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Department of Horticulture

Physiological Studies of the Cracking of Sweet Cherries

BY

Leif Verner and E. C. Blodgett

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Summary

1. A method is described of determining the susceptibility of cherries to cracking by absorption of water through the skin of the fruit when immersed in water. Data thus secured, and expressed by "cracking indices", serve as the bases of measuring the effects of various factors which influence the rate and amount of cracking.

2. With the widest limits of soil moisture likely to occur under irrigation practices in the Lewiston district of Idaho, soil moisture content had no noticeable influence on cracking, either in itself or together with rain.

3. The type of cracking common to the Lewiston district is due to an osmotic absorption of water through the skin of the fruit. This type of cracking is directly affected by (1) the osmotic concentration of the fruit juice; (2) turgor of the fruit; (3) temperature of the water; and (4) by skin permeability.

4. Factors affecting cracking indirectly through their effects on one or more of the direct factors above are: (1) soil moisture below the wilting point; (2) an excessive transpiration rate; (3) inherent varietal characteristics; and (4) local climatic conditions.

5. Systematically picking the trees in the order in which they ripen their fruit is recommended as a measure to reduce average losses from cracking, to increase tonnage, and to improve quality.

6. The use of protective sprays, especially rosin fish-oil soap, has given negative results.

7. Further study of varietal differences in susceptibility to cracking; the determination of the earliest stage at which the fruit can be picked without undue sacrifice in tonnage and quality; and the development of packing and marketing facilities which will shorten the period over which the crop must remain on the trees exposed to the hazard of rain after reaching picking maturity, seem at present to offer the greatest promise for effective further work on this problem.

Physiological Studies of the Cracking of Sweet Cherries

A Preliminary Report

by

LEIF VERNER AND E. C. BLODGETT

WHEN sweet cherries are grown where there is danger of rainy weather near harvest time the cracking of the ripening fruit is always a matter of some concern to the growers. In the Lewiston district of Idaho, where the average annual crop of sweet cherries is approximately 42 cars, the cracking of this fruit has presented a serious problem. In many seasons of the past the losses from this type of injury have exceeded 50 per cent of the crop of the most susceptible varieties. In individual orchards losses of 75 per cent or more have been reported in the worst years. Experiments to determine the cause of cracking and to find, if possible, methods of preventing or reducing its occurrence, were begun in the spring of 1928 and have now continued through three seasons.

Although the literature on the subject of fruit cracking is extremely limited no attempt is made to completely review it in this report. The most common contention has been that cracking is directly related to an excess of soil moisture and that it is likely to be especially severe if this excess follows a period of moisture deficiency. Chandler[1] states that "certain injuries, such as cracking of the fruit, may result from a heavy irrigation late in its development, if growth has been checked by lack of water earlier." Gardner, Bradford and Hooker[2] and Gardner[3] make essentially the same statement. Cherry growers in irrigated districts are inclined to place the blame for cracking, directly or indirectly, on faulty irrigation practices.

The most recent information of an experimental nature is that of Hartman and Bullis[4] who report that under Willamette valley conditions in Oregon cracking of sweet cherries may occur as a result of excessive water absorption either through the root system or through the skin of the fruit. The present report concerns primarily the type of cracking

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caused by an intake of water through the skin of the fruit, since in these experiments no instance was observed in which cracking could be definitely attributed to soil moisture conditions.

General Method of Procedure

Irrigation

These experiments were begun in 1928 in an 11-year-old orchard of Napoleon (Royal Ann), Bing, and Lambert varieties. Four different irrigation treatments were maintained by differences in frequency and duration of applications of water. One row containing at least two trees of each variety was used for each treatment, alternate rows being used as buffers to prevent cross-feeding from one treatment to another. Soil moisture samples were taken at 9 to 12-day intervals at depths of 1, 2 and 3 feet. Wilting points were calculated from moisture equivalents. The irrigation treatments were as follows:

1. Light irrigation every 10 days until after harvest.
2. Heavy irrigation every 10 days until after harvest.
3. Little or no irrigation early in the season, (depending upon absolute needs), followed by heavy irrigation at fruit maturity.
4. Heavy irrigation early in the season, followed by no irrigation for 2 to 3 weeks before fruit maturity.

Sampling and Testing the Fruit

One representative tree of each variety was selected from each treatment. Beginning at the first show of color in Napoleon, (approximately 3 weeks from full maturity), samples were taken from each of these trees at 3-day intervals until after harvest.

Except as otherwise indicated the samples were collected in the early hours of the morning, since it was found that changes in turgor of the fruit in the later hours of the day influenced the extent of cracking. One hundred representative cherries were selected from each tree and taken at once to a field laboratory in the orchard. Here the sample was divided into two comparable lots of 50 cherries each. From one of the lots the stems were cut by means of a sharp knife held flush with the base of each fruit. A volume measurement was made by displacement of water in a 1000 c.c. graduated cylinder, after which the cherries were placed in a 2-gallon earthenware crock half full of tap water.

The second lot of 50 cherries was used for determining firmness by means of a specially constructed pressure tester designed to measure the resistance of the fruit to pressure between two flat surfaces. This apparatus has been described elsewhere[5]. As soon as the pressure determinations had been made the cherries were ground in a meat grinder, the juice extracted in a hand press, and the specific gravity of the juice measured with a Balling scale hydrometer. The hydrometer reading was used as a rough measure of the sugar content and the osmotic pressure of the fruit juice.

Determining Susceptibility to Cracking

The 50 cherries placed in water were removed at 2-hour intervals over a period of 10 hours, and a count made of the number of fruits that had cracked. All skin breaks 1/16-inch or more in length were counted. A final count was made after 22 hours immersion.

In order to express in one figure both the rate of cracking and the total number of fruits cracked during the 10-hour immersion period, each cracking record has been expressed as a "cracking index" computed by multiplying the number of cracked cherries at each reading by the average number of hours, of the 10 in immersion, during which those cherries were cracked. Thus cherries which crack most readily—in other words, those which crack earliest in the period of immersion—contribute more to the cracking index than cherries requiring a longer exposure. All the fruits found cracked at the end of the first two-hour period are arbitrarily assumed to have required, on an average, one hour to cause cracking; some having taken more and some less than this amount of time. Each of these, therefore, contributes 10-1, or 9, to the cracking index. Specimens not found cracked until the 10-hour count is made and having, therefore, required an average of 9 hours, contribute 10-9, or 1, to the index.

Since total percentages of cracked fruits after any given period of immersion may be identical, or nearly so, in lots in which the rate of cracking is quite different, the cracking index as used in this work to express both rate and amount of cracking has proved a useful figure. (Table I.)

The Nature of the Injury

Cherries exhibit three distinct types of cracking. They may develop cracks (1) in circles or semi-circles around the stem end; (2) in very fine, concentric rings together with deeper, crescent-shaped cracks at the apical end; or (3) in the form of long, irregular slits on the sides of the fruit. Of these three the cracks at the apical ends are the most common and the first to occur, but are least noticeable. In many instances the concentric rings of broken tissue are little more than skin deep. In fruit not yet mature injury of this nature is often repaired by corking over. In mature fruit the injury may heal but more commonly a brown, sunken rot area develops, probably as a result of the rupturing of the tissues beneath the skin. Stem-end cracks and side cracks sometimes heal, especially on immature fruits, but more often rot organisms gain entrance and the fruit decays.

TABLE I.

Rate and Amount of Cracking of Sweet Cherries in Relation to Sugar Content, 1929. (By Immersion in Water.)

a. Napoleon.

Per Cent Sugar	No. of Determinations Averaged	Per Cent of 50 Cherries Cracking During Following Consecutive Periods						Total Per Cent in 10 Hrs.	Total Per Cent in 22 Hrs.	Cracking Index
		0-2 Hrs.	2-4 Hrs.	4-6 Hrs.	6-8 Hrs.	8-10 Hrs.	10-22 Hrs.			
10-12	11	0	2	4	6	4	4	16	20	28
12-14	4	0	8	14	12	6	16	40	56	84
14-16	5	4	6	20	16	10	20	56	76	118
16-18	4	0	14	32	22	8	16	76	92	166
18-20	4	2	28	26	18	10	10	84	94	204
20-22	3	6	28	26	18	10	10	88	98	222

b. Bing.

Per Cent Sugar	No. of Determinations Averaged	0-2 Hrs.	2-4 Hrs.	4-6 Hrs.	6-8 Hrs.	8-10 Hrs.	10-22 Hrs.	Total Per Cent in 10 Hrs.	Total Per Cent in 22 Hrs.	Cracking Index
10-12	8	10	13	7	7	6	3	43	46	120
12-14	4	16	13	22	12	10	7	73	80	195
14-16	6	5	26	32	17	7	5	87	92	222
16-18	14	7	29	31	15	8	10	90	100	237
18-20	8	13	31	34	13	2	4	93	97	272
20-22	4	21	49	18	7	1	2	96	98	322

c. Lambert.

Per Cent Sugar	No. of Determinations Averaged	0-2 Hrs.	2-4 Hrs.	4-6 Hrs.	6-8 Hrs.	8-10 Hrs.	10-22 Hrs.	Total Per Cent in 10 Hrs.	Total Per Cent in 22 Hrs.	Cracking Index
10-12	13	2	6	4	2	2	4	16	20	44
12-14	3	2	4	2	6	0	4	14	18	30
14-16	7	0	4	8	8	6	12	26	38	49
16-18	9	2	12	24	18	12	6	68	74	144
18-20	18	4	22	24	18	8	12	76	88	186
20-22	6	12	34	24	12	6	8	88	96	254

Experimental Results and Discussion

Cracking by Absorption of Water Through the Conducting System

It has been impossible under field conditions to establish throughout the entire root zone the soil moisture conditions desired for each of the irrigation treatments. A reserve supply of moisture remaining in the deeper layers of soil from winter precipitation, together with occasional summer rains, has maintained a moisture content above the wilting point in some portion of the root area at all times, even when the average moisture content has been below the wilting point. On plots permitted to become very low in moisture and then heavily irrigated, it has been difficult to secure the desired rapid increase in average moisture content throughout the root zone, due to slow percolation. The extremes obtained have, however, been greater than would result under any system of irrigation in practice in the district at the present time.

Under these conditions no cracking of the fruit has been observed as a result of soil moisture conditions alone. Cracking has been observed only with the occurrence of rain or upon immersion of the fruit in water. When large branches have been protected from rain by means of tarpaulins stretched over specially constructed frames there has been no cracking of the fruit, regardless of previous irrigation treatment, while unsheltered portions of the same trees have suffered much injury.

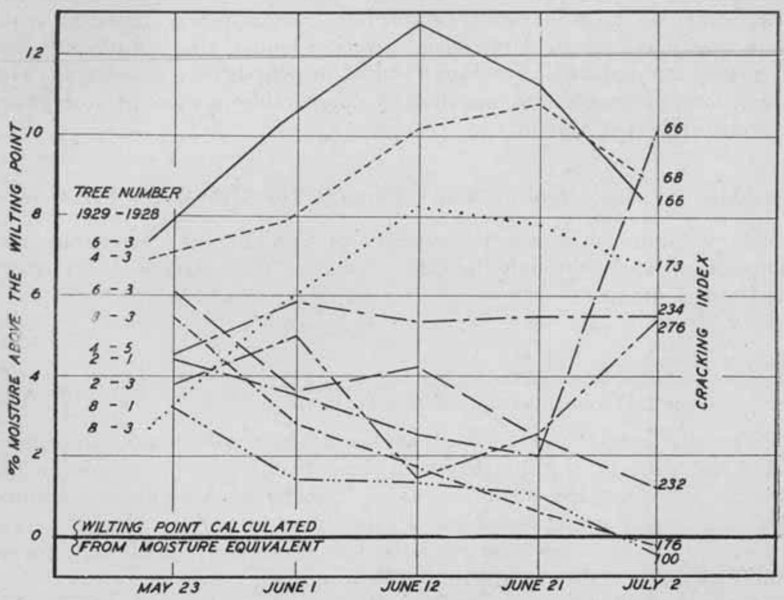

Fig. 1.—Percentage of moisture above the wilting point in the upper three feet of soil and cracking index of Lambert cherries, 1928 and 1929.

As shown by Fig. 1, which gives representative extremes in soil moisture in 1928 and 1929 together with cracking indices of Lamberts immersed in water, no consistent relationship has been demonstated between cracking by absorption of water through the skin and previous irrigation treatment. If a relationship exists it has been concealed by the effects of sugar content, turgor and certain other factors, differences in which largely account for the differences noted in the cracking indices. Excessive or deficient soil moisture might affect turgor sufficiently to have an effect on cracking, but under Lewiston conditions the influence of transpiration rate, size of crop, and rain on turgor, have been more important. Greater extremes in soil moisture than so far established, or the same extremes under higher humidity, might show a direct effect on cracking.

Several days of intermittent rains just prior to the harvest of Bings in 1930 afforded an opportunity to observe cracking under natural conditions. Percentage counts of cracked fruit from the total crops of individual trees showed no correlation between soil moisture and cracking under these conditions.

When the cut ends of branches of cherries were placed in water no cracking of the fruit resulted. This test was made a number of times, using fruit of various stages of maturity. On the supposition that the transpiration rate at Lewiston might be sufficiently high to counteract the effects of excessive water absorption, the test was repeated with branches placed under large glass covers. Under this condition of a saturated atmosphere no cracking resulted in periods of 5 to 8 days. The conditions, of course, were not directly comparable to those of absorption through the root system.

Cracking by Absorption of Water Through the Skin of the Fruit

Many factors influence the severity of cracking of cherries by absorption of water through the skin. Some of these have a direct effect and others indirect.

Direct Factors

1. Osmotic concentration of the fruit juice.

That the cracking of cherries may result from an osmotic absorption of water through the skin has been demonstrated in these experiments by the following observations: (a) A considerable weight and volume increase results upon immersion of the fruit in water; (b) The rate of absorption of water is in proportion to the osmotic concentration of the fruit juice as determined by the Balling scale hydrometer; (c) When cherries are immersed in sugar solutions the volume increase and amount of cracking vary inversely with the concentration of the solution.

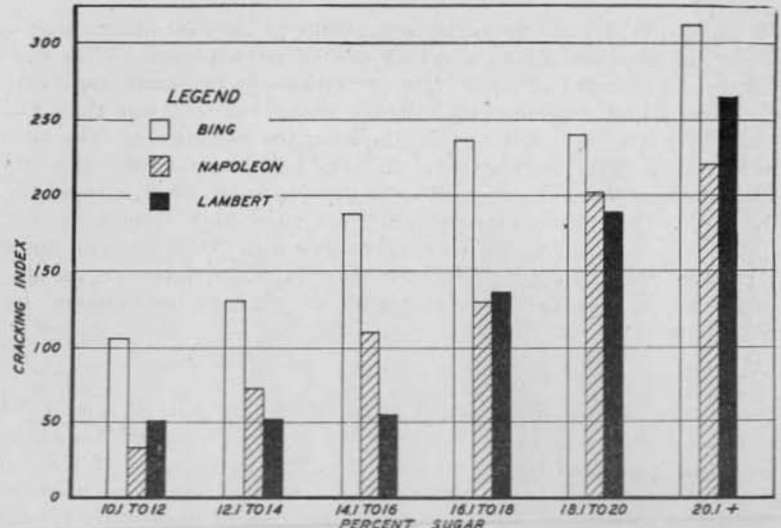

Fig. 2.—Cracking index of sweet cherries in relation to sugar content, 1929.

As cherries ripen there is a rapid increase in the osmotic concentration of the fruit juice, due largely to increases in sugar content. As shown by Fig. 2, this increase in osmotic concentration of the juice is accompanied by an increase in the cracking index, up to about the point of tree ripeness. If the fruit remains on the tree beyond this point there may be a decrease in cracking due to decreased turgor.

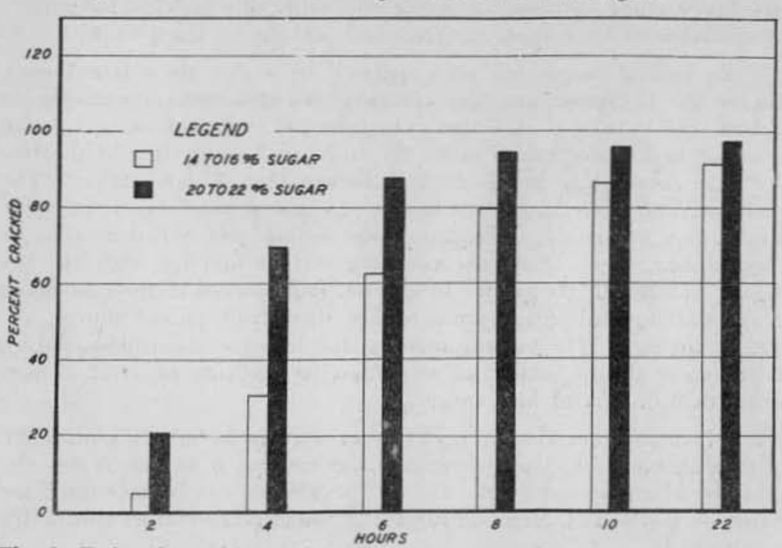

Fig. 3—Rate of cracking of Bing cherries immersed in water, 1929.

As shown by Fig. 3, the sugar content affects the *rate* of cracking as well as the total amount of cracking over a given period. With rains of short duration the effect on rate of cracking is the more important, fruit with a high cracking rate suffering much heavier losses than that with a low rate. In rains of long duration the cracking of fruit of a relatively low sugar content may reach so high a percentage that the effect of sugar content, or stage of maturity, is no longer discernible. Bings of 14-16 per cent sugar showed cracking in only 5 per cent after two hours in water, while in the same variety with 20-22 per cent sugar 21 per cent were cracked. After 22 hours in water, however, the difference was negligible, 92 per cent and 98 per cent, respectively, for the two lots.

2. Turgor.

When cherries lose their normal turgor there is a marked decrease in the amount of cracking that occurs early in the period of immersion. The cracking index of fruit subnormal in turgor, as indicated by reduced pressure resistance and in extreme cases by a wilted appearance, has been observed to be as much as 33 per cent below that of normal fruit from the same tree and comparable in other respects. In these experiments low turgor occurred most commonly as a result of a high transpiration rate under which the trees lost moisture more rapidly than it could be replaced, regardless of the amount present in the soil. This condition, characterized by a drooping of the foilage and sometimes by slight wilting of the fruit, is not uncommon under the high temperature and low humidity conditions of Lewiston. It is most prevalent among trees with very heavy crops. Subnormal turgor was artificially induced by removing branches of fruit from the trees and permitting them to wilt.

When normal turgor has been regained by water absorption during rain or during immersion, the cracking rate becomes comparable to that of fruit in normal condition. On June 24, 1929, following a 3-day period of high transpiration rates, the fruit of 5 Bing trees in the test plot gave consistently lower cracking indices than 3 days earlier. The total percentages of cracked fruit after 22 hours, however, was greater than 3 days previously, indicating a low turgor which had first to be re-established; after which the cracking was in keeping with the increased maturity of the fruit. In general, fruit picked in the cool hours of the morning will crack more readily than fruit picked during the heat of the day. The volume increase due to water absorption during immersion is always greater in proportion to cracking of fruit of low turgor than in fruit of high turgor.

The fact that cracking is most severe slightly before full maturity rather than some days later when the sugar content is higher, as was observed by Hartman and Bullis [4] and by the writers, can be accounted for in part on the basis of decreased turgor, although other factors apparently are involved.

It is conceivable on the basis of turgor differences that a short period of rain following a hot, drying day would be less damaging than a rain of equal duration following a period of cool, cloudy weather. There has been no opportunity to determine this under field conditions.

3 Temperature.

Due to the limited opportunity to observe cracking under natural conditions in the orchard the effects of temperature were observed only under laboratory conditions. With the fruit immersed, the temperature of the water proved an important factor, the rate of cracking increasing with increasing temperatures. Bings placed in ice water in a cold storage room at 35° to 40° F. increased 2.6 per cent in volume with 40 per cent cracking in 18 hours, while a duplicate lot in tap water at a room temperature of 70° to 80° increased 5.4 per cent with 100 per cent of cracking in the same period. Lamberts in water with a mean temperature of 67.3° gave a 10-hour cracking index of 205 while in a comparable lot at a mean temperature of 77.5° the cracking index was 300. (Table II.)

TABLE II.

Rate of Cracking of Lamberts in Relation to Water Temperature, 1930.

Lot No.		0-2 Hrs.	2-4 Hrs.	4-6 Hrs.	6-8 Hrs.	8-10 Hrs.	Total Per Cent in 10 Hrs.	Cracking Index
1	Temperature	66	68	68	67	67		
	Per Cent Cracked	10	20	26	12	14	82	205
2	Temperature	66	76	82	82	82		
	Per Cent Cracked	10	56	20	6	0	92	300

4. Skin Permeability.

The rates of permeability of the skin of several varieties were determined by the rates of volume increase of fruits of equal sugar content when immersed in water. The rate of volume increase of Bing was greater than that of Lambert or Napoleon. The Montmorency, in which only a very low percentage of cracking could be produced at any stage of maturity, exhibited a rate of permeability much lower than any of the sweet varieties.

Indirect Factors

There are certain influences, both in the orchard and inherent within the fruit itself, which affect cracking indirectly by affecting one or more of the direct factors discussed above. From a practical standpoint the indirect factors are the more important, because they are, in most instances, subject to some degree of control through the selection of favorable climates in which to engage in sweet cherry production, through the selection of resistant varieties for new plantings and through proper management methods in orchards already in bearing.

1. Local Climatic Conditions.

At Lewiston the harvest and preharvest periods during which the fruit is susceptible to injury by rain usually fall between June 20 and July 10. In a normal year Lewiston during this period is subject to one or more intervals of rainfall of sufficient duration to cause serious damage if the fruit is far enough advanced when the rain occurs. There is greater danger of rain early in this period than late. At Clarkston, Washington, across the Snake river from Lewiston, where the periods of rainfall are much the same but where, due to a lower elevation, the fruit may ripen a week earlier, the danger of rain at the most critical time is greater. In the vicinity of Moscow, Idaho, some 30 miles from Lewiston and where, due to a higher elevation, the fruit ripens from a week to 10 days later, the danger of rain at the most critical period is less and injury from cracking is not a serious problem.

Weather conditions determine the length of the period of susceptibility to cracking through prolonging or shortening the time required to reach picking maturity after having reached the earliest stage at which cracking will occur. After the fruit has reached this stage, cool, cloudy weather delays maturity to such an extent that the total period of exposure to the possible occurrence of rain before the fruit can be harvested is several days longer than if the weather had been warm and sunny and the fruit ripened in a shorter period. In Lambert, danger of extensive damage by rain begins when the sugar content is between 15 per cent and 16 per cent. In 1929, with high temperatures and a high percentage of sunshine, the interval between this stage and picking maturity was six days shorter than in 1930 when the weather for the same period was cool and cloudy.

Temperature, wind and humidity, through their influence on transpiration rate, have an important indirect effect on cracking through the influence of transpiration rate on turgor. Low turgor reduces the amount of cracking except in rains of long duration. A transpiration rate high enough to have this effect, however, is undesirable due to its interference with the normal development of the fruit.

2. Varietal Susceptibility.

In the present experiments Bing has proved much more susceptible to cracking than have Napoleon and Lambert. The greater sugar content of Bing at maturity accounts only in part for this, since when the three varieties are compared on a basis of the same sugar percentage the Bing still shows a much higher cracking index. (Fig. 2.) Disregarding sugar content, Bing on the whole is more liable to injury than Lambert because it matures earlier when there is greater likelihood of rain. Less difference has been noted between the cracking of Napoleon and Lambert at comparable stages of maturity, but Napoleon suffers the greater loss in average years due to earlier ripening.

The selection of resistant varieties after extensive variety testing seems at present to offer the greatest promise of a practical solution of the cracking problem. The comparatively small average loss suffered by Lambert at Lewiston has done much to offset the disadvantages of its late maturity. Bing on the other hand could be profitably replaced by a less susceptible variety of the same season even at some sacrifice in quality.

Varietal susceptibility to cracking differs in different regions. While at Lewiston, Bing suffers greater injury than Lambert, the reverse is true in Michigan [8]. Weather conditions at the time of ripening probably have much to do with this.

3. Cultural and Harvesting Practices.

Time of picking in relation to maturity is a matter of greatest importance in avoiding injury from cracking. Each day's delay after the cherries have reached a stage where they can be picked without too great sacrifice in tonnage or quality increases the hazard of damage by rain. In extreme cases a delay of one day has meant the difference between no loss and the loss of most of the crop. Further work is necessary to determine the earliest stage at which each variety can be profitably harvested, and to determine how much sacrifice in tonnage is justified as insurance against possible later loss by rain.

Average losses over a period of years can be reduced, tonnage increased, and quality improved, by systematically picking the trees in the order in which they ripen. As a rule trees with light crops mature their fruit first. (Table III.) These trees present the greatest risk of loss and should be picked first, while those trees that are least advanced not only present less risk of loss by cracking but hold greater promise of further tonnage increase and further improvement in quality.

TABLE III

Size of Crop in Relation to Maturity of Sweet Cherries, 1929.

Date	Variety	Tree No.	Yield in Pounds	cc. Volume of 50 Cherries	Per Cent Sugar	Cracking Index
June 15	Bing	2-2	142	205	11.0	18
		8-2	95	258	15.0	133
June 17	Napoleon	12-5	157	187	10.0	25
		8-4	10	215	15.0	186
June 28	Lambert	4-3	323	195	14.5	54
		2-3	113	240	16.0	204

The development of maximum capacity in packing houses in order that the crop may be harvested in the shortest period of time would greatly reduce the average losses from cracking by shortening the period of exposure to possible rains. The rate of harvesting and packing, once the fruit has reached maturity, should be limited only by the available labor supply and by the necessary restrictions of orderly marketing.

Experiments With Protective Sprays

Fisher and others,[7] in 1915-19, found that certain spray materials applied to cherries gave some protection against cracking. Rosin fish-oil soap, casein solution and a mixture of casein and tannic acid were used.

Rosin fish-oil soap reduced cracking in one instance from 12 per cent on unsprayed branches to 5 per cent on sprayed branches; and in another instance from 7 per cent on unsprayed block of trees to 2 per cent on a sprayed block. Britton[8] experimented some years later with an oil spray but discarded it on account of its objectionable effect on the appearance and flavor of the fruit. The authors have found no significant effect on cracking through the use of rosin fish-oil soap when sprayed branches were compared with adjacent untreated branches. Further tests of protective coatings are in progress.

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