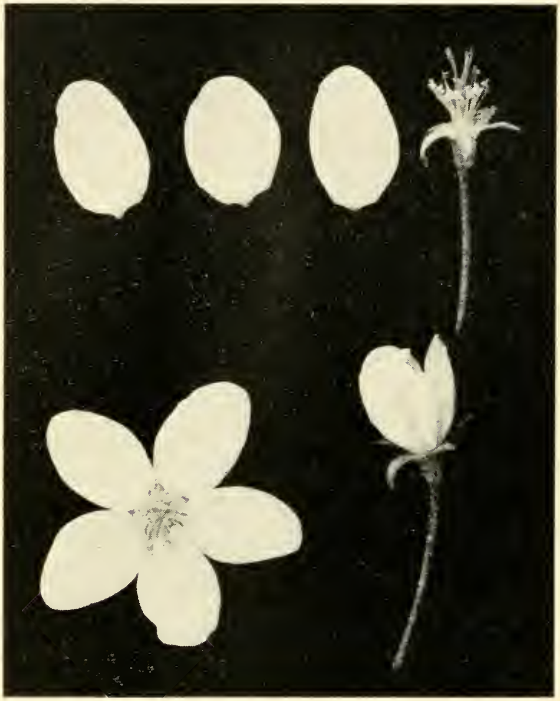
Shoots: medium to rather long, medium in size, nearly straight, slightly curved, with medium to rather short internodes. **Bark**: dark reddish olive — dark olive. **Lenticels**: medium to rather few, rather small, roundish, grayish, slightly raised.

Leaf Blade: medium to above in size, distinctly folded, more or less reflexed, generally waved, generally somewhat ovate, rather dark green, moderately upright. **Serrations**: quite sharp, rather irregular, quite distinct. **Surface**: rather shining, with medium texture and heavy pubescence.

Prominent Characteristics

Rather tall, upright growth; greenish bark; dark green leaves considerably folded and waved, with heavy pubescence.

HUBBARDSTON



HYSLOP

Tree: quite vigorous, ascending, moderately upcurving.

Shoots: rather long, rather slender, distinctly zigazg, moderately curved, with medium internodes. **Bark:** yellowish olive — dark olive. **Lenticels:** medium in number and size, generally oval or elongated, yellowish gray, slightly raised.

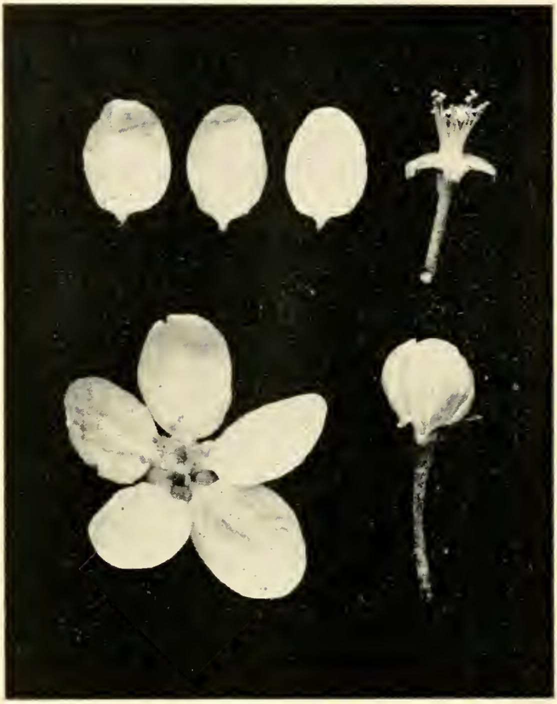
Leaf Blade: medium or above in size, somewhat folded, slightly reflexed, oval, yellowish green, spreading. **Serrations:** rather sharp, quite regular, distinct. **Surface:** moderately shining, rather smooth, with medium pubescence.

Prominent Characteristics

Tall with yellowish bark, zigzag shoots, and yellowish, waved, rather sharply serrated leaves.

Hyslop is a distinct variety seldom confused with others.

HYSLOP



JONATHAN

Tree: rather small, rather broadly diverging.

Shoots: medium long, very slender, nearly straight, with slight curvature· **Bark:** olive, slightly reddish — greenish olive. **Lenticels:** medium in number, small, roundish, yellowish gray, even.

Leaf Blade: small, more or less folded, slightly to moderately reflexed and waved, narrow oval, narrow at base, medium grayish green, spreading. **Serrations:** not very sharp, coarse, very irregular, rather distinct. **Surface:** dull, rather coarse, with much pubescence.

Prominent Characteristics

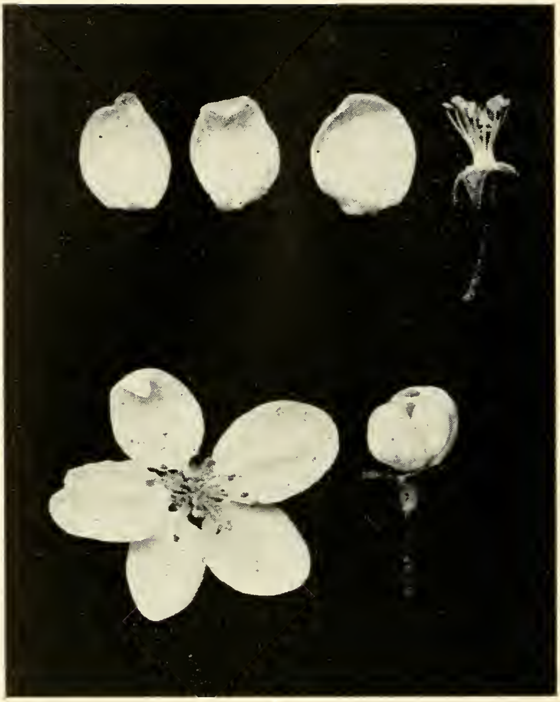
Slender, delicate growth; small, coarsely pubescent leaves, with coarse, irregular serrations; susceptibility to cedar rust.

Differs from —

York Imperial by more slender, spreading growth and leaves narrower at base and more heavily pubescent.

King David by somewhat smaller leaves, narrower at base, and with a little more pubescence.

JONATHAN



JOYCE

Tree: moderately vigorous, rather broadly diverging.

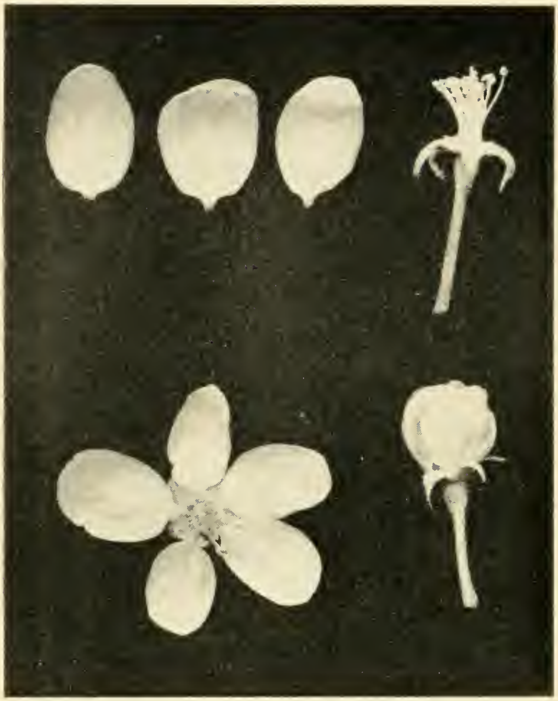
Shoots: medium to rather long, rather stout, nearly straight, slightly curved. **Bark:** reddish — yellowish olive. **Lenticels:** many, very small, roundish, yellowish gray, nearly even.

Leaf Blade: medium to rather large, more or less folded, usually near edge, more or less reflexed, nearly even, broad oval, medium green often slightly yellowish, spreading. **Serrations:** rather dull, rather regular, rather distinct. **Surface:** moderately dull, rather coarse, with moderate pubescence.

Prominent Characteristics

Reddish bark; small lenticels; large, broad, rather coarse leaves, with dull, shallow serrations.

JOYCE



KING DAVID

Tree: moderately vigorous, rather broadly diverging.

Shoots: medium in length, rather slender, nearly straight, slightly curved, with rather short internodes. **Bark:** medium reddish olive — medium olive. **Lenticels:** rather few, small to medium, roundish, yellowish gray, slightly raised.

Leaf Blade: small to medium, more or less folded and reflexed, even or slightly waved, generally ovate, medium green, spreading. **Serrations:** generally rather sharp, somewhat irregular, moderately distinct. **Surface:** rather dull, moderately coarse, with medium pubescence.

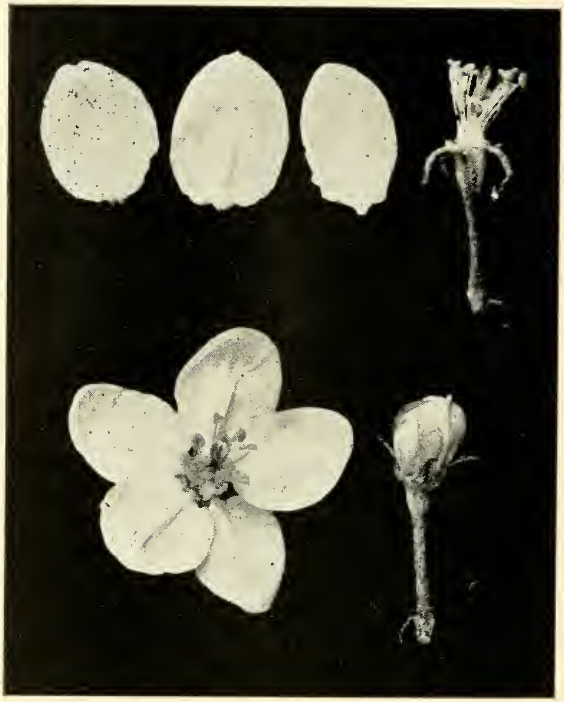
Prominent Characteristics

A moderately vigorous tree with somewhat irregular growth; rather coarse leaves, with moderately sharp, rather irregular serrations.

Differs from —

Jonathan by somewhat less slender growth and somewhat larger leaves, broader at the base, and with less pubescence.

KING DAVID



KING (OF TOMPKINS COUNTY)

Tree: tall, quite vigorous, rather broadly diverging.

Shoots: long, medium to rather stout, nearly straight, somewhat curved, with medium internodes. **Bark**: reddish olive — dark olive. **Lenticels**: rather numerous, rather large, roundish, yellowish gray, raised.

Leaf Blade: medium or above in size, usually considerably folded and reflexed, considerably waved, oval to slightly ovate, medium green, spreading, sometimes drooping. **Serrations**: quite sharp, of medium size, fairly regular, rather shallow. **Surface**: somewhat shining, with medium texture and considerable pubescence.

Prominent Characteristics

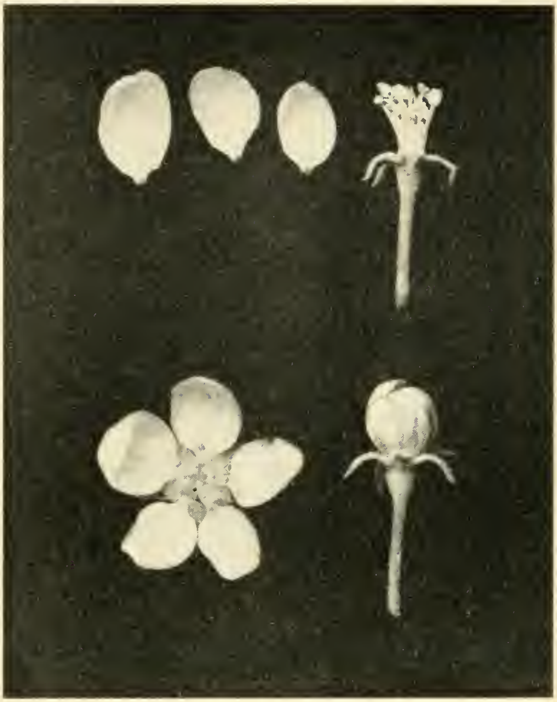
Tall, with long shoots and rather conspicuous lenticels; leaves considerably folded, with sharp, close-set serrations.

Differs from —

Baldwin by taller growth; larger lenticels; leaves folded nearer the midrib and more reflex, with more distinct serrations.

Fall Pippin by less stocky growth, more conspicuous lenticels, and leaves with less sharp serrations.

KING (OF TOMPKINS COUNTY)



LOBO

Tree: moderately vigorous, diverging.

Shoots: medium in length and size, nearly straight, little curved, with medium internodes. **Bark**: reddish olive — dark olive. **Lenticels**: many, small, roundish, gray, nearly even.

Leaf Blade: medium in size, slightly folded, somewhat reflexed, nearly even, generally ovate, dark green, spreading. **Serrations**: rather dull, small, nearly regular, rather shallow. **Surface**: dull, rough, with medium pubescence.

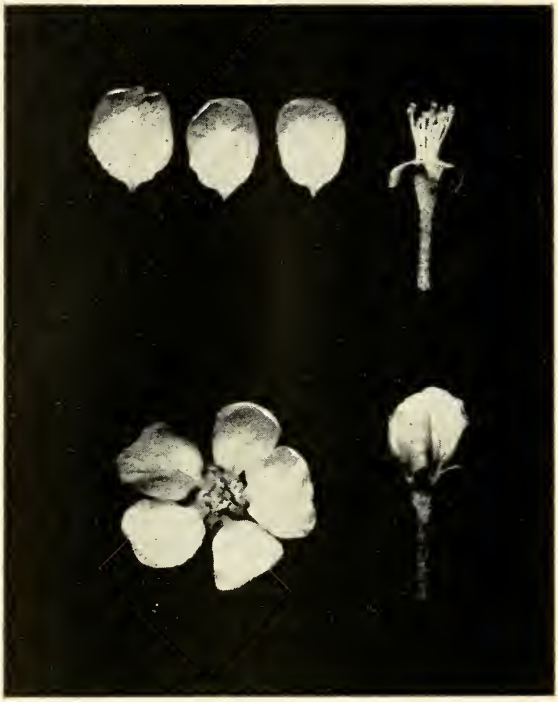
Prominent Characteristics

Dark red bark, many small distinct lenticels. Closely resembles McIntosh.

Differs from —

McIntosh by somewhat smaller, rougher leaves, narrower at the apex and more reflexed at the tip; dark red bark; and more conspicuous lenticels.

LOBO



LODI

Tree: quite vigorous, moderately diverging, slightly upcurving.

Shoots: rather long, medium in size, somewhat zigzag, moderately curved, with medium internodes. **Bark**: reddish olive — dark yellowish olive. **Lenticels**: medium in number, small, roundish, yellowish gray, slightly raised.

Leaf Blade: medium to rather large, moderately folded, slightly reflexed, somewhat waved, broad oval to slightly ovate, medium to light green, generally spreading. **Serrations**. moderately sharp, somewhat irregular, not very distinct. **Surface**: moderately dull, moderately rough, with not much pubescence.

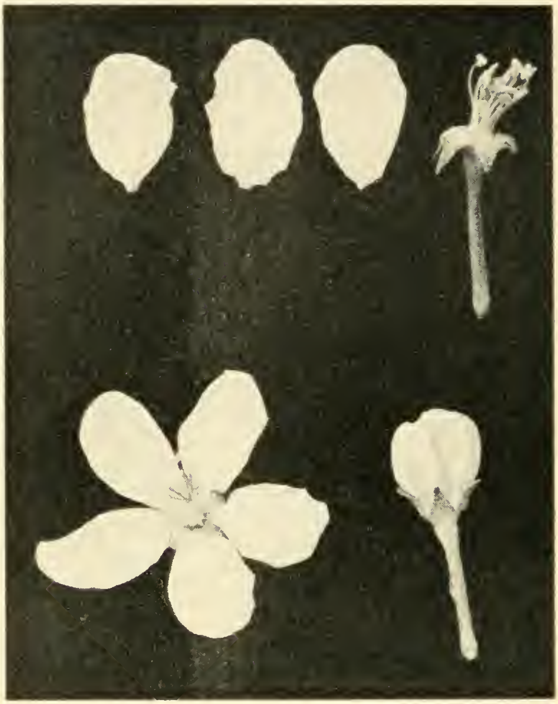
Prominent Characteristics

Yellowish bark, vigorous growth, rather large coarse leaves.

Differs from —

Yellow Transparent by more vigorous growth; less yellowish bark and foliage; and leaves less folded, broader and more spreading.

LODI



LOWLAND RASPBERRY

Tree: moderately vigorous, ascending or diverging.

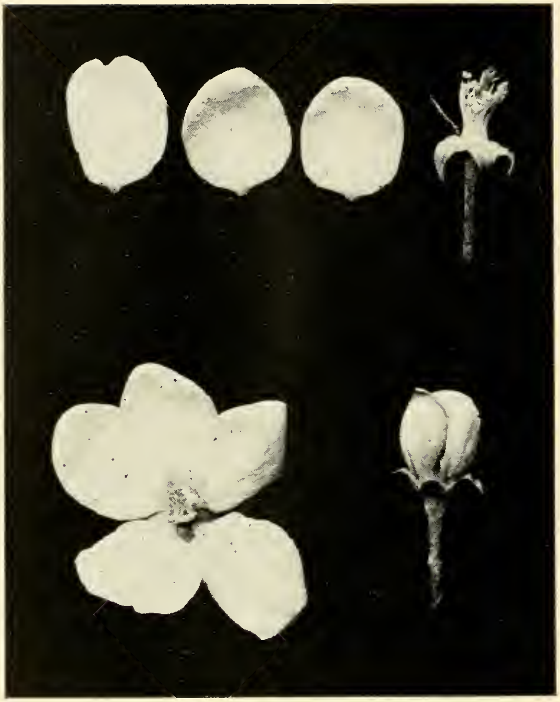
Shoots: medium in length and size, nearly straight, with slight or no curvature and with medium internodes. **Bark**: reddish olive — reddish olive. **Lenticels**: medium in number and size, roundish, yellowish gray, nearly even.

Leaf Blade: medium in size, nearly flat and straight, not waved, broad oval to roundish, medium green, spreading. **Serrations**: moderately dull, rather irregular, not very distinct. **Surface**: rather dull, coarse, with medium pubescence.

Prominent Characteristics

The coarse, broad, roundish or oval leaves rather closely serrated.

LOWLAND RASPBERRY



MACOUN

Tree: not tall, moderately vigorous, upcurving.

Shoots: rather short, rather stout, nearly straight, considerably curved, with medium to short internodes. **Bark**: dark reddish — dark olive. **Lenticels:** meum in number and size, roundish, yellowish gray, raised.

Leaf Blade: medium to rather large, moderately folded near edge, more or less reflexed, nearly even, broad oval, dark green, spreading. **Serrations:** sharp, fairly regular, not very distinct. **Surface**. rather dull, rough, with medium pubescence.

Prominent Characteristics

Not very tall; stout, curved branches; coarse rugose, roundish leaves, often with many drooping leaves at base of trunk. Susceptible to "frog eye" leaf spot.

Differs from —

McIntosh by shorter, stockier, more upcurving growth, and more rugose leaves with sharper serrations.

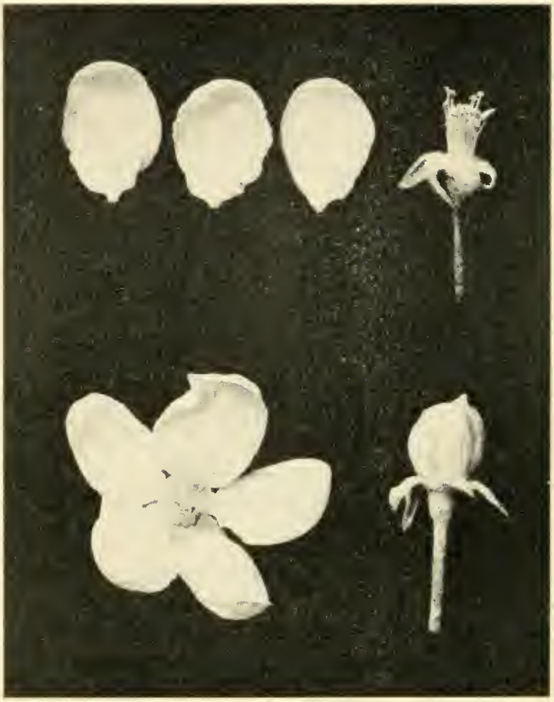
Milton by much stockier growth and more rugose leaves.

Early McIntosh by darker colored bark, stockier growth, and more rugose leaves, with sharper serrations.

Kendall by shorter growth, fewer lenticels, and more roundish, rugose leaves, those at the base more drooping.

York Imperial by darker bark and larger, more roundish leaves.

MACOUN



MAIDEN BLUSH

Tree: moderately vigorous, rather narrowly diverging.

Shoots: medium in length, medium to slender, nearly straight, slightly curved, with medium to short internodes. **Bark**: greenish olive — yellowish olive. **Lenticels**: medium in number and size, roundish, light gray, even.

Leaf Blade: medium to below in size, slightly folded, slightly reflexed, nearly even, rather narrow oval to ovate, medium to rather light green, spreading to slightly upright. **Serrations**: medium sharp, generally regular, shallow, not very distinct. **Surface**: dull with a slight bluish cast, smooth except along the midrib, with medium pubescence.

Prominent Characteristics

Rather upright growth; olive bark; slightly bluish leaves, not distinctly waved and with rather regular, fine serrations.

Differs from —

Winter Banana by less spreading growth; not as tall; with smaller leaves, less folded and with finer, more regular serrations, none of which are double.

MAIDEN BLUSH

MALINDA

Tree. moderately vigorous, broadly diverging.

Shoots: medium in length, rather slender, nearly straight, very slightly curved, with medium internodes. **Bark**: reddish olive — dark olive. **Lenticels**: few, small, roundish, yellowish gray, even.

Leaf Blade: rather small, slightly folded, nearly straight, even, oval, medium green, spreading. **Serrations**: rather sharp, rather small, quite regular, rather distinct. **Surface**: moderately shining, rather smooth, with medium pubescence.

Prominent Characteristics

Spreading growth, few lenticels, and smallish oval leaves with rather sharp and shallow serrations.

MALINDA

MARTHA

Tree: rather vigorous, broadly upcurving.

Shoots: medium to rather long, slender, zigzag, with little or no curvature. **Bark:** pale reddish — yellowish olive. **Lenticels:** few, roundish, yellowish to gray, nearly even.

Leaf Blade: medium or below in size, considerably folded, slightly reflexed, distinctly waved, narrow oval to slightly ovate, rather pale green, spreading, sometimes drooping. **Serrations:** rather sharp, rather small, rather regular, quite distinct. **Surface:** moderately dull, rather smooth, with considerable pubescence.

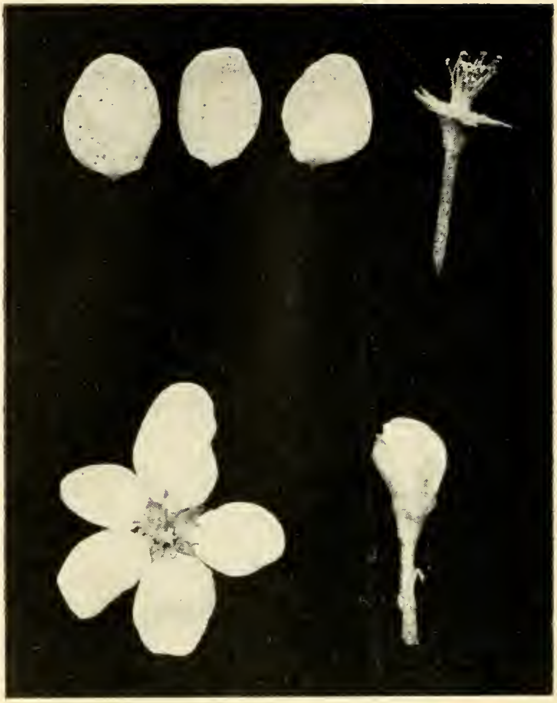
Prominent Characteristics

Vigorous, rather slender growth; and soft, woolly, folded, grayish leaves. One-year whips branch quite freely.

Differs from —

Ben Davis and **Gano** by more pinkish bark, more zigzag shoots, and leaves with somewhat sharper serrations.

MARTHA



McINTOSH

Tree: vigorous, rather broadly diverging.

Shoots: medium to rather long, medium in size, nearly straight, slightly to moderately curved, with medium internodes. **Bark:** bright reddish — reddish olive. **Lenticels:** medium in number, small, roundish, yellowish gray, slightly raised.

Leaf Blade: medium to large, slightly folded, slightly reflexed, even, broad oval with a cordate base, dark green, spreading. **Serrations:** dull, medium in size, quite regular, shallow, not very distinct. **Surface:** rather dull, rather rough, with medium pubescence.

Prominent Characteristics

Vigorous, moderately spreading tree, reddish bark, and broad oval leaves with cordate base and dull serrations.

Differs from —

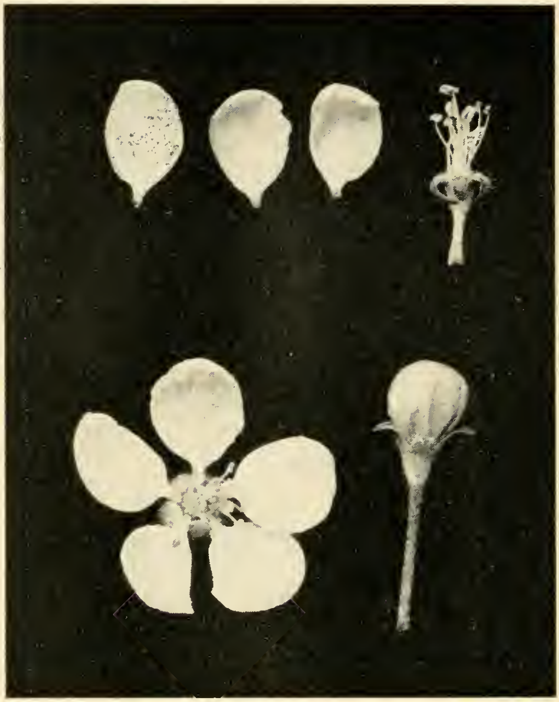
Cortland by lighter red bark and more yellowish leaves with cordate base.

Kendall by lighter colored bark, larger and somewhat fewer lenticels, and smoother leaves.

Macoun by taller, more spreading growth, more reddish bark, less roundish, smoother leaves with duller serrations.

Early McIntosh by little or no yellowish in shoot bark color, somewhat more numerous lenticels, and less folded leaves.

McINTOSH



MEDINA

Tree: fairly vigorous, moderately diverging, slightly upcurving.

Shoots: medium to rather long, medium in size, nearly straight, slightly to moderately curved, with medium internodes. **Bark:** pale reddish olive — dark olive. **Lenticels:** medium in number, rather large, roundish, yellowish gray, raised.

Leaf Blade: medium in size, somewhat folded, somewhat reflexed, even to moderately waved, generally ovate, medium green, spreading. **Serrations:** sharp, medium in size, fairly regular, moderately distinct. **Surface:** moderately shining, fairly smooth, with medium pubescence.

Prominent Characteristics

Rather upright growth, dark colored bark. Leaves somewhat like Delicious but with more regular, sharper serrations.

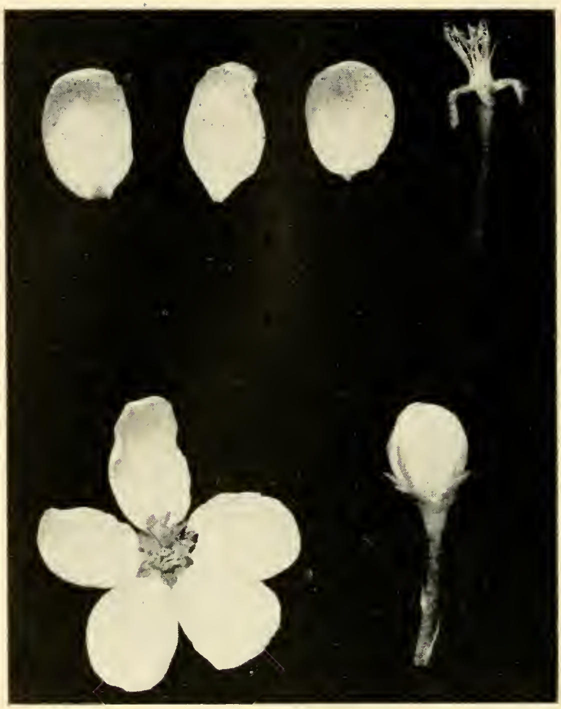
Differs from —

Delicious by less dark colored bark, more conspicuous lenticels, and leaves with somewhat sharper serrations.

Orleans by taller growth, more lenticels, wider leaves with sharper, less coarse serrations and less pubescence.

Newfane by more vigorous growth and more conspicuous lenticels.

MEDINA



MELBA

Tree: vigorous, moderately and rather broadly upcurving.

Shoots: generally long, medium to rather stout, nearly straight, with moderate curvature and medium internodes. **Bark:** bright reddish — greenish olive. **Lenticels:** medium or below in number, small to medium, roundish, yellowish gray, slightly raised.

Leaf Blade: large, nearly flat, straight, nearly even, broad oval, medium green, spreading. **Serrations:** very dull, quite regular, of medium depth, moderately distinct. **Surface:** rather dull, moderately rough, with medium pubescence.

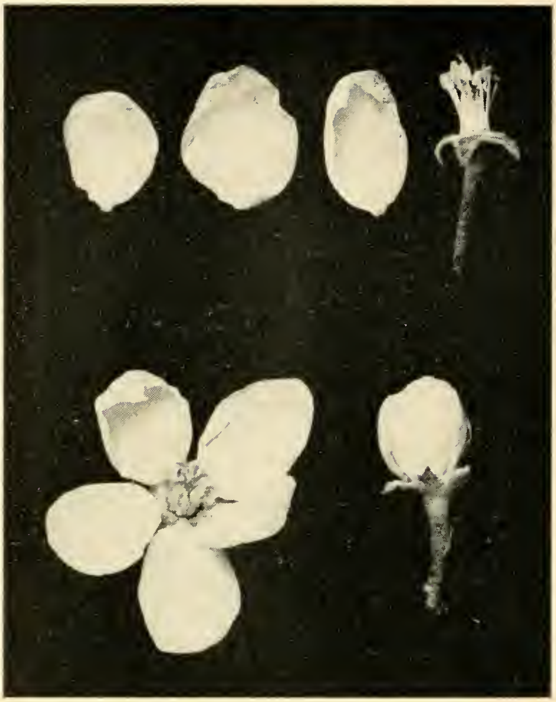
Prominent Characteristics

Vigorous growth; reddish shoots; large, flattish, coarse leaves with very dull, rather shallow serrations.

Differs from —

Early McIntosh by redder bark and larger, flatter leaves.

MELBA



MILTON

Tree: moderately vigorous, rather broadly diverging.

Shoots: medium in length, rather slender, nearly straight, slightly curved, with medium internodes. **Bark.** moderately dark reddish — dark olive. **Lenticels:** medium or above in number, small, roundish, yellowish gray, slightly raised.

Leaf Blade: rather large, slightly folded, slightly reflexed, generally even, medium to broad oval, medium green, slightly yellowish, spreading or slightly drooping, rather thin. **Serrations:** quite sharp, fairly regular, of medium depth, not very distinct. **Surface:** moderately dull, somewhat rough, with rather light pubescence.

Prominent Characteristics

Rather slender growth, roundish head, leaf surface somewhat like pebbly leather, sharp serrations.

Differs from —

Early McIntosh by more slender growth; smaller, more nearly roundish leaves; somewhat darker bark.

Macoun by much more slender, less upright growth and smaller lenticels.

MILTON

MINKLER

Tree: quite vigorous, rather broadly diverging.

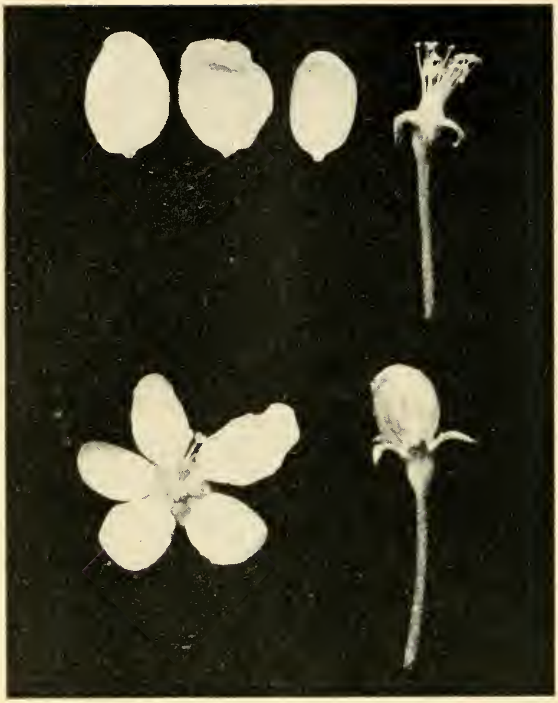
Shoots: medium in length and size, nearly straight, not curved, with medium internodes. **Bark:** rather pale reddish olive — dark olive. **Lenticels:** medium or rather few, small, roundish, yellowish gray, slightly raised.

Leaf Blade: medium in size, somewhat folded, more or less reflexed, nearly even, oval, medium green, spreading, rather thick. **Serrations:** sharp, medium in size, fairly regular, quite distinct. **Surface:** rather dull, with medium texture and rather light pubescence.

Prominent Characteristics

Tall, rather irregular growth; medium sized, sharply serrate leaves.

MINKLER



MOTHER

Tree: not very vigorous, moderately diverging.

Shoots: medium in length and size, nearly straight, not much curved. **Bark:** greenish olive — dark greenish olive. **Lenticels:** medium in number and size, roundish, yellowish gray, nearly even.

Leaf Blade: medium or above in size, moderately folded, moderately reflexed, oval to slightly ovate, dark clear green, spreading, of medium thickness. **Serrations:** only moderately sharp, regular, rather distinct. **Surface:** moderately shining, smooth to slightly rough, with little pubescence.

Prominent Characteristics

Rather upright growth and dark green leaves, moderately folded and reflexed and with even, rather sharp serrations.

Not often confused with other varieties.

MOTHER

NEWTOWN PIPPIN

Tree: not vigorous, rather broadly diverging.

Shoots: medium in length, rather slender, nearly straight, slightly curved, with rather short internodes. **Bark:** greenish olive — greenish olive. **Lenticels:** medium to rather numerous, small, roundish, yellowish gray, nearly even.

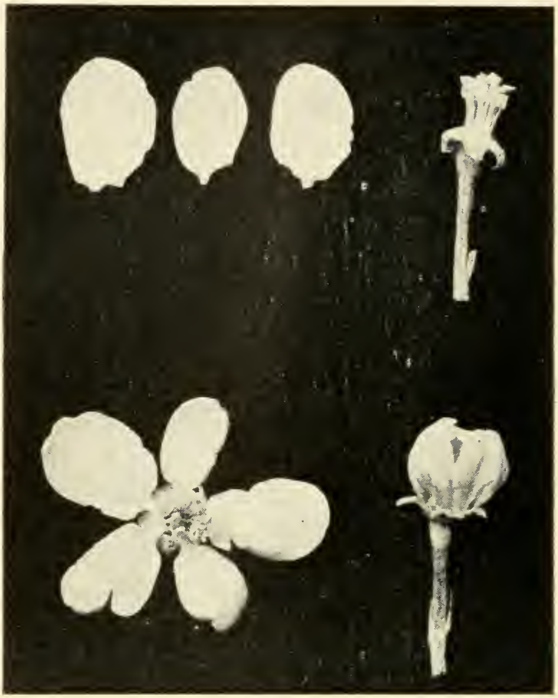
Leaf Blade: medium in size, moderately folded, moderately reflexed, oval to slightly ovate, medium green, slightly bluish, spreading. **Serrations:** not very sharp, irregular, fairly distinct. **Surface:** dull, slightly bluish, rather coarse, with medium pubescence.

Prominent Characteristics

Moderate, somewhat irregular growth; rather small, rough leaves with a bluish cast, which often show browning at the edges; irregular serrations.

Not easily confused with other varieties.

NEWTOWN PIPPIN



NORTHERN SPY

Tree: moderately vigorous, narrowly diverging, slightly upcurving.

Shoots: medium in size, rather slender, nearly straight, often curving, with medium to rather short internodes. **Bark:** reddish or greenish olive — greenish olive. **Lenticels:** many, small, roundish, light yellowish gray, slightly raised.

Leaf Blade: medium or below in size, somewhat folded, sometimes slightly reflexed, even or slightly waved, ovate, upright. **Serrations:** rather sharp, fairly regular, shallow, not distinct. **Surface:** shining, smooth, with medium pubescence.

Prominent Characteristics

Not very large, rather narrow, upright growth; many small, whitish lenticels: rather fine, shallow serrations and distinct principal veins in the leaves.

Differs from —

Mann by more upright growth, leaves less distinctly folded and reflexed, with finer, less regular serrations and less pubescence.

NORTHERN SPY

NORTHWESTERN GREENING

Tree: tall and rather vigorous, rather narrowly diverging.

Shoots: medium to rather long, rather slender, nearly straight, very little curved. **Bark:** dark reddish — dark reddish olive. **Lenticels:** medium in number, rather large, roundish, yellowish gray, distinctly raised.

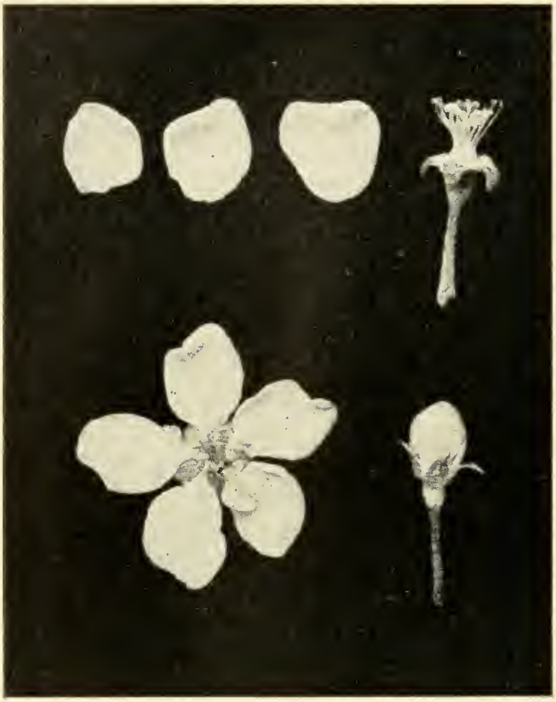
Leaf Blade: medium or below in size, moderately folded, somewhat reflexed, nearly even, generally ovate, medium green, spreading. **Serrations:** moderately dull, rather small, fairly regular, rather shallow, fairly distinct. **Surface:** moderately shining, rather coarse, with little pubescence.

Prominent Characteristics

Tall, upright growth, reddish shoot bark, rather small leaves, with rather small, dull serrations. Conspicuous raised lenticels, easily felt with the thumb and finger.

Not often confused with other varieties.

NORTHWESTERN GREENING



ONTARIO

Tree: quite vigorous, diverging, upcurving.

Shoots: rather long, medium in size, nearly straight, moderately curved, with medium internodes. **Bark:** greenish olive — olive. **Lenticels:** medium in number and size, roundish or elongated, yellowish gray, nearly even.

Leaf Blade: medium in size, considerably folded, somewhat reflexed, coarsely waved, broadly oval to ovate, medium green, generally spreading. **Serrations:** sharp, medium to rather small, regular, shallow, not distinct. **Surface:** rather dull, slightly rough, with medium pubescence.

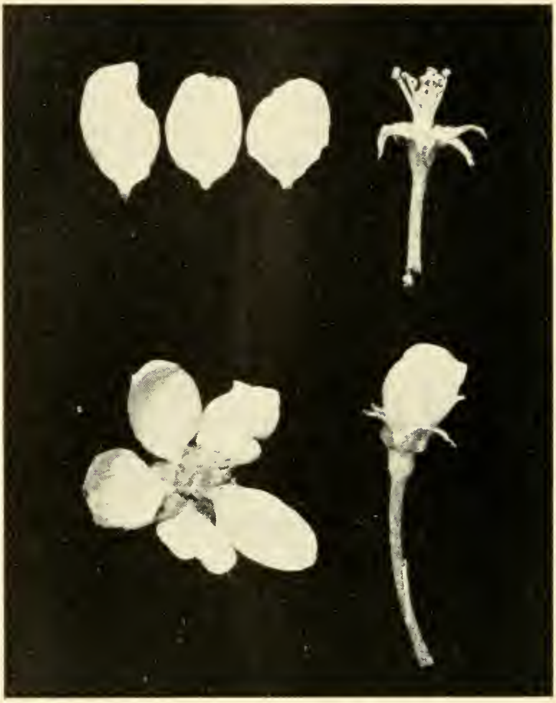
Prominent Characteristics

Rather vigorous, moderately upright growth; greenish olive bark; soft, folded, finely serrate leaves.

Differs from —

Wagener by less narrow upcurving top, and broader, less folded, less pubescent leaves; fewer spur leaves near base of shoots; and finer serrations.

ONTARIO



OPALESCENT

Tree: vigorous, rather narrowly upcurving.

Shoots: rather long, medium to rather stout, almost straight, moderately to considerably curved, with medium internodes. **Bark**: olive — greenish olive. **Lenticels**: few, medium in size, roundish, grayish, even.

Leaf Blade: medium in size, distinctly folded, straight or slightly reflexed, moderately waved, ovate, medium to light green, more or less upright. **Serrations**: only moderately sharp, rather small, fairly regular, of medium depth. **Surface**: moderately dull, fairly smooth, with moderately heavy pubescence.

Prominent Characteristics

Vigorous upright growth; yellowish bark; rather upright, soft pubescent leaves.

OPALESCENT

ORLEANS

Tree: only moderately vigorous, moderately diverging.

Shoots: medium in length, rather stout, straight, with little or no curvature and rather short internodes. **Bark**: dull, dark yellowish olive often slightly reddish — dark olive. **Lenticels**: few, medium to large, roundish, yellowish gray, slightly raised.

Leaf Blade: rather small to medium, considerably folded, somewhat reflexed, scarcely waved, ovate to rather long oval, rather narrow at base, medium to dark green, rather upright. **Serrations**: dull to moderately sharp, fairly regular. **Surface**: rather dull and rough, with rather heavy grayish pubescence.

Prominent Characteristics

Rather stout, upright growth, with many leaves, especially on one-year trees. Usually dull serrations and a grayish, heavy pubescence on the leaves.

Differs from —

Medina by duller serrations and heavier pubescence. Usually not so tall. Leaves often longer and narrower at the base.

Newfane by shorter, more leafy growth, usually fewer lenticels. Leaves more pubescent, with coarser and duller serrations.

ORLEANS

ORTLEY

Tree: moderately vigorous, moderately tall, moderately diverging.

Shoots: medium in length, medium to rather slender, straight, little or no curvature, with rather short internodes. **Bark:** greenish olive — dark olive. **Lenticels:** rather few, small, roundish, yellowish gray, slightly raised.

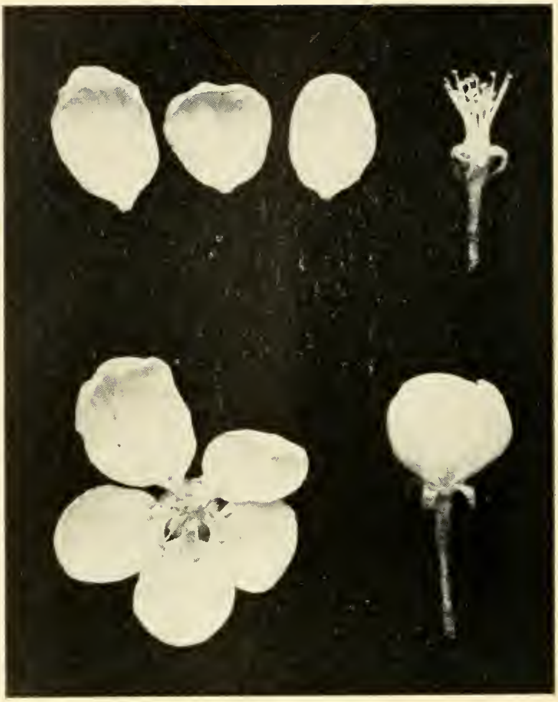
Leaf Blade. medium or below in size, slightly folded, nearly even, oval to somewhat ovate, medium green, spreading. **Serrations:** only moderately sharp, rather small, regular, shallow. **Surface:** rather shining, with medium texture and rather little pubescence.

Prominent Characteristics

Yellowish bark, rather small leaves with regular, only moderately sharp serrations.

Not often confused with other varieties.

ORTLEY



PATRICIA

Tree: moderately vigorous, rather broadly diverging, slightly upcurving.

Shoots: medium in length and size, nearly straight, often slightly curved, with rather short internodes. **Bark:** reddish — greenish olive. **Lenticels:** medium in number and size, roundish, grayish yellow, slightly raised.

Leaf Blade: medium to rather large, generally slightly folded, nearly straight, generally even, rather broadly ovate, medium green, often with faint yellowish tinge, spreading. **Serrations:** moderately sharp, regular, rather shallow, moderately distinct. **Surface:** dull, with medium pubescence.

Prominent Characteristics

Somewhat like McIntosh; rather tall, with ovate leaves.

Differs from —

McIntosh by less sturdy growth, sharper serrations. Leaves much narrower at base and apex.

Milton by less slender shoots and taller growth. It is quite distinct from other McIntosh seedlings.

PATRICIA

PATTEN GREENING

Tree: vigorous, rather broadly diverging.

Shoots: medium to rather long, straight, often slightly curved, with medium internodes. **Bark:** dark greenish olive — dark olive. **Lenticels:** rather few, small, roundish, yellowish gray, slightly raised.

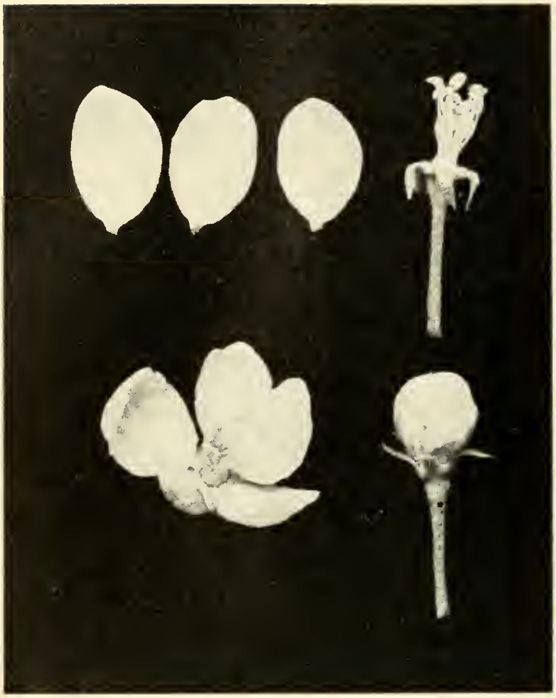
Leaf Blade: medium or above in size, flat or slightly folded, nearly straight, even, broadly round, dark green, spreading. **Serrations:** moderately sharp, irregular, moderately distinct. **Surface:** moderately shining, rather rough, with medium pubescence.

Prominent Characteristics

Sturdy growth; greenish bark; leaves large, roundish, and usually nearly flat.

Few varieties at all resemble Patten Greening.

PATTEN GREENING



PECK PLEASANT

Tree: moderately vigorous, moderately diverging, slightly upcurving.

Shoots: medium in length and size, nearly straight, slightly to moderately curved, with rather short internodes. **Bark:** dark reddish olive — dark olive. **Lenticels:** medium in number and size, roundish, grayish, slightly raised.

Leaf Blade: small to medium, moderately folded, somewhat reflexed especially toward the tip, generally even, oval to slightly ovate, dark green, spreading. **Serrations:** moderately sharp, small, fairly regular, rather shallow, not very distinct. **Surface:** rather dull, moderately coarse, with medium pubescence.

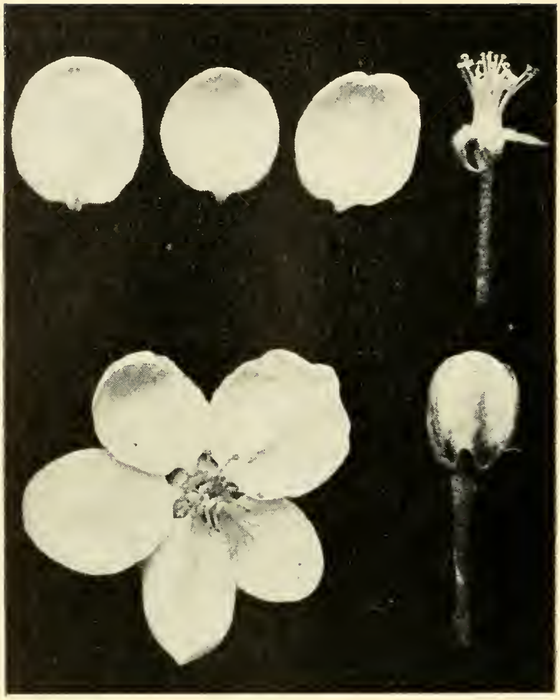
Prominent Characteristics

Dark green leaves, rather stiff, with fine, not very sharp serrations.

Differs from —

Northern Spy by darker green color of leaves, which are more folded and reflexed, especially the tip. Lenticels more distinct and of a lighter color.

PECK PLEASANT



PEDRO

Tree: moderately vigorous, spreading, moderately upcurving.

Shoots: medium in length and size, nearly straight, moderately curved, with medium internodes. **Bark:** dark olive — yellowish olive, sometimes slightly reddish. **Lenticels:** medium in number and size, roundish, yellowish olive, slightly raised.

Leaf Blade: medium to rather large, more or less folded, more or less reflexed, slightly waved, oval to slightly ovate, green with slight yellowish tinge, spreading, rather thin. **Serrations:** moderately sharp, irregular, rather deep and distinct. **Surface:** rather dull, with moderately coarse texture and little pubescence.

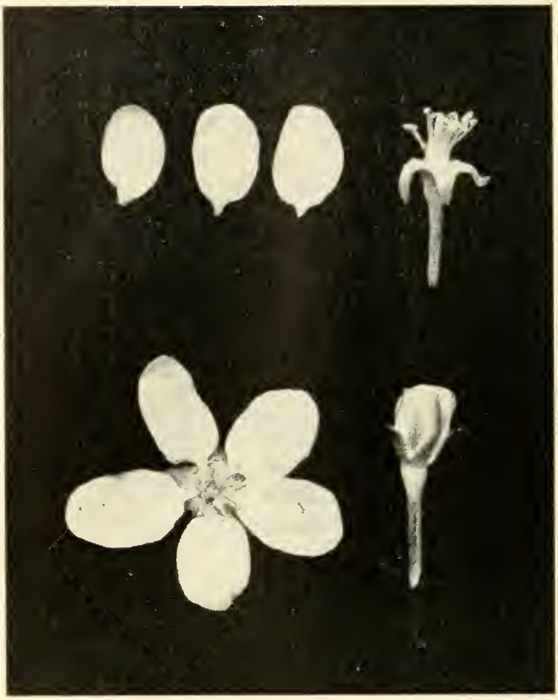
Prominent Characteristics

A slight yellowish tinge to foliage, yellowish bark, and large, rather coarsely serrate leaves.

Differs from —

McIntosh by coarser and sharper serrations and more open growth. Leaves more folded and more often reflexed at the tips.

PEDRO



PEWAUKEE

Tree: quite vigorous, diverging, moderately upcurving.

Shoots: rather long, medium in size, nearly straight, more or less curved, with medium internodes. **Bark:** dark reddish olive — dark olive. **Lenticels:** medium in number, rather small, roundish to oval, yellowish gray, slightly raised.

Leaf Blade: medium in size, moderately folded, moderately reflexed, more or less waved, oval to slightly ovate, rather dark green, spreading. **Serrations:** fairly sharp, fairly regular, quite distinct. **Surface:** moderately shining, slightly rough, with rather sparse pubescence.

Prominent Characteristics

Vigorous, rather upright growth, dark red bark, and rather coarse foliage.

Differs from —

Fallawater by absence of cedar rust spots, more upright growth, and less tendency to rosette leaves at tips. Lenticels are less distinctly raised.

PEWAUKEE

PORTER

Tree: only moderately vigorous, rather broadly diverging.

Shoots. medium in length, rather slender, nearly straight, with little to moderate curvature and medium internodes. **Bark**: reddish olive — olive. **Lenticels**: medium in number, small, roundish or oval, yellowish gray, nearly even.

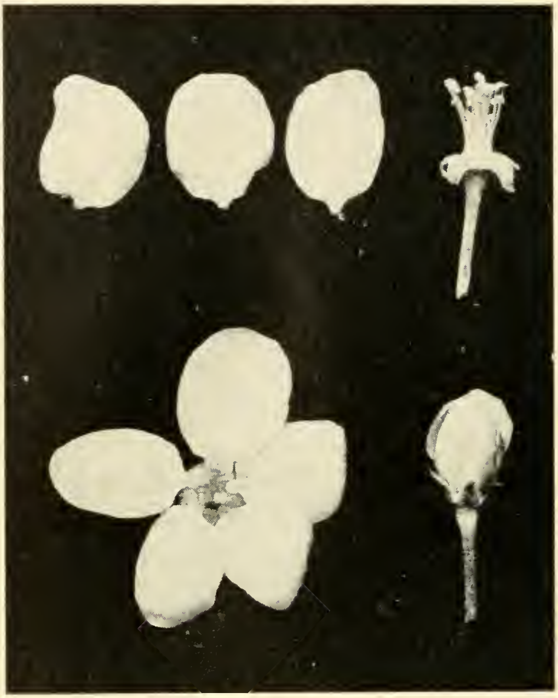
Leaf Blade: rather small, slightly folded, straight or slightly reflexed, generally even, oval, medium green, spreading. **Serrations**: very sharp, rather small, very regular, quite distinct. **Surface**: moderately shining, rather smooth, with little pubescence.

Prominent Characteristics

Moderately vigorous growth, yellowish bark, rather small oval leaves, finely and sharply serrated.

Porter is quite distinct from other varieties.

PORTER



PUMPKIN SWEET

Tree: vigorous, moderately diverging, slightly upcurving.

Shoots: medium in length and size, nearly straight, little to moderately curved, with rather short internodes. **Bark:** greenish olive — greenish olive. **Lenticels:** medium in number, small to medium sized, roundish, grayish, nearly even.

Leaf Blade: medium in size, moderately folded, reflexed, more or less waved, oval to slightly ovate, dark clear green, spreading, rather thick. **Serrations:** moderately sharp, fairly regular, moderately distinct. **Surface:** dull, rather coarse, with medium pubescence.

Prominent Characteristics

Vigorous, rather upright growth; greenish yellow bark; coarse, dark green, folded and waved leaves.

This is probably the true Pumpkin Sweet or Lyman's Pumpkin Sweet. It has been found in nurseries under the name of Pound Sweet; but another variety, very distinct in the nursery tree, is believed to be the true Pound Sweet. The latter has leaves very different from the leaves of this variety, being very broad or roundish, with distinct, rather sharp serrations.

PUMPKIN SWEET

RALLS

Tree: moderately vigorous, rather broadly diverging.

Shoots: medium in length and size, straight, with slight to medium curvature and medium internodes. **Bark**: reddish olive — dark olive. **Lenticels**: many, medium in size, roundish, yellowish gray, nearly even.

Leaf Blade: medium in size, moderately folded, moderately reflexed, usually slightly waved, oval, medium green, spreading. **Serrations**: sharp, fairly regular, quite distinct. **Surface**: moderately shining, with medium texture and slight to medium pubescence.

Prominent Characteristics

Moderately vigorous, with more or less folded, oval, rather sharply serrated leaves.

RALLS

RAMBO

Tree: moderately vigorous, rather distinctly diverging.

Shoots: medium in length, rather slender, nearly straight, with little or no curvature and medium internodes. **Bark:** reddish olive — greenish olive. **Lenticels.** medium to many, very small, roundish, yellowish, even.

Leaf Blade: medium in size, somewhat folded, straight to slightly reflexed, even to irregularly waved, oval to slightly ovate, rather dark, slightly bluish green, generally upright, rather thick. **Serrations:** rather dull, generally irregular, moderately distinct. **Surface:** rather dull, slightly bluish, moderately coarse, with medium pubescence.

Prominent Characteristics

Rather upright growth, somewhat straggly; rather coarse, rough leaves with irregular, dull serrations.

Differs from —

Summer Rambo very distinctly, any confusion arising through similarity of names. Rambo is not so tall, is of more upright, compact growth, and has a bluish cast to the foliage. The leaves are smaller, more upright, with duller, less distinct serrations.

Winter Banana by more upright growth, less yellowish foliage, and the absence of double serrations.

RAMBO

RANIER

Tree: moderately vigorous, rather broadly diverging.

Shoots: medium to rather long, medium in size, nearly straight, with little or no curvature and medium internodes. **Bark:** medium dark reddish — reddish olive. **Lenticels:** very few, medium in size, roundish, yellowish gray, nearly even.

Leaf Blade: medium or above in size, more or less folded, slightly reflexed, coarsely waved, oval to somewhat ovate, moderately dark green, spreading, rather thick. **Serrations:** rather sharp, fairly regular, not distinct, being closely set together. **Surface:** rather dull, rather coarse, with moderate pubescence.

RANIER

RED ASTRACHAN

Tree: moderately vigorous, not tall, generally moderately upcurving.

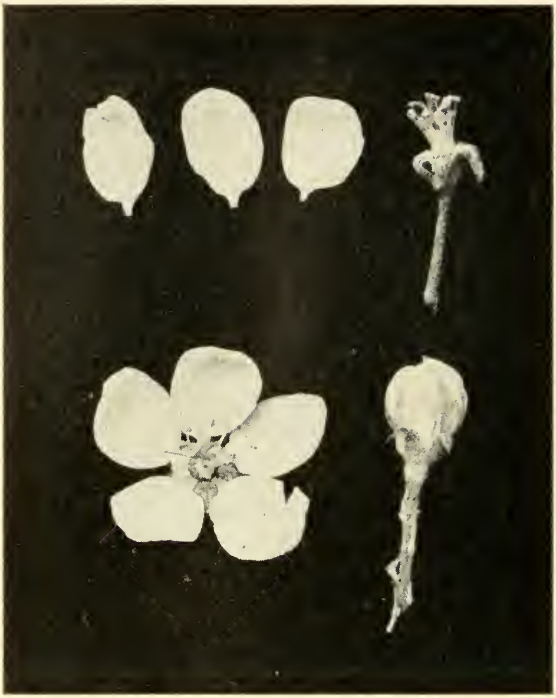
Shoots: medium to rather short, rather stout, nearly straight, more or less distinctly curved, with medium to short internodes. **Bark**: reddish olive — greenish olive. **Lenticels**: medium in number and size, roundish, light gray, even.

Leaf Blade: rather large, slightly folded, generally slightly reflexed, even or slightly waved or wrinkled on edges, broad oval, medium to dark green, spreading to slightly drooping. **Serrations**: rather dull, irregular, rather shallow. **Surface**: dull with a slight bluish cast, rather coarse, with slight pubescence.

Prominent Characteristics ·

Rather short trees and upcurving growth; large, coarse leaves with coarse serrations and a slight bluish cast.

RED ASTRACHAN



RED JUNE

Tree: moderately vigorous, ascending, narrowly upcurving.

Shoots: medium in length, rather slender, nearly straight, with slight or no curvature and medium to rather long internodes. **Bark:** yellowish olive — dark yellowish olive. **Lenticels:** few, medium in size, generally elongated, yellowish gray, slightly raised.

Leaf Blade: medium or below in size, somewhat folded, slightly reflexed, even, rather narrow oval, slightly yellowish green. **Serrations:** sharp, quite regular, rather shallow, moderately distinct. **Surface:** medium, slightly rough, with medium pubescence.

Prominent Characteristics

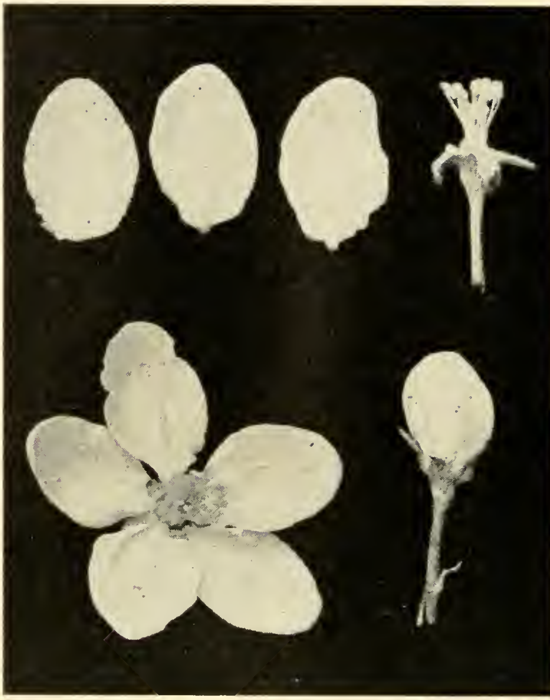
Rather narrow oval leaves with sharp, shallow, fairly regular serrations.

Differs from —

Wilson Red June by less narrow, upright growth, less reddish bark, fewer and less conspicuous lenticels, and less folded and waved leaves.

Carolina Red June as found in the nurseries is very similar if not identical.

RED JUNE



RHODE ISLAND GREENING

Tree: very vigorous, broadly diverging or spreading.

Shoots: medium in length, rather stout, nearly straight, with slight to moderate curvature and medium internodes. **Bark:** reddish olive — dark olive. **Lenticels:** few to medium in number, roundish, yellowish gray, nearly even.

Leaf Blade: medium to large, nearly flat, nearly straight, generally even, broad oval, deep clear green, spreading. **Serrations:** sharp, fairly regular, quite distinct. **Surface:** dull, moderately smooth, with medium pubescence.

Prominent Characteristics

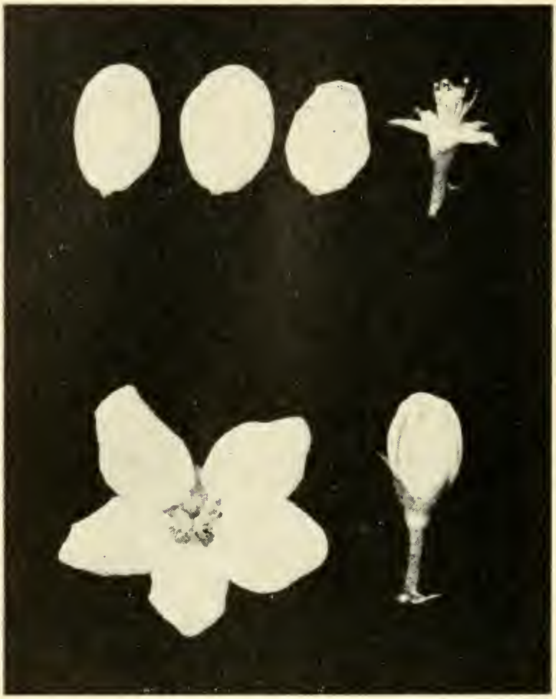
Stout, vigorous growth; large, deep green, flat, sharply serrated leaves; smooth bark with few lenticels.

Differs from —

Baldwin by greener bark and flatter leaves with more distinct serrations.

Roxbury Russet by less tall, more spreading growth, less gray pubescence, and less folded leaves.

RHODE ISLAND GREENING



RIBSTON

Tree: quite vigorous, moderately diverging.

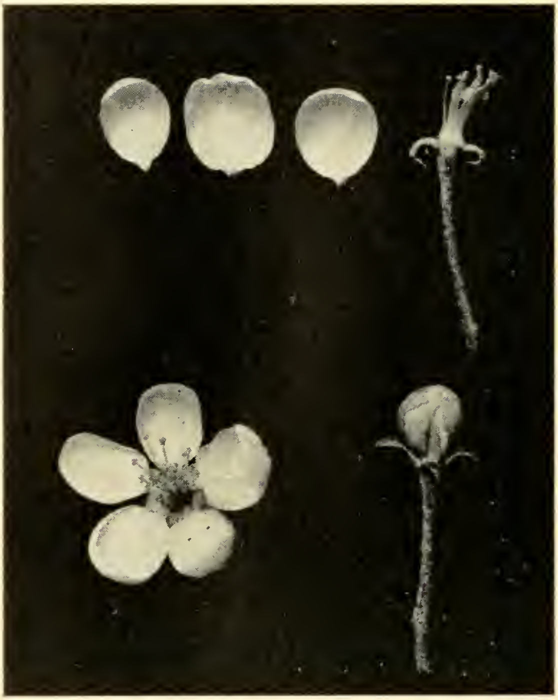
Shoots: medium to rather long, medium in size, nearly straight, slightly curved, with medium internodes. **Bark:** dark reddish olive — greenish olive. **Lenticels:** medium in number, small, roundish, yellowish gray, fairly even.

Leaf Blade: medium in size, distinctly folded, slightly reflexed, nearly even, narrow oval to ovate, deep green, spreading. **Serrations:** rather sharp, quite regular, shallow. **Surface:** dull, rather smooth, with a heavy pubescence.

Prominent Characteristics

Rather vigorous, upright growth; deep green, very pubescent foliage; distinctly folded leaves.

RIBSTON



ROME BEAUTY

Tree: moderately vigorous, ascending, narrowly upcurving.

Shoots: medium in length, rather slender, nearly straight, with moderate curvature and medium internodes. **Bark:** light reddish olive — dark olive. **Lenticels:** medium to few, rather small, roundish, yellowish gray, slightly raised.

Leaf Blade: rather small, moderately folded, usually much reflexed, nearly even or slightly waved, oval, medium light green, spreading. **Serrations:** very sharp, rather small, regular, fairly distinct. **Surface:** moderately shining, fairly smooth, with little pubescence.

Prominent Characteristics

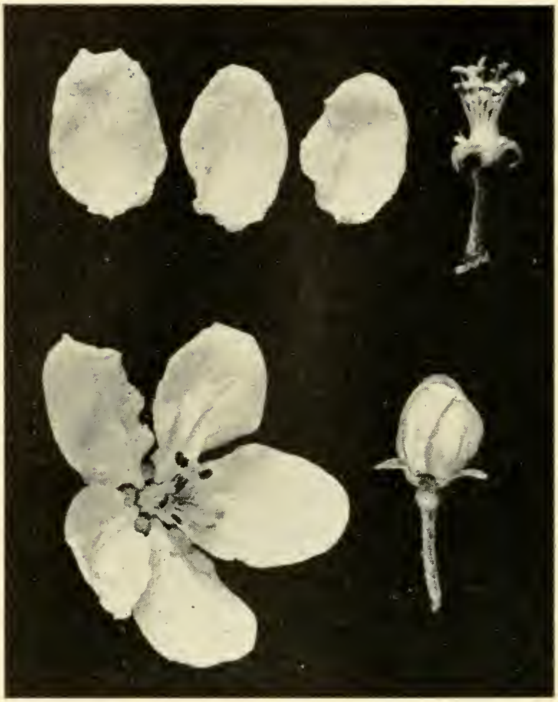
Narrow upright growth, reddish bark, and rather small, oval, sharply serrated leaves.

Differs from —

Grimes and **Golden Delicious** by redder bark and more sharply serrated leaves.

Gallia Beauty and **Red Rome** cannot be distinguished from Rome Beauty.

ROME BEAUTY



ROXBURY RUSSET

Tree: quite vigorous, moderately diverging.

Shoots: rather long, medium in size, nearly straight, with slight or no curvature and medium internodes. **Bark:** reddish olive — dark olive. **Lenticels:** few, medium in size, roundish or oval, grayish, even.

Leaf Blade: medium to large, more or less folded near the edge, slightly reflexed, nearly even, broad oval, deep clear green, spreading. **Serrations:** moderately sharp, quite regular. **Surface:** rather shining, slightly rough, with moderately heavy pubescence.

Prominent Characteristics

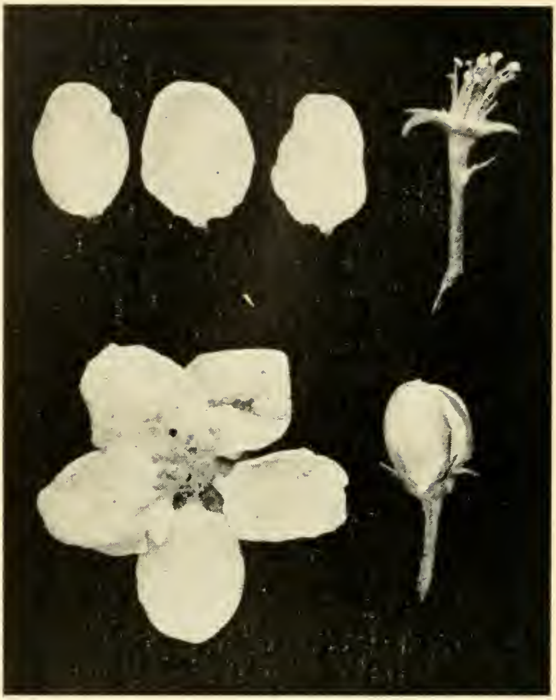
Vigorous growth, greenish bark, rather large serrations, leaves with considerable pubescence.

Differs from —

Baldwin by greener bark, usually much more pubescence, and somewhat darker green leaves, folded nearer the midrib.

Rhode Island Greening by taller, less spreading growth, much grayer appearance, and more folded leaves with duller serrations.

ROXBURY RUSSET



SMOKEHOUSE

Tree: vigorous, broadly diverging.

Shoots: generally long, medium in size, nearly straight, with slight or no curvature and medium internodes. **Bark:** dark reddish olive — dark olive. **Lenticels:** medium in number, rather large, roundish, yellowish gray, raised.

Leaf Blade: rather large, considerably folded, more or less reflexed, nearly even, oval to slightly ovate, deep clear green, spreading. **Serrations:** very sharp, fairly regular, and very distinct. **Surface:** shining, fairly smooth, with medium pubescence.

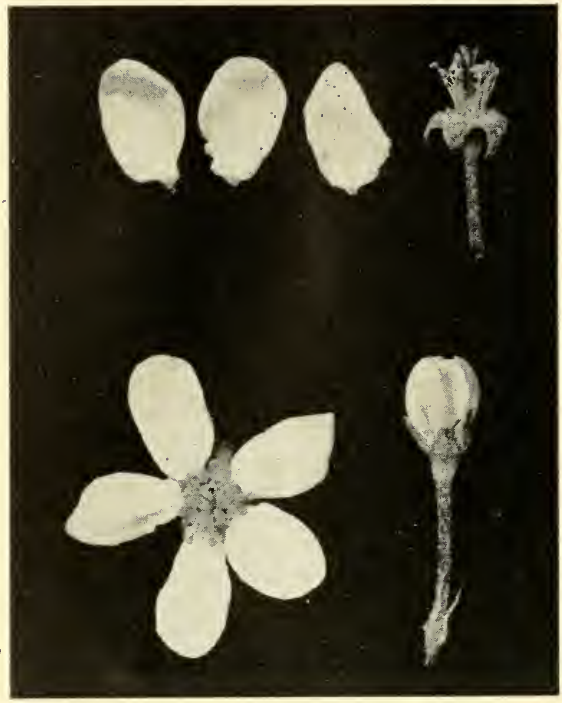
Prominent Characteristics

Vigorous growth, reddish bark, and rather broad leaves with very sharp, distinct serrations.

Differs from —

Summer Rambo by more yellowish color in the bark, finer and more regular leaf serrations, and more shining leaf surface.

SMOKEHOUSE



STARK

Tree: very vigorous, rather broadly diverging.

Shoots: medium to long, medium in size, nearly straight, with slight to medium curvature and medium internodes. **Bark**: dark reddish olive — dark olive. **Lenticels**: few to medium, rather small, roundish, light grayish, slightly raised.

Leaf Blade: large, flat to slightly folded, straight, or slightly reflexed, even or slightly waved, broad oval, rather dark green, spreading. **Serrations**: sharp, fairly regular, quite distinct. **Surface**: moderately shining, rather smooth, with little to medium pubescence.

Prominent Characteristics

Vigorous growth; dark red bark; and large, flat, sharply serrated leaves, often narrower at the base, and with the midrib often showing a tendency to reverse curvature.

Differs from —

Rhode Island Greening by redder bark, rather taller growth, and more upright shoots.

STARK

STAYMAN

Tree: broadly vigorous, broadly diverging.

Shoots: generally long, medium in size, nearly straight, a little curved, with medium internodes. **Bark:** dull reddish — dark olive, sometimes with a characteristic brownish and roughened "rust" towards the base of vigorous shoots. **Lenticels:** few, medium in size, roundish, yellowish gray, even.

Leaf Blade: medium in size, more or less folded, somewhat reflexed, usually somewhat waved, rather broad oval, medium green. **Serrations:** rather sharp, somewhat irregular, moderately deep, moderately distinct. **Surface:** rather dull, rather rough, with medium pubescence having a slight brownish tinge.

Prominent Characteristics

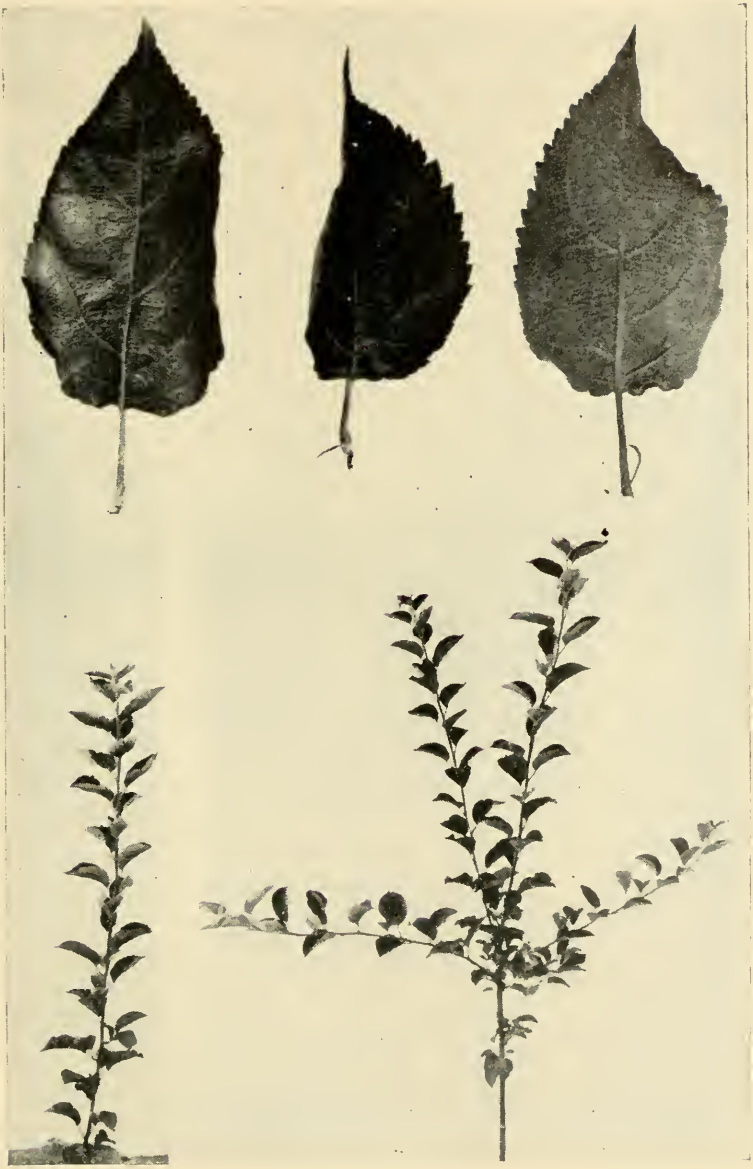
Vigorous, somewhat straggly growth; rather long shoots with few lenticels; leaves rather coarse and sharply serrate; one-year trees often grow in a slanting direction.

Differs from —

Arkansas and **Paragon** by somewhat more sprawling growth; brownish "rust"; fewer, larger, less conspicuous, and less whitish lenticels; leaves more folded with more pubescence; serrations not quite so sharp, not quite so distinct.

Tioga by fewer weak, upcurving shoots in the head of the tree; less spreading, more folded leaves with a more brownish cast and more hairy pubescence.

Turley by less spreading, more folded, more pubescent leaves. These differences are small. Turley is in many ways intermediate between Arkansas and Stayman.



STAYMAN

SUMMER RAMBO

Tree: vigorous, spreading, broadly upcurving.

Shoots: generally long, rather stout, nearly straight, with slight to moderate curvature and medium internodes. **Bark:** dark reddish olive — dark olive. **Lenticels:** medium in size and number, roundish, yellowish gray, raised.

Leaf Blade: medium to large, moderately folded, nearly straight, nearly even, broad oval, medium green, spreading. **Serrations:** sharp, quite regular, very distinct. **Surface:** moderately shining, fairly smooth, with medium pubescence.

Prominent Characteristics

Vigorous, spreading growth; reddish olive bark; and sharply, distinctly serrated leaves.

Differs from —

Smokehouse by more greenish bark, somewhat larger shoots, and less shining leaf surface.

SUMMER RAMBO

SWEET BOUGH

Tree: moderately vigorous, moderately upcurving.

Shoots: medium to rather long, medium in size, nearly straight, moderately curved, with medium internodes. **Bark:** olive, slightly reddish — yellowish olive. **Lenticels:** few, small, roundish, yellowish, nearly even.

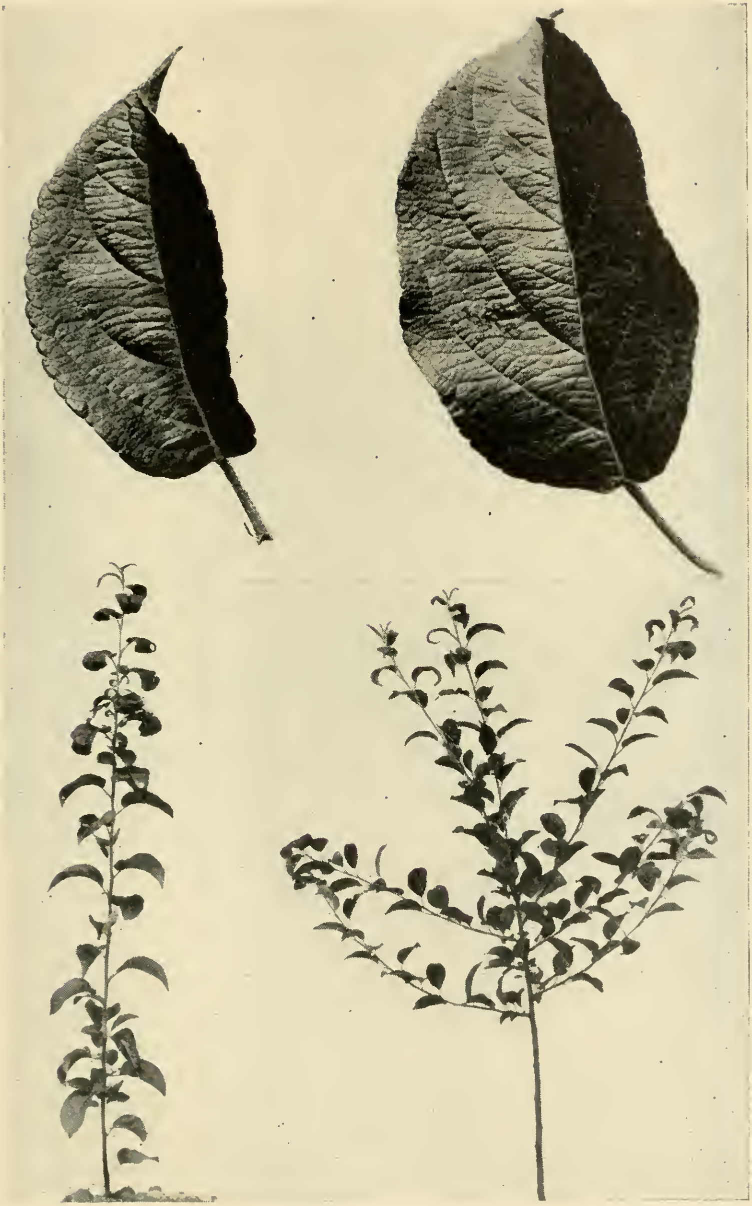
Leaf Blade: medium in size, slightly folded, moderately reflexed, nearly even, generally oval, medium to yellowish green, spreading. **Serrations:** dull, quite regular, very shallow. **Surface:** shining, fairly smooth, with medium pubescence.

Prominent Characteristics

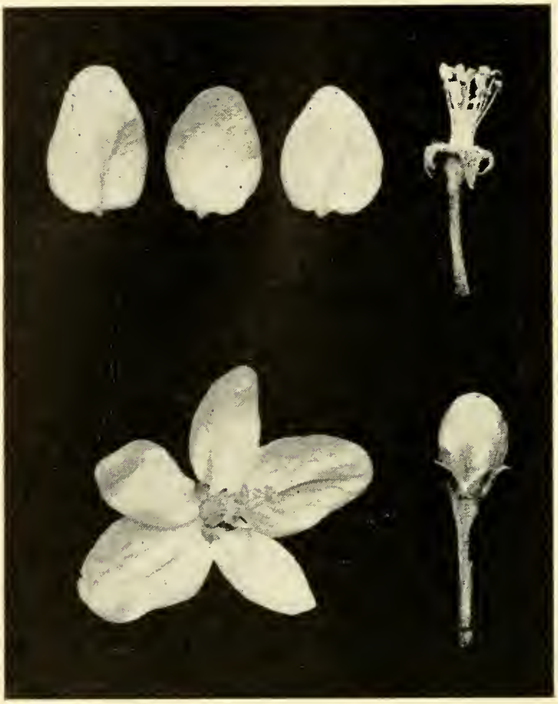
Rather upright growth, yellowish bark, evenly folded leaves with very shallow dull serrations.

Differs from —

Golden Sweet by much shallower and duller leaf serrations.



SWEET BOUGH



TIOGA

Tree: moderately vigorous, moderately upcurving.

Shoots: medium to rather short, medium in size, nearly straight, with moderate curvature and rather short internodes. **Bark:** dark reddish olive — rather dark olive. **Lenticels:** medium or above in number, rather small, roundish, yellowish gray, slightly raised.

Leaf Blade: medium in size, considerably folded, somewhat reflexed, generally waved, ovate, medium green, spreading. **Serrations:** moderately sharp, fairly regular, fairly distinct. **Surface:** somewhat shining, rather rough, with medium pubescence.

TIOGA

TOLMAN

Tree: quite vigorous, diverging to ascending.

Shoots: medium in length and size, nearly straight, moderately curving, with medium internodes. **Bark:** reddish olive -- yellowish olive. **Lenticels:** few to medium, medium in size, roundish, yellowish gray, slightly raised.

Leaf Blade: medium in size, distinctly folded, reflexed, usually distinctly waved, rather narrow oval to slightly ovate, usually with narrow base, deep green with bluish cast, spreading. **Serrations:** rather dull, fairly regular, moderately distinct. **Surface:** dull, rather rough, with rather heavy pubescence.

Prominent Characteristics

Tall trees with rather long shoots; leaves usually folded and distinctly waved, quite pubescent, and dark green with a bluish cast.

TOLMAN

TRANSCENDENT

Tree: very vigorous, broadly diverging.

Shoots: generally long, of medium size, nearly straight, with little curvature and long internodes. **Bark:** bright reddish olive — dark olive. **Lenticels:** medium in number, large, roundish or oval, yellowish gray, raised.

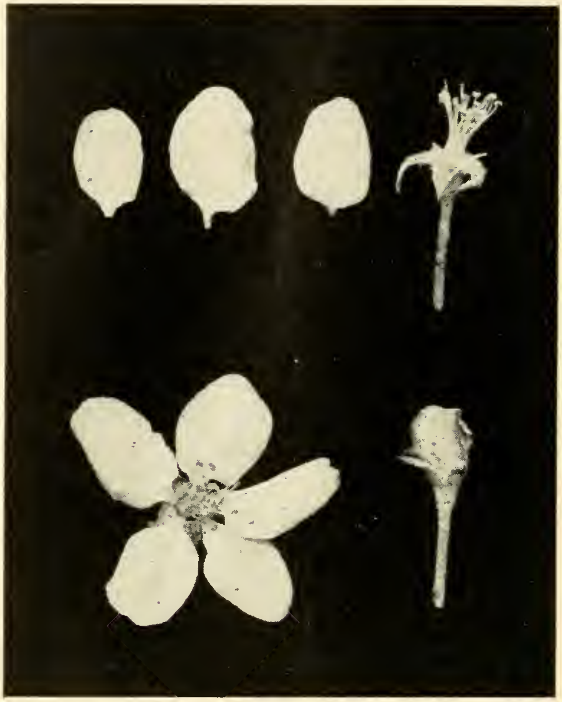
Leaf Blade: rather large, nearly flat, nearly straight, even, distinctly oval, medium green, spreading. **Serrations:** rather sharp, regular, rather shallow, not very distinct. **Surface:** shining, smooth, with little pubescence.

Prominent Characteristics

Large, vigorous tree; spreading growth; reddish bark; smooth, flat, finely serrated leaves.

Transcendent is not easily confused with any other common variety.

TRANSCENDENT



TWENTY OUNCE

Tree: only moderately vigorous, moderately upcurving.

Shoots: medium to rather short, medium in size, nearly straight, with little to moderate curvature and short internodes. **Bark:** greenish olive — olive green. **Lenticels:** medium in number, small, roundish to oval, yellowish gray, even.

Leaf Blade: medium in size, flat or slightly folded, little to moderately reflexed, even or slightly waved, oval, medium green, spreading to drooping, rather thick. **Serrations:** usually dull, quite regular, shallow, not very distinct. **Surface:** very shining, moderately coarse, with little pubescence.

Prominent Characteristics

Rather stocky growth, yellowish bark, oval leaves with shallow, dull serrations very shiny surface.

TWENTY OUNCE

WAGENER

Tree: moderately vigorous, upright, narrowly upcurving.

Shoots: medium in length and size, straight, little to considerably curved, with short internodes. **Bark:** reddish olive — dark olive. **Lenticels:** few, small, roundish, yellowish gray, even.

Leaf Blade: medium in size, much folded, generally reflexed, somewhat waved, oval to slightly ovate, rather light green, rather upright. **Serrations:** moderately sharp, regular, of medium depth, fairly distinct. **Surface:** dull, fairly smooth, with heavy pubescence.

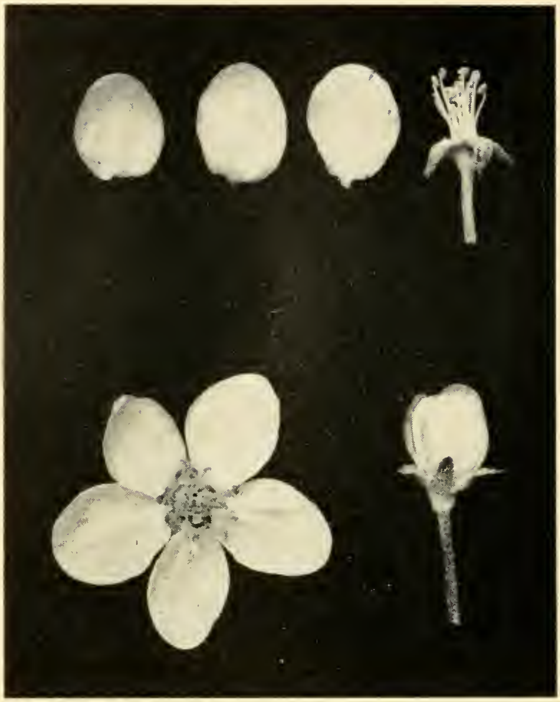
Prominent Characteristics

Rather narrow upright growth, yellowish bark, and leaves much folded and waved, with heavy pubescence.

Differs from —

Ontario by narrower, more upright growth; more spur leaves at the base of the shoots; and leaves not so broad, more folded, and more heavily pubescent.

WAGENER



WEALTHY

Tree: moderately vigorous, rather tall, moderately diverging.

Shoots: medium in length, rather slender, nearly straight, generally little curved, with medium to rather long internodes. **Bark:** reddish olive — yellowish olive. **Lenticels:** medium in number and size, roundish, some distinctly elongated, yellowish gray, nearly even.

Leaf Blade: medium to rather small, flat to slightly folded, somewhat reflexed, frequently with a "spiral tip," generally waved, oval, medium green, spreading to slightly upright, rather thick. **Serrations:** rather dull, medium in size, slightly irregular, rather shallow. **Surface:** dull, pebbled, with moderate pubescence.

Prominent Characteristics

Upright, rather straggly growth; leaves with dull serrations, of a pebbly texture, often with a spiral tip; susceptibility to cedar rust.

Differs from —

Duchess of Oldenburg by taller growth, more oval leaves with a pebbly surface, absence of "hail mark depressions," and susceptibility to cedar rust.

WEALTHY

WESTFIELD

Tree: rather vigorous, moderately diverging.

Shoots: medium in length and size, nearly straight, with slight or no curvature and medium internodes. **Bark:** reddish olive — dark olive. **Lenticels:** medium or below in number, rather large, roundish, yellowish gray, slightly raised.

Leaf Blade: medium in size, more or less folded and reflexed, even or slightly waved, ovate, medium green, spreading. **Serrations:** quite sharp, quite regular, rather large, deep and distinct. **Surface:** somewhat shining, rather smooth, with moderate pubescence.

Prominent Characteristics

Leaves more or less folded, with sharp, distinct serrations.

WESTFIELD

WHITE WINTER PEARMAIN

Tree: quite vigorous, moderately diverging.

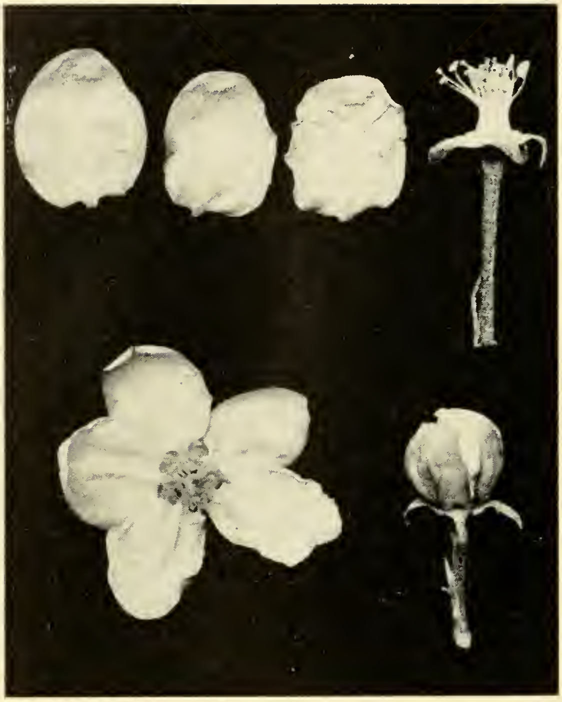
Shoots: medium in length and size, nearly straight, with slight or no curvature and rather short internodes. **Bark**: reddish olive — dark olive. **Lenticels**. many, rather small, roundish, yellowish gray, nearly even.

Leaf Blade: medium or below in size, somewhat folded, slightly reflexed, nearly even, oval, medium to light green, rather upright. **Serrations**: rather sharp, small, fairly regular. **Surface**: moderately shining, fairly smooth, with medium pubescence.

Prominent Characteristics

Tall, upright growth; dark reddish bark with many lenticels; leaves rather narrow, especially at apex, with moderately sharp, fine, shallow, and regular serrations.

WHITE WINTER PEARMAIN



WILLIAMS

Tree: weak, broadly diverging.

Shoots: medium in length and size, nearly straight, with little curvature and medium internodes. **Bark:** dark reddish — dark greenish olive. **Lenticels:** medium in number and size, roundish or slightly elongate, grayish, slightly raised.

Leaf Blade: medium in size, somewhat folded, somewhat reflexed, with a peculiar coarse waving, rather narrow oval, medium green, spreading. **Serrations:** dull, medium in size, quite regular, rather shallow, not distinct. **Surface:** dull, somewhat pebbled, with medium pubescence.

Prominent Characteristics

Rather weak, straggling growth, and coarsely waved, dull serrate leaves.

WILLIAMS

WILLOWTWIG

Tree: moderately vigorous, moderately diverging, upcurving.

Shoots: medium in size, slender, nearly straight, with slight to moderate curvature and rather short internodes. **Bark**: yellowish olive — dark olive. **Lenticels**: rather few, small, roundish, yellowish gray, even.

Leaf Blade: medium or below in size, slightly to moderately folded, somewhat reflexed, even, oval, medium to light green, generally spreading. **Serrations**: sharp, rather small, quite regular, very shallow, moderately distinct. **Surface**: moderately shining, rather smooth, with medium pubescence.

Prominent Characteristics

Yellowish bark; oval leaves, somewhat folded but not waved; very shallow and sharp serrations; susceptibility to cedar rust.

WILLOWTWIG

WINESAP

Tree: small, moderately vigorous, broadly diverging.

Shoots: medium in length, rather slender, nearly straight, sometimes slightly curved, with rather short internodes. **Bark**: dark reddish — dark olive. **Lenticels:** few, small, roundish, yellowish gray, even.

Leaf Blade: small to medium, somewhat folded, only slightly reflexed, nearly even, oval to broad oval, medium dark green, rather spreading. **Serrations:** usually moderately sharp, sometimes very dull, small to large, moderately regular, fairly distinct. **Surface:** rather dull, moderately coarse, somewhat pebbly, with medium pubescence.

Prominent Characteristics

Small tree with roundish, rather compact top and dark red bark, with few lenticels. Most leaves oval with rather fine, moderately sharp serrations; but a few leaves roundish, with very coarse, very dull serrations.

Differs from —

Other varieties of the Winesap group — **Mammoth Black Twig, Stayman,** and **Arkansas Black** — by much less vigorous growth, roundish top, and smaller leaves. The most valuable distinguishing characteristic is the presence of occasional small, roundish leaves with very coarse, dull serrations as shown in the smaller leaf in the picture. Such leaves are usually found near the base of new growth.

WINESAP

WINTER BANANA

Tree: vigorous, rather broadly diverging, somewhat upcurving.

Shoots: rather long, medium in size, slightly zigzag, with little to moderate curvature and medium internodes. **Bark:** yellowish olive — dark yellowish olive. **Lenticels:** medium in number, small, roundish, yellowish gray, slightly raised.

Leaf Blade: medium in size, more or less broadly folded, moderately reflexed, even, ovate to long oval, somewhat yellowish green, rather spreading. **Serrations:** dull, often double, medium in size, somewhat irregular, rather shallow, not distinct. **Surface:** rather dull, rather rough, with rather light pubescence.

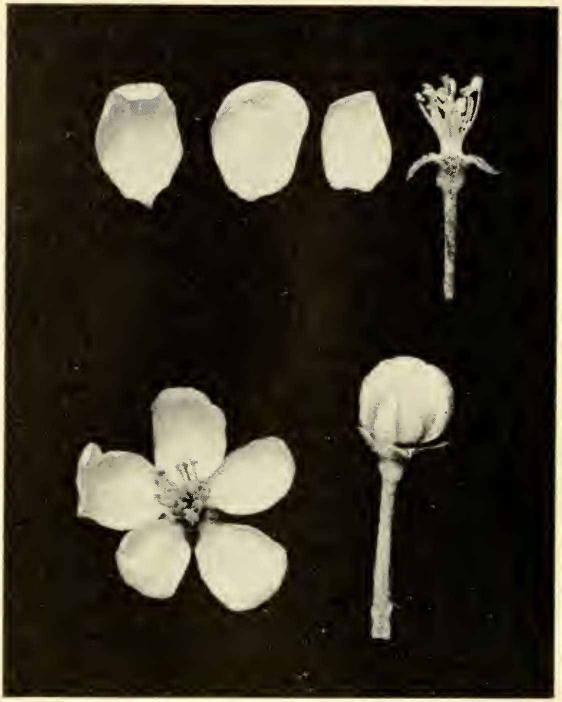
Prominent Characteristics

Vigorous growth; yellowish bark; leaves somewhat folded, often with double serrations, not waved; susceptibility to rust.

Differs from —

Maiden Blush by a more vigorous, less upright growth; larger, more folded leaves, with coarser serrations often showing a tendency to doubleness.

WINTER BANANA



WOLF RIVER

Tree: quite vigorous, broadly ascending, somewhat upcurving.

Shoots: medium to rather long, rather slender, nearly straight, with little to moderate curvature and medium internodes. **Bark:** reddish olive — dark reddish olive. **Lenticels:** rather few, large, roundish, yellowish gray, slightly raised.

Leaf Blade: medium in size, more or less folded, generally reflexed, considerably waved, oval to slightly ovate, medium green, spreading. **Serrations:** dull, rather large, irregular, sometimes double, of medium depth, rather distinct. **Surface:** somewhat shining, coarse, with little pubescence.

Prominent Characteristics

Upright, straggling growth; leaves folded, reflexed, and waved, with dull, irregular serrations.

Differs from —

McIntosh very greatly, by more irregular growth of the tree and leaves much more folded, waved, and reflexed, and with coarser, more irregular serrations.

Alexander by more vigorous, irregular growth and coarser, folded, and reflexed leaves, with more irregular serrations.

WOLF RIVER

YATES

Tree: moderately vigorous, moderately diverging.

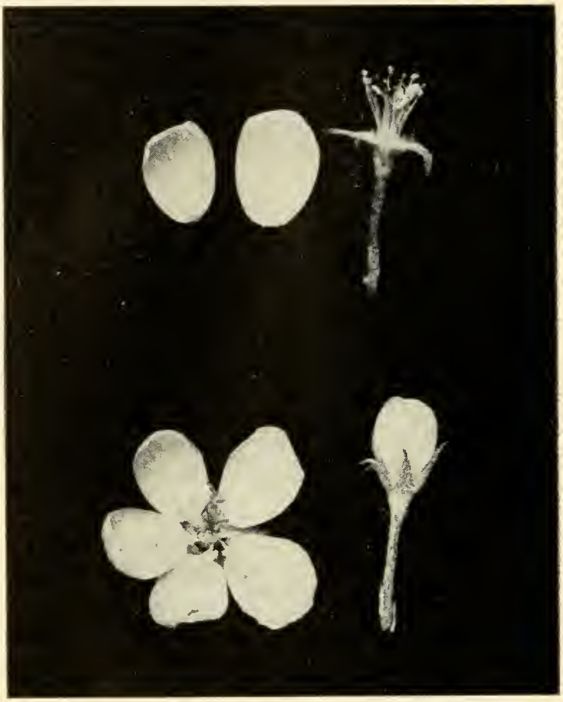
Shoots: medium in length and size, moderately straight, with slight or no curvature and medium internodes. **Bark:** dark reddish olive — dark olive. **Lenticels:** many, medium in size, roundish or oval, yellowish gray, slightly raised.

Leaf Blade: medium or below in size, somewhat folded, somewhat reflexed, rather shiny, waved, oval to slightly ovate, medium green, somewhat upright. **Serrations:** sharp, medium in size, quite regular, of medium depth, and distinct. **Surface:** moderately shining, fairly smooth, with rather light pubescence.

Prominent Characteristics

Reddish bark; leaves shiny, waved, with sharp serrations.

YATES



YELLOW BELLEFLOWER

Tree: quite vigorous, moderately ascending, slightly upcurving.

Shoots: generally long, medium in size, slightly zigzag, with moderate curvature and short internodes. **Bark:** greenish olive — greenish olive. **Lenticels:** medium in number, medium to small, roundish, yellowish olive, even.

Leaf Blade: medium in size, slightly folded, slightly reflexed, even, narrow oval to slightly ovate, medium to dark green, sometimes yellowish, spreading to slightly upright. **Serrations:** moderately dull to moderately sharp, quite regular, of medium depth, rather distinct. **Surface:** moderately dull, slightly rough, with medium pubescence.

Prominent Characteristics

Tall, rather vigorous growth; yellowish bark; and rather long, narrow, slightly reflexed leaves.

YELLOW BELLEFLOWER

YELLOW TRANSPARENT

Tree: only moderately vigorous, upright, upcurving.

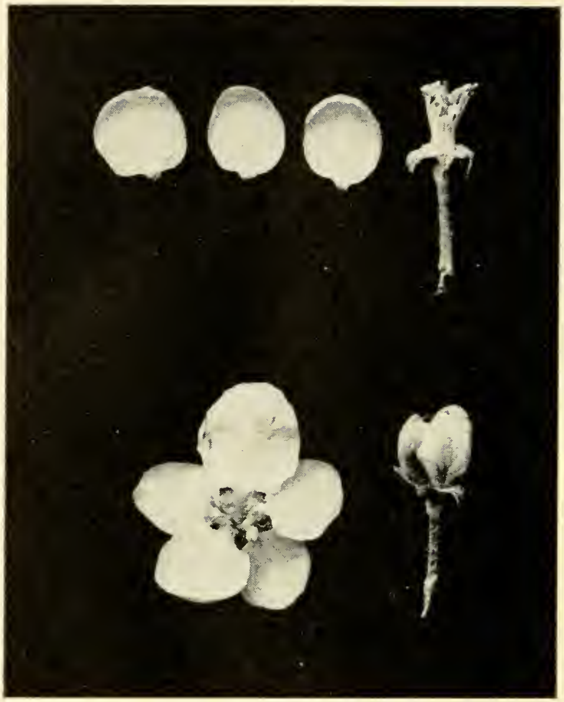
Shoots: medium to rather long, medium to rather slender, slightly zigzag, with slight to moderate curvature and rather long internodes. **Bark:** reddish olive — greenish olive. **Lenticels:** medium in number and size, roundish, yellowish gray, slightly raised.

Leaf Blade: medium in size, little to much folded, slightly reflexed, more or less waved, oval to somewhat ovate, medium to yellowish green, spreading to somewhat upright. **Serrations:** rather dull, medium in size, quite regular, shallow, moderately distinct. **Surface:** rather dull, smooth, with medium pubescence.

Prominent Characteristics

Yellowish bark and foliage, leaves rather dull serrated and distinctly folded, especially near the tips in dry seasons.

YELLOW TRANSPARENT



YORK IMPERIAL

Tree: moderately vigorous, rather narrowly upcurving.

Shoots: short, medium in size, nearly straight, with slight to considerable curvature and short internodes. **Bark**: greenish olive — dark olive. **Lenticels**: rather few, medium to rather small, roundish, sometimes elongated, yellowish gray, nearly even.

Leaf Blade: small to medium, somewhat folded, more or less reflexed, nearly even, oval to ovate, dark green, spreading. **Serrations**: dull, medium in size, slightly irregular, medium in depth and distinctness. **Surface**: shining, rather rough and pebbly, with medium pubescence.

Prominent Characteristics

Rather short, stocky, upright growth; dark green, dull serrate leaves, rather thick and usually rather broad at the base.

Differs from —

Jonathan and **King David** by more stocky growth and darker green leaves, less pubescent and broader at the base.

YORK IMPERIAL

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 404 April 1943

Home Dehydration of Vegetables

By S. Gilbert Davis, William B. Esselen, Jr.,
and Francis P. Griffiths

The emphasis on food conservation as a result of the war has aroused special interest in methods of preservation. The possibilities of home dehydration as a practical method are here presented.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

HOME DEHYDRATION OF VEGETABLES

By S. Gilbert Davis, Technical Assistant, William B. Esselen, Jr., Assistant Research Professor, and Francis P. Griffiths, Professor,
Department of Horticultural Manufactures

INTRODUCTION

THE importance of dehydrated foods to the world at war has been publicized to such an extent that it needs little introduction. In this war one of the major problems is to keep supplies moving to all parts of the world, and among supplies food is always a prime necessity. The ideal way of shipping most foods of which an average of 85 per cent of the fresh weight is water, is in the dehydrated form. In this form foods weigh from one-fifth to one-twentieth as much as the canned products, and occupy from one-half to one-tenth as much space. The importance of dehydrated foods is not limited to the battle fronts. Indications are that an increase in civilian consumption and production of dehydrated foods is vitally necessary. Vegetable production has been greatly increased by the use of land never before under cultivation, in the form of "Victory Gardens" and the like. This factor and the shortage of tin, steel, and rubber, as well as manufacturing restrictions on home freezers and other types of equipment, emphasizes the necessity for alternate methods of domestic food preservation.

In considering dehydrated foods it is well to bear in mind that any dehydrated food has undergone special processing in the course of preparation, and when prepared for the table will retain certain characteristics due to such processes. Just as dried prunes, apricots, or raisins are not comparable with the fresh or canned fruits, so it is impossible to compare dehydrated vegetables with the fresh or canned product on the basis of original flavor and appearance. While it is true that most vegetables do not undergo such marked changes in general characteristics as the examples just cited, those changes which do take place should not be judged as deleterious simply because of taste prejudice and the lack of a proper basis for comparison. The quality of different lots of dehydrated foods of the same type can be readily judged and compared.

Aside from palatability and appearance, the quality of any foodstuff must be judged on the basis of its nutritive value. Unfortunately only meager data are available on the nutritive value of dehydrated foods, although considerable work along this line is in progress in this and other laboratories. In such studies not only the losses in preparation, but the losses under various conditions of storage must be considered. In this respect, the variety of the vegetable may also be of importance.

NUTRITIVE VALUE OF DEHYDRATED VEGETABLES

Tressler (1942), in a review of the available literature, found considerable contradictory data, particularly in relation to vitamin retention. This appears to be due, in many instances, to different methods of preparing the products, and in the light of more recent knowledge of preparation methods many of these data are of little value. While comprehensive research is still lacking, from the limited investigations on processing, certain general statements can be made.

The greatest loss of water-soluble constituents occurs during the blanching process, the loss being greater when water is used as the blanching medium than when the materials are subjected to live steam. Magoon and Culpepper (1924), in studies on the blanching of vegetables for canning, found losses of 1.5 to 20 per cent of the water-soluble constituents in water blanching, and relatively little loss in live steam. More recently Adam, Horner, and Stanworth (1942), in quantitative studies on the effect of blanching on vegetable nutrients, submitted data which again showed the superiority of steam blanching in regard to retention of nutrients.

Little information is as yet available on the nutrient losses that occur during the actual dehydration process, but analysis of foods prepared and dehydrated under properly controlled conditions would indicate that they compare quite favorably in nutritive value with similar products preserved by canning. Morgan and Lackey (1934), in comparative studies on the retention of nutrients in spinach, found 100 per cent retention of thiamin in untreated, dehydrated spinach, and 77 per cent retention in spinach which was steamed for 2 minutes before dehydration. Canned spinach retained 26 per cent of the vitamin. Their report also showed 10C per cent retention of minerals in the untreated dehydrated product. These data indicate little or no loss of the water-soluble constituents during the actual dehydrating process. It should be noted, however, that steaming for 2 minutes is not sufficient to properly blanch spinach. Experiments in this laboratory show 78 per cent retention of the minerals in spinach subjected to live steam for 7 minutes previous to dehydration, which compares quite favorably with data on the canned product.

Although dehydrated foods, like foods preserved by other methods, undergo a proportional loss of some of the vitamins and minerals during the processes of preparation, their value as a source of energy should not be disregarded. In an all out war program, and with the increasing scarcity of foods, the problem of supplying an adequate energy intake is also of paramount importance.

THE DEHYDRATION PROCESS

Dehydration as applied to foods is generally defined as the evaporation of moisture from the product by artificial heat under carefully controlled conditions of temperature, humidity, and air flow. This process involves bringing currents of relatively dry air into intimate contact with the material to be dried. Although the principles of dehydration are well known, a brief summary of the functions of the various factors, heat, humidity, and air flow, in the dehydrating process are included for a clear understanding of the problems involved in small-scale work.

Functions of Air

Air is the common medium used in the dehydration process, acting as a carrier for both heat and moisture. It conveys the heat from the heat source to the product, and at the same time picks up and carries off the moisture liberated by the product. A given amount of heated air passing over a moist surface undergoes a drop in temperature proportional to the amount of moisture picked up. Other conditions being equal, therefore, the rate of dehydration is directly proportional to the volume of air passing over the product. For that reason, a dehydrating unit must be provided with a means of circulating the air.

Functions of Heat

Energy in the form of heat is required not only for vaporization of the moisture, but also to drive the moisture from the cells to the surface of the product where vaporization can take place. The conditions producing these results are fixed by definite physical laws.

The heat requirement is also affected by the moisture content of the raw material, and all of these factors must be taken into consideration in the construction of the dehydrating unit. For successful operation, therefore, the heating capacity of the dehydrator must be adequate for all types of products.

Effects of Humidity

From the preceding discussion the importance of humidity conditions in the dehydration process is obvious, since the moisture-carrying capacity of the air is directly proportional to the relative humidity. The higher the temperature of

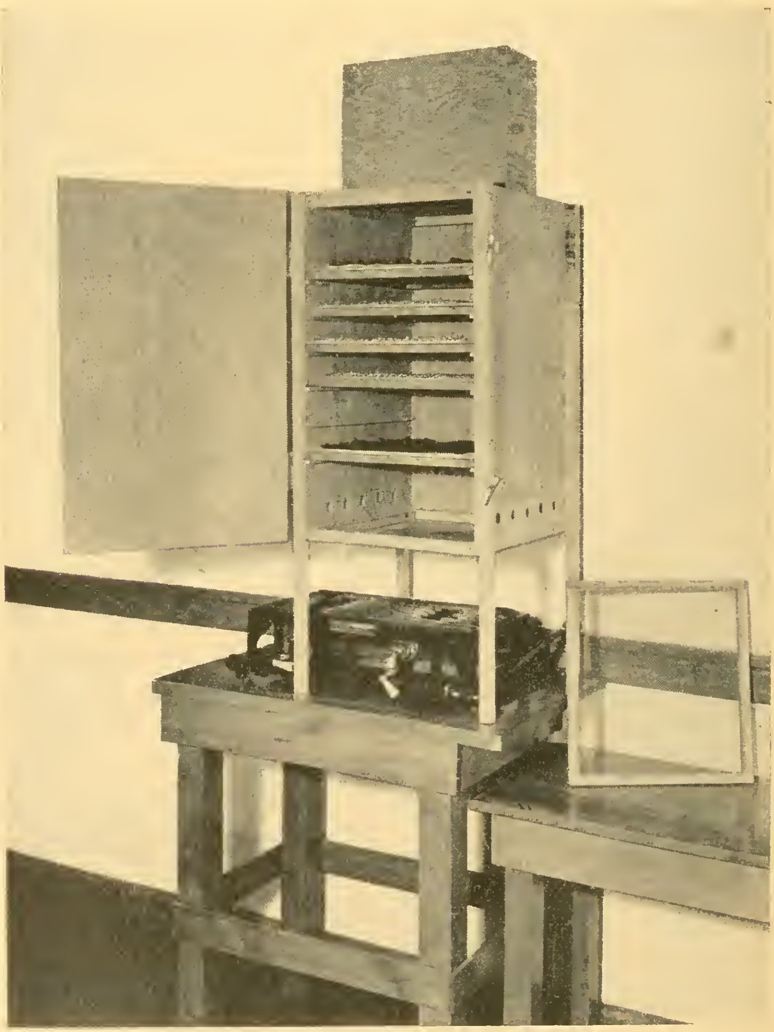


Figure 1. Natural Draft Dehydrator — Type 1.

the air, the greater is its moisture-carrying capacity, and the rate of moisture removal is more rapid at a low humidity than at a high humidity. However, certain limitations are imposed by the nature of the material being dehydrated. Above a certain temperature the product will be injured by excessive heat, particularly during the latter stages of the drying process. The point at which injury occurs is called the "critical temperature," and for most vegetables the finishing temperature should not exceed 150° F. In home dehydration, where control is limited, the temperature throughout the drying process should never exceed this point. Also, if the humidity is too low, moisture is taken from the surface of the product more rapidly than it can diffuse from the inside, so a median point of temperature and air flow relationship must be employed to prevent the formation of a dry outside layer or "case hardening" as it is called.

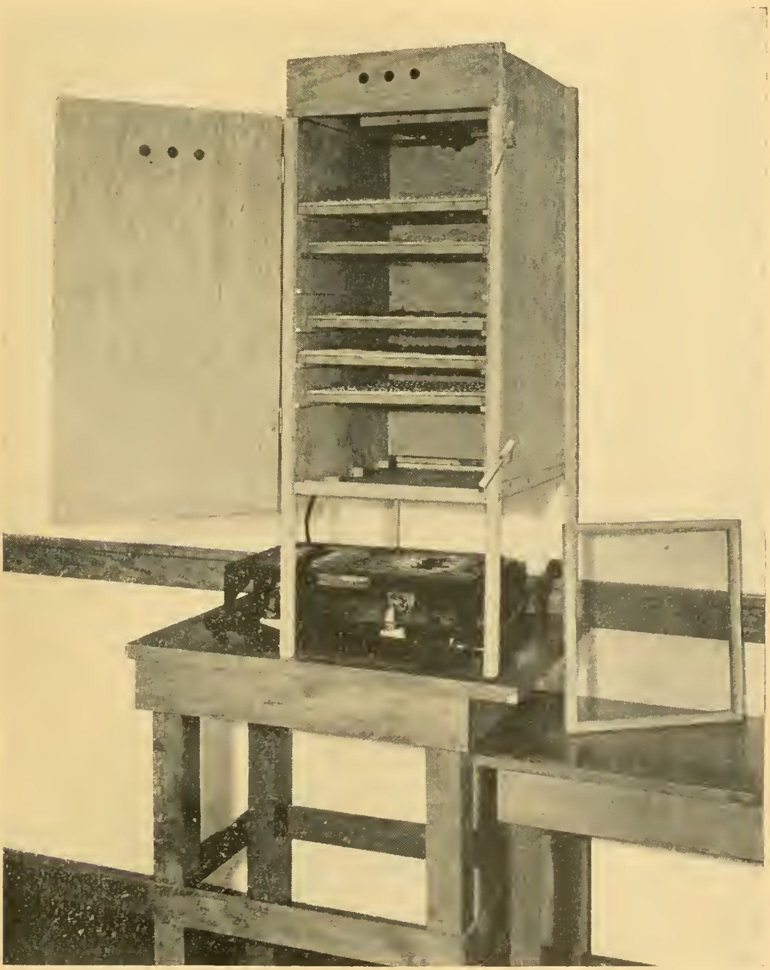


Figure 2. Forced Draft Dehydrator — Type 2.

HOME EQUIPMENT FOR DEHYDRATION

For home dehydration units there are definite limitations to construction. The dehydrator must be simple enough in design so that an average person can build it with ordinary home tools. Critical materials should be avoided as much as possible in construction. However, it should afford maximum control of the factors involved in dehydration, and produce results as quickly and efficiently as possible.

While several units have been built and tested in the laboratory, the following two designs are recommended for both simplicity in construction and efficiency of operation. They are similar in size and structure, the size having been de-

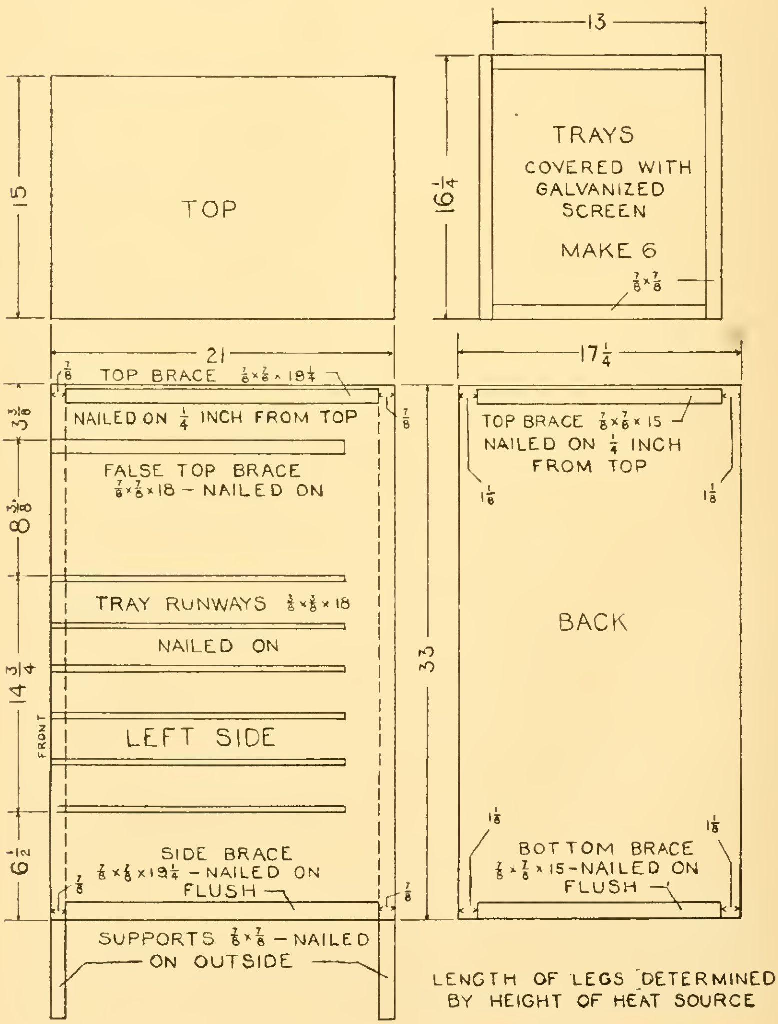
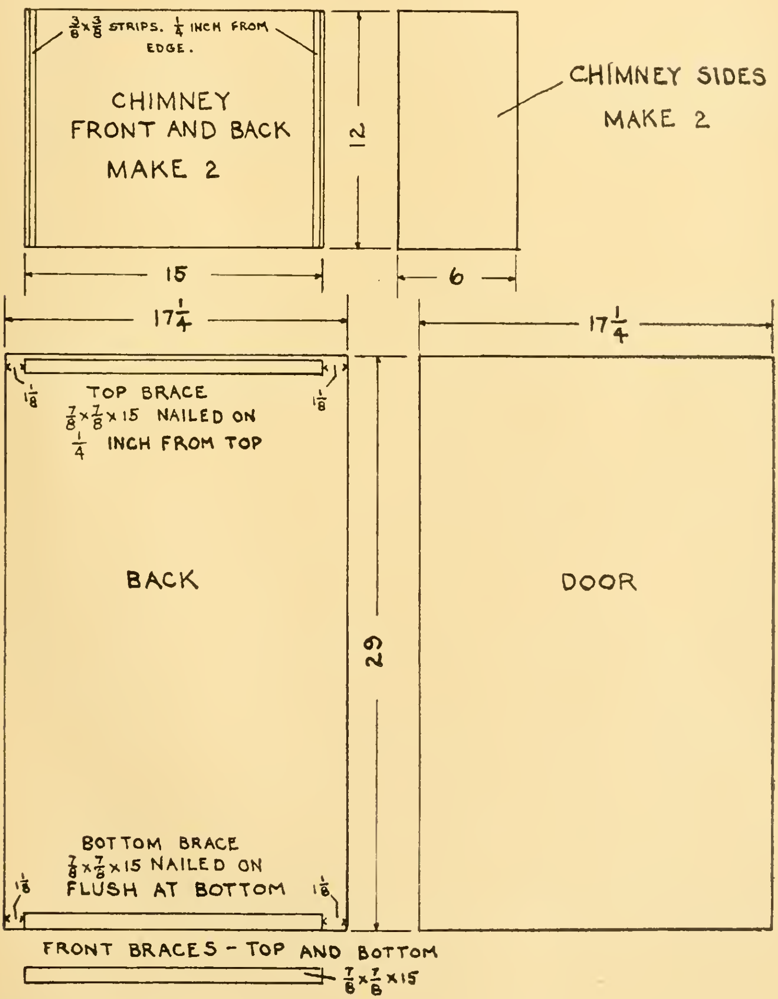


Figure 3. Dimensions and Diagrams

termined on the basis of operation over one gas or electric stove unit. The small one- or two-burner hot plates found in many homes are ideal heat sources for these dehydrators. The volume of drying air is approximately 5¼ cubic feet, and with six trays totalling 16 square feet of drying area the capacity of the dehydrator is 8 to 12 pounds of fresh prepared product (equivalent to 9 to 14 pints of canned product). The tray loading is governed by the type of product to be dried, varying on an average from 1¼ pounds of leafy vegetables to 2 pounds of root vegetables per tray.

When a coal or wood stove is to be used as a source of heat an increase in size of the dehydrator is permissible owing to the increased heating area, but it is well to keep other factors in proportion for maximum efficiency. Since uniformity of temperature is a necessary requisite for satisfactory products, care must be taken that the heat from the stove does not fluctuate widely during the drying period.



for Building Natural Draft Dehydrator.

Construction Details

Figures 1 and 2 show the types of dehydrators recommended. Type 1 is a natural draft dehydrator, and Type 2 is a forced air unit which allows for recirculation of a portion of the heated air. The forced air unit can also be heated with a 250 watt "glocoil" of the type used in the common home reflecting bowl heaters, thereby eliminating the need for an external heat source. The convenience of this arrangement recommends its use whenever possible.

Plywood, one-fourth inch, 3 ply, was used for construction of the dehydrators in the laboratory because of the ease in working with materials of this type. However, heavier plywoods, certain composition boards, and lumber from boxes and crates are equally satisfactory. Lumber from crates was used for the braces

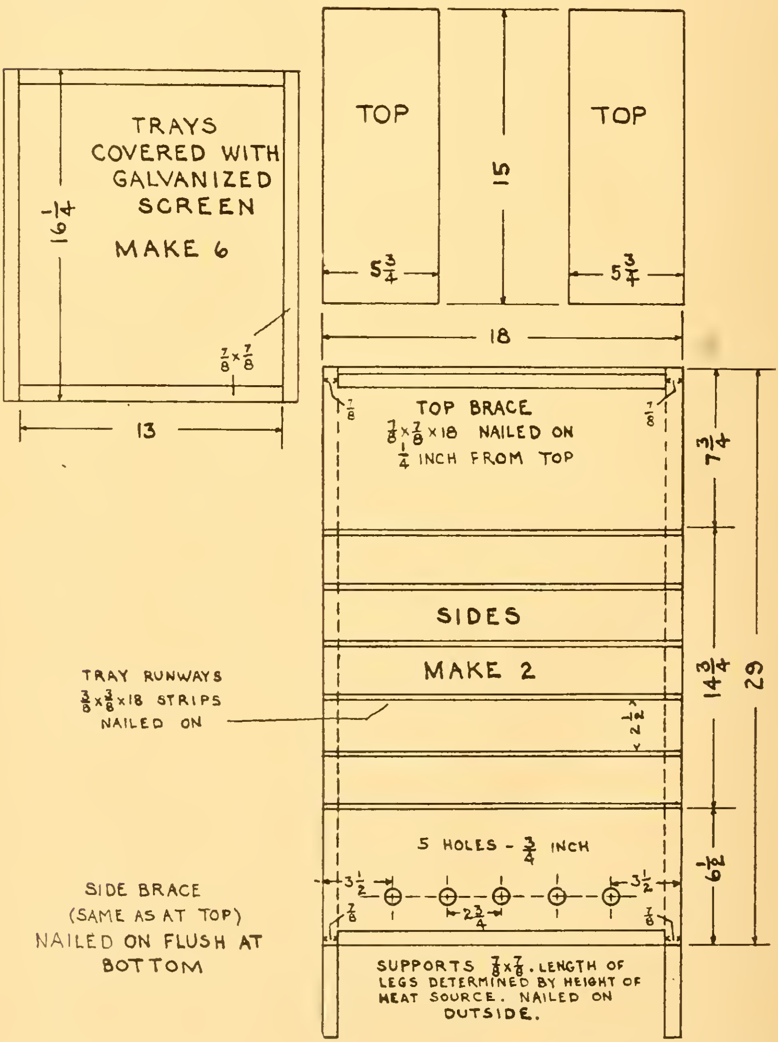
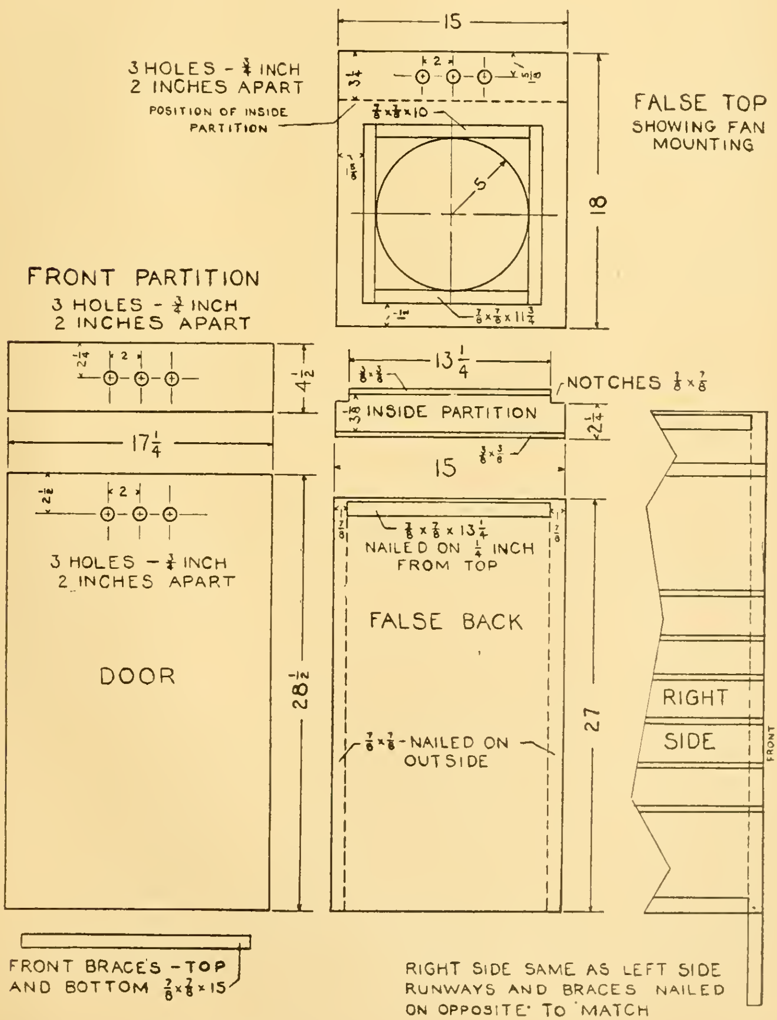


Figure 4. Dimensions and Diagrams

and supports. Tray frames, also made from crate lumber, were covered with galvanized screen, and 24-gauge galvanized iron sheet was used for the bottom heat spreader. If metal is not available, cheesecloth may be used in making the trays, and tin cans may be cut up and joined together to form a suitable heat spreader.

Dimensions and structural details are shown in the line diagrams (Figures 3 and 4). These diagrams are designed for work with one-fourth inch plywood or similar material in which the pieces can be cut complete to size. When individual pieces of wood from crates or boxes are used, the supports should be laid out to size first and the individual boards nailed on to fit. The thickness of the material used must be considered and allowance made when nailing the braces to



for Building Forced Draft Dehydrator.

the finished panels. Care should be taken that braces and cross pieces are measured and cut accurately because these pieces determine the inside dimensions of the cabinet. When the panels are completed they are nailed together to form the cabinet as illustrated. All nailing should be done through the board into a brace or support.

The legs should be of such length that the heat spreader is 6 inches above the source of heat. On dehydrators to be used with wood or coal stoves the legs should be made from spikes, pieces of piping, or scrap metal.

In hanging the door, the hinges are screwed to the outside of the door panel first, and after the door has been fitted into position the other butts of the hinges are screwed to the left hand support so that the door fits tightly.

The bottom dimensions of the cabinet should be checked before cutting the heat spreader to insure proper fit. This piece is then nailed on or tightly wired to the side and bottom braces. While there is little danger of fire if the cabinet is properly constructed, as a safety measure the bottom braces and the lower six inches of the side and back panels and door should be given a thorough coating, inside and out, with a heavy sodium silicate (water-glass) solution or other fireproof material.

The natural draft dehydrator is very similar in appearance to the cabinet dryer described by the U. S. Department of Agriculture Bureau of Home Economics (1942). Dimensions and structural details differ in several respects, however, and a chimney of larger size is employed. A chimney of the dimensions given is necessary in order to produce sufficient draft for distribution of heat in all parts of the cabinet. The air inlets on the sides are so placed and of such size that practically uniform temperature is maintained on all of the trays.

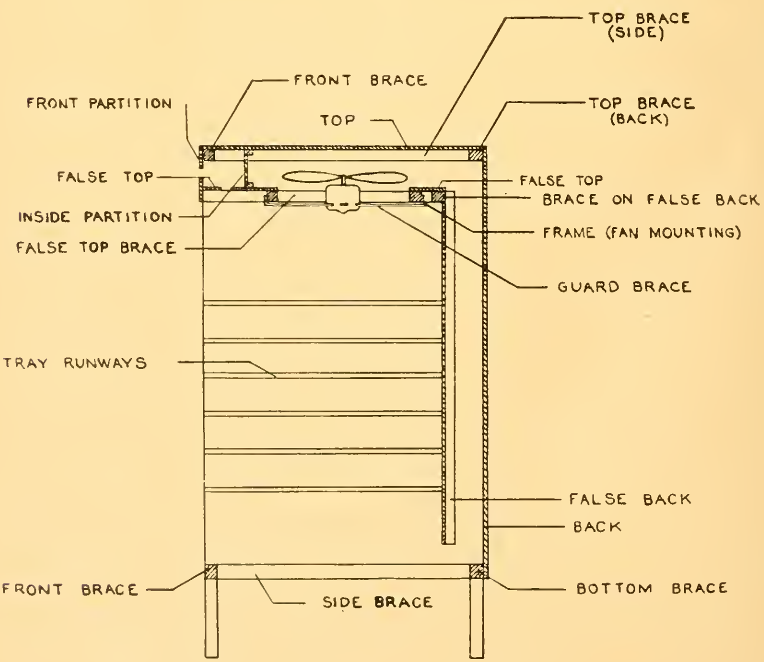


Figure 4-a. Detail of Forced Draft Dehydrator showing method of mounting fan and cross-section view of cabinet

In the construction of the forced air unit an ordinary household fan with a blade diameter of 8 or 10 inches can be used. This is removed from its base and the motor screwed to the framework on the false top by means of the guard braces as illustrated (Fig. 4a). The fan is mounted with the blades facing upward so that a space of approximately 2 inches remains between the blades and the top. The air is blown against the top and is evenly distributed down the channel between the back and the false back. In this manner a maximum area of the heat spreader is covered by the air blast. If the fan has been properly set, the air blast coming over the bottom should be sufficient to blow small pieces of paper placed on the bottom out of the open door. The outlet for the fan wire is a small hole directly below the false top brace, and may be bored on either side of the cabinet.

When an electric heating element is used in this unit, the metal heat spreader can be eliminated and the bottom of the cabinet made from the same material as the rest of the dehydrator. A porcelain socket is screwed to the bottom over sheet asbestos or some similar fireproof material to prevent scorching of the wood by the radiant heat. Likewise, a canopy of similar material — or a cover from a tin can will serve—must be placed over the top of the element to prevent scorching of the product on the lower tray. Since no thermostat is used in this unit, control of the temperature is achieved by an increase or a decrease of the incoming air by varying the number of fresh air apertures.

The following is a list of the material required. The cost as figured is the maximum. In many instances the cost of the items will not approach the listed cost, and considerable saving can be effected by the use of crate lumber and other materials usually available.

32 square feet plywood (1 piece 4′ × 8′) for walls, top, chimney, etc.	$1.75
56 feet 7/8″ × 7/8″ strips for supports, braces, tray frames, etc.	
18 feet 3/8″ × 3/8″ strips for tray slides	
32 feet 7/8″ × 1/4″ strips for screen strips	
All of these pieces can be cut from a 12-foot 2 × 4.	0.50
½ lb. 3-penny nails	0.10
¼ lb. ¾-inch brads	0.10
2 2-inch hinges with ¾-inch screws	0.30
5 feet 14-mesh galvanized screen, 30-inch width, for trays	0.50
1 piece, 18″ × 17¼″, 24 gauge galvanized sheet, for heat spreader	0.50
Total	$3.75

Additional material required for forced air unit with electric heating element:

1 250-watt heating unit and socket	0.75
1 sheet 18″ × 17¼″ asbestos (or other fireproof material)	0.50
10 feet household electric wire	0.30
	$1.55
Less $0.50 for heat spreader	0.50
	$1.05
	3.75
Total	$4.80

There is ample material (plywood, strips, etc.) in the quantities listed for the natural draft dehydrator to take care of the increased size of the forced air unit. The cost of the fan is not included in the estimate.

A dehydrator which has been found extremely useful in the laboratory for the development of new products for commercial dehydration is also adaptable as a relatively inexpensive "several family" dehydrator. Such an arrangement would result in a substantial saving of material, and would allow for a unit of greater capacity, with better control of dehydrating conditions through more elaborate construction. Since steam and steam controls are available in few places, electric heat is generally more practical.

Figures 5, 5a, and 6 show the batch dehydrator used for work of this type in the laboratory.* The cabinet is of plywood and uses a 12-inch ventilating fan

*Unit built by C. I. Gunness, Head, Dept. of Engineering, Mass State College.

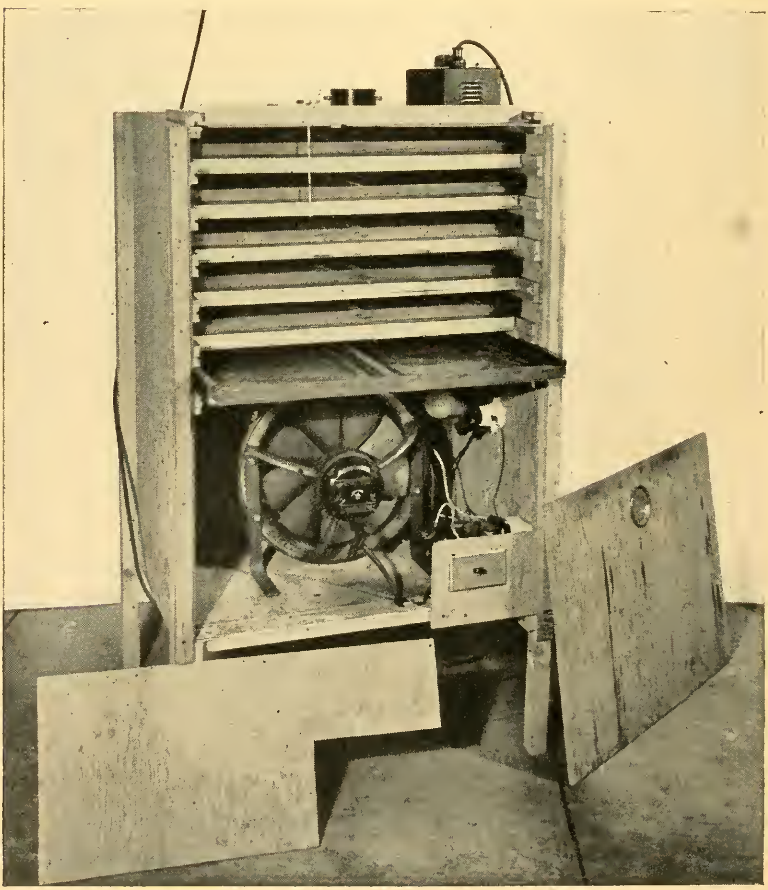


Figure 5. Front View of "Several Family" Dehydralor showing fan and tray arrangemenl.

for circulation of the air. Two "Nichrome" coils, totalling 1650 watts, are used for heating. These are mounted around the interior of the galvanized iron fan housing as shown in the illustration. Simple baffles attached to the rear of the tray holders, widest at the top and tapering to the bottom, are arranged to give uniform air circulation through all the trays at around 300 linear feet per minute. The tray holders are so constructed that the air passes through the trays rather than over them. A simple thermostat is used for temperature controls, a "brooder" type thermostat with a range of 140°-160° F. serving quite satisfactorily. Recirculation of the air and humidity are regulated by an adjustable exhaust outlet. The most practical capacity for the unit as illustrated is 18-22 pounds of fresh, prepared product.

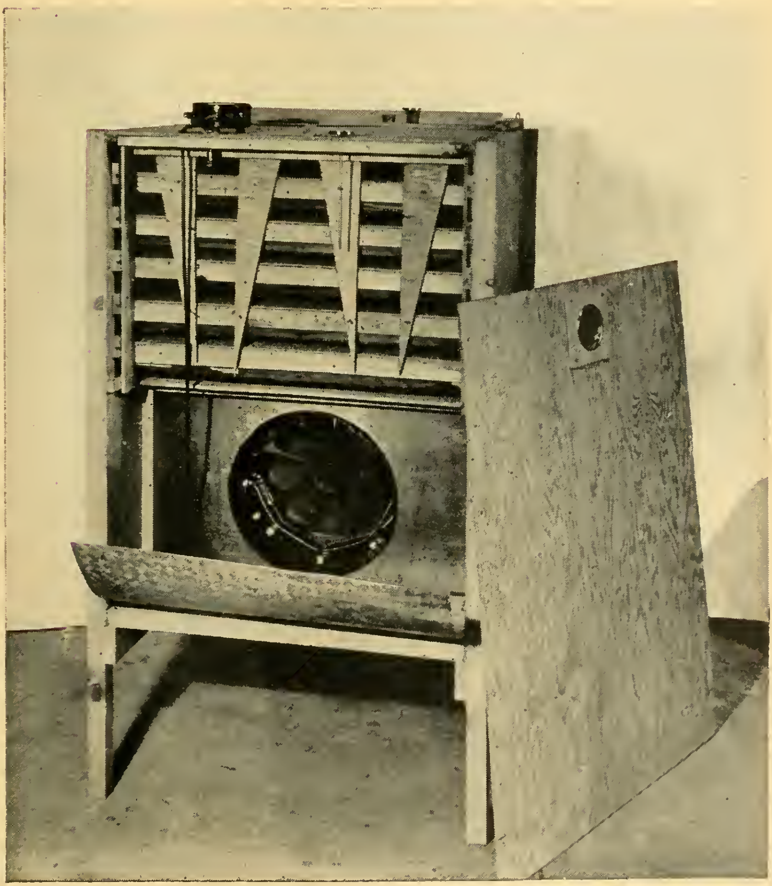


Figure 5a. Rear View of "Several Family" Dehydrator, back panel removed to show baffles, position of air ducts and heating units mounted in fan housing. Thermostat is shown n upper left of picture.

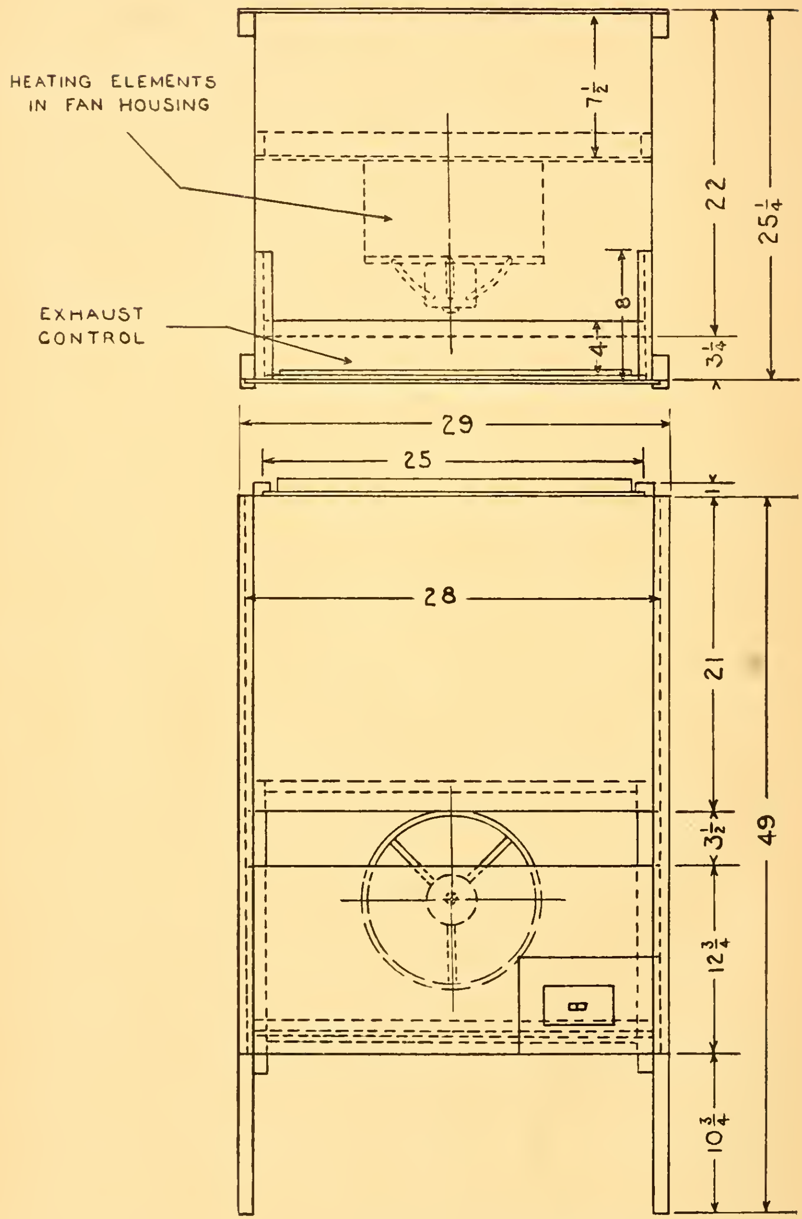
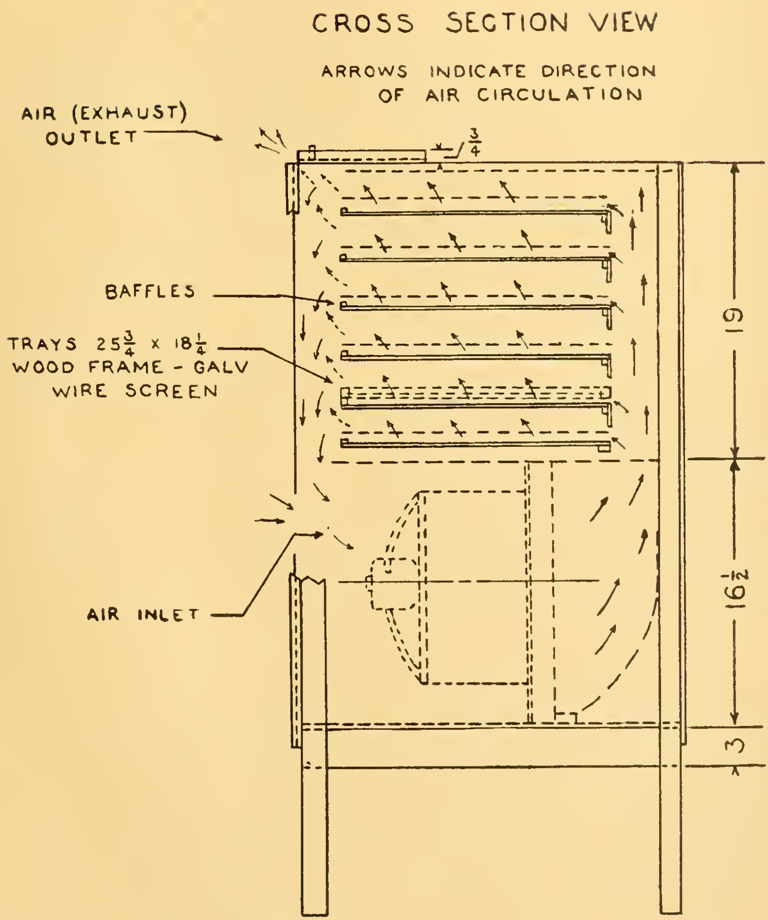


Figure 6. Diagram of "Several Family" dehydrator.



showing dimensions and structural details.

GENERAL DIRECTIONS FOR DEHYDRATING VEGETABLES

Preservation of food is dependent upon the destruction or inactivation of the bacteria, yeasts, and molds which cause spoilage. Growth of these spoilage organisms does not occur when the soluble solids or sugars naturally present in the product are sufficiently concentrated through reduction, by drying or other means, of the water present in the foods. This is the principle employed in the drying of fruits such as figs, dates, prunes, apricots, etc. Also, a reasonable amount of free water is necessary for normal activity of these organisms. With vegetables, which are relatively low in sugar, the moisture content is reduced to a point where there is not enough water to maintain this activity.

Despite their resistance to attack by molds, bacteria, and other outside organisms, dehydrated foods may still spoil owing to chemical agents within themselves known as enzymes. These chemical compounds are necessary to the normal life activities of plants, but damaging to their quality as foods if permitted to continue activity after harvesting and storing. When fruits and vegetables become overripe it is due to the activities of the enzymes, which leave an opening for subsequent infection by bacteria and molds. While enzymes are sensitive to heat, they are not always destroyed or inactivated by the temperatures used in the dehydrating process, so special consideration must be given to this factor in preparation. The treatment for inactivation of the enzymes is called blanching.

Vegetables to be used for dehydration should be dried as soon after harvesting as possible, preferably within a few hours. With the exception of some of the root varieties, most vegetables rapidly deteriorate in flavor and general quality after they are picked. A striking example of this is corn, which within a few hours loses a large part of its flavor and tenderness.

Equally important is the selection of vegetables at their optimum stage of maturity. The effects of overmaturity or undermaturity are unchanged by dehydrating operations, and while such products might be equal in appearance in the dehydrated form to those prepared from properly selected raw materials, the difference in quality can readily be detected in the flavor and texture of the rehydrated product.

The general steps in preparing vegetables for dehydration follow very closely the procedures employed in canning and freezing operations. For that reason they will be treated at length only where a more complete understanding of the reasons behind the operation is considered necessary.

Washing and Trimming

Since steam is preferable to boiling water for blanching, thorough washing is required. Particular care should be taken with leafy vegetables to remove all sand and grit, since even small amounts will show up markedly in the dehydrated product. Thorough washing will also show up bruises, blemishes, and withered leaves, which must also be removed. Even bruises which hardly detract from the appearance of the raw product will in many instances cause undesirable discoloration in the dehydrated product.

Peeling

For home dehydration, hand peeling is the most effective method and results in the least waste.

Subdividing

Since dehydration is achieved mainly by surface evaporation, the greater the surface of the product, the more rapid is the drying process. Tubers and root vegetables are therefore sliced, diced, shredded, or riced, which not only facilitates drying, but also gives a product of distinctive appearance. Dicing or cubing is not recommended because of the resulting waste of product and the added time required for dehydration and rehydration. Slices and shoe-string or julienne style pieces have been found most satisfactory for both dehydration and rehydration. Slices should not exceed 3/16 of an inch in thickness, and products cut in julienne style should be no larger than this in cross section.

Traying

To facilitate handling of the products after dehydration, and to prevent discoloration of the material through contact with residue left by other products previously dehydrated, the trays should be covered with a single layer of cheesecloth. Absorbent gauze, 28 $\times$ 24 mesh of 36-inch width, has been found ideal for this purpose. Each 15-inch double thickness section will provide ample material to cover four trays of the small dehydrators, and each piece can be used several times for the same product.

In loading the trays, care should be taken to allow for intimate contact of the air with the individual pieces of product, and adequate circulation around them. With sliced or julienne style products the shape of the pieces will take care of this to a great extent, and most care should be given to spreading the product uniformly over the trays. With leafy vegetables, such as spinach or chard, on the other hand, the pieces should be so arranged that matting will not take place during subsequent operations.

Blanching

The blanching process consists of heating the material in hot water or preferably live steam for a suitable length of time. While the primary purpose of this treatment is to inactivate the enzymes, at the same time it serves several other functions as in canning and freezing. During the process certain disagreeable odors and flavors are driven off, and with some products, such as snap beans, the waxy outer covering of the product is removed.

In the course of the treatment the product is also partially precooked, which not only sets the color, but also hastens the drying time by softening the tissues and allowing a more rapid diffusion of moisture from the cells. Equally important, the precooking also facilitates rehydration of the material for serving. While in some cases only a relatively short time is required to inactivate the enzymes, the resulting improvement of flavor, texture, and appearance make a longer blanch desirable in many instances. For some vegetables a satisfactory length of blanch is almost sufficient to cook them, and only a short cooking period is required in preparing the product for the table. While prolonged blanching may cause increased loss of the water-soluble constituents and some of the vitamins, the storage qualities are definitely improved. Insufficient blanching, on the other hand, results in a definite lowering of quality. Improperly blanched products rapidly lose their color, and develop off odors and flavors. Spinach, for example, when improperly blanched, becomes a dirty gray color on storage and takes on a pronounced hay-like odor. Similarly, carrots will lose almost all of their color and develop a musty flavor and odor which makes them practically inedible.

With present equipment shortages, particularly in the home, blanching equipment must be improvised. The best procedure for the blanching of most vegetables is to have the product already spread on the trays, and to subject the whole tray to the steaming process. This can be done in a large kettle, or other vessel of sufficient size which can be fitted with a relatively tight cover. Approximately two inches of vigorously boiling water provides ample steam, and a light rack of either wood or wire serves to keep the trays above the level of the boiling water. The trays are stacked one above the other in such a manner that the steam has intimate access to all parts of the tray. This is of extreme importance, since adequate and uniform blanching is a requisite for quality products. Every piece must be heated through to the center. Because of this fact, and the limited height of the average vessel, not more than three trays of material should be blanched at once. It must also be stressed that the water be vigorously boiling during the entire blanching period. Since the size of the individual pieces has a direct relationship to the length of blanching period required, it is advisable to keep the size of the pieces within the limits specified under the individual products for the blanching periods recommended. Exceptions to this procedure are corn and beets. Corn should be blanched in boiling water on the cob, cooled, and the kernels then sliced off and trayed. Beets should be blanched whole in boiling water, peeled, and then subdivided. Compensation for these factors is made in the recommended blanching times.

If no vessel large enough to hold a tray is available, the product must be blanched before traying. This can be accomplished by an arrangement similar to that for the trays, but instead of the trays a wire basket, strainer, or similar container for the product is placed on the rack and subjected to the steam. Only a light layer of product should be put in the container at one time, and it should be loosely spread. For a common eight-quart kettle the batches each time should be no larger than the individual tray load of the product. The advantage of this is twofold, since it not only helps prevent exceeding the steaming capacity of the vessel, but also assures proper tray loads, since a considerable decrease in volume, particularly with leafy vegetables, occurs when they are blanched. With some products it may be necessary to stir up the material once or twice during the blanching period to assure complete heating of all the product. This is important, since all pieces must be uniformly and *thoroughly* heated. Also, care must be taken to spread the blanched material uniformly over the tray and prevent clumping of the pieces. Clumping will greatly retard the escape of moisture during the dehydration process.

Dehydrating

It is recommended that the same amount of heat be used throughout the entire period. While it is possible to vary the temperature somewhat, using higher temperatures during the first part of the drying process, the decrease in time resulting from such practice is negligible in the long run. Furthermore, there is decided danger of harm to the product, since it is difficult to readjust the temperature during the latter stages of drying when the products are most sensitive to heat.

Experimental studies have shown that a temperature of 145° F. is the most satisfactory for dehydration of the common vegetables in the home. A good thermometer with a range up to 212° F. should be kept in the dehydrator throughout the drying period, preferably on one of the middle trays. Before use, the dehydrator, with the trays in place, should be heated to the drying temperature and kept at that temperature, by proper adjustment of the heat, for 10 to 15 minutes in order to make sure that an even heat can be maintained. When an electric heating element is used in the forced air unit, the heat is regulated by variation of the number of fresh air apertures. If the dehydrator has been properly constructed, the temperature during this period should not show a variation of more than two degrees between any of the trays. When the temperature has been adjusted, the trays can be removed and prepared. As little time as possible should elapse between the time the material is prepared, blanched, and placed in the dehydrator.

In loading the dehydrator the trays should be alternately staggered to form a channel for circulation of the air. When the trays are first put in, the temperature may drop as much as 20 to 30 degrees because of the change in humidity conditions and the heat required to bring the temperature of the trays themselves up to the temperature of the drying air. However, *the original heat adjustment must not be changed.* Within a short time the temperature will go up to within a few degrees of the original setting, but will not actually reach this point until the product is nearly dry owing to the presence of the water vapor being carried off by the air. Because the moisture is carried off through the chimney in the natural draft dehydrator, the humidity will always be higher at the top of the cabinet, particularly during the early stages of the drying period. For more rapid and uniform drying, therefore, the tray order should be reversed every two hours during the operation.

Determination of the Finish Point

There is little danger of food becoming too dry and the lower the final moisture content, the better is the keeping quality of the product. In general, the final moisture content of vegetables properly dehydrated in accordance with the above procedure averages around 5 per cent, which is quite satisfactory. In this condition the pieces are rigid and brittle, and leafy vegetables crumble to a powder when squeezed in the hand. If the given procedure has been followed, a simple test for the finish point consists of mounding up some of the dry material on the trays and inserting the bulb end of the thermometer into the mounds. If, after five minutes of continued heating with the thermometer in this position, the temperature of the product on all the trays is the same as that of the air, i.e., 145° F., drying is complete. There should be no soft or moist pieces on any of the trays.

DIRECTIONS FOR DEHYDRATING INDIVIDUAL PRODUCTS

It is not considered economical to dehydrate certain of the vegetables, and those which are not ordinarily canned should not be dehydrated. Products such as dehydrated potatoes and onions are recommended only for use in soup mixes.

Beets: Only tender beets, free from woodiness and of good color and flavor, should be used. Cut away the greens, leaving approximately one-half inch of the stems, wash thoroughly, and blanch in boiling water for 30 minutes (or longer if necessary so that the beets are cooked through). This is one instance in which the product is not peeled and cut up before blanching, since that would cause loss of color. The skin peels off easily after blanching is completed. Cool, trim off the tops and roots, peel, and cut into three-sixteenth inch slices or shoe-strings. Tray load should be 1¼ to 1½ pounds.

Broccoli: Heads should be crisp and green. Trim, wash, and cut into approximately half-inch lengthwise sections. Blanch in steam for 15 minutes or until stalks are heated throughout. Spread one layer deep on the trays. The average tray load is between 1½ and 1¾ pounds.

Brussels Sprouts: Wash, trim, and sort the sprouts. Cut lengthwise into approximately half-inch sections. Blanch in steam for 12 minutes or until pieces are practically cooked. Spread one layer deep on trays. The average tray load is 1½ pounds.

Carrots: Carrots should be tender and crisp. Wash thoroughly, and scrape and trim by hand to remove outer skin. Slices or julienne strips three-sixteenth inch thick dehydrate and rehydrate well. Blanch for 10 minutes in steam. The pieces should be heated throughout. Tray load is 1½ to 1¾ pounds.

Corn: Corn should be fresh, tender, and in the milk stage. Husk the corn and trim out any poor kernels or blemishes. Blanch *on the cob* for 20 minutes in boiling water. Cut the kernels from the cob with a sharp knife, making sure to include the germ. Particular care should be taken that the kernels are spread uniformly over the trays at about 1¾ pounds per tray.

Green Lima Beans: Beans should be young and tender. Remove from pods. Sort to remove defective and overmature beans. Blanch for 12 minutes in steam. Spread uniformly on trays. Load is 1¾ pounds per tray.

Green Peas: The peas should be young, tender, and sweet rather than overmature. Blanch in steam for 12-15 minutes immediately after shelling. Some of the peas are likely to burst during the blanching operation. Load evenly on the trays with an average load of 1½ to 1¾ pounds. Because of their sugary nature peas require a longer time for dehydration than most vegetables. The dried peas should be hard through to the center. Since in some instances the peas are pliable when warm, a few should be removed from the trays, allowed to cool, and tested to see whether they are crisp and hard when cool.

Snap Beans: The pods should be young and tender. Beans in which the cotyledons are not over one-quarter inch in length dehydrate and rehydrate best. They should be washed thoroughly, the ends trimmed off, and any strings and blemishes removed. The pods may be cut crosswise or lengthwise, crosswise slices of approximately one inch giving a rehydrated product of pleasing appearance. Blanch in steam for 20 minutes or until the beans are practically cooked. Tray load should be approximately 1½ pounds.

Spinach: Young, crisp, tender plants give the best product. Wash thoroughly, trim to remove butts, and discard unsuitable leaves. Make sure that all sand and grit are removed, washing and soaking the leaves three or four times if necessary. Blanch in steam for 7 minutes, or until the leaves are practically cooked, but not mushy. Tray load should be approximately 1 pound. Care should be taken that the leaves are evenly distributed and not matted.

Swiss Chard, Kale, Mustard Greens, Beet Tops: Wash very thoroughly. Trim to remove tough stalks, blemishes, discolorations, and unsuitable leaves. Cut into pieces the size of young spinach. Blanch in steam for 9 minutes (or until the heaviest part of the stalk is cooked through). The leaves should be practically cooked as with spinach. Tray load should be approximately 1 pound.

Summer Squash: Only the small, tender squash should be dehydrated. Trim, wash, and halve, removing the seeds. Cut in one-fourth inch slices without peeling. Blanch for 10 minutes in steam. Tray load should be about 1½ pounds, and individual pieces should be separated.

Soup Mixes

Dehydrated soup mixes have recently achieved considerable popularity. They can readily be prepared from home dehydrated vegetables, and offer a tasty, nutritious supplement to the diet. Dehydration of the following products is recommended only for incorporation in soup mixes.

Celery: Use only crisp, garden-fresh bunches, preferably of the varieties having little fiber, such as Pascal. Remove stalks from the bunch and trim off the leaves. Wash thoroughly, remove blemishes, and cut into quarter-inch lengths. Blanch in steam for 5 minutes (the pieces should be soft but still hold their shape). Tray load should be 1½ to 1¾ pounds.

The thoroughly washed leaves may be dried separately and make a good "seasoning" for soup mix. These should be green and not wilted. Blanch for 2 to 3 minutes in steam. Spread on trays evenly and not too heavily. The leaves are very light and dry rapidly.

Onions: Peel off the outer "paper" layer by hand. Trim off ends, and slice the onions into one-eighth inch slices. Blanch in steam for 2 minutes. Tray load is 1½ pounds. For dehydration of onions, the temperature should not exceed 140° F.; hence it is usually best to dehydrate onions alone and not in a mixed batch. Temperatures above this point cause the onions to turn brown.

Potatoes: Peel potatoes and trim to remove eyes, blemishes, and other defects. Until the desired quantity is peeled and trimmed, the peeled potatoes should be placed in a cold brine (one teaspoon of salt per quart of water). Since home dehydration of potatoes is recommended only for soup mixes, they should be cut in the form of julienne or shoe-string pieces approximately three-sixteenth inch thick. The pieces should be thoroughly washed several times in cold water or brine to remove the starch. The last water should be clear. Loose starch will give an undesirable chalky appearance to the dehydrated product. Blanch in steam for 10 minutes, or until the pieces are thoroughly cooked. Tray load is approximately 1¾ pounds.

Parsley: Wash thoroughly and sort to remove undesirable leaves. Blanch in steam for 7 minutes, or until the leaves are practically cooked but not mushy. Trays should be loaded loosely with approximately 1 pound of the product.

Tomatoes: Firm, mature tomatoes are washed, cut into one-fourth inch cross sections, spread one layer deep on trays, and blanched 3 minutes in steam. The skins slip easily from the sections after blanching and can readily be removed with the fingers. Since the dried sections are pliable when warm, they should be tested for completeness of dehydration by removing one or two from the trays, cooling and testing for rigidity when cool.

The following suggested soup formula is easily made up, and can be varied to suit the taste. The dehydrated vegetables should be broken into small pieces, either by hand or by passing through a medium-fine food chopper, so that the pieces are approximately one-fourth inch in size.

Tomatoes	3.00 oz. or 2 cups solidly filled
Potatoes	3.00 oz. or 2 cups
Carrots	1.75 oz. or 1 cup
Onions	0.50 oz. or 1/2 cup
Corn	2.25 oz. or 3/4 cup
Celery	1.50 oz. or 1 cup
Celery leaves or parsley	0.25 oz. or 1/4 cup
Soy flour	0.75 oz. or 1/3 cup
Salt	3.00 oz. or 1/3 cup

Pepper and mixed spices to suit the taste. Only a very small amount is required.

The ingredients should be well mixed before packaging. Soybean flour, in addition to being an excellent source of protein and some of the vitamins, also improves the consistency and body of the soup.

One ounce of the mixture in a pint of water makes soup enough for four average servings. The ingredients in the water should be heated to boiling with stirring, and allowed to stand one hour. Pieces of the proper size will rehydrate in this time, and it is then necessary only to reheat and serve. Noodles, barley, or rice can be added if desired.

REHYDRATION

Rehydration of the vegetables requires anywhere from one-half to six hours, depending on the type of product, the size of pieces, and the pretreatment to which the material has been subjected. In general, the longer the blanching period, the more rapidly the product will rehydrate. It should be remembered that a certain amount of time was required to remove the water from the fresh vegetables, and a proportional amount of time is required for water to be properly reabsorbed. Just enough water to cover the material should be used, and more added as required. Bringing the water and product to a boil with stirring, then allowing it to stand, hastens the process somewhat. After rehydration is complete, the product is cooked as desired (only a short cook is required owing to the pretreatment) in the water in which it was soaked, seasoned to taste, and is then ready for serving. Rehydration time is greatly decreased by cooking in a "Presto" or similar type of small pressure cooker.

COMPARATIVE COSTS OF DEHYDRATING AND CANNING

It is impossible to state specifically the time required for dehydrating the various vegetables. This will vary with the kind of vegetable, the shape and size of the pieces, and the temperature and humidity of the outside air. Snap bean sections, for example, require a longer drying period than spinach or carrots, and diced products a slightly longer time than slices of the same material. However, over a large number of experimental runs in the small dehydrators with normal tray loads of the various products, the average drying time has been found to be 10 hours, with variations of two hours in either direction. Fuel costs are figured on this basis.

Table 1 shows the comparative costs of dehydrating and canning vegetables with gas and electricity. If is impossible to compute fuel consumption with a coal or wood stove. In general the total cost per unit quantity of material preserved is lower for dehydration than for canning, the cost being greater for both methods when electricity is used. Gas rates were based on those in the Greater

Boston area, and were computed at $1.35 per 1000 cubic feet. Electricity rates were based on those in Amherst at $0.03 per kilowatt. Data on canning costs were obtained from Benson (1939). Fuel costs for both methods include both blanching and processing. The average weight of the total contents of a pint jar of ordinary home-canned vegetables was found to be 17 ounces, with a drained weight of 14 ounces. Comparative costs are figured on the drained weight basis.

The cost of a pint jar for canning is figured at one-fourth the original price plus one cent for a jar ring. Total price for the jar and ring is $0.03. Costs of packages for dehydrated foods are discussed in the following section.

TABLE 1.—COMPARATIVE COSTS OF DEHYDRATING AND CANNING VEGETABLES IN THE HOME.*

	Dehydration		Canning (Water Bath—212°F.)		Canning (Pressure Cooker 240°F.)	
	Gas	Electricity	Gas	Electricity	Gas	Electricity
	Cents	Cents	Cents	Cents	Cents	Cents
Vegetables......	4.05	4.05	4.05	4.05	4.05	4.05
Container.......	0.90	0.90	3.00	3.00	3.00	3.00
Fuel...........	0.40	1.60	0.33	2.54	0.20	1.60
Total......	5.35	6.55	7.38	9.59	7.25	8.65

*Costs are compared on the basis of one pint of canned material and its equivalent in dehydrated products.

The vegetables included snap beans, corn, spinach, carrots, and tomatoes.

PACKAGING

Since dehydrated foods readily absorb moisture, they should be packaged in moistureproof, airtight containers as soon as possible after dehydration is completed.

Home-canning jars make excellent containers for dehydrated foods, and their capacity is twice as much as for an equivalent amount of canned product. Used jar rings which are no longer useful for canning, but which have not become hard and brittle, make very satisfactory seals under these conditions, and if necessary two may be used on each jar. When none of these are on hand, melted paraffin poured around the closure to make an airtight seal is also satisfactory. Heavy waxed-paper bags such as are used for potato chips and popcorn, which can be heat-sealed with a flatiron or curling iron, also make good containers. All types of containers should be packed as tightly as possible with the dehydrated product.

A pint jar or the usual size treated paper or cellophane container holds an average of eight ounces of dehydrated product, which is equivalent to approximately 36 ounces of canned material. The cost of available paper or cellophane containers averages 1.5 cents, and is equivalent to the cost of using a pint jar for the same purpose. All containers should be stored in a cool, dark, dry place and protected from insects and rodents.

CONCLUSION

Much still remains to be learned about home dehydration, and it must be remembered that conditions for preservation of food by this method are not the same in the home as in commercial dehydrating plants where automatic controls and trained supervision provide a high degree of uniformity.

The same holds true for the keeping quality of home dehydrated foods. Several of the vegetables undergo changes on storage which are alleviated to some extent in commercially packaged products by the use of inert gases. The facilities required for this cannot be found in the home.

It would be well to guard against overenthusiasm in the application of home dehydration procedures. It cannot be said that dehydration offers any substantial saving in the amount of work required to preserve the products, and the time required to prepare dried foods for serving is greater than that required for other processed foods.

Furthermore, it should be stressed that dehydration is not something for experimentation in the home or a means of saving money in preserving food. It is not considered economical to dehydrate certain of the root vegetables for which cellar storage is available. The usual procedures for common storage are quite satisfactory for these products, and their use should be continued. Dehydration should be considered only for those foods which are ordinarily canned; and for the present, at least, is recommended only if existing supplies of equipment for canning preservation should fail. The advantage of home dehydrated foods at the present time is primarily one of food economy in the war-time need for conservation. It is quite unlikely that dehydration will ever replace canning or freezing in the home preservation of food, but it can be an important supplementary method of food preservation under present conditions, and there are definite indications that commercially produced dehydrated foods will find continued use in the post-war diet.

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