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Sweet cherries thrive best on mahaleb rootstocks in Utah

BING CHERRIES

Cherry Rootstocks

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Abstract

This paper reviews the history and status of the cherry rootstocks problem in Utah and the United States and reports 14 years' results from a sweet cherry rootstocks test orchard on open porous soil at Farmington, Utah.

Although a majority of authorities favor or recommend the mazzard root for sweet cherries, the mahaleb is also widely used and preferred by many nurserymen and growers. Many authorities condemn mahaleb stocks as being dwarfing and short lived. Two orchard tests on heavy soils in the Atlantic states decisively favor mazzard.

In the Utah test orchard, the trees on mahaleb proved to be much superior in vigor, size, hardiness, survival, and yield, as compared to mazzard, and much larger, more vigorous, better anchored and more productive after the ninth year than those on Stockton morello. Trees on morello bore fruit earlier and more abundantly the first 8 years, ripened their fruit earlier, but tended to overbear, lose vigor, were more distressed by high temperatures, and were more subject to wind damage.

Based on the results in the test orchard which agree with observations and experience in Utah, mahaleb stocks are recommended for commercial use in the typically porous gravelly orchard soils of Utah. Stockton morello is not considered promising for commercial use, but is suggested for trial for dwarf home garden trees and for heavier soils. Suggestions are offered for the future improvement of cherry rootstocks.

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CHERRY ROOTSTOCKS[1]

Francis M. Coe[2]

The Cherry in Utah

Cherries rank third in value of Utah fruit crops, while the state ranks fourth in the production of sweet cherries in the United States. The census of 1940 lists 207,487 cherry trees of all kinds growing on 2,615 Utah farms, 159,457 of them being sweet varieties belonging to the species *Prunus avium* Linn. and 48,030 of them sour cherries of the species *P. cerasus* Linn. In 1943, Utah orchards produced 5,700 tons of cherries with a record value of $1,121,000. Average production for the state from 1932-41 was 3,558 tons.[3]

Importance and Distribution

The present importance and distribution of both sweet and sour cherries in Utah is shown in table 1. Utah and Davis Counties lead in sweet cherry tree population, while Box Elder County leads in sour cherry production.

Table 1. *Bearing, nonbearing, and total sweet and sour cherry trees in principal cherry-producing counties of Utah,* 1939*

	Sweet cherries			Sour cherries		
County	Bearing	Non-bearing	Total	Bearing	Non-bearing	Total
Davis	36,789	8,442	45,231	1,873	178	2,051
Utah	34,074	11,950	46,024	11,760	635	12,395
Weber	24,946	3,536	28,482	6,148	128	6,276
Box Elder	24,040	1,885	25,925	25,137	738	25,875
Salt Lake	6,480	1,360	7,840	960	245	1,205
Washington	5,670	285	5,955	217	11	228
State	131,999	27,458	159,457	46,095	1,935	48,030

*Figures from U. S. Census report, 1940.

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[1]Contribution from Department of Horticulture. Report on project 93—Hatch.

[2]Research associate professor of horticulture.

[3]Figures from U. S. Bureau of Agricultural Economics, Utah Crop Report, December 7, 1943.

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LONGEVITY AND CONDITION OF CHERRY ORCHARDS

Generally conceded a difficult fruit to grow successfully, one with exacting requirements as to soils and climates, the sweet cherry generally thrives on the well-drained, warm upper bench soils located along the west slopes of the Wasatch Range in the Great Salt Lake and Utah Valleys of northern Utah. Individual trees are found well over fifty years of age, with branch spreads of over 40 feet. Seasonal yields of over 300 pounds of fruit per tree are common, and one Napoleon sweet cherry tree was known to yield over 1,100 pounds of fruit one season.

Such longevity, however, is the exception rather than the rule, and even though many old orchards are still vigorous and bear profitable crops, sweet cherry orchards as a whole have not been long-lived in the state. Census figures compared in table 2 show

Table 2. *Bearing, nonbearing, and total cherry trees in Utah,* 1909 *and* 1929, *with bearing trees* 10 *years later and trees lost during periods* 1909-1919 *and* 1929-1939.

Census year	Bearing	Non-bearing	Total	Bearing 10 years later	Total trees lost during 10 year period
1909	79,775	109,119	188,894	112,695	76,199
1929	110,050	114,230	224,280	181,553	42,727

Figures from U. S. Census reports

that tree deaths and removals have been high, and that heavy new plantings during the periods 1900-1909 and 1920-1929 did not increase the bearing acreage 10 years later as much as was to be expected. During the first period, a total of 76,199 trees out of a total of 188,894 reported in 1909 was lost or removed. By 1939, 42,727 of the total of 224,280 trees reported in 1929 had failed. What caused the failure of so many of these plantings? Granted that removal of unprofitable varieties during the period 1909-1919, damage by the winter of 1932-1933, and the low price years during the period 1930-1937 accounted for many, it appears likely from observations and reports from growers that failure caused by lack of adaptation of the rootstocks used was in many cases a major contributing factor.

A survey by Wilson and Stark (50)[4] in 1935 showed 45,265 trees out of a total of 274,331 sweet cherries to be in such poor condition that their removal was recommended. Here again at least part of this poor condition probably resulted from rootstock failure.

[4]Figures in parenthesis refer to Literature cited page 40.

THE CHERRY ROOTSTOCK PROBLEM IN UTAH

Determination of the cherry rootstocks best adapted to Utah soil and climatic conditions was one of the objectives of the orchard rootstocks investigations project initiated by the Station in 1928. Preliminary surveys showed most nurserymen and many experienced cherry growers preferred the mahaleb stock for sweet cherries in Utah, in spite of the results of Howe (32) in New York, as well as the advice of most textbooks and authorities which generally favored mazzard stocks for sweet cherries, and condemned mahaleb as dwarfing and short lived.[5]

The preference for the mahaleb stock was by no means universal, however, and many trees were sold and planted on mazzard roots. In many cases ignorance of the problem rather than growers' preferences resulted in planting trees on mazzard roots, although some nurserymen in the state used mazzard in their propagation.

A survey of Utah cherry orchards by the writer in 1931 showed no consistent differences in the size and condition of bearing trees on both stocks in older orchards. Outstandingly large and productive trees were found on both stocks, along with weak and dying trees. In many cases, however, where orchards had failed, growers did not know which rootstock had been used.

In view of the wide divergence of opinion expressed in the literature and by local growers and nurserymen on the problem of cherry rootstocks, it was decided to plant a test orchard of sweet cherries on the Davis Experimental Farm near Farmington, Utah, to obtain additional evidence on this important question. On account of the prominence given the Stockton morello in reports from California, it was decided to include this stock in the test with the mazzard and mahaleb.

DESCRIPTION OF THE ROOTSTOCK SPECIES

MAHALEB

MAHALEB ROOTSTOCKS are seedlings of the related cherry species, *Prunus mahaleb* Linn. When allowed to form its own top mahaleb makes a large round-topped shrub or small tree with

[5]W. W. Knudson of Brigham City, Utah, told the writer that his sweet cherry orchard on mazzard stock had been a failure and had to be removed while another block on mahaleb was doing well. He expressed the opinion that the mazzard roots were shallow. This alleged superiority of the mahaleb stock for Utah conditions was affirmed by Charles H. Smith of Centerville, Utah, and other nurserymen.

Fig. 1. *Typical young fruiting mahaleb tree* (Prunus mahaleb Linn.) growing at Logan. This species is the most popular and successful cherry rootstock used in Utah orchards, and proved superior to the mazzard and morello stocks in the test orchard at Farmington. It is occasionally found in cherry orchards as sprouts from below the bud union

glossy recurved green leaves showing little resemblance to a cherry. This species grows wild in Europe and also as an escape from cultivation in the eastern states. The fruit is small, black, bitter, and inedible. The mahaleb seldom sprouts from the roots of cherry trees, but occasionally does so from the trunk below the bud.

Howard (30) reported that imported mahaleb seed came mostly from hedges in the Rhone Valley, but that he found old trees that were 20 feet high growing wild at 3,000 feet elevation in the French Alps. They seemed to thrive especially well on dry, gravelly soils, and on steep hillsides where moisture was scarce. They appeared to thrive equally well in the deep, moist soils of the Rhone River Valley. In the foothills of the Alps, where soil had washed away and exposed roots of mahaleb a pronounced taproot running straight down was found in practically every case. He observed great uniformity among the wild mahaleb trees. He quoted Armand, leading seed dealer of Angers, France, as stating that about 2,500,000 mahaleb seedling stocks were used annually to about 200,000 mazzards.

MAZZARD

Mazzard stocks used for budding by nurserymen are seedlings of the sweet cherry species from which the cultivated sweet cherries *Prunus avium* Linn, have been derived. These seedlings were formerly imported from Europe, but are now grown from domestic sources. Seedling mazzard trees commonly grow as escapes from cultivation or in neglected orchards in humid regions. These trees usually have small fruit, either red or black, often bitter. Types presumed to be hardier than average have been imported and grown by the New York Agricultural Experiment Station at Geneva, and by Howard of the California Experiment Station.

According to Bradford,[6] mazzard seedlings from different parts

[6]Conversation with writer, 1935.

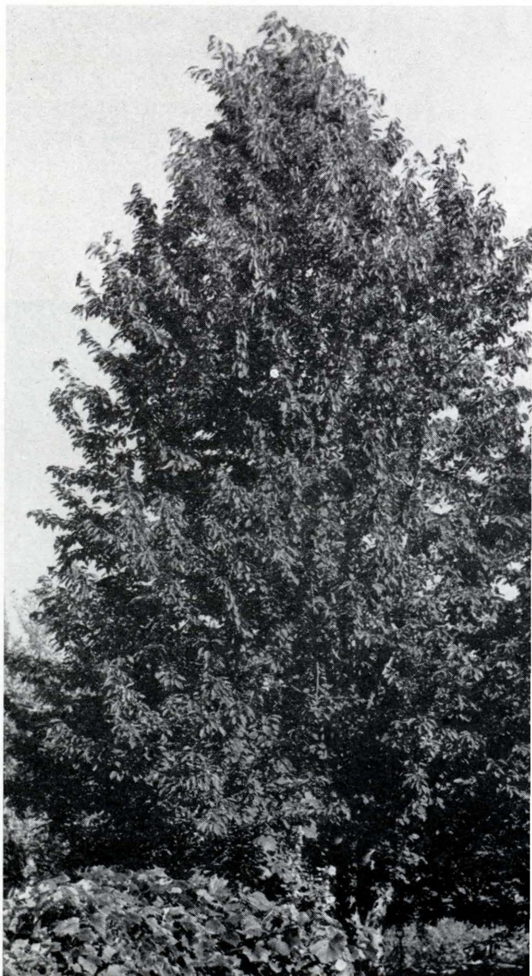

Fig. 2. *Typical mazzard tree* (*Prunus avium* Linn.) of fruiting age, growing in a home orchard at Logan. Mazzard is a wild type of sweet cherry species. Note vigor and upright growth habit. The fruit of this tree is small, firm and bitter. Many mazzards have red, soft fruits of small size. This specimen is one of the trees under test as a source of seed for rootstock purposes. Sweet cherries on mazzard stocks were inferior in vigor and production to those on mahaleb stocks on well-drained soils in the rootstocks test orchard at Farmington. Mazzard trees are occasionally found in cherry orchards where the scion variety has failed, and the rootstock sprouts have been allowed to grow

of the United States vary considerably, and trials of mazzard seed from different seedling trees growing in Utah orchards showed marked individual differences in germination between different trees in the same orchard and section. Mazzard seedlings make tall, vigorous, upright growing trees. The characteristics of mazzard as a rootstock are discussed in the review of literature which follows.

Sources of imported mazzard seed were studied by Howard (30) who reported that wild mazzard trees were found chiefly in Normandy near the English Channel. Mazzard trees there, from which seeds were collected, grew to 40 feet in height. He significantly reported that the bulk of the mazzard seed going into the trade was not collected from wild mazzard trees, but was from cultivated varieties or seedlings, which were apt to be a mixture of sweet and sour cherries. This would account for much of the variation in this stock.

STOCKTON MORELLO

All seedlings of sour cherries used for rootstocks are referred to in the literature as "morello stocks," although the term "morello" is more properly used in pomology to designate those sour cherries which belong to the red-juiced morello group. The Stockton morrello is a selection or clone propagated by suckers which has been used in the vicinity of Stockton, California, to adapt the sweet cherry to heavy, wet soils where trees on mahaleb and mazzard

Fig. 3. *A fifteen year old Stockton morello tree* growing at Farmington, showing characteristics when this type of the species *Prunus cerasus* Linn. is allowed to form a tree. Note dwarf drooping growth habit and small dark-juiced fruit of the morello type. This species is propagated by suckers, and was first used in the Stockton, California, area to adapt sweet cherries to heavy soils with relatively poor drainage. In the open porous soils of the test orchard at Farmington, trees on this stock were severely dwarfed, precocious in fruiting, poorly anchored against winds, tended to overbear and lose vigor. This stock may be useful for home garden trees, and for closely spaced orchards on heavier soils

failed to succeed. It is commonly used as a dwarfing stock. Morello seedling stocks have been recommended where great hardiness is required. The Stockton morello, when allowed to form its own top, grows into a dwarfish morello type tree, with small dark red acid fruit. The fruit is suitable for culinary use, but inferior in size and quality to the standard varieties of this type.

Hansen and Eggers (25) report that Stockton morello stocks are commercially satisfactory for adapting sweet cherries to heavy, shallow or wet soils in California, but have "a dwarfing influence and do not make a good union with some varieties."

HISTORY OF THE CHERRY ROOTSTOCKS PROBLEM[7]

HISTORY IN EUROPE

GRAFTING of cherries was done in ancient times, being mentioned by Varro (B.C. 117-127) as a common operation. Probably mazzard stocks were employed. Mascall (1652), Austen (1653), Reid (1683), Lawrence (1714) mention only mazzard stocks as being used for sweet cherries. Mahaleb (Cerisier de Sainte-Lucie) stocks for other types of cherries were first mentioned by Duhamel du Monceau in 1768. Noting that mahaleb does not sucker, he writes, "It receives very well the graft of all species of cherries and adapts itself to the worst soils." Loudon (1824), described mahaleb as the most effectual dwarfing stock, which did not succeed generally in English soils, but is recommended on the continent for soils of a light, sandy, or chalky nature. Loudon mentions morello as used for dwarfing sweet cherries, regarding it as less dwarfing than mahaleb.

HISTORY IN THE UNITED STATES

In the new world, mazzard was probably used first in the propagation of the cherry by Prince at Flushing, Long Island. It was first mentioned by Coxe in his "Fruit trees" (1817), who noted that "heart cherries do not succeed well on any but the black Mazard stocks, but round or duke cherries do as well on Morello stocks, which are often preferred from their being less liable to the cracks in the bark, from frost and sun on the south-west side. . ." Thatcher (1822) echoes Coxe's statement, but neither mention mahaleb as a stock in use at that time. Nor is it mentioned by later writers until

[7]Condensed from Hedrick, U. P. The cherries of New York. (26).

called attention to by Downing in 1845, who speaks of it as being only occasionally employed when "very dwarf trees" were desired. Thomas (1851) writes that mahaleb was used to dwarf cherries, and that it also "possesses the advantage of flourishing on heavy clay ground. . . The grafts will usually grow quite vigorously for two or three seasons, but they soon form dwarf, prolific bushes." Elliott (1854) stated that both mahaleb and morello roots are used for dwarfing the cherry.

Although used only at first as a dwarfing stock, Hedrick notes that the use of mahaleb became general about 1860, and that by 1880 it had largely superseded mazzard stock. He estimated that by 1914, 95 percent of the cherry trees were budded on mahaleb, this in spite of the fact that the mazzard was recommended as preferable by Bailey (4) and other authorities of that time.

THE MAZZARD VS. MAHALEB CONTROVERSY

WHILE generally favoring the mazzard stocks, authorities are by no means unanimous in their conclusions. Mahaleb stocks are favored by a number of writers on the cherry. The status of opinion thirty years ago is aptly summed up by Hedrick (26): "Curiously enough so fundamental a question as the best stock upon which to grow cherries has not yet been settled; indeed . . . interest as to which is the best seems but recently to have been aroused . . . there is a warm controversy as to which is the better of the two leading stocks. . . Since no systematic attempts seem to have been made to determine the peculiarities and values of these two and other cherry stocks, both sides dispute without many facts . . . a fine crop of misunderstandings has grown up about the whole matter."

Authorities and textbooks differ widely in their recommendations, some declaring categorically that sweet cherries on mahaleb are dwarf, unsatisfactory and short-lived, and that mazzard is the best stock for all conditions, while others concede that mahaleb may have a place or be preferable on light, shallow, or droughty soils. Nearly all join in describing mahaleb as a dwarfing stock, a conclusion not borne out by the results of the present experiment. The often conflicting results and opinions reported in the literature are summarized briefly under the following topics:

DWARFING EFFECT OF ROOTSTOCKS

Hedrick (26) states that mahaleb is a dwarfing stock, but that this effect is delayed and not apparent the first few years, and is not as marked as with dwarfing stocks of apples and pears. Howard (28) reports that many California growers and nurserymen preferred mazzard as less dwarfing and more satisfactory, reporting that 71 percent of all cherries in that state were budded on mazzard. Philp (37) agreed that this opinion was still generally held in California. Schuster (39) in Oregon states that mazzard is more vigorous, while Auchter and Knapp (3) and Chandler (10) repeat the oft-published assertion that mazzard stocks give trees of larger size.

On the other hand, Bailey (4) notes that mahaleb is recommended in the books for dwarfing the cherry, but states that the dwarfing depends more on pruning than on the mahaleb root. Chandler (11) holds that more evidence is needed, and cites Howard's experiment that Napoleon trees on mahaleb were just as large as those on mazzard at 4 years. He concludes, "We know only that good results can be obtained with either stock." Howard (28) and Wisker (51) report many nurserymen and growers in California enthusiastically claim that mahaleb stock is the best. Philp (37) reports many trees on mahaleb stock in California over 50 years of age which show no sign of dwarfing effect. Talbert and Murneek (40) state that mahaleb gives a more vigorous tree for the first few years. Bryant (6) found Montmorency trees on mahaleb in eastern Colorado after 5 years' growth were 2.78 inches larger in trunk circumference than those on mazzard.

Upshall (48) reporting on cooperative sweet cherry rootstock trial blocks in Ontario planted from 1934 to 1936, stated in 1940, "During the past two years, however, the trees on Mazzard are catching up in size to the trees on Mahaleb, all of which were larger at planting time and made greater growth during the first few years in the orchard." Later, in 1945 (49) he reported that not only were the trees on mahaleb larger when planted, but that at the age of 9 to 11 years they have continued to be larger in all but one planting on a poorly drained site. His data show that the trees on mahaleb outgrew comparable trees on mazzard an average of 63.49 sq. cms. of trunk cross-section area or 32.2 percent in six out of seven comparisons. In the seventh, located on low, poorly drained land, half the trees on mahaleb had died, and the others were in poor condition.

LONGEVITY OF CHERRY TREES ON MAZZARD AND MAHALEB

Hedrick (26) states, "though the evidence is somewhat conflicting on this point, it is probable that cherries on mazzard live longer than on mahaleb. It may be that the frequent statements to this effect arise from the knowledge that dwarf fruit trees are generally shorter lived than standard trees since there seem to be no records of actual comparisons." Howe (32) reported the cherry trees on mahaleb root on rather poorly drained loam soil at Geneva, New York, were much shorter lived than those on mazzard stocks. At the end of fourteen years, most of the trees on mazzard were in good condition, while less than half of those on mahaleb were alive and most of those in poor condition. Similar results were reported by Anthony, Sudds, and Yerkes (2) at Rosslyn, Virginia, with plantings on clay loam or silt loams. Sweet cherries were more successful on the mazzard stocks. The results were not so clear with sour cherries. The sweet cherries on mahaleb began to weaken and die until all but one was dead at 10 years, while all but one on mazzard was in excellent condition.

Gould (22) states that growers agree that mazzard appears to increase length of life in comparison to mahaleb. Textbooks by Auchter and Knapp (3), Talbert and Murneek (40), Gourley and Howlett (23) and Chandler (10) all repeat the prevailing idea that trees on mahaleb are shorter lived than those on mazzard. Philp (37) reports that many growers in California feel that cherries on mahaleb are short-lived, but couples this with the contrasting report that many trees in that state on mahaleb over 50 years old are still in good condition. Similarly, Bryant (6) reported a lower death loss with Montmorency sour cherries in Colorado on young trees, 6.3 percent on mahaleb compared to 22.9 percent for those on mazzard at the end of 5 years.

COMPARATIVE HARDINESS OF ROOTSTOCKS

Authorities are in general agreement that cherries on mahaleb are hardier and less subject to winterkilling both in the nursery and in the orchard than they are on mazzard. Price and Little (38) report mahaleb as hardier than mazzard in Iowa, but neither as being hardy enough for the colder regions of the northwest, recommending use of sour cherry stocks, "American morello," where a high degree of hardiness is required, in spite of their fault of sprouting. Hedrick (26) states, "Cherries on mahaleb are hardier to cold than those on mazzard stocks. This hardiness is, in part at least, owing to the fact that cherry wood on mahaleb ripens sooner than on mazzard." Auchter and Knapp (3) note that mahaleb roots are more hardy, a fact confirmed by Tukey and Brase (44) who cite as an example, a block of 60,000 nursery trees on mazzard at Dansville, New York, which was a total loss from winter injury in 1933-34, while adjacent blocks on mahaleb showed little injury. Differences in maturity owing to susceptibility of the mazzard stocks to leaf spot may have been a factor. Anderson (1) found that both sweet and sour cherries on mahaleb stocks suffered less from winter killing in 1933-34 on light sandy soils in the Hudson River Valley than those on mazzard.

COMPARATIVE ADAPTATION TO WET AND DRY, HEAVY AND LIGHT SOILS

Here also authorities do not entirely agree, although the majority opinion is that mahaleb is more sensitive to wet soil conditions, but otherwise not as particular in its soil requirements as the mazzard stock. Hedrick (26) states on this point, "Mahaleb is probably the more cosmopolitan stock, will thrive on a greater diversity of soils than the mazzard. In particular it is somewhat better adapted to sandy, light, stony, and arid soils that are not well adapted to growing cherries. . . It is better adapted to shallow soils than mazzard." Bailey (4) notes that mahaleb is said to be better adapted to heavy clay soils than mazzard. Howard (28) cites the claim of the California nurserymen who favor mahaleb that this stock enables trees to withstand better, extremes of too much or too little water in the soil. Philp (37) makes the statement that more dieback was reported in California on mazzard under unfavorable soil and moisture conditions, while mahaleb adapts the cherry to drought conditions much better than mazzard, but will not stand prolonged saturation of the soil. Howe's (32) results in New York appear to confirm Philp's conclusions as to the failure of the mahaleb stock under wet soil conditions. Hansen and Eggers (25) report mahaleb as more drought resistant in California. Chandler (10) characterizes mahaleb as "not tolerant of wet soils," while mazzard is "moderately tolerant of poorly aerated soils, being as tolerant as peach and apricot roots, but not as tolerant as myrobolan plum, apple or pear roots." Drought resistance is given by Gourley and Howlett (23) as one of the reasons for the use of mahaleb. Schuster (39) on the other hand, states that in Oregon mazzard is more vigorous and able to cope with adverse conditions, such as dry seasons, than is mahaleb. It is likely that trees on mahaleb are adversely affected by the poor drainage common in western Oregon. Upshall[8] reports that on well drained cherry soils in Ontario, mahaleb seems to be quite satisfactory but not so on marginal or poor cherry soils. Where there are high water tables in the spring

[8]Personal communication.

he (49) advises giving preference to mazzard roots or preferably planting kinds of fruit more tolerant of "wet feet" than cherries.

RESISTANCE TO INJURY FROM PESTS

Butcher (8) reported that mazzard is subject to root-knot. Philp (37) observed mahaleb to be seriously attacked by gophers. Hansen and Eggers (25) state that trees on mahaleb root are more resistant to "buckskin disease," a virus trouble, in California than those on mazzard, but are more subject to nematode and gopher injury. Bryant (6) in Colorado found 12.4 percent of his Montmorency trees on mahaleb were severely chlorotic compared to 27.3 percent for mazzard on rather heavy loam soil with 6 to 8 percent lime. Gourley and Howlett (23) quote Tufts and Day that cherry trees on mahaleb are less affected by little-leaf disorder caused by zinc deficiency. Chandler (10) states that trees on mahaleb are immune to "buckskin" virus disease when scions are high budded upon it.

QUALITY OF GRAFT UNIONS

Hedrick (26) states that better unions are made with mazzard than mahaleb. Butcher (8) reports that some trees on mazzard "pinch off" at the union and never make good trees, the trunk being always larger than the rootstock. Philp (37) observed overgrowth of the scion with many varieties on mahaleb stock, especially where high-budded. Tukey and Brase (44) state that both stocks overgrow the Montmorency scion, but that mazzard makes a stronger union than mahaleb, observing that the top breaks off at the union more often with mahaleb when trees are pulled with a tractor. Tests by Brase (5) showed sweet cherry scions to be less compatible with mahaleb when bench grafted during winter, and transplanted less readily than those on mazzard.

EASE OF PROPAGATION IN NURSERY

Chandler (11) states on this point, "It is, of course, well known that much better results are obtained in the nursery when mahaleb roots are used." Gould (22) observes that nurserymen find mazzard difficult to use, refusing to "take" buds when weather conditions are unfavorable. Upshall[9] writes, "Our nurserymen have a great deal of difficulty growing trees on mazzard because of its susceptibility in the nursery to black aphis and leaf spot. From their standpoint, they are much better pleased with mahaleb." The marked

[9]In personal communication.

differences in hardiness in the nursery reported by Tukey and Brase (44) which are probably caused by susceptibility of mazzard to the cherry leaf spot disease, have already been referred to.

THE EXPERIMENTAL ORCHARD

SOIL AND SITE

THE orchard in which the study reported was made is located on the Davis Experimental Farm near Farmington, Davis County, Utah, at an approximate elevation of 4,300 feet, on a site with a moderate slope and fair air-drainage. The soil is alluvial fill from Shepherd Creek, a coarse gravelly loam with a sprinkling of stones throughout the entire profile. The fine material ranges from weak brown to brownish grey when dry to dusky brown or brownish black when wet.[10] The soil is quite well drained, and high in organic matter for Utah soils. The land had been used the previous 10 years for vegetable crops and strawberries, and frequently fertilized with barnyard manure.

SOURCE OF TREES AND PLANTING TECHNIQUE

Most of the trees on mazzard, mahaleb and Stockton morello stocks were budded on seedlings from commercial sources. The trees were planted April 10, 1931, were watered in, headed back to 30-36 inches, disbudded to 5-7 buds, and waxed with warm brush wax. About April 25th, a severe windstorm damaged the new shoots. July 5th the strongest leaders were pinched back to cause branching. Unusually high temperatures of 115° F. caused sunscalding of the leaves, and loss of some of the trees. The trees on Stockton morello from California were budded out the most when planted, and suffered the greatest losses the first season.

Eight trees of each variety on each rootstock were used, arranged in blocks of four trees of each combination, the blocks being located at random to reduce the effects of soil variation, in eight rows of 14 trees each, both rows and trees being 15 feet apart. In 1939 after 9 years' growth, alternate filler trees were removed to prevent crowding, leaving two trees of each combination in each block, except where trees had died. Missing trees were replanted, but these trees were not included in the experiment.

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[10]This description of the soil was furnished by D. S. Jennings of the Agronomy and Soils Department, Utah Agricultural Experiment Station.

Fig. 4. *A typical tree of the Napoleon (Royal Ann) variety on the mahaleb rootstock* in the test orchard at Farmington, at the age of 15 years. This tree has not been headed back but shows good vigor for a bearing tree not recently pruned and is heavily loaded with fruit of fair size for the variety. Note large size, spread and bearing surface attained on the mahaleb stock under well drained soil conditions generally prevailing in Utah orchards. This tree yielded 390 pounds of fruit the season photographed (July 6, 1945)

Varieties and Management

Varieties used were: Bing, Lambert, Napoleon, Black Tartarian, Black Republican, Centennial, Seneca. One block of Bing on Stockton morello proved to be misnamed, and the Black Tartarian trees proved to be of a distinct type, later designated "Milton Tartarian" by the writer (14).

The experimental trees were given care comparable to that of a commercial orchard, cultivated and irrigated until August, when a cover crop of hairy vetch was sown. In May 1932, the cover crop next to the trees was plowed in, the center rows being left to reseed. The trees were pruned each spring except following the severe winter of 1932-33 which caused much injury. Modified leader training was used.

PRESENTATION OF RESULTS

WINTER INJURY

IN early December 1932, following several weeks of mild weather, the temperature dropped to approximately —16° F., on three successive nights, causing severe blackheart injury to sweet cherries, and peaches as well as other fruits. Many of the experimental trees, especially those on mazzard, were killed outright, or the tops killed to the ground. Others had to be cut back the following year to a vigorous sprout from below the snow line. Some of the lack of uniformity in size was probably the result of this killing back and the reshaping necessary. Of the 18 trees which had the tops three-fourths or more killed, or which died during the following two years as a result of the injury sustained in 1932, 15 were on mazzard root and 3 were on mahaleb root. None were on morello root. The greater hardiness of the trees on mahaleb and morello root as compared to those on mazzard was strikingly evident. It has been suggested by Tukey (44) that this difference is the result of earlier maturity of scions on the mahaleb stocks. This factor would apply to those on morello stocks also.

COMPARATIVE TRUNK CIRCUMFERENCE AFTER 7 YEARS' GROWTH

After seven seasons' growth, the 76 surviving trees were measured and the differences analyzed statistically. The results are summarized in table 3. Trees on mahaleb varied from 11.5 to 18.5 inches in circumference with a mean value of 16.05; for morello the corresponding values were 4.5 to 18.5 inches, with mean circumference of 12.75; for mazzard the trees varied from 4.5 to 15.5, the mean being 11.02. At this stage, the trees on mahaleb averaged 5.02 inches or 45.6 percent larger than those on mazzard, and 3.30 inches or

Table 3. *Trunk circumference of sweet cherries on mazzard, mahaleb, and morello rootstocks after 7 years' growth*

Rootstock comparisons	No. trees	Mean circum. (inches)	Difference (inches)	Percent increase	Percentage relation of stocks
Mahaleb	31	16.05±.24	5.02±.52**	45.6	100.0
vs. mazzard	20	11.02±.46			68.7
Mahaleb	31	16.05±.24	3.30±.51**	25.9	100.0
vs. morello	21	12.75±.45			79.4
Morello	21	12.75±.45	1.73±.64	15.7	100.0
vs. mazzard	20	11.02±.46			86.5

**Differences highly significant.

25.9 percent larger than those on morello. These differences were statistically significant. The trees on morello showed a tendency to be larger on the average than those on mazzard, but this difference was within the limits of experimental error.

SIZE DIFFERENCES AFTER 10 YEARS' GROWTH

The 34 sweet cherries on mahaleb, the 29 on mazzard, and the 19 on Stockton morello remaining were measured in 1939 after ten years in the orchard, prior to removing the filler trees to prevent damage from crowding. Comparative sizes of the trees on the three stocks are given in table 4. At this stage, trees on mahaleb were markedly larger than those on the other stocks, although a few of the trees on mazzard equalled some of those on mahaleb. Considerable variation was evident in all lots, and many dwarfish, stunted trees were in evidence, especially in the mazzard lot.

Table 4. *Mean circumferences of 10 year old sweet cherry trees on mahaleb, mazzard, and Stockton morello stocks*

Rootstock comparison	No. trees	Mean circumference (inches)	Difference (inches)	Percent difference	Percentage relation of stocks
Mahaleb vs.	34	20.34	6.30**	44.9	100.00
mazzard	29	14.04			69.03
Mahaleb vs.	34	20.34	4.67**	29.8	100.00
morello	19	15.67			77.04
Mazzard vs.	29	14.04	1.63	11.6	89.59
morello	19	15.67			100.00

**Differences statistically significant (.01).

The measurements of trunk circumferences showed substantially significant differences of 44.9 percent in favor of the trees on mahaleb roots as compared to those on mazzard stocks, and 29.8 percent as compared to those on Stockton morello. The difference between mazzard and morello showed a trend in favor of morello, but was much smaller and not statistically significant.

Considering only the differences which were larger than the calculated experimental error, if the mean circumference of the trees on mazzard was taken as equal to 100, the mean circumference of the trees on mahaleb was equal to 144.87. Or, assuming the mahaleb lot to be 100, the mazzard lot equalled only 69.03, and the morello lot equalled 77.04. As shown later, these moderate differences in trunk circumference represented much larger differences in size of the tops of the trees, and productive capacity.

RESULTS AFTER 13 YEARS' GROWTH

Following thirteen years' growth and preliminary to removal of part of the remaining trees, the cherry trees in the rootstocks test block were measured again for trunk circumference, height and spread.

Comparison of Trunk Circumference

The results for the trunk diameter measurements are presented in table 5. In similar experiments, trunk circumference has been found to be a satisfactory index to the size and growth of fruit trees.

Table 5. *Trunk circumference measurements, cherry rootstocks block, all varieties, as of Dec. 4, 1943 (13 years old)*

	Rootstock		
Variety	Mahaleb *inches*	Mazzard *inches*	Morello *inches*
Bing	24.5	18.5	18.0
	34.5		24.0
	30.0		24.8
Lambert	23.3	15.0	17.3
	25.5		17.0
	19.7		17.8
	25.3		
			17.5
Napoleon	26.5	18.8	24.0
	32.0	19.5	18.5
	30.0	14.5	17.8
	26.5		22.0
Seneca	30.5	33.8	19.5
	36.0		
	33.0		
Black Republican	29.3	19.5	19.3
	28.0	20.5	
Black Tartarian	26.8		25.6
Milton Tartarian	25.0		
	26.8		
Centennial	27.5		
	29.5		

In table 6, the mean circumferences of the trees on the different rootstocks are compared in order to present the differences, with their statistical significance.

The data for all varieties indicate that the trees on mahaleb were 40 percent larger in trunk circumference than those on maz-

Table 6. *Summary of mean circumference of 13 year old sweet cherry trees of all varieties on mahaleb, mazzard and Stockton morello*

Rootstock comparisons	No. trees	Mean circum. (inches)	Difference (inches)	Percent difference	Differences required for .01 significance
Mahaleb with	21	28.10	8.09**	40.43	3.08
mazzard	8	20.01			
Mahaleb with	21	28.10	7.89**	39.04	2.557
morello	14	20.21			
Morello with	14	20.21	.20	.99	2.45
mazzard	8	20.01			

**Differences statistically significant (.01).

zard, and almost the same percentage larger than those on morello. Calculation of the trees of Bing, Lambert, and Napoleon, the three important commercial varieties separately summarized in table 7, gave an even larger difference of 49.35 percent in favor of mahaleb over mazzard, a difference which was highly significant mathematically. With these important varieties, the trees on morello were on the average 13.18 percent larger in circumference than those on mazzard, but this difference was not great enough to reach the .05 level of significance and so is considered to be within the error of the experiment.

Table 7. *Comparison of trunk circumference measurements of twenty-seven 13 year old Bing, Lambert, and Napoleon cherry trees on mahaleb, mazzard, and Stockton morello rootstocks at Farmington, Utah*

Rootstock	No. trees	Mean trunk circumference in inches	Increase over mazzard (inches)	Differences required for significance† .05	.01	Percentage increase over mazzard	Relative circumference compared to mahaleb as 100
Mahaleb	11	27.07	9.81**	2.064	2.797	49.35	100
Morello	11	19.88	2.62*	2.064	2.797	13.18	73
Mazzard	5	17.26	0			0	64

*Difference significant (.05).
**Difference highly significant (.01).
†Snedecor, George W. Calculation and interpretation of analysis of variance and covariance. Ames, Iowa, Collegiate Press, 1934.

Comparison of Top Volume of Trees

Since the differences in trunk circumferences do not accurately portray the great differences that exist in the actual size and bearing surface of the trees on the three rootstocks, the cubical contents or volume of the tree tops were calculated from the height and spread of the branches and compared. These data are given for the individual trees in table 8 and the means and differences are compared in table 9.

Table 8. *Calculated volumes of tops of 13 year old cherry trees of all varieties on mahaleb, mazzard, and Stockton morello rootstocks*

Variety	Mahaleb	Mazzard	Morello
		cubic feet	
Bing	2,144.6	1,436.7	294.0
	2,572.5	....	1,288.2
	4,033.7	....	1,949.8
Lambert	2,896.4	1,288.2	381.7
	2,572.5	....	962.5
	1,857.0	....	796.3
	2,572.5	....	....
Napoleon	3,315.1	650.5	220.9
	3,735.0	1,767.1	2,045.8
	2,572.5	1,288.2	1,436.7
	1,949.8	....	414.4
			563.8
Seneca	3,451.5	4,510.8	904.8
	5,964.0	....	....
	4,849.0	....	....
Black Republican	3,591.1	1,150.4	696.9
	1,494.8	745.5	....
Black Tartarian	1,436.7	....	1,596.3
Milton Tartarian	1,680.1	....	....
	1,436.7	....	....
Centennial	2,144.6	....	....
	2,806.4	....	....

Table 9. *Comparison of cherry rootstocks on basis of calculated volumes of tops of trees (cubic feet)*

Rootstocks compared	No. trees	Mean volume (cu. ft.)	Diff. (cu. ft.)	Min. difference required for .01 significance	Percent vol. increase
Mahaleb	21	2,808.97	1,204.30**	1,117.9	85.05
Mazzard	8	1,604.67			
Mahaleb	21	2,808.97	1,870.96**	928.8	193.28
Morello	14	968.01			
Mazzard	8	1,604.67	636.66	886.1	65.77
Morello	14	968.01			

**Differences statistically significant (.01).

The differences calculated as mean volume of the tops of trees are much larger, and are thought to represent more nearly actual differences in leaf surface and bearing capacity than the smaller differences in trunk circumference. When all varieties are considered, the trees on mahaleb had over 85 percent larger tops (calculated as volumes based on height from lowest branch and spread of branches) than those on mazzard, and over 193 percent larger tops than those on Stockton morello.

Fig. 5. *A typical tree of Bing on mahaleb rootstock* in the experimental block at Farmington. This tree was cut back into 2 year old wood to study effect of dormant pruning on size of fruit, yield, and vigor. Note vigorous growth response and lighter fruit load as compared to tree in figure 4. Yield of fruit in 1945 of this tree was 213 pounds. Close up view of fruit in figure 6

These differences are strikingly large and of major importance to fruit growers because of their relation to yields, unit cost of production, and profits. They are also of importance to consumers because of their effect on cost of production and prices.

The difference in favor of mazzard over morello, while large, constituting 65.77 percent of the latter, fails because of high variability between trees of the same lots and the small numbers of trees on mazzard remaining to be measured at this stage of the test, to reach the .05 level of significance. With larger numbers of trees, this trend in favor of mazzard over morello could probably be confirmed statistically.

These data also show that at this age, the trunks of trees on the more dwarfing morello stock are much stockier and thicker in proportion to height and spread of branches than the trees on either mahaleb or mazzard, therefore the trees make a much better showing on morello when size is measured by trunk circumference than by calculated volumes of the tops of the trees. The yield data also, while incomplete, bear out the conclusion that the differences in favor of the trees on mahaleb stocks are much greater than those indicated by the trunk circumference measurements, and correspond more closely with the differences in volumes of the tops of the trees.

Comparison of Height, Spread, and Girth

The data for mean trunk circumferences, height, branch spread, and calculated volume of tops on the three rootstocks are compared separately for the important commercial varieties, Bing, Lambert, and Napoleon in table 10.

Table 10.. *Comparative trunk circumference, heights, spread and calculated volume of tops of Napoleon, Lambert, and Bing trees on 3 rootstocks, age 13 years*

	Napoleon			Lambert			Bing		
	Mahaleb	Mazzard	Morello	Mahaleb	Mazzard	Morello	Mahaleb	Mazzard	Morello
Number trees	4	3	5	4	1	3	3	1	3
Mean circumference .... (inches)	28.75	17.6	19.96	23.45	15.0	17.36	29.66	18.50	22.26
Relative circumference (Mahaleb equals 100)	100	61.2	69.4	100	64.0	74.0	100	62.4	75.1
Mean height (feet)	17.62	14.33	12.30	18.88	14.0	13.2	19.33	16.00	14.50
Relative height (Mahaleb equals 100)	100	81.3	69.8	100	74.5	69.9	100	82.8	75.0
Mean branch spread (feet)	12.87	10.50	8.30	19.00	16.0	13.7	20.66	16.0	14.66
Relative spread (Mahaleb equals 100)	100	81.5	64.5	100	84.2	72.1	100	77.4	71.0
Calculated volume (cu. ft.)	2,893	1,235	936	2,452	1,288	713	2,916	1,436	1,177
Relative volume (Mahaleb equals 100)	100	42.7	32.4	100	52.5	29.1	100	49.2	40.4

From these data, the outstanding superiority in size and bearing surface of the trees on the mahaleb stock at the age of 13 years is clearly evident. In calculated mean volume of tops of the trees, for example, when the trees on the mahaleb stock were taken as 100, those on mazzard equalled 42.7 cubic feet for Napoleon, 52.5 for Lambert, and 49.2 for Bing, those on mahaleb averaging over twice the calculated volume and bearing surface of the trees of the same varieties on mazzard. Likewise, taking the trees on mahaleb root as equalling 100, those on morello roots equalled 32.4 cubic feet for Napoleon, 29.1 for Lambert, and 40.4 for Bing, averaging approximately two and one-half to three and one-half times the size of the trees on morello. It is noteworthy that this marked superiority of the trees on mahaleb over those on mazzard and morello holds good on all varieties tested. Under the conditions of this test, the mahaleb stocks were not generally dwarfing, but made outstandingly vigorous trees while many of the trees on mazzard were badly dwarfed or even stunted. All of the trees on the Stockton morello were markedly dwarfed, some more severely than others. These results are at variance with those noted by many other authorities, and are presumably the result of differences in environmental conditions.

Root Anchorage, Wind and Heat Damage

A severe September windstorm in 1941 tested the anchorage provided by the three rootstocks. Most of the trees on morello root were either blown down or leaned to the west and had to be braced back into an upright position, indicating weak anchorage by roots of this stock, which should be staked when planted in windy locations. The trees on the other stocks suffered little or no damage from blowing down or being made to lean to leeward from this windstorm.

The trees on morello root also seemed to suffer more from lack of water during heat waves in June and July than the trees on the other two stocks. The leaves appeared more wilted and sunburning of the cherries more extensive, although all varieties suffered considerably in certain seasons of excessively high temperatures and high transpiration, even though ample available moisture was maintained in the soil by frequent irrigation during the ripening period. The greater productivity of the trees on morello for their size, which often resulted in overbearing, setting more fruit than they could mature well, resulting in a marked decline in vigor, was likely a factor in these trees wilting more than those on the other stocks, since overbearing probably caused a reduction of root growth and a smaller absorbing surface for moisture because of lower carbohydrate supply. This tendency to overbear so weakened many of the trees on morello roots that many died, and others had to be rejuvenated by heavy dormant heading back pruning, which appears to be necessary after the trees on this stock reach heavy bearing age.

Age of Fruiting, Season of Ripening, and Quality of Fruit

While trees on all the rootstocks began to bear lightly the fourth year after planting, the trees on morello set more buds, blossomed more heavily, and set more fruit from the fourth through the ninth year. One Napoleon tree on morello bore 6 pounds of fruit in its fourth year. This early and heavy fruiting for the size of the young trees further dwarfed the trees and caused a loss of vigor. The trees on morello outyielded those on mahaleb and mazzard the first seven years, equalled those on mahaleb and outyielded those on mazzard during the eighth year, but after that the larger trees on mahaleb and mazzard substantially outyielded those on morello on a per tree basis.

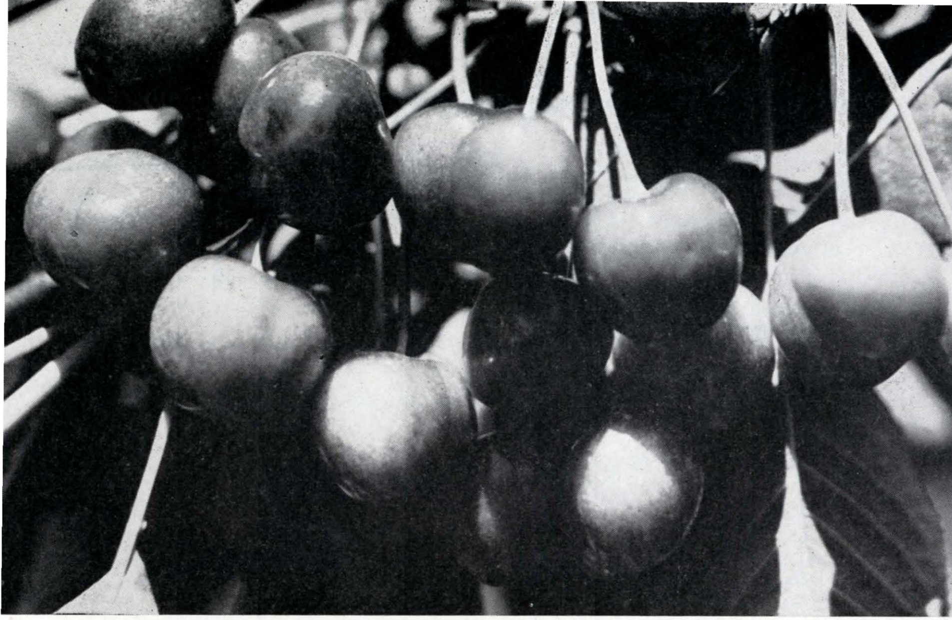

Fig. 6. *Bing cherries*—Close up view of a cluster of fruit on pruned Bing on mahaleb tree shown in figure 5. Under conditions favoring overbearing prevailing in the test orchard in 1945, heading back pruning markedly improved size and quality of fruit, and improved vegetative vigor.

When the trees on morello were not overloaded, they usually matured their fruit several days earlier than trees on the other two stocks. One year the fruit on the trees on morello stocks ripened 10 days earlier, and every season trees on morello that were not overloaded were ready to pick several days to a week earlier. Trees that were overloaded were later in ripening than the trees on other stocks. In severe cases the heavily laden clusters of fruit failed to develop full color and sugar content and were unsalable.

Aside from the earlier ripening, which resulted in the fruit on the trees on morello stocks having higher color and sweeter flavor early in the harvest season, there appeared to be no differences in size and quality of the fruit, when set of fruit was considered in relation to vigor and leaf surface of the trees.

Yield Relationships

Because of frost damage, labor shortages, bird damage, and other causes, complete yield records on the test trees were not obtained. Yields of fruit were affected by so many other factors, such as weather and pollination, besides the rootstock used, that too much reliance cannot be placed on the yield data as an index of rootstock value. Too few yield records were obtained on some varietal-rootstock combinations to give reliable means for each

Table 11. *Yields of Bing, Lambert, Napoleon, and Black Republican sweet cherries on Mahaleb, Mazzard, and Morello stocks at 8 years* (1938)

Rootstock		Mahaleb				Mazzard				Stockton morello			
Scion variety	No.	Bing	Lambert	Napoleon	Black Republican	Bing	Lambert	Napoleon	Black Republican	Bing	Lambert	Napoleon	Black Republican
Individual	1	91	85	133	92	50	18	22	30	96	78	132	35
	2	54.5	73	126	78.5	39	13	21	22.5	51.5		100	43.5
tree	3	51.5	71	90	63.0	25	11	19.5	5			81	
	4	39	66	84.5	55.5			5				67	
yields	5	31.5	52.5	66	30							55	
	6		22	43								54	
(lbs.)	7											45	
	8											35	
No. trees each combination		5	6	6	5	3	3	4	3	2	1	8	2
Mean yield (lbs.) per tree		47.5	61.6	90.4	63.8	38	14	16.9	19.2	73.7	78	71.1	39.7
No trees each rootstock			22				13				13		
Mean yield per tree* (all 4 varieties)				65.8				22				65.6	

*Minimum difference required for .05 significance is 34.25 lbs. per tree combination. The value of the yield data presented is principally corroborative, since they in general support the conclusions made by observation and those from study of the more accurate and complete tree measurement data. Some generalizations, however, appear to be warranted.

The yields for each tree of the four varieties, Bing, Lambert, Napoleon, and Black Republican, in their eighth year (1938) are tabulated in table 11 and the mean yields for each rootstock, with their differences, are compared in table 12.

Table 12. *Comparison of mean yields of 8 year old Bing, Lambert, Napoleon and Black Republican cherry trees on 3 rootstocks,* 1938

Rootstock comparisons	No. trees	Mean yield per tree (lbs.)	Diff. lbs. per tree	Diff. percent	Comparative yield—(lowest yielding stock =100)
Mahaleb	22	65.8	43.8*		299
			——	199	
vs. mazzard	13	22.0			100
Mahaleb	22	65.8			100
			.2	—	
vs. morello	13	65.6			100
Morello	13	65.6			298
			43.6*	198	
vs. mazzard	13	22.0			100

*Differences statistically significant (.05).

At this young bearing stage, the trees on mahaleb and morello yielded equally well, and both produced nearly double the fruit borne by the trees on the mazzard root. While the trees on morello were much smaller than those on mahaleb, they were more fruitful for their size. In subsequent years, however, the faster growing trees on mahaleb drew rapidly ahead, averaging nearly 50 percent more during the period 1940-43. It appears probable that this trend will continue with the markedly larger standard trees on mahaleb producing during their mature years several times as much per tree as the dwarf trees on morello. The larger trees on mazzard likewise overtook the trees on morello in production after the ninth year, but many of the trees on this stock were dwarfed and remained less productive than the trees on morello.

The yield data available for the three commercial sweet cherry varieties, Bing, Lambert, and Napoleon, on the three rootstocks for the period 1940-43 are summarized in table 13. High variability was evident between various trees in each combination and between years. The 1939 and 1941 crops were both badly damaged by frosts and rainy periods during blossoming.

Table 13. *Mean yields of Bing, Lambert, and Napoleon trees on 3 rootstocks, 1940-43, by variety and rootstock combination (pounds per tree per year)*

		Mahaleb				Mazzard				Morello			
		1940	1941	1942	1943	1940	1941	1942	1943	1940	1941	1942	1943
	No. trees	5	3	7	1	0	0	0	0	1	0	3	0
Bing	Mean yields......	105.6	19.7	35.6	178	—	—	—	—	59	—	12.3	—
Lambert	No. trees	4	3	4	—	—	1	—	—	4	—	3	1
Napoleon	Mean yields......	58.8	30.3	44.5	—	—	13	—	—	30.5	—	34.7	50
Total	No. trees	4	3	2	—	—	3	3	1	4	4	5	1
all 3	Mean yields......	122.7	11.0	85.5	—	—	48.3	29.0	123	83.8	23.3	19.2	119
varieties	No. trees	13	9	13	1	—	4	3	1	9	4	11	2
Total	Mean yields......	95.7	20.3	55.2	178		30.7	29.0	123	57.8	23.3	22.1	84.5
2 varieties	No. trees		36					8				26	
1940-43	Mean yields......			87.3				60.9				46.9	

With these three varieties, the trees on mahaleb gave a mean yield of 87.3 pounds per tree, compared with 60.9 pounds per tree for those on mazzard, and 46.9 pounds per tree for morello. Compared with mazzard, the trees on mahaleb yielded 26.4 pounds or 43.3 percent more fruit; compared with morello, those on mahaleb produced 40.4 pounds per tree, or 88.3 percent more. These incomplete yield data tend to confirm the conclusions made from the tree measurements as to the superiority of the mahaleb stock under the conditions of the test orchard.

DISCUSSION OF RESULTS

MAZZARD VS. MAHALEB

MEASURED by hardiness, vigor, size of trees, and yield, the data as well as observations in the test orchard point conclusively to the superiority of the mahaleb stock under the conditions of the

Fig. 7. *Typical 15 year old Napoleon tree on mazzard rootstock,* heavily pruned. Note smaller size than comparable trees on mahaleb rootstock shown in figures 4 and 5. Excellent growth response from heading back pruning indicates that lighter pruning might have been more profitable; 1945 yield was 45 pounds. Compare with figure 4. Rootstocks trial block, Farmington

experimental planting at Farmington. Broadly viewed, these results are quite the opposite of results of similar experiments reported by Howe (32), and Anthony, Sudds, and Yerkes (2) in the Atlantic States as well as the opinions of a majority of authorities on the subject over the entire country. The question arises then as to why this divergence in results, and what conclusions are justified.

The results of the present experiment emphasize the danger of broad generalizations such as those repeated so often in the literature on cherry rootstocks to the effect that mahaleb stocks are always dwarfing in effect and result in short-lived trees, since the present test gave just the opposite result, the mazzard proving to be more dwarfing than the mahaleb. Statements on this subject, to be accurate, should be limited to certain classes of soils or combinations of conditions, and exceptions be provided for.

In the present case, the fact that this orchard is located on a fast draining, rather coarse, open soil, which, although it allows for deep rooting of the trees, is rather low in water holding capacity, so that lack of available moisture rather than lack of aeration commonly encountered with heavy subsoils such as those used in the two eastern experiments cited, is likely to be the limiting factor. Soil reaction, high transpiration conditions in summer, and low winter temperatures which emphasized the importance of early maturity and hardiness, were other conditions that may have combined to give a different result.

Another unknown factor is the origin and characteristics of the particular commercial mazzard and mahaleb seedlings used in propagating the trees in the experimental block. It is possible that in spite of the good size and uniformly healthy appearance of the trees and roots at planting time, that the strain of the mazzard seedlings used was not of a type or source best adapted to the conditions where the trees were planted. Perhaps better adapted strains and sources of mazzard can be found.

Since the results of this test, however, coincide with observations and experiences of Utah nurserymen and growers with long experience in cherry growing under Utah conditions, it is likely that the mazzards used were no worse than the usual run of commercial mazzards that have been available to the industry. The fact that old trees are found on this stock in good condition, and that some trees in the mazzard plots were superior in their growth and performance, point to the conclusion that certain selected strains or sources of mazzard stocks may be equal to or even superior to mahaleb in adaptability and performance under local conditions. However, until such stocks are proved under typical conditions here, it would appear advisable to plant only sweet cherry trees on mahaleb stock in commercial orchards where soil and other conditions are similar to those of the present experiment.

Comparing mazzard and mahaleb stocks for sweet cherries under these conditions, the conclusion appears justified that ordinary commercial mahaleb stocks are superior to ordinary commercial mazzard stocks in vigor of growth; in maturity and hardiness to winter injury as reported by Tukey and Brase (44) and Anderson (1) in New York; in adaptability to the open, porous, often droughty soils commonly used for cherry growing in this region; in productiveness and yielding, ability, and in survival. It is still too early to draw conclusions on longevity, but no evidence has appeared in the first 14 years of the life of this orchard or in Utah cherry growing experience that would indicate any superiority for mazzard stocks in longevity; in fact, observations point to the contrary. Philp's report (37) that many trees on mahaleb over 50 years old are still growing and fruiting in California tends to confirm the evidence of the present work that mahaleb stocks are not necessarily short-lived under soil conditions to which they are adapted, and may indeed be more successful and longer lived than trees on mazzard under these conditions. Certainly an unsuccessful orchard is soon pulled out in commercial practice.

The results in the test orchard constitute an exception to the statements and conclusions that mahaleb is a dwarfing stock compared to mazzard, made by Downing (1854), Thomas (1851), Elliott (1854), and in recent years by Hedrick (6), Bailey (4), Schuster (39), Auchter and Knapp (3), Chandler (10) and Howe (32). They tend rather to confirm the results of Howard as cited by Chandler (11) that trees on mahaleb grew as fast as those on mazzard and showed no dwarfing; the statement by Bailey (4) that dwarfing effect depends more upon pruning than upon the mahaleb root, and the statement by Chandler that more evidence is needed in order to justify conclusions. The intolerance of mahaleb roots to wet soils as noted by Philp (37), Upshall (47) and Chandler (10) seems to explain many of the failures of this stock both in the East and on the Pacific Coast. Upshall, working in Ontario, writes:[11] "It looks to us as if it is largely a question of tolerance

[11]Personal communication.

Fig. 8. *Typical dwarf 15 year old sweet cherry tree on Stockton Morello stock* in rootstocks trial block at Farmington. Lambert variety. Trees on this stock required heading back pruning every two or three years to maintain vigor and prevent overbearing with resultant small size and poor quality of fruit and exhaustion of the tree. Compare the size and bearing capacity of this tree with those in figures 4 and 5. This tree bore 85 pounds in 1945

to wet soil conditions. On well-drained cherry soils Mahaleb seems to be quite satisfactory but not so on marginal or poor cherry soils. The question then comes up, should cherries be planted on the latter type anyway? . . . Much of the cherry stock work already reported has had to do with soils in the latter class." In a current report (49) he writes, "In the early years of these trials and where the soil is reasonably favourable for sweet cherries, Mahaleb has not been a dwarfing stock as is its reputation. Perhaps this idea arose from comparisons made on unfavorable soils for cherries."

Other advantages of the mahaleb stock in soils where it is adapted noted by other workers are: (1) superior ability to withstand drought, shallow soils, and other unfavorable soil conditions (except wet feet); (2) good root anchorage; (3) it is less affected by little leaf disorder caused by zinc deficiency; (4) it is cheaper to grow, being less subject to leaf spot and winter injury in the nursery; (5) when high-budded it appears to be more resistant to buckskin disease, a virus disease.

Disadvantages of the mahaleb stock where it is adapted to soil conditions are: (1) trees transplant with more difficulty and are harder to get a good stand the first year than is desirable, a trait probably associated with the fact that the roots of nursery trees are not usually fibrous, but all too often form several stubby prongs which do not regenerate rootlets readily, leading to loss of expensive nursery trees and a poor start and stunting of the remainder; (2) preference which pocket gophers show for them; and (3) a tendency to be overgrown by the sweet cherry scions when high-budded.

The present experiment provides direct evidence only on the value of the three rootstocks used for sweet cherries. If soil conditions are the determining factor in the superiority of the mahaleb in this experiment, as appears likely, it is probable that the mahaleb stock would also be the best risk for sour cherries of the Montmorency variety, especially in view of the results of Bryant (6) in Colorado favoring mahaleb over mazzard for Montmorency stock.

Fig. 9. *Royal Duke cherry on morello rootstock* at Farmington, at 15 years. This tree has been headed back to correct its tendency to overbear. It bears a moderately heavy crop of high quality fruit. This variety is the earliest semisweet cherry commonly grown in Utah, and appears to do well on morello stock for home use. Photo July 6, 1945

STOCKTON MORELLO IN UTAH ORCHARDS

As discussed earlier in this paper, the Stockton morello stock proved to be very dwarfing for sweet cherry scions, causing the growth to be checked earlier and the tree to bear heavily several years before trees on the standard stocks. This reduced root development and activity, led to loss of vigor, overbearing, distress in hot weather, poor anchorage against winds, and greater loss by death, unless mitigated by heavy pruning and bracing. These characteristics render this stock unsatisfactory for commercial planting or home use where a large dual-purpose fruit, ornamental, and shade tree is desired.

Where there is room only for two or three small trees in a home garden, however, the dwarfness and early fruiting induced by this stock may make its use worthwhile where extra care is taken to prevent overbearing by annual pruning when vigor declines and in staking against winds, in fertilization, mulching, and irrigation. The reported success of this stock on heavier soils near Stockton, California, makes it likely that it would make a better showing in heavier, more retentive soils than it has in the Station orchard at Farmington.

While lower, more spreading trees that would allow closer planting and less high ladder work than required for trees on mahaleb would be desirable in reducing harvesting costs, experience so far with the Stockton morello stock in Utah does not warrant further commercial trial in porous soils in this region. However, where growers have heavier soils with a high water-holding capacity, closely spaced plantings on this stock might succeed, and be more profitable than wide spaced plantings on mahaleb.

IMPROVEMENT NEEDED IN CHERRY ROOTSTOCKS

While the commercial mahaleb stocks used made the best showing in the test orchard planted in 1931, the high degree of variability shown by the trees on both the mahaleb and mazzard stocks, and the considerable numbers of small and comparatively unproductive trees on all three stocks, together with other weaknesses shown by each of them, emphasizes the need for more effort by research and commercial agencies interested in the development of the cherry industry for the improvement of cherry stocks, since even the best adapted commercial stocks so far available constitute serious limiting factors in cherry production, reducing average yields per acre through trees inferior in size, vigor, and productiveness, and losses of trees at transplanting time and all through the life of the orchard through winter injury and disease. As a rule many trees are too lacking in size and vigor to produce heavy crops.

Possibilities in the improvement of cherry rootstocks are suggested as follows:

1. Selection of hardy, congenial types of mahaleb, mazzard, or morello, as
   a. clonal stocks, vegetatively propagated with the aid of hormones; or
   b. seeding stocks, from parent trees tested for germination, hardiness, uniformity, congeniality, adaptability, disease, and insect resistance.
2. Testing of other related species of Prunus as cherry rootstocks.
3. Trial of hardy clones of sweet, sour and duke cherries, mahaleb, and other species, as intermediate stocks for double working and topworking, as well as understocks, alone or in combination. The existence of many varieties of cherries, sweet, sour, and duke with large, vigorous, hardy, and disease resistant trees, many of them superior to the commonly cultivated scion varieties in these respects, provides a reservoir of material worth testing for bodystocks, intermediate stocks and understocks.

SUMMARY AND CONCLUSIONS

1. The primary purpose of this paper is to report the results obtained in the comparative tests of mazzard, mahaleb, and Stockton morello rootstocks with sweet cherries in the orchard of the Utah Agricultural Experiment Station at Farmington. The extensive and controversial literature on cherry rootstocks is reviewed, and the present results are discussed in relation to the findings of other workers.

2. According to the 1939 census, Utah had 162,133 sweet and 50,410 sour cherry trees and ranked fourth in the nation in sweet cherry production. Cherries ranked third among Utah fruit crops, with a value of $1,121,000 in 1943. Utah and Davis Counties ranked highest in production of sweet cherries and Box Elder County in sour cherries.

3. Failure of many sweet cherry trees to survive through the full bearing period, and the poor condition of one-fifth of the

sweet cherry trees surveyed in 1935 are thought to be partially the result of rootstock failure. Mahaleb stocks were recommended by experienced nurserymen and growers, and have been most widely used by Utah nurserymen in recent years, in spite of the recommendation for mazzard made by most authorities on the cherry in the East and Pacific Coast, and the failure of mahaleb to be satisfactory as a sweet cherry stock in eastern experiments.

4. Commercial mahaleb seedlings were formerly grown from seed from the Rhone River Valley district of France, and trees grow wild on dry, gravelly hillsides in the French Alps where they are reported to be deep-rooted and drought-resistant. Commercial mazzard seed came from Normandy and was commonly mixed with seed of cultivated varieties and seedlings and sour cherry seed. Stockton morello stocks are propagated from suckers and are used in the Stockton, California, district to adapt sweet cherries to heavy, wet land.

5. Mazzard stocks were probably used since the time of the Romans, while mahaleb was first used in Europe about 1768 and in this country about 1950 as a dwarfing stock for sweet and sour cherries, and by 1914 had largely superseded the mazzard stock. The opinion is commonly held that this predominance of mahaleb is owing to preference of nurserymen and is detrimental to the interest of fruit growers. Mahaleb stock is commonly condemned in the literature for having a dwarfing effect and being short-lived, although various authorities credit it with being hardier, more drought-resistant, and better adapted to shallow soils, also as being less subject to "little leaf" and "buckskin" disease.

6. The experimental block at Farmington is located on a coarse, gravelly, quick-draining loam soil. Cultivation, vetch cover crops, and supplementary nitrogen and irrigation culture were given. Varieties used on the three stocks were: Bing, Lambert, Napoleon, Black Republican, Black Tartarian, Seneca, and Centennial. Eight trees of each varietal-rootstock combination were used in randomized blocks.

7. Trees on mahaleb outgrew those on mazzard and morello, suffered less loss from winter injury than those on mazzard, and outyielded mazzard each year and morello after the ninth year. After 13 years' growth, the trees on mahaleb were 40 and 39 percent larger, respectively, in trunk circumference than those on mazzard and morello, and the volumes of the tops were calculated to be 85 percent larger than those on mazzard, and 193 percent larger than those on morello.

8. Trees of 13 year-old Bing, Lambert, and Napoleon on mahaleb were 49 percent larger in trunk circumference than those on mazzard, 13 percent larger than those on morello, and their tops averaged 26 percent taller, 24 percent broader, and 109 percent greater in volume than the trees on mazzard; also 39 percent taller, 45 percent broader, and 200 percent greater in volume than those on morello stocks.

9. Trees on morello stock suffered more wind damage because of poor anchorage; leaves and fruit wilted and sunscalded more during heat waves; trees bore more heavily when young, overbore and lost vigor from the ninth to thirteenth year, and required heading back dormant pruning to maintain vigor and prevent overbearing. Fruit ripened about a week earlier on morello stocks where not overloaded.

10. Over a four year period, 1940-1943, the trees on the three important commercial varieties, Bing, Lambert, and Napoleon, on mahaleb stock gave a mean yield per tree of 87.3 pounds, compared with 60.9 and 46.9 pounds per tree for those on mazzard and morello, respectively. This was a difference in favor of mahaleb over mazzard of 26.4 pounds or 43.3 percent larger yield. Compared to those on morello, the trees on the larger mahaleb produced 40.4 pounds or 88.3 percent more fruit.

11. The divergence of these results from those obtained in eastern experiments where mazzard was superior to mahaleb is thought to be the result of the coarser, more open, faster draining soil in the Utah experiment to which the mahaleb is evidently better adapted, although it is possible that soil reaction and high summer transpiration may have been factors.

12. It is clearly evident that under the conditions of this experiment, commercial mahaleb proved less dwarfing than mazzard and morello and more satisfactory where large trees and yields are desired. In view of these results it is concluded that mahaleb stocks may well be preferable for commercial planting under many similar conditions where this stock is adapted, especially where porous soils provide good drainage and aeration.

13. Compared to mazzard, mahaleb stocks, *where they are adapted*, appear to have the following advantages: (1) superior ability to withstand drought, shallow and unfavorable soils (except wet feet); (2) good root anchorage; (3) less affected by little leaf; (4) cheaper to grow in nursery; (5) more resistant to "buckskin disease" when high budded.

14. Disadvantages of mahaleb stock where adapted appear to be: (1) trees on this stock transplant with more difficulty than is desirable; (2) susceptibility to gopher injury; (3) tends to be overgrown by sweet cherry scions.

15. Stockton morello stocks are not recommended for further trial for commercial purposes in Utah, but are suggested for dwarf trees for home use, especially where heavier, more moisture-retentive soils and special care in staking, pruning, fertilization, and mulching are given to maintain vigor and prevent wind damage.

16. Further improvement in cherry rootstocks is much needed and may well come through selection of superior seed trees, propagation of selected clonal vegetatively propagated stocks, and the use of hardy, vigorous, compatible, disease-resistant body and understock combinations for topworking.

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ADDENDA

Since the manuscript for this paper was sent to press, the yield data for the test trees on different rootstocks for 1945 have been tabulated for study. Except for missing trees on the mazzard rootstock in the Bing and Lambert comparisons, these data are more complete than in previous years, and show more strikingly than the yield data in the bulletin the present marked superiority of the trees on mahaleb root in size and yielding ability. The fruit set was generally poor on Lambert throughout the orchard, but was uniformly heavy on other varieties and reflects well the productive capacity of the trees. The yields are summarized in table 1.

The superiority of the trees on mahaleb is clearly evident. The mean yield of 11 trees of all varieties on mahaleb was over four times that of the 4 trees remaining on mazzard, and nearly three and one-half times that of the 10 trees on morello. Similarly the mean yields per tree of the important commercial varieties Bing and Napoleon (Royal Ann) on mahaleb was over four times as large as that of trees on Stockton morello stock. Likewise, the mean yield of trees of Napoleon on mahaleb was over six times that of trees on mazzard, and nearly four times that of trees on morello.

The yields for 1945 strongly confirm the less complete yield data in favor of the mahaleb stock given for previous years, as well as the tree measurement data and observations upon which the recommendation in favor of mahaleb was based.

Table 1. *Yields per tree of five varieties of sweet cherries on mahaleb, mazzard, and morello rootstocks in* 1945

Rootstock	Mahaleb		Mazzard		Morello	
Scion variety	No. trees	Mean yield per tree (lbs.)	No. trees	Mean yield per tree (lbs.)	No. trees	Mean yield per tree (lbs.)
Bing	5	299.0	0	......	3	73.7
Napoleon	2	265.0	2	38.5	3	67.3
Lambert	2	40.6	0	......	3	86.3
Republican	1	185.0	2	91.5	1	76.5
Centennial	1	270.0	0	......	0	.00
All varieties	11	265.3	4	65.0	10	75.85

Conclusions:

(1) Mean yield of trees on mahaleb (all varieties) was over 4 times that of trees on mazzard, and 3.49 times that on morello.

(2) Mean yield of trees of Bing and Napoleon on mahaleb was 4 times as large as that of trees of the same varieties on morello stock.

(3) Mean yield of trees of Napoleon on mahaleb was over 6 times that of trees on mazzard, and 3.9 times that of trees on morello.