THE EFFECTS OF ORGANIC FUNGICIDES, COPPER FUNGICIDES, AND TIME OF HARVEST ON SIZE, FIRMNESS AND CHEMICAL COMPOSITION OF FRUIT OF THE SOUR CHERRY

(*PRUNUS CERASUS* L.)

By

Oliver Clifton Taylor

A THESIS

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

DOCTOR OF PHILOSOPHY

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AN ABSTRACT

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An investigation was made during the period, 1949 through 1952, to determine the effects of time of harvest and the effects of organic and inorganic fungicides on the physical and chemical changes in the development of Montmorency cherry fruits (Prunus cerasus L.). Physical measurements included weight, transverse diameter, firmness of flesh and specific gravity of fruits. Chemical determinations included soluble solids, total solids and total sugar content.

In a detail study in 1951 and 1952 at the Michigan State College Horticulture Farm, East Lansing, the soluble solids content, total solids content, total sugar content and specific gravity of fruits increased significantly as the harvest season progressed. The most pronounced increases occurred during the first two weeks of the prolonged harvest season. Highly significant positive correlations were found between the increases in soluble solids and total solids and between increases in soluble solids and total sugars as the harvest season progressed.

The total solids and total sugar content of cherry fruits decreased immediately following a rain, which occurred at approximately mid-harvest season. The average weight of fruits increased following the rain at mid-harvest season. The average transverse diameter of the cherries changed very little throughout the harvest period. The flesh of the fruit gradually became less firm during the first two weeks of harvest, after which time the firmness increased until the fruits began to shrivel on the trees.

It was found also in this study that fruits from trees sprayed with fixed copper were lighter in weight and higher in soluble solids content than fruits from trees sprayed with ferbam. Fruits from trees sprayed with lead arsenate tended to be lighter in weight and higher in soluble solids than fruits from trees sprayed with parathion. There was evidence that the dry weather in 1951 and 1952 had a greater influence than spray treatments on the weight of the cherry fruits.

In a second portion of this investigation made from 1949 through 1952 in five commercial orchards, trees of moderate vigor sprayed with fixed copper produced fruits lighter in weight than trees sprayed with ferbam or nabam. However, trees of very high vigor, sprayed with fixed copper, produced as heavy or heavier fruits than trees of less vigor sprayed with ferbam or nabam. This was especially true during seasons of high rainfall. There was generally no difference in average weight of fruits between the ferbam spray treatments and the nabam spray treatments.

Even though trees sprayed with fixed copper produced fruits with lower soluble solids content than those sprayed with ferbam or with nabam, the differences in soluble solids content of fruits from different orchards and in different seasons were as great or greater than the differences resulting from the use of spray materials.

Fixed copper sprays had a greater unfavorable influence on number of fruits per 454 grams and a more favorable influence on soluble solids content of fruits when used on trees of low vigor than did sprays of ferbam or nabam.

Changing soil management from sod to clean cultivation resulted in a significant decrease in soluble solids content and increase in weight of harvested fruit which was related to increased vigor of the trees.

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INTRODUCTION

It has been the belief of many food processors that the use of certain of the newly introduced organic fungicides on sour cherries (*Prunus cerasus* L.) for control of leaf spot (*Coccomyces hiemalis* H.) has reduced the quality of the processed product and has caused the processed cherries to be low in drained weight. This reasoning has been based on reports (14, 20, 21, 22, 23, 32) that the use of organic fungicides reduced the soluble solids content of the harvested fruit. Also a report by Lewis and Groves (23) included the statement that the increase in the solids content of harvested fruit from 14 to 18 percent may increase the number of No. 10 cans obtained in processing 1,000,000 pounds of raw cherries by 11,500 cans.

It is common knowledge that cherries received by processing plants come from orchards of varying ages and vigor. Kenworthy and Mitchell (19) found that vigor of trees had a pronounced effect on the soluble solids content of the harvested fruit. There was some indication (21) also that sour cherries harvested at the time fruits may be picked without pulling the pits, are lower in soluble solids content than if allowed to hang until the end of the harvesting period. In Michigan the duration of harvest is approximately three weeks.

The available published information on sour cherries still leaves many questions yet unanswered. Thus the following study was undertaken to determine: (1) The effects of certain fungicidal chemicals on the soluble solids content and size of sour cherry fruits when used on trees varying in vigor and when used on trees growing under different soil conditions in more than one cherry producing area of Michigan; (2) The relation of time of harvest on the soluble solids content and size of cherry fruits; (3) Whether or not there is a direct correlation between the increase in soluble solids content, total solids content and sugar content of cherry fruits as the harvesting season progressed.

REVIEW OF LITERATURE

For many years the copper fungicides, Bordeaux and fixed copper, were the principal chemicals used to control leaf spot (*Coccomyces hiemalis* H.) on sour cherry trees (*Prunus cerasus* L.) (17). However, after the introduction of ferbam (ferric dimethyl dithiocarbamate) in 1939 other new chemicals were found which had acceptable fungicidal properties with less unfavorable physiological effects on the tree. Some of these materials have received widespread use in the cherry growing industry. Numerous references are available on the physiological effects of Bordeaux and fixed copper on sour cherry trees when these chemicals are used to control leaf spot. The information on the physiological effects of certain organic fungicides, when used in place of the copper materials, is less numerous.

The first report that physiological changes of sour cherry fruits are related to spray chemicals was made in 1923 by Dutton and Wells (8). They reported a noticeable reduction in size of fruits from Montmorency trees and from English Morello trees sprayed with Bordeaux. In fact, the cherries were so much smaller than the fruits from trees of other spray treatments that the pickers objected to picking them. Further work by Dutton and Wells (8) showed the comparative sizes of Montmorency cherry fruits from different spray plots as follows: unsprayed check 100, dusted with sulfur 95, sprayed with lime-sulfur 85 and sprayed with Bordeaux 63. The fruit from the unsprayed treatment was given the arbitrary figure of 100 for purposes of comparison. There was no defoliation from leaf spot of any trees before harvest.

According to Blodgett and Magie (2) and Keitt and Clayton (18) Bordeaux was a more efficient spray material for leaf spot control than lime-sulfur. Blodgett and Magie (2) found very little differences in size of fruit from plots sprayed continuously with Bordeaux and with lime-sulfur. This does not agree with other findings (6, 14, 18). Mills, Lewis and Adams (30) reported a significant negative correlation between spray injury and size of fruit and positive correlation between size of fruit and total yield.

Cation and Rasmussen (6) found that trees thoroughly and timely sprayed with lime-sulfur in an orchard where primary leaf-spot infection was slight produced greater yields of larger sized fruits than trees sprayed with high-calcium-lime Bordeaux. Trees sprayed with fixed copper were comparable with those sprayed with lime-sulfur in yields and in size of fruit. Bordeaux caused dwarfing of fruit in years of low rainfall. In earlier studies Rasmussen (36) stated that the size of cherry fruits appeared to be inversely proportional to the concentration of the Bordeaux mixture. However, Miller (28) found no relation between size, color, and sugar content of sour cherry fruit and the concentration of the copper in the spray.

Langer and Fisher (20) and Fisher (12) working with ferbam and with fixed copper found in one orchard that the sour cherries sprayed with fixed copper were no smaller than those receiving ferbam. In the second orchard, however, the ferbam treatment increased the size of the fruit. Even when a heavy spring application of ammonium nitrate was used, the fruits of the trees receiving the ferbam treatment were larger than those from trees of the fixed copper treatment. In this study, the size of cherries was measured by volume and weight.

Work in West Virginia and Pennsylvania as reported by Lewis and Groves (21) and Lewis (24) indicated that the use of ferbam resulted in cherries of smaller size than did treatments of either fixed copper or nabam plus monohydrate zinc sulfate. The suggested reason for this was that ferbam failed to control leaf spot. Moore and Keitt in Wisconsin (32) found both ferbam and nabam plus monohydrate zinc sulfate as favorable as fixed copper for the control of leaf spot on Montmorency cherries and at the same time the use of these two organic chemicals increased the size of fruit over those from the trees sprayed with fixed copper.

Groves, Miller and Taylor (14) in 1940 and 1941 found that Bordeaux significantly reduced the size of fruit in their investigations in Virginia, Pennsylvania, and West

Virginia when compared with cherries from trees sprayed with sulfur compounds, fixed copper and Crag 341 (2-heptadecylglyoxalidine). In 1940 Bordeaux significantly reduced the size of fruit as compared with fixed copper and fixed copper reduced the size of fruit as compared to the unsprayed check. In 1941 Bordeaux significantly reduced the size of fruit below that of the check, the fixed copper treatments and the organic treatments. The differences between the fruit from the fixed copper and organic spray treatments were minor.

The reduction in size of cherry fruits from trees sprayed with alkaline sprays which contain copper such as Bordeaux has been acknowledged by many workers (8, 10, 11, 31, 36, 42). The first reports of reductions in size of fruits owing to alkaline sprays were by Fisher (11) in work on sweet cherries, and by Dutton and Wells (8) in their studies of sour cherries. Fisher (11) stated that in each case reduction in size of the ripe cherries (sweet) was in proportion to the amount of alkaline material in the spray. And, a wash of lime and lamp-black resulted in no greater dwarfing than occurred from the application of lime alone, indicating that the reduction in illumination was not the cause of smaller fruit. Dutton and Wells (8) found also that a hydrated lime spray reduced the size of sour cherries. Fisher (11) stated further "The results indicated that dwarfing by alkaline sprays is brought about through excessive transpiration or water loss occasioned by the destruction of the wax bloom." Verner (42) concluded from his observations that calcium was the effective constituent of Bordeaux mixture in its action on cracking of sweet cherries and that probably only the calcium in solution was effective. He suggested that the presence of calcium in the spray modified the degree of permeability of the sweet cherry fruit skin and the plasticity of the peripheral tissues, reducing the tendency for cracking from excessive absorption of water.

The possibility of internal effects of lime on physical changes of the fruit of Bing cherry trees was investigated by Bullock (4). The calcium salts were inserted into the trunk of the tree beyond the cambium. He found a tendency toward a reduction in fruit size when the cation, calcium, was injected as a solid in a gelatin capsule; but, when the calcium was injected in liquid form, there was no effect on fruit size.

The effect of calcium on the physiological processes of sour cherry fruits was investigated also by comparing high-calcium and high-magnesium Bordeaux mixtures. Rasmussen (36), Dutton and Farish (10), and Moore (31) have shown that injury was less when the high-magnesium Bordeaux was used. Rasmussen (36) suggested that the copper in the high-magnesium lime Bordeaux is apparently held in a less soluble form and thus it was less toxic to foliage and not as readily absorbed as the copper in the high-calcium lime Bordeaux. The toxicity of lime may be associated with its capacity to make copper less soluble.

Copper injury has been reported on crops other than sour cherries. Suit (39) observed that Concord grapes were injured by sprays containing neutral copper compounds which had a copper content equal to that of 4-4-100 Bordeaux mixture. The injury was characterized by reduced vine growth, by smaller yellowish-green leaves and by reduced yield. He found that the yield obtained the year following the spray applications was reduced even more, although a copper fungicide was not used. The second year following the injury by copper compounds, the yield from the previously injured vines had increased so that it was equal to that of vines which had not been injured by copper. This indicated that the spray material caused the injury. Observations of the cane indicated that fixed coppers at a copper concentration equal to 4-4-100 Bordeaux caused severe reduction in growth but the addition of lime appeared to alleviate the injury. Suit (38) reported further that in other experiments, plants sprayed with Bordeaux were stunted, leaves were deformed and yields were reduced. This did not occur when Bordeaux substitutes were used.

Lewis and Groves (23) and Taylor (40) found that during many seasons cherry trees sprayed with copper base fungicides were defoliated almost as extensively as the trees heavily infected with leaf spot. They also described a common type of Bordeaux injury to be yellowing and dropping of leaves, similar to drought injury and a leaf spot almost identical with that caused by *Coccomyces hiemalis* H. However, the fungus leaf spot was identified readily by the presence of spore masses on the lower surface of the spot.

Dutton and Wells (9) have reported that drought injury of sour cherry trees sprayed with copper compounds was increased during prolonged, dry, hot periods which they feel indicated that copper may accentuate the rate of transpiration of the leaves. This was verified by Moore (31) and Rasmussen (37). In contrast to this, Daines (7) observed that during wet periods certain copper fungicides gave considerable injury especially where lime was omitted. Lewis and Groves (23) reported increased injury to cherry leaves during either excessively wet or dry periods.

Numerous workers have acknowledged generally that fruits from trees sprayed with Bordeaux or other forms of copper contain a higher solids concentration than fruits sprayed with fulfur compounds and organic materials (1, 2, 3, 6, 14, 19, 20, 21, 23, 24, 30, 36, 44), and that an increase in solids concentration was usually related to a decrease in size of fruit. However, this relationship of size of fruit to solids content was not always true. This was shown by data from reports of Cation and Rasmussen (6), Lewis and Groves (22, 23) and Groves, Miller and Taylor (14).

Langer and Fisher (20) and Fisher (12) found that fruits from trees sprayed with ferbam contained a higher percentage of soluble solids than fruits sprayed with fixed copper. However, results with these same materials were less conclusive in the work by Groves, Miller, and Taylor (14).

Studies reported by Lewis and Groves (21) and Langer and Fisher (20) indicated that dwarfing of fruit concentrated the soluble solids in less juice thus increasing the percentage of soluble solids in the small fruits. However, Lewis and Groves (23) stated that the low soluble solids content of fruits from trees sprayed with Crag 341 appeared to be too low to be accounted for by the increased size of the fruit.

It has been suggested by Rasmussen (37) that the increased solids and sugar content of cherries from trees sprayed with the higher concentrations of Bordeaux may be due to the increased rate of transpiration of the leaves thus reducing the water content of the fruit and increasing the concentration of solids and sugar in the fruit. The decrease in water content of cherry fruits through transpiration was pointed out also by McMunn (26). He stated that several investigators have shown that cherry fruits may have marked diurnal changes in volume, even though there is ample moisture in the soil. Such diurnal fluctuations are brought about, he explained, by the transpiring leaves creating a deficit of water which cannot be supplied by the root system even though moisture is available. He also reported that a study of weather records for ten years indicated that low humidity was probably the most influential factor in creating deficits of water. Rasmussen (37) adds that the low solids and sugar content of fruits from cherry trees sprayed with lime-sulfur may be attributed to a reduced photosynthetic activity of leaves. Murphy (33) found that lime-sulfur, 6-8-100 Bordeaux, and Coposil (fixed copper) reduced the amount of photosynthate in the cherry leaves, indicating a reduction in the rate of photosynthesis. However, Laustalot (25) working with mature pecan leaves found no appreciable effects on either photosynthesis or transpiration with as many as three sprays of 8-8-100 Bordeaux or lead arsenate even though the leaves receiving these sprays were so well covered that the green color was hardly visible.

Groves, Miller, and Taylor (14), working with organic spray chemicals, suggested the possibility of arsenical materials increasing the soluble solids content of fruits. Their results showed an increase in soluble solids where lead arsenate was included in the spray schedule. Relating to this, Miller, Bassett, and Yothers (29), working with citrus, found that arsenical compounds hastened the maturity of oranges, although the effect was more one of altering the ratio between solids and acid content rather than an absolute increase in sugar content. However, Juritz (15) found that lead arsenate sprays reduced the sucrose content in orange juice below that of unsprayed fruit, from 4.14 percent in the unsprayed fruit to 3.65 percent in lightly sprayed fruit, and to 1.12 percent in heavily sprayed fruit.

The work of Kenworthy and Mitchell (19) indicated that soil management practices such as sods, cultivation, mulches and fertilizers as well as climate and seasons may have a significant effect upon the soluble solids content of Montmorency cherries. They report that a significant negative correlation of leaf nitrogen with the soluble solids content of the fruit was found in 1949, suggesting a possible correlation of tree vigor with soluble solids as indicated by Langer and Fisher (20).

It has been suggested by Johnsen, Kenworthy, and Mitchell (16) that the relation of soluble solids to leaf nitrogen and tree vigor might be associated with internal leaf structure. According to Meyer and Anderson (27), if the supply of nitrogen compounds to any growing meristem is abundant relative to the supply of carbohydrates, a large quantity of protoplasm will be synthesized relative to the amount of cell wall material formed. Thus the resulting cells will usually be large, thin-walled, and well stocked with protoplasm. Pickett and Birkeland (35) have shown that the extent of the internally exposed cell walls in the apple leaves was closely associated with their photosynthetic activity as measured by the increase in dry weight of the tree per unit of leaf area.

Work by Johnsen, Kenworthy, and Mitchell (16) showed that spray treatments had a very marked effect upon the depths of the palisade mesophyll of cherry leaves. Leaves sprayed with fixed copper had a thinner palisade layer than leaves sprayed with ferbam. Leaves sprayed with liquid lime-sulfur had a thicker palisade layer than the leaves receiving either fixed copper or ferbam. They found also that including parathion with the fungicide resulted in greater palisade depth than the use of either benzene hexachloride or lead arsenate. As a result of this study they felt that the sprays which result in the greatest depth of palisade mesophyll of the leaves should be favorable also to the best vegetative growth and the highest yields.

Caldwell (5) reported on some of the physical and chemical changes normally occurring in cherry fruits from the time the fruits were six to eight millimeters in length and four to six millimeters in diameter until fully ripe. He found, that for the Montmorency variety, the most rapid increase in acidity occurred between June 5 and 18 and during this period the solids in the fruit increased only 6.5 percent while the water increased 248 percent. In the very young fruits there was an initial stage of rather high moisture content, followed by a very abrupt decline. He reports "As the fruit whitens, water content again rises rapidly to a maximum, then declines as the fruit becomes fully ripe." In all the varieties of cherries there was a rapid hydration of the tissues accompanying the period of most rapid increase in acid concentration.

Tukey (41) found three distinct stages in the development of the sour cherry fruit; namely, a period of rapid increase in size following fertilization (Stage I), a period of delayed increase in size during mid-season (Stage II), and a second period of rapid increase in size to fruit ripening (Stage III). In Montmorency cherries the duration of each stage was as follows: 22 days for Stage I, 12 days for Stage II, 23 days for Stage III, making a total of 57 days from full bloom to fruit ripening. The volume as measured by water displacement showed strikingly the rapid fruit development during "Stage I" and "Stage III". During "Stage I" Montmorency fruits increased in volume nearly 30,000 percent and during the 25 days preceeding ripening increased 296 percent. The mean diameter of fruits, representing the length diameter, suture diameter, and check diameter was proportional throughout fruit development to the "volume diameter", computed by determining the diameter of a sphere having a volume equal to the volume of water actually displaced by the fruit. He found that the cheek diameter measurement reflected the rate of growth in volume of the cherry fruit as the season progressed.

Little to no studies have been made on the changes that take place in the cherry fruits during the prolonged period of harvest. The only work of this nature that has come to the attention of the author was that of Lewis and Groves (21) on the changes in soluble solids content of the fruit. They reported an increase in soluble solids content of the fruit from June 23 to July 13, a period during which there was no appreciable rainfall. However, from July 13 to 21, following a light rain, the soluble solids content remained fairly stable but decreased slightly in some instances. The differences between treatments varied during the entire period (June 23 to July 23), with the greatest differences occurring between July 13 and 23 when the cherries were fully ripe and had started to shrivel badly on the Bordeaux sprayed trees. The findings in this study did not agree with preliminary data secured in 1943, as the solids content of the cherries of different spray treatments did not reach a similar peak on different dates.

MATERIALS AND METHODS

The fruits for this investigation were obtained from a seven-year-old Montmorency planting of 64 trees growing on the Horticultural Farm, Michigan State College, East Lansing and from five commercial Montmorency cherry orchards located in the cherry growing areas of Michigan. Four of the commercial orchards consisted of large trees in good bearing vigor while the fifth orchard was made up of bearing eight- to ten-year-old trees which had been producing 50 to 75 pounds of cherries for the past four years.

Soil Management

The five commercial orchards varied in soil management as follows:

Orchard A (Morrison orchard, Acme) - Sod plus straw mulch in 1949; trashy cultivation in 1950 and 1951; and clean cultivation plus cover crop sown in August, 1952. All trees received spring applications of nitrogen and barnyard manure was broadcast in the orchard annually. The trees were in good bearing vigor.

Orchard B (Morrison orchard, Acme) - Clean cultivation plus a cover crop sown in August. All trees received spring applications of nitrogen and barnyard manure was broadcast in the orchard annually. The trees were in good bearing vigor.

Orchard C (McLachlan orchard, Kewadin) - Trashy cultivation. The grass and weed cover was checked periodically by cultivation but was not incorporated into the soil. All trees received spring applications of nitrogen. The trees were in good bearing vigor in 1949 and 1950. However the occurrence of winter injury in 1950 and 1951 reduced the vigor of the trees.

Orchard D (Stokeley orchard, Hart) - Clean cultivation plus a cover crop sown in August. All trees received spring applications of nitrogen. These trees were approximately six years old at the beginning of this study and were in good vigorous condition.

Orchard E (Fox and Sons, Shelby) - Trashy cultivation. The grass and weed cover was checked periodically by light cultivation. All trees received heavy spring applications of nitrogen annually. In 1949 these trees were low in vigor, however, through the continuance of heavy fertilizer applications, the vigor was increased greatly so that in 1951 and 1952 the trees were in a high state of vigor.

The cherry orchard on the Michigan State College Horticulture Farm at East Lansing was maintained in sod plus straw mulch. Fertilizer was not used in this block the two years this study was in progress in hopes that the performance of the trees would reflect the physiological effect of the spray chemicals which were used for pest control. The trees, generally, were low in vigor because of the omission of nitrogen fertilizer and the competing sod.

Design of Experimental Spray Blocks

Three spray blocks, each containing three rows of trees, were used in each commercial orchard. Two of the blocks received organic fungicides and the third block (control) was sprayed with fixed copper. Five single tree replicates were selected for uniformity of size and vigor from the center row of trees of each plot. Replication of location was accomplished by duplicating the treatments in five orchards in various locations in the cherry producing areas of the State.

For the spray studies on cherries in the Michigan State College Orchard on the Horticulture Farm, East Lansing, groups of two trees were selected randomly, each treatment containing four groups of two trees making eight trees per treatment.

Spray Application

The five commercial orchards received five pre-harvest spray applications and one post-harvest spray application during each of the four years. The sprays were applied with automatic equipment by the grower at the time he sprayed the remaining portions of his orchard. The pre-harvest spray treatments and the amounts used per 100 gallons in each of the five commercial orchards were as follows:

a. Ferbam (ferric dimethyl dithiocarbamate) $1\frac{1}{2}$ pounds

b. Fixed copper - 0.75 of a pound of metallic copper plus 3 pounds of hydrated lime

c. Nabam (disodium ethylene bisdithiocarbamate) one quart plus $\frac{1}{2}$ pound of monohydrate zinc sulfate

d. Lead arsenate - 2 pounds in all pre-harvest sprays

In three of the four years (1950 through 1952) Orchards A and B received added applications of parathion at the time of the first cover to control case-bearer (Coleophora malivorella Riley). Parathion was used in Orchard C in 1952 in place of lead arsenate at petal fall and first cover to control the Mineola moth (Mineola scituilla Hulst).

A post-harvest application of fixed copper, using 0.75 of a pound of metallic copper per 100 gallons, was standard practice each year in each of the five commercial orchards.

Five pre-harvest sprays and one post-harvest spray each season was used also in the Michigan State College Horticulture Farm Orchard. The pre-harvest spray treatments and the amounts used per 100 gallons were as follows:

1. Fixed copper - 0.75 of a pound of metallic copper plus 3 pounds of hydrated lime and 2 pounds of lead arsenate
2. Fixed copper - 0.75 of a pound of metallic copper

plus 3 pounds of hydrated lime and 1 pound of 15 percent wettable parathion

3. Fermate - 1.5 pounds plus 1 pound of parathion
4. Ferbam (ferric dimethyl dithiocarbamate) - 1.5 pounds plus 2 pounds of lead arsenate

The post-harvest spray on all plots consisted of 0.75 of a pound of metallic copper plus three pounds of hydrated lime.

Sampling Procedure

Samples of fruit were collected from the five commercial orchards just a few hours before the growers harvested the cherries in that particular orchard. Approximately 700 grams of cherries from clusters of three or more fruits were picked at random from one side of each of the large trees in Orchards A, B, C and E and from the entire tree in Orchard D. The samples were taken from the same portion of the tree each year.

In the spray plots at Michigan State College Horticultural Farm, East Lansing, samples of fruits were collected approximately 10 days after the beginning of commercial harvest. Each sample included approximately 700 grams of cherries which were taken at random from the entire tree. Only cherries from clusters of three or more fruits were harvested at each time of sampling.

For detailed studies to determine the effects of time of harvest on chemical composition and size of cherry fruits, four trees of uniform size and crop load were selected in the spray plots at the Michigan State College Horticultural Farm. Fruits were harvested twice weekly, beginning as soon as the fruits could be picked without the pit being removed from the fruit and continued until the fruits started to shrivel on the trees. Here again samplings were made from the entire tree and each sample included approximately 700 grams of cherries taken from clusters of three or more fruits.

Procedure for Gross Measurement and Chemical Determinations

Gross measurements and chemical determinations were made on the harvested fruit as follows:

a. Weight of fruits - the number of fruits required to make 454 grams (one pound).

b. Size of fruits - the average transverse diameter in millimeters of 20 fruits, an imaginary line perpendicular to the plane formed by the dorsal and ventral sutures, Tukey (41).

c. Soluble solids - determined from the juice of 20 fruits using an Abbe' refractometer.

d. Total solids - average of three samples of five fruits each, including the pits and flesh, using the procedure as described by A. O. A. C. (34). The pits were cracked to reduce drying time.

e. Firmness of flesh - percent compression of the flesh of 20 cherries using the method described by Whittenberger and Marshall (43).

f. Total sugars - determined by Munson-Walker General Method (25) as described by A. O. A. C. (34).

g. Specific gravity - calculated from the volume of water displaced by the fruit.

RESULTS

Effect of Time of Harvest on Physical and Chemical Changes of Sour Cherry Fruits

The progressive physical and chemical changes taking place in sour cherry fruits harvested from the Michigan State College Horticulture Farm orchard, East Lansing, during the commercial harvesting period of 1951 and 1952 are given in Tables 1 through 12.

Number of fruits per 454 grams

In 1952 the average number of fruits per 454 grams decreased significantly during the first three days of harvest, from 162 fruits per 454 grams on June 30 to 152 fruits on July 3, then remained fairly uniform through July 14 (Table 1). However, on July 17, the number of fruits per 454 grams had decreased significantly, from 156 fruits on July 14 to 146 fruits on July 17 and continued to a low of 139 fruits on July 21, after which time the number had increased again to 151 fruits on July 24 and continued to be the same on July 28. This pronounced decrease in number of fruits per 454 grams may be explained in part by a continued period of wet weather from July 14 through July 23 giving a total of 1.93 inches of rain for this 10-day span.

TABLE 1

THE EFFECT OF TIME OF HARVEST ON THE NUMBER OF SOUR CHERRY FRUITS PER 454 GRAMS

(East Lansing, 1952)

Tree	Dates of harvest								
	June	July							
	30	3	7	10	14	17	21	24	28
1	155	148	151	146	152	137	135	142	142
2	164	156	155	153	163	150	143	153	155
3	160	148	151	142	142	141	128	140	140
4	170	158	161	161	167	156	149	168	165
Average	162	152	155	151	156	146	139	151	151

L.S.D. 5% - 6; 1% - 10

Note: 1.93 inches of rain was received between July 14 and 23.

<u>Size of fruits</u>

Linear measurements of the greatest transverse diameter of the cherry fruits, called cheek diameter by Tukey (41), reflected no apparent increase in the average size of the fruit in 1951 or in 1952 after the first three days of commercial harvest, from June 30 to July 3 (Table 2).

Tukey (41), comparing various methods of determining increase in size of fruit, found that the cheek diameter of the Montmorency cherry fruits increased but slightly, only 0.1 of a millimeter, the first seven days of commercial harvest. He found an increase of only 0.2 of a millimeter for the volume diameter computed from the actual volume of water displaced by the cherry fruits, and an increase of only 0.1 of a millimeter for the mean diameter which was a computed measurement, an average of the suture diameter, cheek diameter, and the length of the cherry fruit. Accordingly, as the results of these different methods of measuring increase in size of Montmorency cherry fruits varied only slightly, it seems safe to assume that the cheek (transverse diameter) may reflect any appreciable change in size of fruit.

The average increase in transverse diameter of fruits was 0.4 of a millimeter for the first five days of harvest in 1951, from 18.7 to 19.1 millimeters and 0.6 of a millimeter during the first three days of harvest in 1952, from 18.2 to 18.8 millimeters (Table 2). Although the transverse diameter fluctuated slightly during the entire harvest-

TABLE 2

EFFECT OF TIME OF HARVEST ON THE TRANSVERSE DIAMETER (IN MILLIMETERS) OF SOUR CHERRY FRUITS

(East Lansing)

Season	Tree	Dates of harvest						
		July					August	
		14	19	23	26	30	2	6
1951	1	18.5	18.9	18.6	19.2	18.5	19.0	18.5
	2	17.8	18.3	19.0	17.7	18.2	18.6	18.6
	3	19.5	20.0	19.6	19.4	19.1	19.5	19.0
	4	18.8	19.2	19.2	18.9	18.8	19.1	18.6
Average		18.7	19.1	19.1	18.8	18.7	19.1	18.7
L.S.D. 5% - 0.5								

		June	July					
		30	3	7	10	14	17	21
1952	1	18.3	19.0	19.0	18.9	18.4	19.5	19.1
	2	18.3	18.6	18.9	19.2	19.0	18.6	18.9
	3	18.3	19.4	18.9	19.4	19.6	19.3	19.7
	4	18.0	18.1	18.6	18.5	18.2	18.7	19.0
Average		18.2	18.8	18.9	19.0	18.8	19.0	19.2
L.S.D. 5% - 0.5; 1% - 0.7								

ing period in 1951, none of the changes, increases or decreases, were significantly different from the average transverse diameter of 18.7 millimeters obtained at the first time of sampling, July 14. In 1952 there was a significant change in average transverse diameter on the second date of sampling after which time there were only slight fluctuations in size until July 21. On this date the fruits had increased 0.4 of a millimeter, from 18.8 millimeters on July 14 to 19.2 millimeters on July 21. Although this increase was not significant it may have been influenced by a rainy period which started on July 14 and continued through July 23.

The fluctuations of the average transverse diameter of cherry fruit in 1952, just described, were reflected also by the calculated "mean" diameter of fruits selected randomly from the same picked sample (Table 3). The average "mean" diameter of the fruits was consistently slightly less than the average transverse diameter, throughout the harvest season.

The trends in average transverse diameter of 20 fruits from each sample were similar to those shown by the average number of fruits per 454 grams. However, the average transverse diameter did not show the increase in fruit size on July 17 and 21, indicated by the significant decrease in number of fruits per 454 grams on those dates. This could not be explained, unless the increase in transverse diameter per fruit was too small to be detected by the means used to

TABLE 3

RELATION OF TRANSVERSE DIAMETER AND MEAN DIAMETER (IN MILLIMETERS) OF SOUR CHERRY FRUITS TO DIFFERENT DATES OF HARVEST

(East Lansing)

	Dates of harvest						
	June	July					
	30	3	7	10	14	17	21
Average transverse diameter	18.2	18.8	18.9	19.0	18.8	19.0	19.2
Average mean diameter	17.8	18.2	18.1	18.3	18.2	18.6	18.9

make this measurement, or unless the changes in weight were the result of changes in density.

Firmness of flesh

A comparison of firmness of flesh as related to date of sampling is given in Table 4. As shown by these data, fruit collected on July 26, 1951, were significantly less firm than fruits of July 14, and July 23, 1951. Similarly, fruits picked on July 10, 1952, were significantly less firm (an increase in percent compression) than fruits of June 30 and July 3, 1952. The fruits became more firm after July 26, 1951, and after July 14, 1952. The rapid increase in firmness after July 26, 1951, was probably a result of the rapid loss of water by the fruit.

The firmness of flesh of cherry fruits appeared to have very little relation to average diameter of fruit (Table 2). This was not entirely in agreement with the report of Whittenberger and Marshall (43), who found the larger cherries slightly firmer than the smaller ones with the method of evaluation of firmness used in this study. A possible explanation for that difference is that their findings were based on measurements of cherries selected for uniformity of diameter and maturity while the findings reported herein are measurements of cherries selected at random from tree-run fruits.

Soluble solids content

The average soluble solids content of the cherry fruits

TABLE 4

THE INFLUENCE OF TIME OF HARVEST ON FIRMNESS OF FLESH (PERCENT COMPRESSION IN MILLIMETERS) OF SOUR CHERRY FRUITS

(East Lansing)

Season	Tree	July					August	
		14	19	23	26	30	2	6
1951	1	23.8	24.2	23.5	26.4	25.5	22.0	23.3
	2	26.5	25.7	24.0	25.9	25.7	20.6	17.9
	3	22.3	22.8	23.2	25.0	24.8	23.5	23.2
	4	21.5	23.8	23.3	25.8	24.8	22.6	21.7
Average		23.5	24.1	23.5	25.8	25.2	22.2	21.5

L.S.D. 5% - 0.9

Season	Tree	June	July						
		30	3	7	10	14	17	21	24
1952	1	15.8	17.7	20.5	18.6	21.0	19.3	17.3	15.9
	2	15.8	18.3	21.7	20.4	20.0	21.2	17.0	16.7
	3	14.8	17.0	20.2	18.9	19.8	19.8	19.6	19.1
	4	15.9	18.5	21.5	20.6	20.8	20.5	19.7	19.9
Average		15.6	17.9	21.0	19.6	20.4	20.2	18.4	17.9

L.S.D. 5% - 1.7; 1% - 2.5

increased significantly as the harvest season progressed in 1951 (Table 5). However, in 1952 the soluble solids content increased significantly only during the first two weeks of harvest after which time there was no significant change (Table 5 and Figure I). Comparing the soluble solids content of the fruits of individual trees at the beginning of harvest in 1951 and 1952, the variation was considerable, from 15.1 to 17.5 percent in 1951 and from 12.9 to 14.5 percent in 1952. A similar variation between trees was found in every commercial orchard. In both years, 1951 and 1952, trees with fruits high in soluble solids at the beginning of harvest continued to produce fruits high in soluble solids at the end of the harvest period, while those trees producing fruits low in soluble solids at the beginning of harvest continued to produce fruit low in soluble solids by comparison when the experiment ended. These data indicate that time of picking during the harvesting period will influence the soluble solids content of the fruit.

Total solids content

The increase in the average total solids of the harvested fruit followed a trend very similar to that described for soluble solids during both 1951 and 1952 harvest seasons (Table 6). Throughout the entire periods of harvest in 1951 and 1952, there continued to be only a slight variation between the total solids content of the fruits from trees 1, 2, and 4. But, the total solids content of the fruits from tree 3 was always the lowest on each date of sampling.

TABLE 5

EFFECT OF TIME OF HARVEST ON SOLUBLE SOLIDS CONTENT (PERCENT OF FRESH WEIGHT) OF SOUR CHERRIES

(East Lansing)

Season	Tree	Dates of harvest						
		July					August	
		14	19	23	26	30	2	6
1951	1	16.2	17.9	19.1	19.6	20.7	20.0	20.0
	2	17.5	19.9	20.4	21.1	19.9	19.7	21.1
	3	15.1	15.8	16.0	16.1	16.9	17.5	17.9
	4	15.4	17.0	17.6	18.8	19.4	20.9	20.8
Average		16.0	17.6	18.3	18.9	19.2	19.5	19.9
L.S.D. 5% - 1.5								

Season	Tree	June	July							
		30	3	7	10	14	17	21	24	28
1952	1	13.1	14.6	16.0	16.9	19.0	18.7	19.0	19.1	19.9
	2	14.5	15.0	16.2	17.3	18.5	18.8	19.0	19.0	19.1
	3	12.9	12.8	14.0	15.0	16.0	16.1	15.7	16.5	16.8
	4	14.0	14.5	16.3	17.1	19.7	19.2	19.3	20.4	19.9
Average		13.6	14.2	15.6	16.6	18.3	18.2	18.3	18.7	18.9
L.S.D. 5% - 0.9; 1% - 1.3										

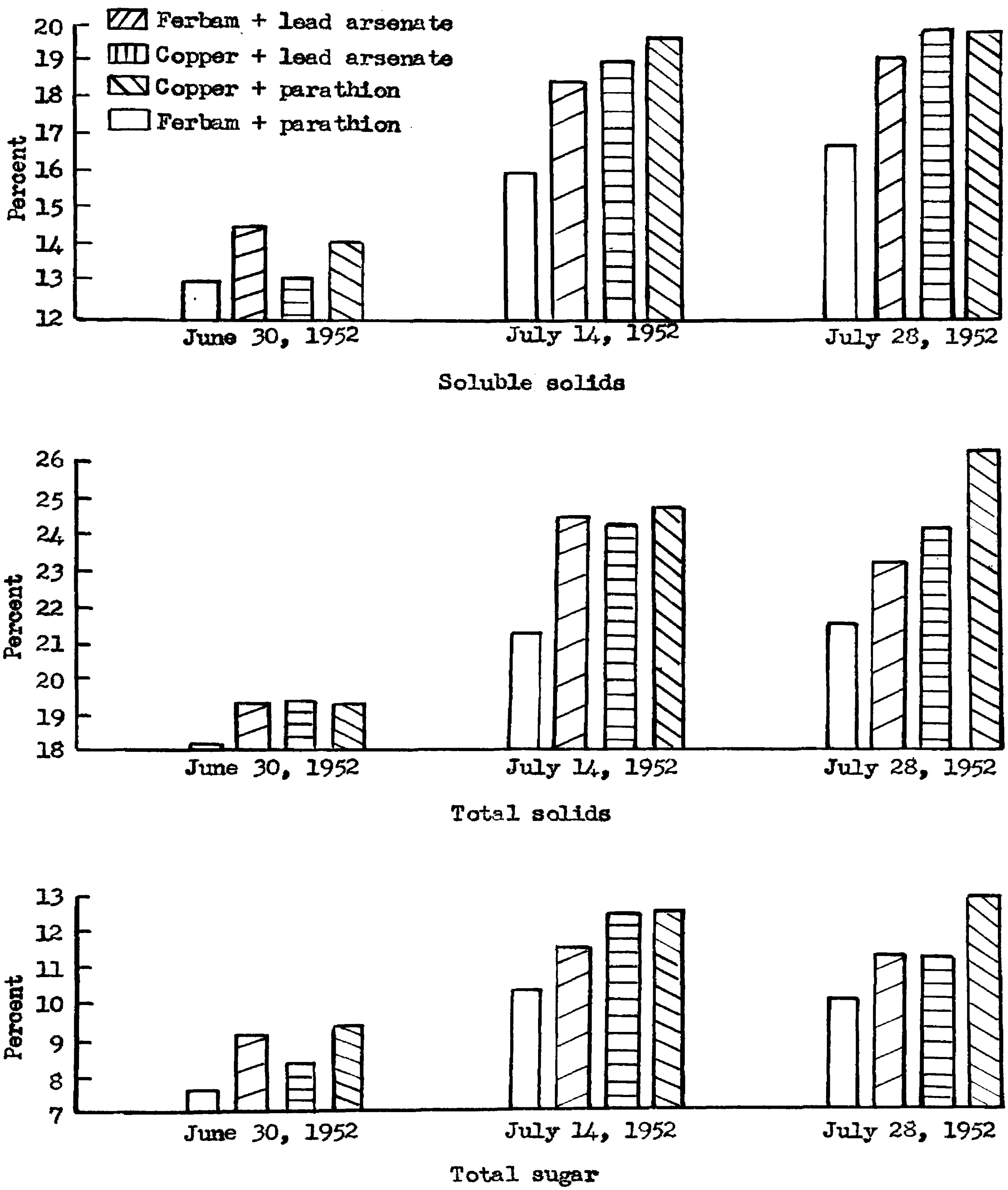

Figure I. The effects of time of harvest, as related to spray treatment, on the soluble solids, total solids and total sugar content of sour cherry fruits in 1952 (East Lansing).

TABLE 6

THE EFFECT OF TIME OF HARVEST ON TOTAL SOLIDS* CONTENT (PERCENT OF FRESH WEIGHT) OF SOUR CHERRY FRUITS

(East Lansing)

Season	Tree	Dates of harvest						
		July					August	
		14	19	23	26	30	2	6
1951	1	20.25	22.16	23.81	24.80	23.60	25.69	24.91
	2	21.86	23.85	24.31	26.65	25.43	26.02	27.64
	3	19.04	18.90	20.22	21.16	21.60	21.81	22.34
	4	22.12	21.37	22.18	23.53	22.90	26.02	25.16
Average		20.82	20.78	22.63	24.03	23.38	24.89	25.01
L.S.D. 1% - 1.7								

Season	Tree	June	July							
		30	3	7	10	14	17	21	24	28
1952	1	19.54	20.09	21.16	22.07	24.26	23.20	24.12	24.66	24.24
	2	19.46	19.47	21.54	22.76	24.49	23.44	24.08	24.54	23.20
	3	18.16	18.06	19.59	19.49	21.26	21.25	20.39	21.22	21.45
	4	19.04	20.48	21.60	22.57	24.84	24.18	23.94	25.77	26.28
Average		19.05	19.52	20.97	21.71	23.62	23.17	23.13	23.80	23.79
L.S.D. 5% - 1.83; 1% - 2.77										

*pits were included in the determination of total solids

This was true also for the soluble solids content (Table 5 and Figure I).

The average total solids and the total solids of the cherries of each of the four trees decreased on July 30, 1951, and on July 17, 1952. This may be explained in part by 1.27 inches of rain that fell on July 27, 1951, and by a 10-day rainy period from July 14 through July 23, 1952. Very little rain had fallen during the growing season previous to July 26 in 1951. However, approximately one inch of rain had fallen during the growing season previous to July 14 in 1952. The soil had been considered generally as very dry during the first part of both harvesting seasons.

Even though the decrease in total solids of the fruits following the rain in both years (Table 6) was not significant, it is recognized generally by processors that a larger "put-in" weight of cherries is required after a rainy period to obtain a certain drained weight than is required before the rain.

The correlation of soluble solids content with total solids content of fruits as the harvest season progressed was highly significant in 1951 ($r = 0.816$) and in 1952 ($r = 0.966$) (Figures II and III).

Total sugar content

Based on preliminary observations in 1951 of the increase in sugar content of cherry fruits as the period of harvest progressed (Table 7), a more detailed study of sugar content was made in 1952. The results of this study

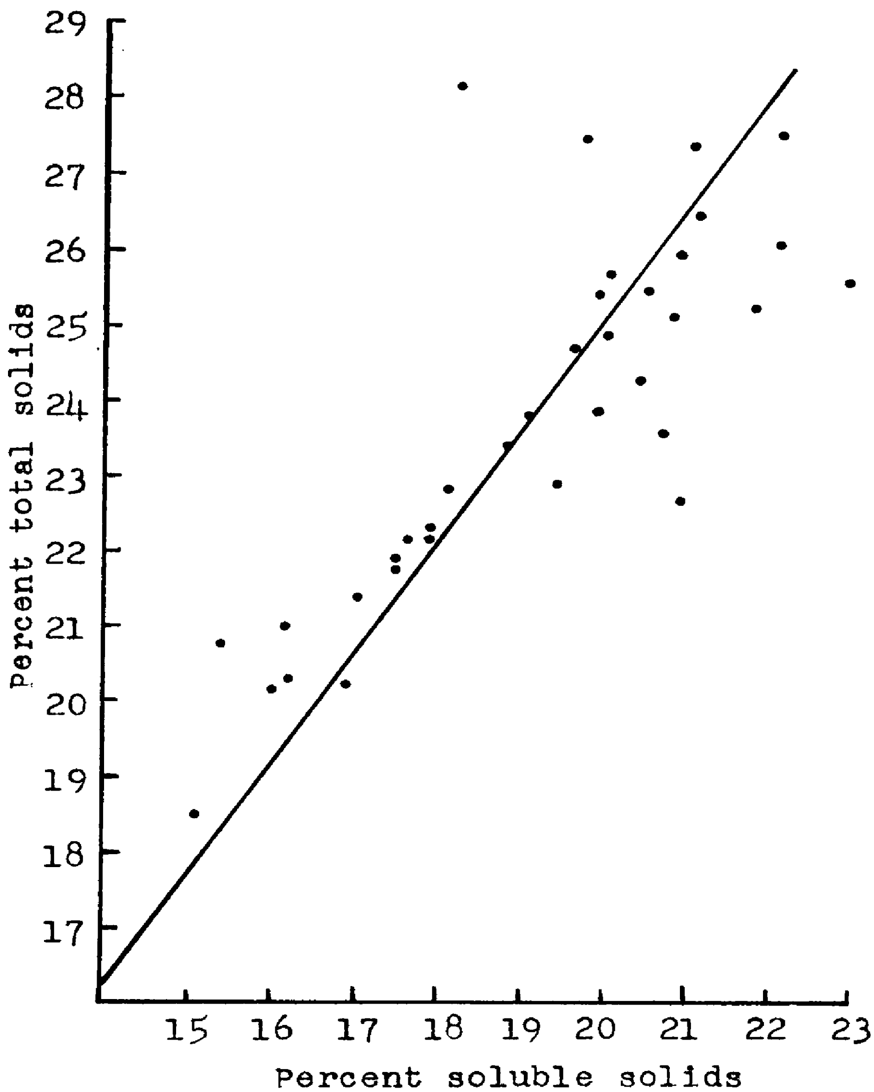

Figure II. Regression of percent total solids on the percent soluble solids of sour cherry fruits. Fruits harvested twice weekly from four Montmorency cherry trees in 1951.

(E = 0.675X + 3.01) (r = 0.816)

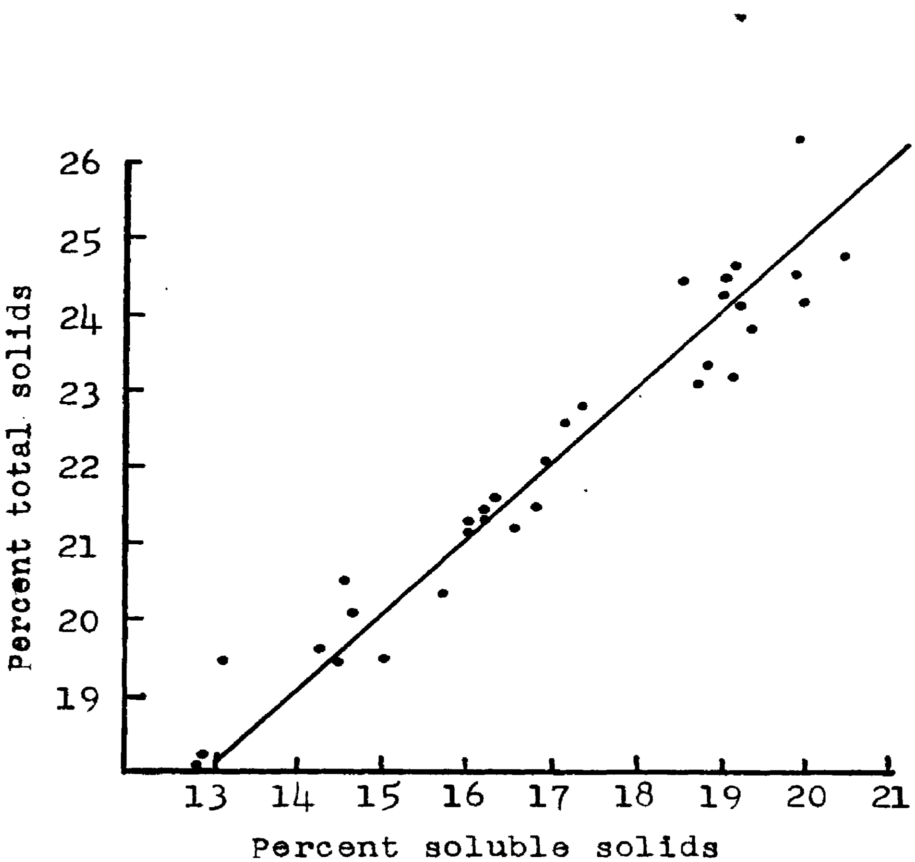

Figure III. Regression of percent total solids on the percent soluble solids of sour cherry fruits. Fruits harvested twice weekly from four Montmorency cherry trees in 1952.

(E = 1.00X - 5.13) (r = 0.966)

TABLE 7

THE EFFECT OF TIME OF HARVEST ON THE PERCENTAGE OF TOTAL SUGAR OF SOUR CHERRY FRUITS IN 1952

(East Lansing)

Season	Tree	Dates of harvest July 14	July 23
1951	1	10.5	12.6
	2	11.8	11.9
	3	10.1	10.6
	4	11.0	12.8
	Average	10.9	12.0

L.S.D. between dates: 5% - 1.3

Season	Tree	June 30	July 3	7	10	14	17	21	24	28
1952	1	8.4	9.2	10.2	10.6	12.4	11.5	11.0	11.7	11.2
	2	9.1	9.3	10.5	10.8	11.5	10.8	10.5	11.4	11.3
	3	7.6	8.0	8.6	9.0	10.3	10.1	9.8	8.9	10.0
	4	9.3	9.5	10.6	11.3	12.5	12.0	11.7	12.3	13.0
	Average	8.6	9.0	10.0	10.4	11.7	11.1	10.7	11.1	11.4

L.S.D. 5% - 0.6; 1% - 0.8

are included in Table 7 and Figure I.

The gradual increase in sugar content of the cherries during the prolonged harvesting period in 1952 was very similar to that of the soluble solids content (Table 5) and total solids content (Table 6). The correlation of 1952 data of soluble solids content with total sugar content on different dates of harvest was highly significant ($r = 0.923$) (Figure IV).

The average sugar content of the fruit decreased from 11.7 percent on July 14 to 11.1 percent on July 17. It continued to drop until a low of 10.7 percent was reached on July 21 after which time it returned to the former level of 11.1 percent on July 24.

This decrease in sugar content was probably due to the rain received daily in 1952 from July 14 through July 23. The effect of this rain appeared to be reflected also by the variations in the average number of fruits per 454 grams (Table 1) and to a less extent by the slight variations in the average transverse diameter (Table 2). The effect of rain was not reflected to the same degree by the other measurements made on the fruits.

Specific gravity of fruits

The average specific gravity of cherry fruits harvested on different dates during the commercial harvest season in 1952 increased significantly from 1.053 on June 3 to 1.068 on July 7 and to 1.078 on July 14 (Table 8). After July 14

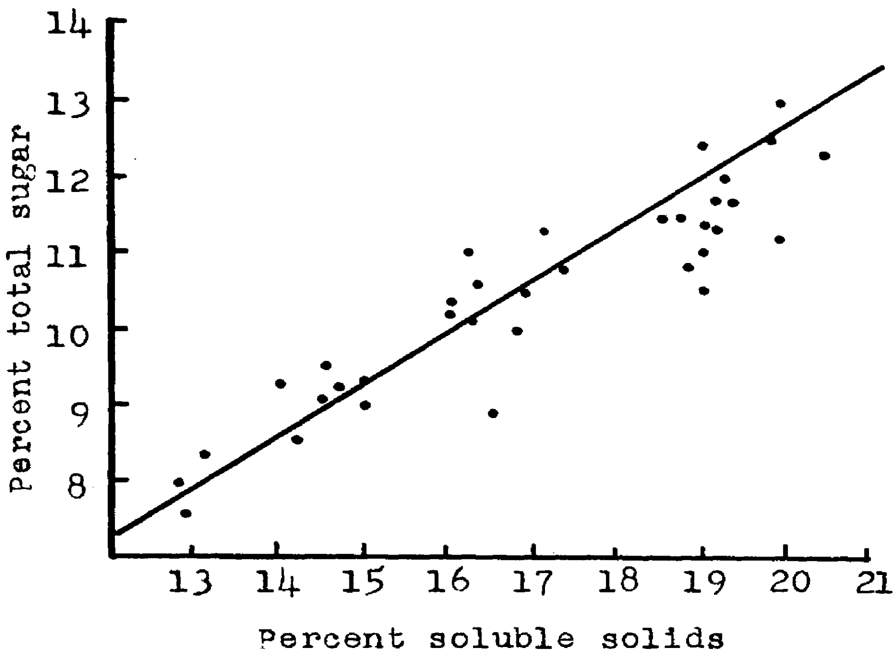

Figure IV. Regression of percent total sugars on the percent soluble solias of sour cherry fruits. Fruits harvested twice weekly from four Montmorency cherry trees in 1952.

(E = 1.57X + 0.58) (r = 0.923)

TABLE 8

EFFECT OF TIME OF HARVEST ON SPECIFIC GRAVITY OF SOUR CHERRY FRUITS IN 1952

(East Lansing)

Tree	Dates of harvest							
	June	July						
	30	3	7	10	14	17	21	24
1	1.042	1.061	1.069	1.071	1.079	1.086	1.079	1.082
2	1.063	1.065	1.074	1.076	1.085	1.080	1.082	1.083
3	1.047	1.054	1.059	1.056	1.068	1.063	1.082	1.068
4	1.061	1.053	1.072	1.073	1.083	1.079	1.085	1.088
Ave.	1.053	1.058	1.069	1.069	1.079	1.077	1.081	1.080

L.S.D. 5% - 0.009; 1% - 0.013

there was no significant change. These variations in the average specific gravity of the cherry fruits were very similar to the variations of soluble solids content, total solids content, and total sugar content (Tables 5-7 inc.).

The variations in specific gravity data for fruits from individual trees on any one date of sampling corresponds very closely with those found for soluble solids, total solids, and total sugar. Also, tree 3 consistently produced fruits lower in specific gravity than trees 1, 2, and 4 on any one date of sampling.

Effect of Organic versus Inorganic Spray Materials on Physical and Chemical Changes of Sour Cherry Fruits

The results of studies made on the Michigan State College Horticulture Farm, East Lansing, showing the effects of organic and inorganic fungicides, and these chemicals combined with organic and inorganic insecticides on the development of sour cherry fruits are presented in Tables 9-12.

Number of fruits per 454 grams

In 1952, the specific combinations of spray chemicals used on eight-tree replicates did not significantly affect the average number of fruits per 454 grams during any of the three periods of harvest, made at weekly intervals (Table 9A). However, there is a trend in the data which indicates that the fruits harvested from each spray treatment were heavier at the end of the picking season than at

TABLE 9A

THE EFFECT OF ORGANIC VERSUS INORGANIC SPRAY MATERIALS ON NUMBER OF SOUR CHERRY FRUITS PER 454 GRAMS HARVESTED DURING DIFFERENT PERIODS IN 1952

(East Lansing)

Tree	July 7-10				July 15-17				July 21-24			
	Fixed copper + lead arsenate	Fixed copper + parathion	Ferbam + lead arsenate	Ferbam + parathion	Fixed copper + lead arsenate	Fixed copper + parathion	Ferbam + lead arsenate	Ferbam + parathion	Fixed copper + lead arsenate	Fixed copper + parathion	Ferbam + lead arsenate	Ferbam + parathion
1	149	156	136	147	145	146	130	146	144	144	123	136
2	151*	148	141	144	152*	143	139	141	135*	125	129	142
3	145	174	175	136	147	166	180	128	138	153	159	128
4	205	153	161	151*	194	155	157	141*	188	150	144	128*
5	156	152	146	159	151	149	148	148	152	140	150	147
6	160	153*	158	169	156	150*	159	149	150	143*	160	141
7	154	168	158	161	154	162	159	152	155	162	172	155
8	154	159	161*	182	154	152	156*	177	157	156	168*	181
Average	160	158	154	155	157	154	154	148	152	147	151	145
Average of all treatments				157				153				149

L.S.D. between treatment averages: 5% - 14; 1% - 19
L.S.D. between grand averages: 5% - 7

TABLE 9B SINGLE TREES HARVESTED ON THE DATES INDICATED

Date	July 7-10				July 15-17				July 21-24			
July 7	151*	155	161	151*								
10	146	153*	161*	142								
14					152*	163	167	142				
17					137	150*	156*	141*				
21									135*	143*	149	128*
24									142	153	168*	140
Average	149	154	161	147	144	157	161	142	138	148	158	134
Average of all treatments				153				151				145

*Indicates fruit harvested from the same tree within each spray treatment the beginning.

Comparing the averages of all treatments at each time of harvest (Table 9A), the number of fruits per 454 grams was significantly greater at the beginning of harvest, 157 cherries, as compared to 149 cherries two weeks later. These data are similar to the findings made to determine the influence of time of harvest on increase in weight of fruit (Table 1).

Individual trees, one from each spray treatment, selected for detail study, reflected an increase in weight of individual fruits as the picking season progressed (Table 9B) which was similar to the findings shown by the eight-tree replicates (Table 9A). However, the differences between individual trees are greater (Table 9B). Nevertheless, the picture shown by the replication of trees is the true picture as possible variation in tree performance is partly eliminated by the larger numbers of trees.

Even though not significant, the differences in the average number of cherries required to make 454 grams found at the beginning and at the end of harvest were greater for the two spray treatments receiving parathion than those receiving lead arsenate. This is shown by the fact that there were little differences at the time of the first harvest July 7-10, 1952, 160 cherries for fixed copper plus lead arsenate, 158 cherries for fixed copper plus parathion, 154 cherries for ferbam plus lead arsenate, and 155 cherries for ferbam plus parathion. Two weeks later the change was slight for the treatments including lead arsenate, 152 cherries for fixed copper plus lead arsenate and 151 cherries for ferbam plus lead arsenate, while the change was much greater for the treatments including parathion, 147 cherries for fixed copper plus parathion and 145 cherries for the treatment ferbam plus parathion. Differences of this nature are not reflected by individual tree data (Table 9B). This may be expected owing to possible variations of single trees.

The added reduction of number of fruits per 454 grams during the period July 21-24 for all treatments was probably the result of the daily rainfall from July 14 to July 23, and the 1.06 inches of rain received on July 23, 1952. The reduction of number of fruits per 454 grams as influenced by this rainy period was shown also in the detail study of increase in weight of fruits (Table 10).

In 1951 the cherries in the replicated plots were sampled at only one time, during the first week of the prolonged harvest period, nevertheless it seems desirable to compare the differences in weight of cherries of the various spray treatments for the two years 1951 and 1952. Thus the first time of harvest, July 7-10, 1952, was chosen for the comparison with the results of 1951. These data are given in Table 10.

The trend of influence on weight of cherry fruits by spray treatments was similar for both years except that in 1951 the cherries sprayed with ferbam plus lead arsenate and with ferbam plus parathion were significantly heavier

TABLE 10

THE EFFECT OF FIXED COPPER AND FERBAM WITH PARATHION AND LEAD ARSENATE ON THE NUMBER OF SOUR CHERRY FRUITS PER 454 GRAMS

(East Lansing)

Tree	Spray treatments							
	Fixed copper				Ferbam			
	Lead arsenate		Parathion		Lead arsenate		Parathion	
	1951	1952	1951	1952	1951	1952	1951	1952
1	157	149	158	156	149	136	151	147
2	149	154	161	148	130	141	157	144
3	161	145	154	174	144	175	126	136
4	183	205	179	153	144	161	131	141
5	169	156	159	152	148	146	148	159
6	166	160	159	150	164	158	144	169
7	159	154	172	168	144	158	142	161
8	149	154	162	159	141	156	136	182
Average	162	160	163	158	146	154	142	155
Average of treatments		161		160		150		148

Comparison of treatment averages of a single season:
L.S.D. 5% - 12; 1% - 16

Comparison of combined treatment averages:
L.S.D. 5% - 9; 1% - 12

than the cherries sprayed with fixed copper plus lead arsenate and with fixed copper plus parathion. There were no significant differences between the results from the spray treatments in 1952. The growing season prior to harvest was drier in 1952 than in 1951. Because of this there was some indication the dry weather may have had a greater influence on the weight of cherries in 1952 than the spray treatments. This appeared to be true by the data on cherry weights obtained later in the season. As previously stated, cherries from the treatment ferbam plus parathion were heavier than fruits from the other treatments after the period of rain during the harvesting period of 1952, while there was very little difference in weight of cherries between treatments before the rain.

Soluble solids content

The use of the organic fungicide, ferbam, with an organic insecticide, parathion, in the spraying schedule on sour cherries reduced the average soluble solids content of the fruits when compared to the soluble solids content of fruits from plots sprayed with fixed copper plus lead arsenate, fixed copper plus parathion, and ferbam plus lead arsenate. But, the differences between these last three spray treatments during any of the three periods of harvest were only slight (Table 11A). This same effect of spray treatments on soluble solids content of fruits was shown also by the similar trend of the data obtained from

TABLE 11A

THE EFFECT OF ORGANIC VERSUS INORGANIC SPRAY MATERIALS ON PERCENT SOLUBLE SOLIDS OF SOUR CHERRY FRUITS HARVESTED DURING DIFFERENT PERIODS IN 1952

(East Lansing)

Tree	July 7-10				July 15-17				July 21-24			
	Fixed copper + lead arsenate	Fixed copper + parathion	Ferbam + lead arsenate	Ferbam + parathion	Fixed copper + lead arsenate	Fixed copper + parathion	Ferbam + lead arsenate	Ferbam + parathion	Fixed copper + lead arsenate	Fixed copper + parathion	Ferbam + lead arsenate	Ferbam + parathion
1	17.0	16.8	15.2	15.4	18.5	18.4	16.1	17.9	18.6	18.0	16.2	17.2
2	16.0*	15.2	14.9	16.7	19.0*	17.5	16.2	19.2	19.0*	17.4	16.0	18.1
3	19.2	17.8	17.5	14.5	19.4	19.1	19.2	15.8	19.6	19.5	20.2	16.2
4	17.1	19.1	16.8	14.0*	20.1	21.1	19.0	16.1*	18.9	20.2	18.0	15.7*
5	18.1	18.6	17.5	15.3	20.9	20.1	19.0	17.9	21.4	19.2	19.0	17.9
6	18.7	17.3*	19.4	15.5	20.2	18.8*	20.4	17.8	20.5	19.0*	21.5	17.4
7	19.4	17.1	17.8	16.5	21.2	19.7	19.5	18.6	21.8	22.1	22.3	21.0
8	19.1	18.3	17.1*	15.8	20.8	19.4	19.2*	18.0	21.8	20.0	20.4*	21.2
Treatment ave.	18.1	17.5	17.0	15.5	20.0	19.3	18.6	15.2	20.2	19.4	19.2	18.1
Average of all treatments				17.0				18.3				19.2

L.S.D. between treatment averages: 5% - 1.4; 1% - 1.9

L.S.D. between grand averages of the period of harvest: 5% - 0.7; 1% - 1.0

TABLE 11B SINGLE TREES HARVESTED ON THE DATES INDICATED

July 7	16.0*	16.2	16.3	14.0*								
10	16.9	17.3*	17.1*	15.0								
14					19.0*	18.5	19.7	16.0				
17					18.7	18.8*	19.2*	19.2*				
21									19.0*	19.0	19.3	15.7*
24									19.1	19.0*	20.4*	16.5
Average	16.4	16.8	16.7	14.5	18.9	18.7	19.5	16.1	19.1	19.0	19.9	16.2
Average of all treatments				16.1				18.3				18.6

*Indicates fruits harvested on the same date and from the same tree within each spray treatment individual trees of each spray treatment which were selected for detail study and were sampled twice at three-day intervals during the three periods of harvest (Table 11B). In each case, the soluble solids content was lower in fruits treated with two organic compounds (ferbam and parathion), while there were no significant differences between the treatments containing two inorganic chemicals (fixed copper and lead arsenate), or with the combinations of inorganic and organic pesticides, ferbam plus lead arsenate or fixed copper plus parathion.

A comparison of the results of treatments in which eight replicates were used per treatment the average soluble solids content of the fruit sprayed with fixed copper plus lead arsenate was always the highest on each time of sampling, 18.1, 20.0, and 20.2 percent, while cherries sprayed with ferbam plus parathion were always the lowest in soluble solids content, 15.5, 15.2, and 18.1 percent. In detailed studies made in 1951 and 1952 of cherries harvested at three- and four-day intervals from the time the cherries could be first picked commercially until they shriveled on the trees, generally the trees producing cherries highest in soluble solids by comparison at the beginning of harvest continued to produce cherries highest in soluble solids by comparison at the end of the prolonged harvest period (Table 5). Also, generally trees producing cherries low in soluble solids by comparison at the beginning of commercial harvest continued to produce cherries lowest in soluble solids by comparison at the end of commercial harvest. The maximum soluble solids content was not the same for all trees of a single planting in any one season.

The average soluble solids content of fruits from all treatments increased significantly from one period of harvest to the next, 17.0 percent during the period July 7-10, 18.3 percent during the period July 15-17, and 19.2 percent during the period July 20-24 (Table 11A). This increase was similar to the increase of soluble solids content as the season progressed shown by the detail study made in 1951 and 1952 to determine the effect of time of harvest on soluble solids content (Table 5).

It was of interest to compare the average soluble solids content of the cherries from the different spray treatments of the replicated plots found in 1951 to those found in 1952. Only one sampling was made in 1951 and this was taken the first week of the prolonged commercial harvest, the data in 1952 obtained from samples taken during the period July 7-10 were selected for comparison (Table 12). The two-year averages of the soluble solids content of fruits from the four spray treatments were as follows: fixed copper plus lead arsenate - 18.5 percent, fixed copper plus parathion - 17.9 percent, ferbam plus lead arsenate - 17.0 percent, and ferbam plus parathion - 15.9 percent (Table 12). These data showed that the fixed copper sprays had a more pronounced effect on the soluble solids content than ferbam, and that lead arsenate treat-

TABLE 12

THE EFFECT OF FIXED COPPER AND FERBAM WITH PARATHION AND LEAD ARSENATE ON THE SOLUBLE SOLIDS CONTENT (PERCENT) OF SOUR CHERRY FRUITS

(East Lansing)

	Spray treatments							
	Fixed copper				Ferbam			
	Lead arsenate		Parathion		Lead arsenate		Parathion	
	1951	1952	1951	1952	1951	1952	1951	1952
	16.3	17.0	15.3	16.8	13.8	15.2	14.7	15.4
	16.5	16.4	15.6	15.2	14.6	14.9	15.2	16.7
	19.4	19.2	19.5	17.8	18.8	17.5	14.6	14.5
	19.5	17.1	19.4	19.1	16.4	16.8	15.4	16.1
	20.0	18.1	18.1	18.5	16.0	17.5	16.5	15.3
	20.1	18.7	17.6	18.8	20.1	19.3	17.7	15.5
	18.8	19.4	20.5	17.1	16.8	17.8	17.9	16.4
	20.4	19.1	19.7	18.2	17.1	19.2	17.6	15.8
Seasonal average	18.9	18.1	18.2	17.7	16.7	17.3	16.2	15.7
Treatment average		18.5		17.9		17.0		15.9

Comparison of seasonal averages:
L.S.D. 5% - 1.1; 1% - 1.5

Comparison of combined treatment averages:
L.S.D. 5% - 0.8; 1% - 1.0

ments had a more pronounced effect than parathion. However, the combined effect of an inorganic fungicide, and an inorganic insecticide, on the soluble solids content of fruits were most striking, fixed copper plus lead arsenate was 18.5 percent as compared to only 15.9 percent for ferbam plus parathion.

From these data spray materials may be assumed to affect total solids and sugar content of cherry fruits because of the highly significant positive correlations of soluble solids with total solids and sugar content (Figures II-IV inc.).

Individual Orchards

The findings resulting from studies conducted in five commercial orchards, located in the Hart-Shelby area and the Grand Traverse area, from 1949 through 1952, are presented in Tables 13A through 17B. Data relating to soluble solids content are included in Tables 13B through 17B, and data relating to weight of cherries (number of fruits per 454 grams) are given in Tables 13A through 17A.

Orchard A (Morrison orchard S)

Number of fruits per 454 grams

The influence of fixed copper on the average number of fruits per 454 grams in Orchard A decreased from 1949 through 1952 (Table 13A). The average number of fruits per 454 grams was significantly higher in the fixed copper

TABLE 13A

INFLUENCE OF FUNGICIDAL SPRAY MATERIALS ON THE NUMBER OF SOUR CHERRY FRUITS PER 454 GRAMS IN ORCHARD A

Tree	Seasons of harvest											
	1949			1950			1951			1952		
	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam
1	112	120	120	97	109	126	85	108	91	90	100	97
2	114	132	124	104	126	119	94	125	105	94	103	94
3	128	129	116	112	120	106	112	98	115	100	95	105
4	115	126	115	111	115	99	100	139	94	102	111	91
5	110	126	107	92	96	99	86	97	88	85	106	94
Ave.	116	127	116	103	113	110	95	113	99	94	103	96
L.S.D. between treatment average:												
5%		8			13			18			10	
1%		12			19			27			14	

Comparison of treatment averages of different seasons:
5% - 12
1% - 17

treatment in 1949, 127 fruits for fixed copper spray treatments as compared to 116 fruits for the ferbam and nabam treatments. During the three years that followed, 1950, 1951, and 1952, no similar significant differences between spray treatments were evident.

The reason for the differences in 1949 may be attributed to the fact that the trees were growing in sod mulch in 1949. However in 1950 the grower changed soil management to clean cultivation plus a cover crop. This increased vegetative vigor of the trees, brought about by increased cultivation could have resulted in an increase in the size of the fruit which in turn increased the weight of the individual fruits. Observations indicated that the fruits from the fixed copper treatment were smaller than those from the other two treatments in 1949. In 1950, 1951 and 1952, however, such differences could not be distinguished. Rainfall was ample for cherries of good size in all four years.

The increase in tree vigor in Orchard A decreased also the average number of fruits per 454 grams from the trees sprayed with organic compounds; however, this decrease in number of fruits per 454 grams from the nabam treatments was not significant until 1951 (Table 13A). Except for the decrease from 110 fruits per 454 grams for the nabam spray treatment in 1950 to 96 fruits in 1952, there was no significant change in average weight of fruits after cultivation was started in 1950. The 6.83 inches of rain in July, 1952, may have had a direct influence on the increase in weight of the fruit of all treatments that year (Table 21).

Soluble solids content

The percent soluble solids of fruits from the fixed copper treatments in Orchard A decreased progressively from 16.4 percent in 1949 to 13.4 percent in 1952. However, during this same interval, the percent soluble solids of fruits from the ferbam treatments decreased from 14.8 percent to 11.3 percent and from 15.9 percent to 13.3 percent for the nabam treatments (Table 13B). This indicated that the increased cultivation, as it affected tree vigor, also decreased the soluble solids content of fruits from all spray treatments. The relationship between soluble solids and spray treatments was not materially affected. Kenworthy and Mitchell (19) reported also an inverse relation between the soluble solids content of fruits and tree vigor.

Observations of the trees in this orchard before the experiment was started indicated that those trees selected for the ferbam treatment were more vigorous than the trees of the other treatments. This was reflected by the soluble solids content. However, the over-all findings of this study including all orchards (Table 23) indicate that the continued high soluble solids content of the cherries sprayed with fixed copper was a direct result of the spray treatment.

The percent soluble solids of fruits in Orchard A

TABLE 13B

INFLUENCE OF FUNGICIDAL SPRAY MATERIALS ON THE SOLUBLE SOLIDS CONTENT (PERCENT) OF SOUR CHERRY FRUITS FROM ORCHARD A

Tree	Seasons of harvest											
	1949			1950			1951			1952		
	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam
1	14.5	16.2	16.1	14.3	15.3	14.8	12.8	13.7	14.5	11.3	12.2	13.1
2	15.4	17.5	15.7	13.7	15.5	14.0	12.8	15.6	13.6	11.0	13.9	11.5
3	15.7	14.7	16.5	14.5	15.1	14.7	13.0	14.8	14.9	11.6	12.7	14.5
4	13.9	16.9	16.2	13.8	15.7	14.9	13.4	14.9	14.4	11.5	13.2	14.0
5	14.6	16.4	15.0	14.0	15.3	13.3	11.8	15.9	14.4	11.4	15.0	13.7
Ave.	14.8	16.4	15.9	14.0	15.4	14.3	12.7	14.9	14.3	11.3	13.4	13.3
L.S.D. between treatment average:												
5%		1.3			0.7			1.4			1.4	
1%		2.0			0.9			2.0			2.0	

Comparison of treatment averages of different seasons:

5% - 0.8
1% - 1.2

appeared to be directly related to the number of fruits per 454 grams. As the number of fruits per 454 grams increased, there was a corresponding decrease in soluble solids. Apparently much of the increase in average weight of individual fruits was due to increased water content. This agrees with the reports of other workers (20, 21) and findings relating total solids and soluble solids previously reported in this study (Figures II and III).

Orchard B (Morrison orchard C)

Number of fruits per 454 grams

Fixed copper sprays did not affect the average number of fruits per 454 grams when compared with fruit sprayed with ferbam and nabam in Orchard B. In fact, the fruit from fixed copper sprayed trees were significantly heavier than those of the ferbam treatments in 1950, 118 fruits for the ferbam treatment as compared to 107 fruits for the fixed copper treatments (Table 14A). These results indicate that under conditions of adequate rainfall and constant moderate tree vigor the spray materials may not materially affect the average number of fruits per 454 grams.

As was true for Orchard A, the trees in this orchard were not all of equal vigor when this study started in 1949. By contrast to Orchard A, the trees of the ferbam treatment were less vigorous than the trees of the other treatments even though they were similar in size. This would account for the differences in weight of individual fruits of the

TABLE 14A

INFLUENCE OF FUNGICIDAL SPRAY MATERIALS ON THE NUMBER OF SOUR CHERRY FRUITS PER 454 GRAMS IN ORCHARD B

Tree	Seasons of harvest								
	1950			1951			1952		
	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam
1	125	109	125	118	118	119	117	111	113
2	117	108	126	108	109	135	115	125	132
3	122	104	110	125	120	111	125	122	107
4	114	114	112	122	121	102	122	122	103
5	111	98	102	120	105	97	121	107	112
Average	118	107	115	119	115	113	120	117	113
L.S.D. between treatment averages: 5%		9			16			12	
1%		13			23			17	

Comparison of treatment averages of different seasons:

L.S.D. 5% - 11
1% - 15

trees sprayed with ferbam as compared to the fruits from the other treatment.

As the years progressed the trees sprayed with fixed copper produced cherries progressively lighter in weight. By contrast, the weight of cherries from the treatments ferbam and nabam changed but little. This could have been due to the physiological effect of the fixed copper on the vigor of the trees, reducing the vegetative vigor of the trees. Before starting this study, the entire orchard had been sprayed with ferbam for more than five years.

Soluble solids content

The average percent soluble solids of fruits from trees sprayed with fixed copper was significantly higher than that of fruits from trees sprayed with ferbam in 1949, 1950 and 1951, and significantly higher than that of fruits sprayed with nabam in 1949 (Table 14B). The differences in soluble solids content between spray treatments were: in 1949 ferbam 14.2 percent, fixed copper 15.5 percent and nabam 13.9 percent; in 1950, ferbam 13.9 percent, fixed copper 15.0 percent; and in 1951, ferbam 13.1 percent, fixed copper 15.2 percent. There were no differences between the soluble solids content of fruits from the fixed copper and organic spray treatments in 1952. This may have been due to a reduction of the influence of fixed copper as a result of the increased rainfall of 6.83 inches during July, 1952 (Table 18).

TABLE 14B

INFLUENCE OF FUNGICIDAL SPRAY MATERIALS ON THE SOLUBLE SOLIDS CONTENT (PERCENT) OF SOUR CHERRY FRUITS FROM ORCHARD B

Tree	Seasons of harvest											
	1949			1950			1951			1952		
	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed coppe	Nabam
1	14.4	17.0	13.4	14.0	15.0	13.4	14.0	16.8	13.8	12.6	15.4	13.1
2	12.9	15.1	14.7	14.2	14.8	16.0	12.1	15.3	16.2	12.7	14.6	16.0
3	15.3	14.9	13.7	13.7	15.4	14.4	13.0	14.8	14.8	13.5	12.9	12.6
4	13.7	15.4	13.7	14.0	14.9	13.8	13.7	13.5	14.8	13.1	12.0	12.7
5	14.9	15.3	13.9	13.8	15.0	14.1	12.7	15.8	13.8	13.4	12.7	12.5
Ave.	14.2	15.5	13.9	13.9	15.0	14.3	13.1	15.2	14.7	13.0	13.5	13.4
L.S.D. between treatment average:												
5%		1.3			0.9			1.7			1.7	
1%		1.9			1.3			2.5			2.5	

Comparison of treatment averages of different seasons:
5% - 1.0
1% - 1.5

The percent soluble solids of fruits from Orchard B did not appear to be related to the weight of fruit, as has been suggested by other workers (6, 14, 22, 23). Even though the number of fruits per 454 grams from the fixed copper spray treatments was smaller (107) than the number of fruits from the ferbam spray treatment (118) in 1950, the percent soluble solids was significantly higher for fruits of the fixed copper spray treatments. There were no significant differences between the soluble solids content of the fruit of the nabam and ferbam treatments even though the trees of the ferbam treatment appeared to be less vigorous at the beginning of this study.

Orchard C (McLachlan orchard)

Number of fruits per 454 grams

The average number of fruits per 454 grams increased significantly from 1950 to 1952 for all spray treatments, from 117 fruits in the fixed copper spray treatment in 1950 to 130 fruits in 1952, from 117 fruits in ferbam spray treatments in 1950 to 130 fruits in 1952, and from 113 fruits in the nabam spray treatments in 1950 to 132 fruits in 1952 (Table 15A). There was an increase in the number of cherries in the fixed copper treatments in 1951, from 117 cherries in 1950 to 136 cherries in 1951. This was perhaps due to cold injury which occurred in November, 1950. The trees of the organic spray treatments were not apparently injured. The increase in the number of fruits

TABLE 15A

INFLUENCE OF FUNGICIDAL SPRAY MATERIALS ON THE NUMBER OF SOUR CHERRY FRUITS PER 454 GRAMS IN ORCHARD C

Tree	Seasons of harvest											
	1949			1950			1951			1952		
	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam
1	123	134	117	121	115	111	139	158	106	135	140	125
2	113	118	108	114	121	115	121	134	111	126	123	133
3	102	120	115	111	115	110	107	135	108	125	127	125
4	113	119	118	111	116	110	118	124	118	130	134	128
5	124	112	130	126	114	121	105	128	121	136	131	148
Ave.	115	121	118	117	117	113	118	136	113	130	131	132
L.S.D. between treatment average:												
5%		11			6			16			9	
1%		16			9			24			14	

Comparison of treatment averages of different seasons:

5% - 11
1% - 14

per 454 grams in 1952 in the organic spray plots was probably due to similar cold injury which occurred in early November, 1951. Apparently in 1950 dormancy of trees sprayed with fixed copper was delayed as compared to trees sprayed with the organic compounds resulting in injury by the early cold weather. The fixed copper sprayed trees held their leaves into October while the trees of the other treatments were almost completely defoliated by September 25, 1950.

There were no differences in the influence of spray materials on the number of fruits per 454 grams in Orchard C, except for the injurious effect of fixed copper which appeared to be related to cold injury in 1950.

Soluble solids content

The percent soluble solids of fruits from trees sprayed with fixed copper was significantly higher than the fruit from trees sprayed with ferbam and nabam in 1949 and 1952 and was significantly higher than the fruit of the ferbam treatment in 1950 (Table 15B). In 1951 there was no difference between spray treatments, which could not be explained unless the cold injury mentioned previously reduced the vigor of the trees sprayed with fixed copper and the resulting fruit was smaller in size than the fruits from the other spray treatments. Actual observations of the fruit would verify this explanation.

The effects of increased rainfall in July, 1952, on

TABLE 15B

INFLUENCE OF FUNGICIDAL SPRAY MATERIALS ON THE SOLUBLE SOLIDS CONTENT (PERCENT) OF SOUR CHERRY FRUITS FROM ORCHARD C

Tree	Seasons of harvest											
	1949			1950			1951			1952		
	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam
1	12.2	14.8	12.9	12.9	14.7	13.4	12.0	12.7	12.0	13.4	17.5	13.4
2	14.5	15.5	12.4	13.2	14.6	13.5	12.1	11.5	13.9	13.8	16.2	12.5
3	13.8	15.1	12.9	12.8	16.9	13.8	13.0	13.0	13.4	13.5	15.0	12.0
4	14.2	14.1	13.3	13.2	14.4	14.7	12.1	13.5	12.8	13.0	14.4	12.5
5	12.1	13.9	13.1	12.4	13.7	14.3	12.8	13.0	13.2	13.2	13.9	11.5
Ave.	13.4	14.7	12.9	12.9	14.8	13.9	12.4	12.7	13.1	13.4	15.4	12.4
L.S.D. between treatment average:												
5%		1.1			1.2			0.9			1.0	
1%		1.6			1.8			1.4			1.5	

Comparison of treatment averages of different seasons:
5% - 1.4
1% - 2.2

the percent soluble solids content of fruits was not apparent. If variations in tree vigor did exist in this orchard, such variations were not reflected by the soluble solids content of fruits; except perhaps for the decrease in soluble solids of fruits from the fixed copper treatment in 1951.

The percent soluble solids of fruits in Orchard C did not appear to be related to the number of fruits per 454 grams. This was verified by the fact that in 1951 the number of fruits per 454 grams varied significantly, 118 for the ferbam treatment, 136 for the fixed copper treatment and 113 for the nabam treatment, while the soluble solids content for the fruits from these treatments were 12.4 percent, 12.7 percent and 13.1 percent, respectively.

Orchard D (Stokeley orchard)

Number of fruits per 454 grams

The number of fruits per 454 grams in Orchard D was significantly higher for trees sprayed with fixed copper than for trees sprayed with ferbam or nabam in 1949, 1950 and 1951, but was significantly lower than fruit from trees sprayed with nabam in 1952 (Table 16A). The increase of average weight of individual fruits from the fixed copper treatment in 1952, from 129 fruits to 108 fruits per 454 grams, was probably due to the excessive rainfall (7.4 inches in July) in 1952 (Table 16A). The reduction in the intensity of copper injury on cherries, in years of high

TABLE 16A

INFLUENCE OF FUNGICIDAL SPRAY MATERIALS ON THE NUMBER OF SOUR CHERRY FRUITS PER 454 GRAMS IN ORCHARD D

Tree	Seasons of harvest											
	1949			1950			1951			1952		
	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam
1	123	128	109	116	138	114	114	139	97	101	115	129
2	119	139	114	117	127	107	112	131	100	106	99	115
3	121	133	115	118	124	111	113	126	101	107	107	139
4	124	142	106	127	128	113	120	122	102	121	111	116
5	126	127	114	120	130	111	114	128	102	110	106	115
Ave.	123	134	112	120	129	111	115	129	100	109	108	123
L.S.D. between treatment average:												
5%		8			6			7			13	
1%		12			9			11			18	

Comparison of treatment averages of different seasons:

5% - 7
1% - 10

rainfall has been shown by other workers (9, 23, 31, 37). The number of fruits per 454 grams for trees sprayed with ferbam was also significantly higher than that for trees sprayed with nabam in 1949 and 1951, but the fruits of the ferbam sprayed trees were significantly larger than those of the nabam treatment in 1952. The decrease in weight of individual fruits of trees sprayed with nabam in 1952, could not be explained except that the crop on these trees was light in 1951 and heavy in 1952.

Contrary to the report by Fisher (12), the small size of the trees in Orchard D as compared to the mature trees of other orchards was not reflected by the number of fruits per 454 grams or by the effects of spray chemicals on the number of fruits per 454 grams (Table 19).

Soluble solids content

Trees sprayed with fixed copper in Orchard D produced fruits significantly higher in soluble solids content than either of the organic compounds in 1949 and 1950. Fruits from trees sprayed with nabam were significantly higher in soluble solids than fruits from trees sprayed with ferbam in 1950. However, in 1951 and 1952 there were no significant differences in soluble solids content of fruits from any of the spray treatments (Table 16B). The decrease in percent soluble solids and uniformity of percent soluble solids of all spray treatments in 1951 and 1952 can not be explained from information available in this study, except that all trees were heavily

TABLE 16B

INFLUENCE OF FUNGICIDAL SPRAY MATERIALS ON SOLUBLE SOLIDS CONTENT (PERCENT) OF SOUR CHERRY FRUITS FROM ORCHARD D

Tree	Seasons of harvest											
	1949			1950			1951			1952		
	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam
1	16.2	18.3	16.5	15.8	19.4	18.8	15.0	15.4	16.0	14.0	12.6	13.0
2	16.6	18.4	16.4	16.5	20.6	17.6	15.1	15.2	16.1	13.7	15.3	12.5
3	14.9	18.8	16.4	16.7	20.4	19.8	15.9	16.4	16.0	12.9	13.7	14.5
4	18.9	18.9	16.1	18.1	20.0	19.8	17.8	16.7	15.7	14.4	15.6	12.0
5	16.3	17.9	15.3	18.6	18.8	18.7	16.0	15.2	15.7	15.1	13.6	14.5
Ave.	16.7	18.5	16.1	17.1	19.8	18.9	15.9	15.8	15.9	14.0	14.1	13.3
L.S.D. between treatment average:												
5%		1.3			1.4			1.0			1.8	
1%		1.9			2.1			1.4			2.6	

Comparison of treatment averages of different seasons:

5% - 1.7
1% - 2.5

pruned in the winter of 1950-1951. This heavy pruning did increase the vegetative vigor of all trees and the increased vigor may have been responsible for the decrease in soluble solids content. The high rainfall in July, 1952, might conceivably have had some effect on all treatments during that season in reducing the soluble solids below the findings of 1951.

In Orchard D the percent soluble solids and average weight of individual fruits appeared to be directly related, as the number of fruits per 454 grams decreased, indicating an increase in average weight of the fruit, the percent soluble solids decreased.

The increased percent soluble solids of all samples of fruit from Orchard D as compared to the findings in Orchards A, B, and C may have been due to time of harvest or fruit maturity. This orchard invariably was picked 7 to 10 days later than Orchards A, B, and C. The detailed study made at East Lansing showed a definite increase of soluble solids of fruits during the first two weeks of harvest (Table 6).

Orchard E (Fox and Sons orchard)

Number of fruits per 454 grams

The increased tree vigor in Orchard E, resulting from the heavy annual application of nitrogen fertilizers, reduced the injurious effects of fixed copper spray materials on the average number of fruits per 454 grams (Table 17A).

TABLE 17A

INFLUENCE OF FUNGICIDAL SPRAY MATERIALS ON THE NUMBER OF SOUR CHERRY FRUITS PER 454 GRAMS IN ORCHARD E

Tree	Seasons of harvest											
	1949			1950			1951			1952		
	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam
1	146	126	134	121	104	123	116	84	125	119	96	110
2	121	133	131	120	97	128	108	99	124	93	100	116
3	135	139	114	125	105	111	108	115	128	111	102	114
4	130	129	115	117	113	111	120	113	112	103	100	112
5	132	129	114	118	99	115	120	109	106	111	96	113
Ave.	133	131	122	120	104	118	114	103	119	107	99	113
L.S.D. between treatment average:												
5%		13			10			16			10	
1%		18			15			24			15	

Comparison of treatment averages of different seasons:

5% - 10

1% - 13

The number of fruits per 454 grams from trees sprayed with fixed copper was significantly smaller than for the trees sprayed with either ferbam or nabam in 1950, and smaller than the number of fruits from trees sprayed with nabam in 1951 and 1952 (Table 17A). There was no significant difference between the ferbam and nabam treatments for any year in this orchard. There was, also, no significant difference between the fruits of the three spray treatments in 1949.

The number of fruits per 454 grams from the trees sprayed with ferbam decreased progressively throughout the study; from 133 fruits in 1949 to 120 fruits in 1950 and 107 fruits in 1952. The number of fruits per 454 grams from trees sprayed with nabam and fixed copper did not change significantly from one year to the next. The data for the trees sprayed with fixed copper in 1949 should not be compared with the averages for the fixed copper treatments from 1950 to 1952, because new trees were selected by the grower for this treatment in 1950. These newly selected trees were smaller and more vigorous than the trees sprayed with organic fungicides. This progressive increase of fruit weight in the ferbam spray treatments seemed to indicate a greater response of the tree to the spray treatment than trees sprayed with nabam or fixed copper. This orchard was in a low state of vigor two years before this study was started and the grower was using heavy nitrogen applications to increase yield.

Soluble solids content

The percent soluble solids of fruits from trees sprayed with fixed copper in Orchard E was significantly higher than that of fruits from the ferbam or nabam treatments in 1950, and higher than that of fruits from the nabam treatments in 1952 (Table 17B). The general uniformity of the average percent soluble solids of fruits in the different spray treatment of this orchard may have been due to the high state of vigor of the orchard owing to the high annual rates of nitrogen fertilizer used to maintain production.

The progressive increase in percent soluble solids of fruits from each spray treatment, from approximately 13.0 percent in 1949 to a high of 15.0 percent in 1951, followed by the sudden decrease to approximately 12.8 percent in 1952 may be explained by corresponding changes of rainfall during that four-year period. The changes in total rainfall for June and July were from 7.02 inches in 1949 to 4.97 inches in 1950, 4.16 inches in 1951 and 8.56 inches in 1952 (Table 18).

The percent soluble solids did not appear to be related to the number of fruits per 454 grams in Orchard E, because in several instances an increase in the number of fruits per 454 grams was accompanied by an increase in soluble solids, while in other instances, the increases in number of fruits per 454 grams were accompanied by decreases in soluble solids.

TABLE 17B

INFLUENCE OF FUNGICIDAL SPRAY MATERIALS ON SOLUBLE SOLIDS CONTENT (PERCENT) OF SOUR CHERRY FRUITS FROM ORCHARD E

Tree	Seasons of harvest											
	1949			1950			1951			1952		
	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam	Ferbam	Fixed copper	Nabam
1	12.0	14.0	12.5	13.8	15.4	13.8	14.7	13.8	15.0	13.6	12.5	12.9
2	13.0	13.3	11.7	14.1	16.2	12.8	16.1	16.5	15.1	12.8	13.1	12.1
3	12.3	14.2	12.0	13.8	14.7	14.3	14.7	14.8	14.8	12.8	13.7	11.5
4	12.0	13.0	14.0	14.2	16.0	13.7	14.9	15.7	15.1	13.7	12.8	12.1
5	14.7	13.8	12.5	14.3	15.6	13.9	14.8	14.8	14.8	14.3	13.3	12.1
Ave.	12.8	13.7	12.5	14.0	15.6	13.7	15.0	15.1	15.0	13.4	13.0	12.1
L.S.D. between treatment average:												
5%		1.4			0.8			2.4			0.9	
1%		2.0			1.2			3.5			1.2	

Comparison of treatment averages of different seasons:

5% - 1.0
1% - 1.5

TABLE 18

INCHES OF RAINFALL RECEIVED DURING MAY, JUNE AND JULY OVER THE PERIOD 1949 THROUGH 1952 IN THE AREAS INDICATED

Season	Traverse City			Hart-Shelby			East Lansing		
	May	June	July	May	June	July	May	June	July
1949	1.60	3.62	3.08	1.11	3.48	3.54	2.34	4.89	4.78
1950	1.85	1.70	4.70	1.80	2.55	2.42	1.96	4.71	4.34
1951	2.00	1.92	3.24	1.35	2.18	1.97	3.08	3.27	1.07
1952	1.70	3.24	6.83	3.00	1.16	7.40	4.98	1.46	3.24
Normal rainfall for 30-year period							3.75	3.37	2.28

Combined Results from Five Commercial Orchards

The combined results from five commercial orchards showing the average number of fruits per 454 grams are given in Tables 19-21 and the average percent soluble solids of fruits are presented in Tables 22-24.

Number of fruits per 454 grams

Effects of spray chemicals: The use of fixed copper as a fungicide increased the number of fruits per 454 grams when compared with fruits sprayed with ferbam and nabam in Orchards A, C, and D. This is shown by the averages for the four-year period in Table 19. In Orchards B and E the average number of fruits per 454 grams was significantly less for the fixed copper treatments than for the ferbam and nabam spray treatments, 109 fruits as compared to 119 and 118 fruits from ferbam and nabam spray treatments respectively in Orchard E, and 113 fruits for the fixed copper spray treatments as compared to 119 fruits in the ferbam spray treatments in Orchard B. These results indicated that the injurious effects of fixed copper sprays was decreased by the increased tree vigor resulting from heavy applications of nitrogen in Orchard E and by continuous cultivation and fertilization in Orchard B. High vigor was maintained in Orchard E by "trashy" cultivation and heavy applications of nitrogen while Orchard B was clean cultivated and received moderate annual applications of nitrogen and barnyard manure.

TABLE 19

INFLUENCE OF FUNGICIDAL SPRAY MATERIALS AND ORCHARD VARIATION ON THE AVERAGE NUMBER OF SOUR CHERRY FRUITS PER 454 GRAMS DURING THE PERIOD 1949-1952

Spray material	Orchard A	Orchard B*	Orchard C	Orchard D	Orchard E	L.S.D. between orchard averages within a treatment 5%	L.S.D. between orchard averages within a treatment 1%
Ferbam	102	119	120	116	119	5	7
Fixed copper	114	113	126	125	109	6	9
Nabam	105	114	119	111	118	7	10
L.S.D. between treatment averages within an orchard:							
5%	6	6	5	4	5		
1%	8	9	7	5	7		

*Data for 1949 not included for Orchard B

The inter-relationships of effects of variations in seasons and of spray chemicals on the number of fruits per 454 grams for the five commercial orchards are shown in Table 20. In 1949 the differences were significant between the average number of fruits per 454 grams for the spray treatments, 117 fruits for the nabam treatments, 122 fruits for the ferbam treatments, and 128 fruits for the fixed copper treatments. These differences could not be explained on the basis of the known seasonal conditions and thus were assumed to be the results of the spray treatments. However, the significant increase of average number of fruits per 454 grams of the fixed copper treatment in 1951 was obviously due to the pronounced increase in Orchard C which was considered to be the result of cold injury occurring in November, 1950.

It is interesting to note that the grand average of number of fruits per 454 grams of each spray treatment in the five orchards, which includes the four seasons, was not significantly different, 112 fruits for the ferbam treatment, 115 fruits for the fixed copper treatment, and 112 fruits for the nabam treatments (Table 20). This indicated that the effects of spray materials on the number of fruits per 454 grams was dependent upon climatic factors and tree vigor as related to fertilizer application and soil management. The differences resulting from variations of seasons for any one orchard were as great as variations resulting from spray treatment.

TABLE 20

THE INFLUENCE OF SPRAY MATERIALS AND SEASONAL VARIATIONS ON THE NUMBER OF SOUR CHERRY FRUITS PER 454 GRAMS IN FIVE COMMERCIAL ORCHARDS

Season	Orchard	Spray treatment			Seasonal average	L.S.D. between treatment averages	
		Ferbam	Fixed copper	Nabam		5%	1%
1949	A	116	127	116		8	12
	B	-	-	-		-	-
	C	115	121	118		11	16
	D	123	134	112		8	12
	E	133	131	122		13	18
Average		122	128	117	-		
L.S.D. 5% - 5; 1% - 6							
1950	A	103	113	110		13	19
	B	118	107	115		9	13
	C	117	117	113		6	9
	D	120	129	111		6	9
	E	120	104	118		10	15
Average		115	114	113	114		
L.S.D. 5% - 5							
1951	A	95	113	99		18	27
	B	119	115	113		16	23
	C	118	136	113		16	24
	D	115	129	100		7	11
	E	114	103	119		16	24
Average		112	119	109	113		
L.S.D. 5% - 7; 1% - 10							
1952	A	94	103	96		10	14
	B	120	117	113		12	17
	C	130	131	132		9	14
	D	109	108	123		13	18
	E	107	99	113		10	15
Average		112	112	115	113		
L.S.D. 5% - 5							
Treatment average*		112	115	112			
L.S.D. 5% - 9							

*1949 data omitted from the treatment average because the size of fruit in Orchard B was not available

Effects of orchard management: The significant decrease in the average number of fruits per 454 grams from the ferbam and nabam spray treatments of Orchard A (Table 19) was apparently due to the progressive annual increase of tree vigor which resulted from the change from sod to clean cultivation in that orchard.

Application of fertilizer, pruning and soil management, as they affect tree vigor, are apparently responsible for much of the variation of the weight of cherry fruits. The average number of fruits per 454 grams in Orchards A, D, and E was significantly less in 1952 than in 1949, when the trees in these orchards had reached their highest state of vigor (Table 21). The average for Orchard C was excessively high in 1952 because of the cold injury to the trees in 1950 and 1951.

Effect of variations in seasons: Variation in seasons had no effect on the over-all average number of fruits per 454 grams from all spray treatments in the five orchards. This was shown by the figures, 114 fruits in 1950 and 113 fruits in 1951 and 1952 (Table 20).

The increase in average number of fruits per 454 grams in Orchard C in 1951 and 1952, from 115 fruits in 1949 to 122 in 1951 and 131 in 1952 (Table 21) was apparently due to cold injury in 1950 and 1951, as explained previously. The consistent decrease of number of fruits per 454 grams from Orchards A, D, and E (Table 21) from 1949 through 1952, was probably also the result of increased tree vigor and not variation in seasons.

TABLE 21

EFFECT OF SEASONAL AND ORCHARD VARIATIONS ON THE AVERAGE NUMBER OF SOUR CHERRY FRUITS PER 454 GRAMS FROM FERBAM, FIXED COPPER AND NABAM SPRAY TREATMENTS

Season	Orchard A	Orchard B	Orchard C	Orchard D	Orchard E	L.S.D. between orchard averages within a season 5%	1%
1949	120	--	118	123	129	6	9
1950	109	113	115	120	114	6	8
1951	102	115	122	115	112	9	12
1952	98	117	131	113	106	7	9

L.S.D. between seasonal averages within an orchard:

	A	B	C	D	E
5%	7	6	6	4	6
1%	10	9	8	6	8

The absence of apparent effect of moisture on the average number of fruits per 454 grams was not surprising, as the rainfall was adequate for good cherry production during each of the four seasons.

Soluble solids content

Effect of spray materials: The use of fixed copper resulted in a significant increase of percent soluble solids in Orchards A, B, and C as compared to the soluble solids content of fruits from trees sprayed with ferbam, and in Orchard E as compared to trees sprayed with nabam (Table 22).

In all spray treatments the percent soluble solids of fruits from Orchard D was approximately 3.0 percent higher than the soluble solids content of fruits from the other orchards. This was apparently due to delay in time of harvest in Orchard D each year as compared to time of harvest of Orchards A, B, and C. In the detailed study at East Lansing a delay in time of harvest was shown to increase, significantly, the percent soluble solids of the fruit.

In 1952 the high rainfall resulted in a reduction of percent soluble solids in fruits from all spray treatments and reduced the tendency of fixed copper to increase soluble solids of the fruit, because the differences between spray treatments were not significant in that year (Table 23). However, an increase of soluble solids of fruits from the fixed copper spray treatments was shown by the averages for

TABLE 22

THE EFFECT OF SPRAY TREATMENT AND ORCHARD VARIATION ON THE AVERAGE SOLUBLE SOLIDS CONTENT (PERCENT) OF SOUR CHERRY FRUITS (1949-1952)

Spray material	Orchard					L.S.D. between orchard averages within a treatment	
	A	B	C	D	E	5%	1%
Ferbam	13.3	13.6	13.0	15.9	13.8	1.5	2.0
Fixed copper	15.0	14.8	14.4	17.0	14.4	2.0	2.8
Nabam	14.5	14.1	13.1	16.1	13.3	1.7	2.3

L.S.D. between treatment averages within an orchard:	A	B	C	D	E
5%	0.7	0.9	1.3	1.4	0.9
1%	1.0	1.3	2.0	2.2	1.3

TABLE 23

THE INFLUENCE OF SPRAY TREATMENT AND SEASONAL VARIATIONS ON THE AVERAGE SOLUBLE SOLIDS CONTENT (PERCENT) OF SOUR CHERRY FRUITS (1949-1952)

Season	Orchard	Spray treatment: Ferbam	Spray treatment: Fixed copper	Spray treatment: Nabam	Seasonal average	L.S.D. between treatment averages: 5%	L.S.D. between treatment averages: 1%
1949	A	14.8	16.4	15.9		1.3	2.0
	B	14.2	15.5	13.9		1.3	1.9
	C	13.4	14.7	12.9		1.1	1.6
	D	16.7	18.5	16.1		1.3	1.9
	E	12.8	13.7	12.5		1.4	2.0
Average		14.4	15.7	14.2	14.8		
L.S.D. 5% - 0.6; 1% - 0.8							
1950	A	14.0	15.4	14.3		0.7	0.9
	B	13.9	15.0	14.3		0.9	1.3
	C	12.9	14.8	13.9		1.2	1.8
	D	17.1	19.8	18.9		1.4	2.1
	E	14.0	15.6	13.7		0.8	1.2
Average		14.4	16.1	15.1	15.2		
L.S.D. 5% - 0.5; 1% - 0.6							
1951	A	12.7	14.9	14.3		1.4	2.0
	B	13.1	15.2	14.7		1.7	2.5
	C	12.4	12.7	13.1		0.9	1.4
	D	15.9	15.8	15.9		1.0	1.4
	E	15.0	15.1	15.0		2.4	3.5
Average		13.8	14.8	14.6	14.4		
L.S.D. 5% - 0.8; 1% - 1.0							
1952	A	11.3	13.4	13.3		1.4	2.0
	B	13.0	13.5	13.4		1.7	2.5
	C	13.4	15.4	12.4		1.0	1.5
	D	14.0	14.1	13.3		1.8	2.6
	E	13.4	13.0	12.1		0.9	1.2
Average		13.1	13.9	12.9	13.3		
L.S.D. 5% - 1.2; 1% - 1.5							
L.S.D. between yearly averages: 5%		1.3	1.8	1.5			
1%		1.8	2.5	2.1			
Treatment average		13.9	15.1	14.2			
L.S.D. 5% - 0.6; 1% - 0.9							

Comparison of seasonal averages of all orchards and treatments:

1949, 1950 and 1951, and by the averages for the five orchards during the four years, which were: ferbam 13.9 percent, fixed copper 15.1 percent and nabam 14.2 percent (Table 23).

Effects of orchard management: The average percent soluble solids of all fruits from Orchard D during the four harvest seasons was from 2.2 to 2.9 percent higher than the fruit of the other orchards (Table 24). This difference may have been the result of delayed harvest, because the detailed study at East Lansing showed that percent soluble solids increased throughout the harvest season and increased most rapidly during the first two weeks of harvest.

Effects of seasonal variation: The yearly average soluble solids content of all fruits from the five commercial orchards did not change significantly in 1949, 1950 and 1951, however, in 1952 there was a significant decrease, from 14.4 percent in 1951 to 13.3 percent in 1952 (Table 23). This decrease was probably due to a higher moisture content of the fruit in 1952 as a result of the excessive rainfall occurring in July, 1952, which has been pointed out previously.

TABLE 24

THE INFLUENCE OF SEASONAL AND ORCHARD VARIATIONS ON THE AVERAGE SOLUBLE SOLIDS CONTENT (PERCENT) OF SOUR CHERRY FRUITS FROM FERBAM, FIXED COPPER AND NABAM SPRAY TREATMENTS

Season	Orchard					L.S.D. between orchard averages within a season	
	A	B	C	D	E	5%	1%
1949	15.7	14.6	13.7	17.1	13.0	0.8	1.0
1950	14.6	14.4	13.9	18.6	14.4	0.6	0.8
1951	14.0	14.3	12.7	15.9	15.0	1.0	1.4
1952	12.7	13.3	13.7	13.8	12.9	1.5	2.0
Average	14.2	14.2	13.5	16.4	13.8		

L.S.D. 5% - 1.5; 1% - 2.1

L.S.D. between seasonal averages within an orchard:

	A	B	C	D	E
5%	0.8	1.0	1.4	1.7	1.0
1%	1.2	1.5	2.2	2.5	1.5

DISCUSSION

The cherry growers of Michigan are interested in spray chemicals from the standpoint of: (1) their effectiveness to control pests, (2) their effect on size and weight of individual fruits, (3) total yield of fruit, (4) their accumulative effects on the productiveness of the trees over a period of years, and (5) the economy of purchase. This interest has prompted the search for new fungicides owing to the fact that numerous investigators have shown that the use of spray chemicals such as Bordeaux mixture and proprietory fixed copper compounds have caused dwarfing of fruit and leaves and have reduced yields of fruit (6, 8, 14, 20, 21, 24, 30, 36).

Fruit processors, on the other hand, are vitally interested in spray chemicals as they affect the quality of processed fruit, and especially as they affect the soluble solids content of fruit. The soluble solids content of the fruit has been reported to be related to drained weight (20, 23). However this was not found by Bedford and Robertson (1). Langer and Fisher (20) reported a definite decrease in soluble solids and total solids from the use of ferbam as compared to the use of fixed copper for the control of leaf spot. They stated also that, with a constant put-in weight of 85 ounces per No. 10

can, without exception the drained weight of processed cherries from trees sprayed with ferbam was lower than the drained weight of processed cherries from trees sprayed with fixed copper. Lewis and Groves (23) stated that "a variation in soluble solids content from 14 to 18 percent may mean a difference of 11,500 No. 10 cans of cherries that can be obtained from a million pounds of fresh fruit." If this is true, although contrary to the findings of Bedford and Robertson (1) who reported on the results from processing cherries from the different spray plots of the commercial orchards reported herein, the fungicides favorable to the processor could be somewhat unfavorable economically to the grower.

The time of harvest as it affected maturity of fruits did not apparently change the weight or size of fruit except during the first three to seven days after the fruits could be harvested commercially in the study carried on at the Michigan State College Horticulture Farm. A comparison of results from Orchard C with those of Orchard D in 1949 and 1950 seems to verify these findings. Orchard D was located farther south than Orchard C, blossomed several days earlier than Orchard C and was harvested seven to ten days later than Orchard C. Yet, there was little to no difference between the weights of cherry fruits of these two orchards (Table 9). These two orchards were similar in vigor, in soil management practices and general tree conditions. The occurrence of rain such as the 10-day rainy period from July 14 to July 23, 1952, at the Michigan State College Horticulture Farm caused a significant increase in the weight of fruit which was probably due to an increased water content. Fisher (11) and McMunn (26) reported similar increases in weight during rainy periods, and suggested that the increase in weight was probably due largely to reduced transpiration during periods of high relative humidity. However, when moisture was ample, excessive rains did not appear to increase the weight of fruits.

The time of harvest had little if any effect on the relation of fruit size and weight to spray materials at the Michigan State College Farm. Trees from the spray treatments which produced the largest fruits early in the season continued to have the largest fruits throughout the season (Tables 1 and 9) with no apparent change in size. This was shown also by comparing Orchard C and Orchard D in 1949 and 1952.

Lewis and Groves (21) found that the soluble solids content of cherry fruits increased significantly during the first two weeks of harvest. This finding appeared to be verified by the higher soluble solids content of fruits from Orchard D as compared to those from Orchard C. It has already been stated that Orchard D blossomed earlier and was picked later than Orchard C. This was clearly demonstrated in the study made in East Lansing. The increase of soluble solids content, as the picking season progressed, was accompanied by an increase in total solids content, an increase in total sugar content, and an increase in specific gravity which indicated a prolonged ripening process of the sour cherry fruits. Also, the occurrence of rain during the prolonged harvest period in 1952 caused a leveling off of the foregoing increases. Lewis and Groves (21) reported a similar happening for soluble solids content of fruits.

The effect of the increased rainfall was generally more pronounced in certain of the commercial orchards which was shown by the definite decrease of soluble solids content of the fruits in 1952 (Table 24). The season of 1952 was one of high rainfall compared to the three previous years. The 10-day rainy period at the Michigan State College Farm did cause a significant decrease of sugar content and increase of weight of fruits (Tables 1 and 7). These changes were probably due to increases of water content of the fruit. Fisher (11) and McMunn (26) reported similar findings of cherry fruits during periods of rainfall and high relative humidity. The greater decrease of sugar content as compared to the decrease in soluble solids content during the rainy periods in 1952 might be related, to the more favorable environmental conditions for vegetative growth and to greater enzymatic activity in assimilating the sugars into higher carbohydrate compounds.

The study at the Michigan State College Horticulture Farm, East Lansing, revealed that the weight of sour cherry fruits was reduced by the use of fixed copper sprays below those from trees sprayed with ferbam (Table 10). This agreed with the reports of other workers (6, 8, 14, 20, 21, 24, 30, 36). However, the study made in five commercial orchards showed that the effect of fixed copper sprays on the weight of cherries was greater in some seasons than others. This conforms with previous reports (9, 31, 37). Trees injured by cold as in Orchard C during the winter of 1950-1951 were more severely affected by fixed copper sprays the following season than when sprayed with ferbam or nabam (Table 15A). Studies conducted at East Lansing showed that during dry seasons the fruits from trees sprayed with copper were more severely affected than fruits from trees sprayed with organic chemicals (Table 10). In seasons when rainfall was not abundant as in 1949 in the commercial Orchards A, B, and C, the soluble solids content of the fruit was significantly higher than in the fruits sprayed with ferbam or nabam (Tables 13B, 14B, and 15B).

The differences in results of the study made in the Michigan State College Horticultural Farm, East Lansing, in 1951 and 1952 and those made in the commercial orchards during the same years may be explained by the differences in tree vigor and seasonal rainfall in the two areas of the State. The trees on the Michigan State College Farm were very low in vigor, due primarily to the fact that they were growing in sod and had received no fertilizer, and both seasons of fruit development, 1951 and 1952, were very dry. By contrast, in the commercial orchards the trees generally were vigorous and the rainfall during all four years of the study, 1949 through 1952, was adequate for good fruit development. This accounts for the fact that the fruits from the commercial orchards were heavier and were lower in soluble solids content than those from the East Lansing orchard. The effects of vigor of the trees and available moisture on the weight of fruits were clearly shown by the fact that the average fruit weight at East Lansing, expressed as the number of fruits per 454 grams was 155 fruits for the East Lansing orchard compared to 115 fruits for the commercial orchards. Also in the commercial orchards fruits from the fixed copper spray treatments were often as heavy or heavier than those from the organic spray treatments, ferbam and nabam (Tables 13A through 17A).

The soluble solids content of fruits was used in this study as an indication of the composition of sour cherry fruits. This was found to be possible in view of the high correlations of soluble solids content with total solids content and with total sugar content (Figures II - IV). No previous reports of correlations of total solids, soluble solids and sugars of the sour cherry have come to the attention of the author.

The soluble solids content was higher generally in fruits sprayed with fixed copper than in fruit sprayed with the organic materials in both the commercial orchards and at East Lansing. This agreed with the reports of other workers (1, 2, 4, 6, 14, 19, 20, 21, 23, 24, 30, 36, 44). However, as was reported by Kenworthy and Mitchell (19), the average soluble solids content of fruits was influenced by variations in tree vigor and in seasons. In this study the effect of fixed copper spray treatments on soluble solids content was clearly shown to be influenced by tree vigor (Tables 13B and 17B), and by seasonal variations (Table 23). In Table 13B the use of the sod plus mulch type of soil management in 1949 in Orchard A resulted in trees that were lower in vigor than when the sod was replaced by clean cultivation. Also, trees low in vigor owing to cold injury produced fruit higher in soluble solids than in the years 1951 and 1952 before the cold injury occurred (Table 15B). However, copper-sprayed fruits were, generally, higher in soluble solids content than fruits from the same environment sprayed with organic chemicals even though the number of fruits per 454 grams was similar for all treatments. This disputed the common thought that larger fruits are always lower in soluble solids content than smaller fruits.

In the study made at the Michigan State College Farm Orchard, East Lansing, fruits sprayed with lead arsenate were found to be higher in soluble solids and were lighter in weight than fruits sprayed with parathion. Fixed copper combined with lead arsenate definitely increased the soluble solids content and slightly decreased the weight of the fruit when compared with fruits sprayed with ferbam plus parathion (Tables 11 and 12).

A possible explanation of the injurious effect of fixed copper on the development of sour cherries may be associated with an inhibitory effect of soluble salts on amylase activity. According to Gortner (13) and Meyer and Anderson (27) even very minute concentrations of the soluble salts of copper may inhibit amylase activity, and this may interfere with the translocation of carbohydrates from the leaves to various parts of the plant. Vegetative growth would be limited because of the reduction in the quantity of carbohydrates translocated, which might reduce the development of new absorbing areas of the root system, thus limiting the amount of water that may be absorbed. McMunn (26) reported diurnal changes in water content of sour cherry fruits, and stated that it was due probably to a rate of transpiration in excess of the absorptive capacity of the root system and the transfer of water from the fruits to the leaves. Therefore, it might be conceivable that a reduced carbohydrate supply, through the inhibition of amylase by soluble salts of copper, might reduce root absorption below the demands of transpiration, especially during periods of low relative humidity.

A possible explanation of the effects of lead arsenate on the soluble solids content of cherry fruits might be the inhibiting action of arsenicals on growth substances. Bonner (3) has reported that arsenate inhibited the IAAinduced growth of excised _Avena_ coleoptiles through the inhibition of phosphate metabolism. Assuming this to be true in sour cherries, the increase in soluble solids of the fruit might be a result of accumulations of carbohydrates due to decreased vegetative growth.

From the foregoing discussion and the data presented it may be concluded that fixed copper sprays used on sour cherries may reduce the weight of fruit and increase the soluble solids content, total solids content and total sugar content of the fruits when compared with fruits sprayed with ferbam and nabam. However, the physiological effects of any pesticide chemical on the quality of sour cherries may be modified to a great extent by the influences of variation in growing season and by differences of tree vigor. Also, differences in weight and soluble solids content of cherry fruits may be as great or greater between orchards or between harvest seasons than between spray treatments in any one orchard for any one growing season.

SUMMARY

An investigation was made in 1951 and 1952 at the Michigan State College Horticultural Farm, East Lansing, to determine the effects of time of harvest on the progressive physical and chemical changes in the development of Montmorency cherry fruits (Prunus cerasus L.) during a three-week harvesting period. Four trees were selected from a planting of 64 trees for uniformity of size and vigor. Approximately 600 grams of fruit were harvested bi-weekly from each tree for analysis as follows: fruit weight - determination of number of fruits required for 454 grams; size of fruit - average transverse diameter of 20 fruits; firmness of flesh - determination of percent compression in direction of transverse diameter; soluble solids content - refractive indices of expressed juice; total solids content - average oven dry weight of entire fruits; total sugar content - percent invert sugar determined by the Munsen Walker gravimetric procedure; specific gravity - calculated from weight of fruit in air and when submerged in water.

1. There was a significant increase in soluble solids, total solids, and total sugar content and in specific gravity of the fruits as the harvest progressed. The most pronounced increase was during the first two weeks of the

harvesting period. Highly significant positive correlations were found between increases in soluble solids and total solids in 1951 ($r = 0.816$), and 1952 ($r = 0.966$) and between the increase in soluble solids and total sugar in 1952 ($r = 0.923$), as the harvest season progressed.

2. A decrease in the total solids content of the fruit was noted in all treatments immediately following a 1.27-inch rain on July 27, 1951. A similar decrease in total sugar and increase in weight of fruit were noted in all treatments following a 10-day rainy period, from July 14 to July 23, 1952, during which time 1.93 inches of rain fell.

3. The fruits became gradually less firm for two weeks following the beginning of harvest, after which time they became more firm.

4. The average transverse diameter of the cherries changed very little throughout the harvest period.

A second study was made in 1951 and 1952 at the Michigan State College Horticultural Farm, East Lansing, to determine the effects of certain inorganic and organic spray chemicals on the weight and soluble solids content of sour cherry fruits.

1. Trees sprayed with fixed copper produced fruits higher in soluble solids content and lower in weight than fruits sprayed with ferbam.

2. Fruits from trees sprayed with lead arsenate tended to be lower in weight and higher in soluble solids content

than those from trees sprayed with parathion. Trees sprayed with fixed copper plus lead arsenate definitely produced fruits lower in weight and higher in soluble solids than trees sprayed with ferbam plus parathion.

3. There was evidence that the dry weather during the 1952 harvest season had a greater influence than spray treatments on the weight of cherry fruits.

A third investigation was made from 1949 to 1952, in five commercial orchards located in two of the cherry producing areas of Michigan, to determine the effects of spray materials, variations in orchards, and variations in seasons on the weight and soluble solids content of Montmorency cherry fruits. The fungicidal spray materials used in this study were ferbam, fixed copper, and nabam. The sprays were applied by the grower as a part of his regular spraying program. Samples of fruit were collected in each orchard at the same time the grower was harvesting the crop.

1. Trees of moderate vigor, sprayed with fixed copper produced fruits lighter in weight during 1949 than trees sprayed with ferbam or nabam. However, trees of very high vigor, sprayed with fixed copper, produced as heavy or heavier fruits than trees sprayed with ferbam or nabam. This was especially true in years when rainfall was high during July just before harvest. There was generally no difference between the weight of fruits sprayed with ferbam and nabam.

2. Even though trees sprayed with fixed copper pro-

duced fruits with lower soluble solids content than those sprayed with ferbam or nabam, differences in soluble solids content of fruits from different orchards and in different seasons were as great or greater than the differences due to spray materials.

3. In Orchard C, low tree vigor caused by winter injury resulted in increased soluble solids content and reduced weight of fruits from all spray treatments. However, the use of fixed copper had a greater unfavorable influence on number of fruits per 454 grams (weight of fruits) than did nabam and ferbam, and a more favorable influence on the soluble solids content than nabam and ferbam.

4. In Orchard A changing soil management from sod to clean cultivation resulted in a significant decrease in soluble solids content of harvested fruit from all spray treatments and significantly increased the number of fruits per 454 grams (weight of fruits) harvested from all three spray treatments.

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