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The Search For
Hardier Fruits and Nuts

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About This Report . . .

Cold damage is a major limiting factor in the successful production of fruits and nuts. In large measure, the northerly limits for economic production of the various crops are determined by their inherent ability to tolerate extreme cold or sudden drops in temperature. Even where production of a particular fruit or nut is established, cold damage is a hazard that varies with the kind of crop and the climate. Every year individual farmers suffer light to heavy losses due to cold damage. And in infrequent years of major freezes, whole areas are hard hit.

Scientists have long been searching for hardier fruits and nuts. Steady progress has been made through systematic exploration, breeding, and evaluation of potentially useful plants. Many promising varieties have been introduced and some of them are widely used for fruiting or as hardy rootstock or interstock. As a result, present-day farmers in some instances are better able to protect themselves against cold damage. But despite progress, cold damage continues to be a problem that varies in kind and degree with the crop and environmental conditions under which it is grown. Fortunately, new research techniques are continually being developed to hasten the development of hardy varieties having other desired traits. For example, monoembryonic seed parents are being used to accelerate the production and testing of citrus hybrids. And new methods for objectively rating the hardiness of experimental plants in advance of fruiting will expedite the evaluation of crops that are slow in coming into production.

Many factors affect cold hardiness. This complicates the search for plants that will survive adverse winter conditions. Characteristics that promote hardiness under one combination of circumstances may make a plant more susceptible to cold under another set of circumstances. To be truly hardy in many areas of the Great Plains, for example, a plant must be able to tolerate dessicating winter winds as well as extreme cold. And plants that tend to bloom early—such as apricots, almonds, and tung—can be expected to succeed only in areas with mild winter and spring temperatures. Consequently plant explorers and breeders search for plants that are adapted to growing under widely varying conditions or are adapted to the particular area in which they will be planted. And farmers in the market for hardy fruit and nut stock need to make sure that they obtain trees adapted to the climate of their particular area.

This report brings together information from various sources on cold hardiness research, particularly information regarding cold hardy varieties of fruits and nuts introduced or developed by the Department of Agriculture working independently or in cooperation with the various States. Its purpose is to provide agricultural agents and other educational leaders with up-to-date background information for answering general questions about this broad subject.

Information for this report was provided by the Crops Research Division, Agricultural Research Service.

THE SEARCH FOR HARDIER FRUITS AND NUTS

Every year many individual farmers suffer small to heavy crop losses due to cold damage. Even in years when ordinary cold conditions prevail, these losses add up to millions for the country as a whole. And in the infrequent years of major freezes losses are sometime devastating for individuals and areas involved. At such times, consumers are also losers, due to shortages and resultant high prices, and low quality produce.

In the case of fruit trees and nuts, whole orchards have been heavily damaged or lost in some severe freezes. When this occurs, the crop potential is seriously curtailed for a period of years until the damaged trees can be replaced and brought back into production.

Use of cold hardy plants has long been the farmer's major defense against extreme or unseasonably cold weather when protective cultural practices such as mulching and the use of shelterbelts or emergency measures including the use of wind machines or portable heaters would be ineffective or uneconomic.

But hardy varieties with other desirable traits are not always available for the particular area or crop to be planted. However, crops research scientists have been working for many years to discover plant varieties which are more tolerant to extreme cold or sudden and untimely drops in temperature than those currently being cultivated in this country. And, as a result of these investigations, farmers in many instances are now better able to defend themselves against the vagaries of the weather than were farmers in the past.

A COMPLEX PROBLEM

Many factors affect the ability of fruit and nut crops to withstand cold damage under particular conditions.

The different kinds and varieties of plants vary in the minimum cold they will tolerate when they are fully hardened and other conditions are optimum. The lowest temperature that a plant can tolerate under the most favorable circumstances is referred to as its *ultimate* (or *absolute*) cold resistance.

Because of the many variables affecting hardiness, a plant's ultimate cold resistance is only one measure of its ability to survive adverse winter conditions. For example, a fruit tree that is hardy in terms of ultimate cold hardiness may have early-blooming flowers that are very susceptible to frost. Or a berry bush that can survive extreme cold may not be truly hardy in many sections of the Northern Great Plains because it is unable to tolerate winter drought conditions prevailing there.

Within the different plant varieties, cold hardiness varies with the general condition of the individual plant, its maturity, the extent to which it is exposed to minimum outside temperatures or is protected by vegetative ground cover, snow, or windbreaks. Plants can withstand much lower temperatures during dormancy or periods of rest than when they are growing. The amount of cold a plant can stand under a particular set of climatic conditions is also affected by when and how rapidly the variety develops cold resistance with the coming of cold weather and how long it maintains this resistance or the speed with which it regains it following the advent of unseasonably warm weather during winter.

Among the many factors that indirectly affect the cold hardiness of a particular plant by affecting its general condition are drought, soil fertility, the extent of any injury due to insect pests or diseases, the weakening effect of heavy crop production, time of fertilizer application, mechanical or chemical injury, or rodent injury.

The task of horticultural scientists seeking fruit and nut varieties which will tolerate cold is obviously complicated by the many variables involved such as drought. Characteristics that promote cold hardiness under one combination of circumstances may make a plant more susceptible to cold under another set of circumstances. Consequently plant explorers and breeders need to obtain plants that are adapted to growing under widely varying conditions or are fitted to the particular area in which they will be grown.

Horticulturists generally agree that early maturity combined with a long rest period is a reliable index to cold hardiness but other more objective indices for accurately predicting cold hardiness are being sought.

The terms *rest period* and *state of dormancy* are sometimes confused by non-technical readers. Rest period refers to an inactive state of the plant that is brought about by internal plant controls. Dormancy refers to the state in which the plant is either in its required rest period or is inactive due to environmental factors such as drought.

Duration of the rest period varies inherently with the kind of plant. Until its rest period is complete, the plant remains inactive regardless of the weather. And even after the rest period has been completed, the plant continues in an inactive state until stimulated into growth by moisture and warm weather. The amount of warm weather required to stimulate growth following completion of the winter rest period differs with the kind and variety of plant. By affecting readiness to bloom, these differences in rest period requirements and dormancy affect the vulnerability of some plants to frost damage.

Cold hardiness is only one of the traits needed to make a plant commercially desirable. High yield, good quality, and resistance to insect pests and diseases are also sought by plant researchers in selecting and developing cold-hardy fruits and nuts. Such combinations of desirable traits are rarely found in native plants or imports brought home by plant explorers because of superior quality or other specific characteristics. Therefore recourse to plant breeding is frequently necessary. And plant breeding takes time—especially in the case of certain crops, such as apples, which require many years to get into commercial production. Furthermore, the various areas and the different crops have their particular problems which must be solved. Some crops, for example, have a short minimum required rest period. Consequently a few days of mild weather in the winter or spring can break their dormancy and render these plants extremely vulnerable to cold damage. Extreme winter cold, such as characterizes the Northern Great Plains, is an example of a regional problem which has limited the economic production in those areas of fruits that are damaged by prolonged exposure to low temperatures.

DECIDUOUS TREE FRUITS

Deciduous fruit trees require a certain amount of winter cold in order to bear fruit and most kinds can stand temperatures far below freezing while dormant. However, the different kinds and varieties vary in their ability to withstand cold damage and all kinds are more susceptible to cold during periods of growth. Consequently, varieties that have a short rest period and that require only a few days of warm weather following completion of rest to induce bloom are especially liable to freeze damage in the early spring or after unseasonably warm weather in winter.

Based on hardiness of wood to ultimate cold, the tree fruits are ranked as follows from the most to the least hardy: American plums, apples, pears, sour cherries, sweet cherries, apricots, European plums, peaches, and Japanese plums. Sweet cherries are susceptible to early freezes occurring before they can harden. And although both the wood and fruit buds of apricots will withstand more cold than peaches when they are dormant, apricot blossoms are susceptible to freezes during spring bloom.

Besides the variations in cold hardiness between the different kinds of fruits, there is considerable difference in cold hardiness among varieties within a particular kind of fruit. Plant breeders and explorers seek to capitalize on this difference to extend areas in which the various fruits can be successfully grown and to cut down on freeze damage through the discovery, development, and introduction of hardier fruits having other desirable characteristics.

As in the case of citrus, commercial varieties of many deciduous fruits are grown on rootstock selected for hardiness, disease resistance, vigor, dwarfing effect, or other traits contributing to economic production. However, some rootstocks that are desired because of other characteristics are susceptible to cold damage. When trunks of the desired rootstock variety are subject to cold damage, a hardy interstock is sometimes used between the rootstock and the scion. Such a double-grafting technique is a more time-consuming and costly process than grafting directly on rootstock. Consequently plant breeders are working to incorporate hardiness in some non-hardy but otherwise desirable rootstocks. A case in point is a rootstock that is badly needed because of its resistance to destructive pests but is susceptible to cold.

A major obstacle in the search for hardy deciduous tree fruits having other desired horticultural traits is the relatively long time required to bring promising new selections into production and to evaluate them. In some cases fruit growers have only recently begun to reap the benefits of plant exploration, breeding, and testing experiments begun many years ago.

Status of cold hardiness research on some of the more common deciduous tree fruits grown in various sections of the United States is reported briefly in this section.

Apples

Although apples rate ahead of most other deciduous tree fruits in ability to withstand cold damage, increased winter hardiness has long been sought in selecting and breeding varieties for most of the apple belt and is an all-important requirement for successful apple production in colder sections such as the northern Northeast and the Northern Great Plains.

The selection and breeding of hardier apples have been conducted on a systematic basis in this country for more than half a century, with plant scientists of USDA, interested States, and industry participating. At the present time the bulk of the Department's search for hardier apples having other desirable traits is limited to work at the Northern Great Plains Field Station, Mandan, N. Dak.

As many as 30 to 40 years are required to get a new apple variety from seed into commercial production. However, hybridization experiments begun many years ago are beginning to pay off in a number of varieties combining cold hardiness with other desired characteristics. In 1959, the Mandan field station named and introduced four reliably hardy apple varieties adapted to growing in most sections of the Northern Great Plains. Other selections developed in the breeding program are in advanced stages of testing and expected to merit introduction. All four hardy varieties introduced by the Department at Mandan were hybrids resulting from crosses using one or two hardy parents. The new varieties and their parentage are: Garrison and Thorberg, both made by crossing Duchess and Starking Delicious; Peach Garden, a cross of Melinda and Duchess; and Killand, a hybrid of McIntosh and Dolgo.

Another approach to the problem of developing improved apples is by the use of mutant strains. One objective in the selection, propagation, and testing of bud mutations has been to increase the ability of already established varieties to survive and produce in northern areas.

At the Department's field stations at Cheyenne, Wyo., and Mandan, N. Dak., large collections of apple varieties and selections are maintained for hardiness evaluation under conditions of extreme winter cold, dry winter winds, late spring frosts, and short growing season prevailing in much of the Great Plains.

Although results of apple breeding experiments and evaluation of the collections of apple stock indicate that some of the more hardy apples can be grown satisfactorily in the Great Plains regardless of adverse temperature and moisture conditions, the commercial apple production potential of the area is limited. However, hardy fruits are useful for farm and home orchards and breeding and selection programs aimed at this use.

In the Pacific Northwest there is little interest in possibilities for breeding new apple varieties because of popularity of apples now being grown there. Instead, interest centers chiefly on finding new rootstocks on which to bud established varieties.

In addition to the apple hardiness research conducted at its Mandan field station, ARS supplies interested States with potentially hardy selections from plant breeding experiments and foreign introductions for testing. For example, the Maine State Agricultural Experiment Station has about 85 apple introductions under test for hardiness. In long-term tests, 5 introductions from Russia and 1 from Manchuria have shown considerable promise as a source for hardy rootstock or interstock on which to graft established commercial varieties. Trees on Cestra Bellfleur Kitaika variety are the most promising in that they appear to be semidwarfs.

Pears

In the selection and breeding of improved pear varieties, the primary objective has been to secure resistance to fire blight, a highly destructive bacterial disease of pears, combined with satisfactory dessert quality. However, a second aim has been to develop hardier pears of good quality for growing in the northern Great Plains and the East as well as other areas that have very cold winters.

European-type pears have good quality and are grown extensively on the West Coast. However, only a few sections of the Eastern States, such as relatively narrow strips on the south and east sides of Lake Michigan, Lake Erie, and Lake Ontario, have the relatively cool summers and mild winters required for successful culture of European varieties. As European varieties are susceptible to the fire blight, they cannot be grown in areas where warm, humid summers are favorable to this disease.

Most of the pears now grown in the Eastern States are hybrids of Chinese or sand pears which were introduced into this country more than 100 years ago. Although inferior in quality to European varieties, Chinese pears are relatively resistant to fire blight and some of them are cold hardy. These cold hardy Chinese varieties, together with varieties introduced from Northern Russia, have been used by plant breeders as a source of hardiness. In the experimental orchard at the Central Great Plains Field Station, Cheyene, Wyo., 43 trees of 28 pear varieties have been grown to maturity under adverse winter conditions prevailing and evaluated for hardiness and other qualities. At the Northern Great Plains Field Station, Mandan, N. Dak., plant breeders are hybridizing pear varieties having drought tolerance and winter hardiness with high quality commercial varieties. Hybrids that survive the severe winter conditions and have other desired traits are propagated for further evaluation.

Apricots

Susceptibility of apricot buds to cold damage is a major problem in the culture of this fruit. Generally speaking, the trunk and branches of apricot trees can be severly damaged by temperatures of $-18°$ F. even when other conditions are most favorable. Buds and flowers are damaged at much higher temperatures. When apricots are in the small green fruit stage just after the shucks have split, they are most susceptible to cold. During this stage, prolonged exposure to a temperature of 30° F. has resulted in considerable damage. There is also some evidence that long periods at 32° F. can cause excessive June drop. This lack of bud hardiness has limited the culture of apricots to a small part of the U.S. and tends to make crop yield erratic even in areas where apricots are grown commercially. The apricot makes a good shade tree where it seldom produces fruit. However, crop researchers of USDA and the interested States are making progress in their systematic efforts to develop hardier apricots.

Propensity of apricots to bloom early makes most varieties vulnerable to spring frosts. Bud and flower hardiness, as well as late blooming and wood hardiness, are therefore important among the characteristics sought in apricot breeding programs. Plant explorers have long been looking for varieties with these traits in cold countries where hardiness would be essential for survival. Since 1925, hardy varieties from Manchuria have been added to the Department's collection of selections available for possible use for fruit production, or use in breeding improved varieties or as rootstock. Also, new varieties and mutations have been sought domestically. In Michigan, for example, an apricot tree with superior fruit that had survived the rigors of Michigan winters was located through a proprietary advertisement offering a prize of $25.

In 1957, following extensive testing, the Department recommended Mantoy (P.I. 65075),[1] a Manchurian introduction, for trial in milder sections of the Great Plains. Although the Mantoy tree is reliably winter hardy, the fruit buds are subject to winterkilling and its early blooms to frost damage. For this reason Mantoy cannot be expected to produce annual crops consistently in the Great Plains area. Nevertheless, Mantoy represents an advance in hardiness and has quality fruit which is larger in size than most Manchurian varieties.

Studies have also been going forward since 1950 at the Irrigation Experiment Station near Prosser, Wash., toward developing hardy apricots with fruit characteristics equal or superior to present varieties. An early phase of the investigation evaluated different varieties for their superiority as parents in transmitting hardiness to progeny in crosses with other varieties. Among varieties studied, Riland and Perfection were found to be superior in transmitting hardiness. This and similar research-developed information has helped to speed up the search for hardy apricots.

In 1957 the varieties Earliril and Blenril were introduced jointly by the Department and the Washington Agricultural Experiment Station. Earliril, a Riland open-pollinated seedling, survived a severe winter freeze which killed Tilton trees of comparable age and condition. With this improved winter hardiness, Earliril combined improved firmness and texture with early ripening, acceptable processing quality and medium size. It requires a pollinizer for good production, however. Blenril combines a fairly hardy tree with excellent quality and good production.

Continuing progress from earlier studies, the Prosser Station in 1962 made 4 selections for winter hardiness and high quality from among 350 hybrid seedlings having Earliril and larger fruited varieties as parents. These are being further evaluated for use in the Pacific Northwest.

At the USDA plant introduction station in Chico, Calif., seedlings of another foreign plant introduction (P.I. 121466) from Turkey are currently being evaluated as a source of hardiness and other characteristics contributing to consistent cropping. Following preliminary evaluation, two promising seedlings from this Turkish introduction (P.I. 248779 and 255319) were selected for long term observation. Their performance to date encourages plant researchers to hope that they will prove to be a useful source of hardiness and other desirable traits. In 1958, for example, P.I. 248779 and P.I. 255319 were the only apricot selections out of a large test orchard that produced more than 8 to 10 fruits following a succession of late frosts. Although neither selection is commercially acceptable, P.I. 248779 rates about the same as Tilton for flavor quality.

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[1] P.I. refers to accession number of the New Crops Research Branch, Crops Research Division.

Cherries

A major objective of cherry improvement programs of the USDA and the various States has been high quality sweet cherries with hardier wood and blossom than those available in the past.

Although sour cherry trees can tolerate temperatures as low as −30° F. when fully winter hardened, sweet cherry trees are likely to be damaged at −20° F. Flowers of both sweet and sour varieties are quite susceptible to cold, making them vulnerable to frost. This and other special climate requirements [2] have tended to limit large-scale commercial production of sour cherries to districts along the Great Lakes and production of sweet cherries to the Pacific and Intermountain States. Even in these areas, cherries are subject to cold damage when winters are unusually severe.

USDA efforts to provide hardier cherries for the Great Plains have relied primarily on breeding new varieties through the hybridization of winter-hardy sour cherries with sweet cherries. At the same time, a sizable collection of wild and cultivated varieties and mutations of both sweet and sour cherries has been gathered in this country and abroad and is continually being increased by new selections. This facilitates testing and evaluating a wide range of cherries to locate hardy kinds suitable for use as germ plasm, rootstocks, or commercial varieties.

Several promising new varieties have been named and introduced as a result of this systematic research.

Rainier is a hybrid of Bing and Van which combines the superior bud hardiness of Van with the large size and firmness of a Napoleon type cherry. Developed in a Federal-State project at the Washington Irrigation Experiment Station, Rainier was introduced in 1960.

Another new hybrid developed at the Washington Agricultural Experiment Station at Prosser is *Chinook,* a cross between Bing and Gil Peck. Although it is not particularly cold hardy, Chinook ripens 4 to 10 days earlier than Bing without being any more susceptible to cold. Although neither the Rainier nor Chinook has all the desirable traits such as rain-cracking resistance sought by plant breeders, they were selected and introduced for commercial trial. At the same time these hybrids and other sweet-cherry crosses are being used as a basis for developing and selecting still better varieties in the future.

Also at Prosser, 20 sweet cherry selections have been made from among 750 progeny of the Rainier and Chinook varieties and sister seedlings. One selection is particularly outstanding for its hardiness and vigor.

In breeding experiments at the Northern Great Plains Field Station, Mandan, N. Dak., the sandcherry has been crossed with hardy plums. These experiments have produced two sandcherry-plum hybrids that are sufficiently hardy for planting in milder sections of the Northern Great Plains, especially in sheltered sites. These sandcherry-plum hybrids, Sacagawaea and Hiawatha, are bush-type plants that bear high quality fruits.

At the USDA Horticultural Field Station in Cheyenne, Wyo., several hybrids made by crossing sweet and sour cherries are currently being evaluated for adaptability to the Northern Great Plains areas too cold for sweet and sour cherry varieties presently available.

The tree-fruit testing program at Cheyenne is a long term one, having been under way for more than 28 years. From evidence of these tests and fruit growing experiments in other

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[2] In addition to being vulnerable to spring frosts because of their tender flowers, cherry trees are adversely affected by hot, dry summers and are susceptible to brown rot in the more humid areas.

locations with similar winter climate, it appears doubtful that commercial tree fruit production will ever become important in the central Great Plains.[3]

Performance of some of the hardier varieties of sour cherries which survived the adverse climatic conditions at Cheyenne has led investigators to conclude that some varieties can be grown satisfactorily for use in farm and home gardens in the Central Great Plains area.

The search for hardy and disease tolerant rootstocks and interstocks is also going forward along with the breeding and selection of varieties for fruiting, either grown on their own roots or budded on compatible rootstocks. Use of Montmorency sour cherry as an interstock is being studied at Prosser and a number of other cherries are being evaluated as potential hardy rootstocks for sweet cherry in the Northwest. Among the possibilities being investigated are *Prunus fortanesiana, P. fruticosa, P. dropmoreana, P. mahalab,* and virus-free Stockton Morello sour cherry.

Peaches

Development of cold-hardy peaches adapted to the needs of various sections of the United States has long been a major objective of peach improvement programs. However, the task is complicated by the wide variation in climatic conditions in this country and the need for combining cold hardiness with other desirable characteristics such as high quality and nematode resistance.

USDA scientists have worked to develop varieties to meet the varying needs of the different areas—varieties resistant to cold winter temperatures for the Northern States; varieties resistant to spring frosts for the Central States; varieties resistant to rapid changes in temperature and having low chilling requirements for the Southern States; and varieties resistant to extreme winter cold and to drought for the Great Plains.

At the State experiment stations, breeding projects have usually been geared to local needs: In Iowa, to hardiness of tree and flower buds to low temperatures; in Missouri, to superior fruit qualities with winter hardiness and late blooming; in New York, to commercial varieties relatively resistant to low winter temperatures with special emphasis on winter hardiness of flower buds; in South Dakota, to sufficient drought resistance and winter hardiness for growing in farm and home orchards of the Great Plains.

A major difficulty in the search for peach varieties adapted to growing in areas with severe winters is the tendency of most kinds to begin to bud after a short period of exposure to warm temperatures.

In greenhouse experiments, only 15 to 20 days at constant temperatures of 70° F. were required to induce blooming in most peach varieties after their rest period had been completed. Apples, on the other hand, required about 25 days of 70° F. temperature following rest.

Budding trees are much more tender than dormant ones. Although peaches will withstand temperatures as low as −20° F. when fully hardened, temperature of −10° F. will kill buds of many peach varieties. For this reason prospects for developing varieties adapted to growing commercially in the Great Plains do not appear encouraging for the foreseeable future at least.

Even the addition of 1 degree in ultimate cold hardiness of buds could mean a partial crop rather than none when temperatures are in the critical range for cold damage. Hence the search for hardier varieties is going forward, with the prospect that even small gains in

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[3] Although some sour cherries are produced commercially in the locality between Loveland and Wellington, Colo., on the sheltered plains immediately East of the Rocky Mountains, production in 1960 was only a fourth of what it formerly was.

cold hardiness will help stabilize production in commercial peach-growing areas as well as increase the possibility of having peaches adapted to growing in colder areas.

Peach breeding research by USDA and the Washington Agricultural Experiment Station at Prosser is directed at the development of bud hardiness and quality fruit for marketing fresh and for canning. During 1961, 21 selections were made from among 1,100 seedlings for further testing there and at other experiment stations. Among the Prosser selections now being tested under various climatic conditions is one that has already proved especially winter-hardy in Canada.

At the Central Great Plains Field Station, Cheyenne, Wyo., several selections chosen for cold hardiness have been propagated and distributed to experiment stations in States where cold damage is a problem.

Since hardiness in peach trees is affected by rootstocks, rootstock varieties which are cold hardy are being sought. With rootstocks as in other areas of cold hardiness research, the need to combine cold hardiness with other desirable characteristics enlarges the scope of the task. For example, resistance to nematodes and root rot is very much needed in rootstocks since damage from these sources has increased to such a degree that it is believed to account for the decrease in the average life of commercial peach trees from 20 to 10 years. USDA scientists have developed and recently introduced a nematode-resistant peach rootstock, Nemaguard. However, since Nemaguard is not particularly cold hardy, plant breeders are now trying to improve the rootstock by adding cold hardiness.

In New Jersey, the State Agricultural Experiment Station has successfully used peach selections brought home by USDA explorers in developing hardy canning peaches. Although the original peach imports were not acceptable for commercial production they provided a source of hardiness in crosses with peaches having other desired traits. The result is a number of promising introductions which are all extremely cold hardy and suitable for canning. In the past, canning varieties hardy enough to stand cold Eastern winters have not been available to New Jersey fruit growers and canners.

Plums

Plum varieties vary widely in their ability to stand cold. Most American varieties tolerate temperatures as low as $-30°$ F. without serious damage when fully winter hardened. European plums are more vulnerable but usually stand temperatures of $-15°$ F. without severe wood damage. However, buds of most plum varieties may be damaged at temperatures somewhat higher than the absolute temperature for cold damage to wood. Also some plum varieties are very early blooming and so particularly vulnerable to spring freezes.

For more than half a century, American plant scientists have sought to obtain, by breeding and selection, quality plums that are sufficiently hardy to grow successfully in areas with long, cold winters as well as to survive the severe freezes that occasionally strike in milder areas with a minimum of crop loss.

A number of State agricultural experiment stations in northern areas have long-standing plum improvement research programs which emphasize cold hardiness—stations in South Dakota, Minnesota, New York, and Iowa among others. And stations in States with more temperate climates, such as Washington and California, have also considered hardiness in breeding and evaluating plum varieties.

USDA crops researchers have likewise done considerable work aimed at selecting and breeding improved varieties of hardy plums adapted to various sections of the country. Some of this has been in Federal projects at the regional field stations and some in Federal-State cooperative research projects at various State agricultural experiment stations.

Among the recent results of this research are two varieties of plums with superior qualities for home gardens and orchards in the Northern Great Plains region. These varieties —named *Gracious* and *Chinook*—were introduced by USDA in 1957 after extensive testing at the Northern Great Plains Field Station at Mandan, N. Dak., for trial in that area. *Gracious,* a seedling of Emerald, strongly resembles another variety, Redwing, in some ways and is probably a cross of Emerald and Redwing but is hardier than the latter. *Gracious* bears rather large fruit (about 12 to a pound) which is mottled red with yellow flesh. *Chinook* is a seedling of Ojibwa. Although smaller than *Gracious, Chinook* is a large plum (about 20 to the pound) which rated very well in cooking tests. The fruit is bright red, round, firm, and semi-freestone. Both of the introductions ripen in late August.

The Northern Great Plains Field Station is also making progress in breeding improved varieties of hardy plums. By hybridizing high quality Japanese plums with winter hardy native and European varieties, a number of promising selections have been developed and are currently being evaluated.

Plum breeding work is also going forward at the Irrigation Experiment Station at Prosser, Wash. In this project, several varieties from Vineland, Ontario, Canada, are being crossed with the large-fruited Edwards variety, an Italian Prune type with quality fruit, and with President.

CITRUS RESEARCH

Cold damage being the constant threat that it is to citrus growing, USDA plant researchers have long been concerned with the problem. Early investigators of the United States Department of Agriculture uncovered much useful information regarding the relative cold hardiness of different kinds and varieties of citrus and the many factors affecting the cold hardiness of individual plants.

An important recent development in citrus breeding is the use of monoembryonic seed parents to speed up the production of hybrids. Unlike polyembryonic seeds, monoembryonic seeds contain only one embryo and are capable of producing only one seedling. The systematic use of monoembryonic seed parents to speed up the production of hybrids developed from the discovery that a few citrus varieties, such as Clementine tangerine and Temple orange, produced only hybrid plants when used as seed parents in crossing with other varieties. Prior to this discovery, attempted crosses resulted in a high percentage of nucellar seedlings to true hybrids. Nucellar seedlings inherit only characters from the mother plant. Consequently their inadvertent production in hybridizing attempts has been a delaying factor in the development of new varieties combining cold hardiness and other desired traits. By using monoembryonic seed parents for hybridization, plant breeders can avoid using time and land for growing nucellar seedlings which are virtual replicas of the mother plant but often cannot be recognized as such until they are fruited.

Another major line of research going forward at this time is on the effect of various rootstocks on the cold hardiness of different varieties of citrus scions. Evidence from recent studies supports the generally held belief that rootstocks that are cold resistant themselves tend to induce cold resistance in the scion variety. However, there are indications that physiological factors in the rootstock-scion combination also have some influence. For example, although the Clementine tangerine is rather cold hardy when fruited on its own roots, it rates lower as a rootstock than some other less cold-hardy varieties in ability to induce hardiness in the scion. On the other hand, sweet oranges have a high cold-hardiness rating when used as rootstocks but when used as scions they are not as cold hardy as many varieties which ranked much lower when rated on the basis of performance when grown from their own roots. On the evidence of studies to date investigators are generally of the opinion that the degree of cold hardiness induced by rootstocks in scion citrus varieties is related to dormancy—that those rootstocks that induced early and prolonged dormancy in the scion increased its cold hardiness.

Effect of rootstocks in inducing cold hardiness in scions varied somewhat with the part of the country in which the citrus was grown. In California and Florida, *P. trifoliata* induced cold hardiness in satsuma mandarin scions but failed to do so at Weslaco, Tex. Researchers conducting the Texas experiment concluded that the difference in performance of *P. trifoliata* as a cold-hardy rootstock there and in the other areas might be explained by the fact that the soil at the Texas location is generally warmer than in California and Florida.

Further emphasizing the complexity of the factors affecting hardiness, recent studies have yielded evidence that cold tolerance in citrus is also affected by soil nutrient conditions, such as salinity. Although normally rather cold resistant, grapefruit grafted onto sweet orange or Rusk citrange became susceptible to cold injury when grown on saline soil.

Severe freezes of recent years have intensified the interest of citrus growers in cold hardiness. Present-day citrus research gives a high priority to the breeding, selection, and introduction of new and improved citrus varieties and rootstock-scion combinations that are tolerant to cold.

The need for combining cold hardiness with quality fruit, high yield, resistance to pests and plant diseases, and other specific requirements such as suitability for canning, freezing, or fresh fruit sales indicates that the job ahead is a big one. However, improved techniques for breeding and testing citrus varieties for cold hardiness should help speed up the work. As mentioned earlier in this report, the increased use of cold-hardy monoembryonic seed parents for the production of true hybrids enables plant breeders to accelerate the production and selection of new citrus varieties combining cold hardiness and other needed characteristics.

Recently developed techniques for testing the cold hardiness of citrus trees grown under field conditions have expedited the selection of hardy experimental field plants for breeding. A portable freezer of sufficient dimensions to surround several trees was used for this purpose in experiments conducted by ARS in cooperation with the Texas Agricultural Experiment Station at Weslaco. By means of light and temperature controls, researchers were able to reduce or break dormancy in trees before they were enclosed by the freezer unit and to subject the plants to freezing at times related to dormancy. In one experiment, 7 citrus species were exposed to night temperatures that were gradually reduced from 60° F. to 48° F. over a 38-week preconditioning period. The plants were then exposed to below freezing temperatures (21° F.) for 4 hours. When the plants were examined for freeze injury, citrus varieties that required rather low night temperatures to become dormant were found to be less cold hardy than those that become dormant in response to higher night temperatures. As a result of these findings, investigators hope they may soon be able to rate the cold hardiness of young citrus seedlings quickly and accurately by inducing dormancy and relating them, by means of the night temperature required to go into dormancy, to varieties of known cold hardiness.

SMALL FRUITS

With small fruits, as with tree fruits, greater cold hardiness is among the characteristics sought by plant scientists in their quest for improved varieties. Aiding in the search is the relatively shorter time required to get most small-fruit plants into production. For example, a minimum of about 10 to 15 years is required for an apple tree grown from seed to bear fruit and be initially evaluated, as compared to 4 years for blackberries and only 2 years for strawberries.

Among bush fruits, raspberries are generally more hardy than blackberries and blueberries vary widely as a group in their ability to withstand cold. Although currants and gooseberries are relatively cold hardy, new plantings of these fruits are not advised at this time because of serious pest problems involved.

Another common fruit grown in cold areas is the strawberry. However, the strawberry does not properly belong in the group of hardy fruits. An evergreen, the strawberry is susceptible to extreme cold but frequently survives severe freezes because it grows close to the ground and is protected by snow or naturally occurring or applied mulch. Another nonhardy small fruit plant, which frequently survives freezing weather because of its growth habits, is the cranberry. Commercially, the cranberry is grown in bogs which can be flooded at the approach of extremely cold weather.

A brief report on problems, progress, and prospects in developing improved varieties of some of the more common kinds of small fruits follows. Most of the small fruits discussed in this section—including red and black raspberries, blackberries, blueberries, and grapes—are deciduous. Although they are evergreen and not truly hardy, strawberries and cranberries are also discussed briefly because they too are grown in northern areas where cold damage is a problem.

Raspberries

Although both red and black raspberries are somewhat more cold hardy than blackberries, they are subject to winter damage in some areas of the United States. The canes may be killed by sudden freezes and the blossoms hurt by late spring frosts. Consequently, cold hardiness is among the important objectives of raspberry improvement programs along with disease resistance.

As a group, red raspberries are more tolerant of cold than are black raspberries. For example, some varieties of red raspberries will survive in the upper Mississippi Valley where black raspberries are frequently winterkilled.

In 1951, the red raspberry variety Canby was introduced after testing in a cooperative breeding project of USDA and the Oregon Agricultural Experiment Station at Corvallis. A seedling of the cross of Viking and Lloyd George, the Canby produces large red raspberries of good color and flavor. The Canby is hardy under Western conditions but not in the East. Raspberry work is continuing at Corvallis.

At Carbondale, Ill., USDA and Southern Illinois University scientists are hybridizing Asiatic and American species of black and red raspberries to develop disease-resistant and winter-hardy varieties. Some full-fruiting seedlings of these crosses show commerical promise.

Blackberries

In blackberry improvement projects of ARS and various Northern States, a major objective is to reduce crop losses through the development of new varieties that are more cold hardy. Their susceptibility has precluded the successful production of blackberries in some areas with severe winters and made them vulnerable to sudden freezes in milder sections of the country. For commercial growers in established blackberry-growing areas, there is particular need for varieties that combine hardiness with disease resistance and thornlessness. The sharp decline in the blackberry industry during recent years has been attributed to inability to obtain labor to harvest the old productive, cold-hardy, thorny types of blackberries. In colder areas, the emphasis is on hardier varieties.

The search for hardier blackberries has taken USDA plant explorers to far places. In 1957, for example, two varieties of large and hardy blackberries were brought back from the high Andes for evaluation and possible use in blackberry improvement programs.

Although a number of improved varieties have been developed in recent years, the need to combine cold hardiness with other desired characteristics complicates the problem. For example, none of the thornless blackberry selections being tested at the Plant Industry Station, Beltsville, Md., was fully winter hardy during the severe 1961 winter and none was as hardy as Darrow and Eldorado varieties. And Williams, a 1962 introduction developed by USDA in cooperation with the North Carolina and Mississippi Agricultural Experiment Stations, is resistant to many diseases prevalent in the South but is not sufficiently cold hardy for growing north of Virginia and Tennessee. However, Aurora, which was introduced in

1961, is winter hardy for Western Oregon. An early-ripening blackberry, Aurora was developed by USDA and the Oregon Agricultural Experiment Station, Corvallis, for use in the Pacific Northwest.

Breeding work aimed at developing thornless, winter-hardy and disease-resistant varieties is continuing at the Oregon Station and the Southern Illinois University, Carbondale, with USDA and State scientists cooperating. As one phase of the project, a germ-plasm collection of blackberry varieties and selections was recently planted for field tests.

Blueberries

Improved varieties of blueberries developed in USDA and USDA-State breeding projects have brought about a rapid growth in the blueberry industry and increased demand for the fruit. However, the need for breeding more cold hardy varieties of superior berries has been demonstrated by extensive crop losses due to cold damage. Out of 10 superior varieties now being grown commercially in Eastern areas, only Bluecrop escaped cold damage and set a full crop in the 1962 season, for example.

In the continuing search for hardier blueberries, plant researchers have looked for promising selections among wild varieties growing north of North Carolina, New Jersey, and New Hampshire areas where parents of the present cultivated varieties were found. Several selections from northern New York and northern New England are now being tested for their value as parents.

Notable among these northern selections is the Ashworth blueberry which was found in a field about 4 miles from Heuvelton, N. Y. Ashworth is reported to have fruited following temperatures as low as $-50°$ F. and ripens early. Whereas commonly cultivated varieties are hybrids derived from complex crossing of highbush swamp species *(Vaccinium australe* and *V. corymobosum)* and the lowbush species *(V. lamarckii),* Ashworth is apparently a pure tetraploid highbush species *(V. corymobosum).*

With a view to transferring its cold hardiness and early-ripening characteristics, Ashworth has been crossed with a number of commercial varieties and the seedlings are being tested at a number of locations with generally encouraging results. In Michigan in 1956, a cross of Ashworth and Earliblue had a full crop although named varieties grown in the same field suffered serious low-temperature damage. The chief advantages of Ashworth as a parent appear to be its tolerance of low winter temperatures, resistance to frost damage at blossom time, and early ripening; its chief limitation is smallness of fruit.

Blueberry breeding work is going forward at a number of locations and progress is being made toward obtaining new cold hardy types having large fruit, high quality, and small scars for better shelf life. In Massachusetts, 10 selections had acceptable crops in 1960 when most varieties had none due to hurricane damage followed by severe winter temperatures. And at the Maine Agricultural Experiment Station, Jonesboro, 28 new winter-hardy selections were made from hybrids of previously selected varieties and plants having other desired characteristics. The most productive seedlings occurred in crosses in which Sebatis (a hardy highbush selection found growing wild in New Hampshire) was a parent. High bush varieties capable of growing in cold areas are desired because of their characteristically large berries.

Grapes

Considerable grape breeding research is currently being done by ARS at Fresno, Calif., and Beltsville, Md. On the West Coast where much work is being done, the major emphasis is on developing superior varieties of seedless grapes which are disease resistant. More needs to be known about cold hardiness, however. At Beltsville, major emphasis is on development of hardy disease-resistant types.

Some of the hardiest native American grape varieties will endure as much cold as apples. However, Old World (vinifera) varieties grown in California and other Western States are not hardy enough to succeed in the Northeast, where native American varieties or varieties developed from them alone or by hybridization with vinifera varieties are grown. A high quality seedless grape hardy enough to grow in colder areas would be useful in the Northeast.

Strawberries

Strawberries are probably grown as far north as any fruit but few established commercial varieties are genuinely cold hardy in the sense that vital plant parts will stand exposure to extreme cold.

Although plants of most strawberry varieties will tolerate temperatures as low as 0° F. when fully hardened and a few varieties (such as Howard 17, Senator Dunlap, and Gem) will tolerate extreme cold, unhardened strawberry plants of most commercial varieties may be killed by temperatures of 20° F., if their crowns are exposed. Consequently most varieties are able to survive the severe winters of the northern part of the United States only when protected by snow, natural vegetative cover, or applied mulch. And even in milder areas, early blooming and blossom-tender varieties are subject to damage from spring frosts.

In the search for hardier strawberries, plant researchers have collected and studied wild strawberry plants growing in colder areas of the United States and in foreign countries. A wide variation in cold hardiness was observed among varieties, selections, and selected clones of species. An unusual degree of winter hardiness was found in some clones of *Fragaria ovalis,* a wild Rocky Mountain strawberry, while unusual blossom hardiness was found in selected clones of *F. virginiana,* found growing in North Dakota, and of the Rocky Mountain strawberry. These selections along with other promising sources of hardiness are being used in breeding experiments. Among these are South American selections of *F. chiloensis,* which was brought back to this country by USDA plant explorers because of its large fruit size and firmness and ability to survive the extreme cold and drought of the Andes.

Strawberry breeding work has been going forward in this country for well over a century. Early breeding work was done on a rather limited scale by a few private breeders but since 1920 the tempo of research has been stepped up by participation of public agencies.

Hovey, a new strawberry variety originated in 1834, was the first variety of any kind of fruit developed in this country through breeding. Since that time, many improved varieties of strawberries have been originated.

Breeding experiments using blossom-hardy clones of *F. virginiana* and Midland (an early, blossom-tender variety) resulted in a high percentage of hardy seedlings. Earlidawn and Howard 17 are two early varieties that possess blossom hardiness.

Breeding experiments using hardy clones of Rocky Mountain strawberries *(F. ovalis)* in crosses with cultivated varieties have resulted in a number of improved varieties which combine extreme winter hardiness with large fruits, vigorous plants, high runner production, and high fruit quality. Introductions resulting from this work include Early Cheyenne 1, Cheyenne 2, Cheyenne 3, Sioux, Arapahoe, Radiance, and Ogallala. The ability of these crosses to stand extreme cold makes them a good source for further breeding.

Despite advances that have been made through breeding, improved varieties that combine tolerance to low temperatures and bud hardiness with other desired traits, such as disease resistance, firmness of flesh, and toughness of epidermis of fruit, are needed.

The task of developing winter-hardy strawberries to meet the needs of U.S. growers and consumers is magnified by the fact that strawberries are very subject to their environment and a variety that is good in one locality is likely not to be good in another. Consequently plant breeders are faced with the job of originating superior varieties for particular localities and then breeding cold hardiness into them. This probably accounts for the relatively large number of State agricultural experiment stations currently engaged in strawberry breeding work, four of them in cooperation with ARS. The work of selecting and breeding blossom-hardy strawberries is complicated by the fact that critical temperatures may not occur each year. To help overcome this, an objective screening method for freezing blossoms artificially in the field is needed. However, the great improvements already made in strawberries through breeding and selection provide encouraging evidence of what can be accomplished in the future.

Cranberries

Although cranberry plants, like other evergreen fruit plants, are not truly winter hardy, they are grown commercially as far north as Massachusetts and Wisconsin. This is done by simulating the swamp conditions under which wild cranberries are found. The fruit is grown in bog fields that can be covered by water during the winter months. In western Washington where cranberries are winter hardy but subject to blossom damage from late spring frosts, the bogs are equipped with sprinklers. A fine spray of water over the vines prevents injury from freezing temperatures as low as 20° F. during bloom.

No new cranberry breeding has been started by ARS but final evaluation of 14 selections for cold hardiness and other desired characteristics is continuing. Of three new varieties recently introduced in cooperation with the Massachusetts Agricultural Experiment Station, none is outstandingly cold hardy.

TREE NUTS

With demand for edible nuts exceeding production and most commonly grown kinds and varieties subject to cold damage in varying degrees, hardier varieties of most species are needed to stabilize production. Because of their early-blooming habits, almonds are particularly liable to frost damage but other kinds of nuts are also susceptible to low winter temperatures and late spring frosts. Tung, an important nonedible nut used as a source of oil in the manufacture of paint, is also extremely liable to frost damage because of its early blooming characteristics.

Almonds

Commercial production of almonds at the present time is limited almost entirely to a few relatively small areas in California because of the almond's exacting climate requirements. The almond requires a definite, although short, period of complete dormancy but is among the earliest of the deciduous tree fruits to bloom in the spring. In this country, the almond's blooming period is from January to March, which makes its blossoms extremely vulnerable to frost damage.

To help stabilize production in present almond-growing areas and extend the climatic range in which almonds can be grown successfully, ARS and the California Agricultural Experiment Station are emphasizing late blooming along with other desired traits in their cooperative almond-breeding experiments at Fresno. At present no variety combines disease resistance, late bloom, and high productivity of nuts containing small flat kernels desired by the candy trade.

Numerous crosses aimed at producing a late blooming variety which escapes spring frosts or produces small kernels have been made and nine promising selections chosen from progeny of the crosses are currently being field tested. Almond-producing areas are also being explored for promising chance-seedling trees or sports. These, together with the controlled crosses, are evaluated for possible use as commercial varieties or use in breeding. Evaluation of untested selections for hardiness and other characteristics is hastened by taking buds from young seedlings as soon as they develop and budding them on mature trees.

Pecans

Although severe freezes in the winter or late spring have occasionally caused damage to pecan trees and crops, first fall frosts are the most frequent cause of cold damage. This is especially true of the northern part of the southern pecan belt where commercial varieties do not ripen early enough to avoid frost injury.

Consequently pecan improvement projects of ARS emphasize early maturity along with winter hardiness, disease resistance, fruitfulness, and other desired characteristics. At the U.S. Pecan Field Station in Brownwood, Tex., more than 8,000 hybrids have been fruited during some 30 years of breeding and 5 superior pecan hybrids named and introduced. Other promising selections are being evaluated and two of them will probably be introduced in the near future if their performance is up to expectations. At the U.S. Horticultural Field Station, Meridian, Miss., several new varieties originated by State experiment stations and private individuals are being evaluated for desired characteristics including hardiness.

In developing hardy pecans, a problem is the long, hot growing season required to mature the nuts, coupled with their late-blooming characteristic. Most common varieties of pecans require more warm weather to induce bloom (about 200 hours of frost-free weather) than do most other deciduous fruits.

A member of the hickory family, the pecan tends to be less cold hardy and disease resistant than other kinds of hickory. With the aim of combining the good quality of the pecan with the early maturity and disease resistance of other hickories, ARS scientists are working to develop improved varieties of the *hican*—a hybrid made by crossing pecan with other hickories. Forty-six second generation hybrids are now being back crossed to obtain the desired characteristics of both the pecan and other hickory nuts. Breeding and evaluation research on hicans is being done at Beltsville, Md.

Walnuts

Commercial production of Persian (English) walnuts in this country is mostly confined to California and Oregon due to lack of cold hardiness. Some Persian walnut trees grow and bear fruit in northern and eastern sections of the country but usually only where they are sheltered.

Black walnuts or some varieties of them are hardy in most parts of the United States. Though the nuts are harvested from wild trees and sold in considerable volume, commercial plantings are limited. The major emphasis in walnut research has been to develop improved Persian walnuts or hybrids combining the desirable characteristics of Persian varieties with the hardiness and disease resistance of other kinds of walnuts.

Manregian (Plant Introduction 18256), a hardy walnut collected many years ago in West China by a USDA plant explorer, is an example of a foreign plant introduction which has contributed to the development of hardier commercial walnuts. Seedlings of this variety are now widely used as hardy rootstock by walnut growers in Oregon. Also the hardy new fruiting variety Adams originated as an open-pollinated seedling of P.I. 1826.

Another source of hardiness used in selecting and breeding new walnut varieties is material brought home by USDA plant explorers from the Carpathian mountains of Poland. A few of the varieties of Carpathian origin have a bitter after-flavor but several have kernels of acceptable quality and show promise over a wide area because of their hardiness. In test plantings at the Plant Industry Station, Beltsville, Md., the Carpathian varieties Colby, Burtner, and McDermid are very productive. Burtner vegetates and blossoms 3 weeks later than other varieties which may enable trees of this variety to escape late spring frosts in many areas.

Crosses are also being made with Eastern black walnuts and Persian varieties but partial sterility of F-1 hybrids has complicated such hybridization. More hybrids will be made, however, and the most promising ones backcrossed to better varieties of Persian and Eastern black walnuts.

Chance seedlings of both the Persian and Eastern black walnut are also being evaluated for hardiness and other desired traits.

As selections and varieties are evaluated and found superior to standard varieties they will be named and introduced. In evaluation studies at Beltsville, Md., the Hansen variety of Persian walnut continues to be outstanding from the standpoint of production, winter-hardiness, and quality. It is being widely planted as a dooryard and utility tree.

Filberts

More winter hardy varieties of filberts are being sought by ARS researchers at Corvallis, Oreg., and Beltsville, Md., for growing in the Pacific Northwest and the Northeast.

Neither of the established European varieties grown in the Pacific Northwest (Barcelona in Oregon and DuChilly in Washington) is reliably winter hardy in commercial plantings. In fact, all existing commercial varieties mature so late in Washington and Oregon that in some years a high percentage of the crop is lost.

To help overcome this hazard, crosses between Barcelona and other western varieties have been made, selections from superior progeny backcrossed, and several promising selections from later generations of the same parentage chosen on the basis of early maturity and disease resistance.

Since the American filbert is winter hardy, it is currently being crossed with English varieties to produce hybrids combining hardiness with desired qualities of the Barcelona and other European filberts. Two of these hybrids, which were propagated by the Department and introduced in 1951 as the varieties Reed and Potomac, are being widely planted in Eastern and Northern areas where filberts have not been grown before.

In a long-term breeding project at Beltsville, Md., selections showing superior winter hardiness potential have been chosen from second generation progeny of various crosses.

Chestnut

With the destruction of native chestnut forests by the chestnut blight, the need for blight resistant varieties which are hardy enough to grow throughout the range for American chestnuts has increased.

To meet this need, USDA scientists are actively working to develop by means of selection and hybridization varieties that combine these characteristics with other desired traits such as resistance to attack by weevils.

As Japanese and Chinese chestnuts are more resistant to the blight than American or European varieties, breeding work has been largely confined to selections or hybrids of oriental varieties. At present the Chinese chestnut appears to offer the greatest promise for improvement by breeding. However, Chinese varieties characteristically have some defects such as liability to attack by weevils and some susceptibility to blight. Also, the young trees are very subject to winter injury although mature Chinese chestnuts are generally hardy in areas where the American chestnut succeeds.

Tung

Hardiness is a major objective in tung improvement research by ARS and cooperating States.

The early blooming habit of the tung species *(Aleurites fordii)* grown in this country constitutes a serious hazard in the commercial production of this subtropical oil crop in the

United States. Although fully hardened plants will stand temperatures as low as 6° to 8° F., the blooming plant is very susceptible to spring frosts. In the major freeze of 1955, for example, the entire tung crop was wiped out from Tallahassee, Fla., west to Texas, and serious crop losses were suffered in areas east of Tallahassee where the cold was less severe.

To help avert such heavy losses to tung growers, plant breeders are seeking to introduce the late blooming habit into the commercial tung species, *A. fordii,* by crossing it with the related, late-blooming *A. montana* species. Backcrosses of this interspecific hybrid have been made and are being evaluated for late blooming. Any trees with this characteristic will be inbred to fix this character. This is necessary to assure late blooming progeny, since tung is propagated from seed.

Tung growing areas and breeding collections have also been surveyed for late blooming seedlings of *A. fordii.* Selections having this characteristic have been selfed and progeny grown to check whether late bloom was a seedling characteristic or caused by other factors.

Several promising seedlings have been turned up by the study. One is L. 301, which was selected in 1955 because it produced a crop when all others growing in the area were wiped out by the March 25-26 freeze. Another is a tree found 200 miles north of the tung belt at Tupelo, Miss., where it is reported to have had crops consistently over a 10-year period.

Another possible means of minimizing frost damage to tung crops currently being investigated by plant scientists is the use of chemicals to prolong dormancy after the chilling requirements of tung have been met. Extensive research is under way at Bogalusa, La., to find chemicals that will do this job effectively. In 1961, buds from tung sprayed with maleic hydrazide opened 3 to 4 days after normal but this delay was not sufficient to prevent injury from a late frost occurring that year. Also, when maleic hydrazide was used during the growing season, growth was stopped and the fruit crop was reduced. Thus the fight to reduce frost damage to tung crops is going forward on two fronts—a long-term project to produce hardier tung varieties reinforced by an intensive effort to find chemicals that will prolong the dormancy of the plant.

OUTLOOK

Despite progress made in developing hardier varieties of many kinds of fruits and nuts. cold hardiness continues to be a problem that varies in kind and degree with the crop and environmental conditions under which it is grown.

For some crops, a backlog of basic information accumulated through years of research should hasten efforts to obtain improved hardy varieties. For other crops, cold hardiness research is only beginning. And for certain kinds of fruit and nut crops, particular problems—such as a characteristic tendency for early blooming or a lack of suitable breeding stock capable of transmitting cold hardiness—present obstacles to quick progress. However, modern breeding techniques and methods for speeding up the evaluation of promising selections obtained by plant exploration or by breeding will help. Past progress combined with these new research aids suggest that substantial advance will be made toward developing hardier crops adapted for growing in areas where the need is felt to warrant the considerable research effort required to obtain new varieties having cold hardiness and other desired characteristics.