THE INFLUENCE OF MATURITY AND STORAGE TREATMENT ON THE STORAGE LIFE AND CERTAIN PHYSIOLOGICAL RESPONSES OF STAYMARED AND YORKING APPLES

by

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INTRODUCTION

The apple is the most important pomological fruit in Virginia, and harvesting at the proper maturity is one of the most difficult problems which confronts our apple producers. The stage of maturity at which the apple is picked determines to a great extent the disorders that occur in storage, and the marketable length of storage life of the fruit.

Probably more research has been done on the storage of apples than with any other fruit. Rather extensive tests have been made with different storage temperatures to determine the best temperature to store apples. Generally speaking, with some varietal exceptions, the nearer the storage temperature is to the freezing point of the apple, without actually freezing the apple tissue, the longer the fruit will remain in good condition. Magness in 1926 showed that a storage temperature of 30° F. will increase the storage life of apple fruits about 25 per cent over 32° F. storage. However, this temperature is not recommended because it is too close to the freezing point (about 28° F.) of the apple. For this reason a temperature of 31-32° F. has long been recommended for the storage of most varieties of apples.

Although storage at a temperature of 32° F. may be recommended for apples, storage temperatures of 36° F. may be found in Virginia apple storages and temperatures up to 40° F. may occur in the common apple storages of Virginia.

Several maturity studies have been made in other apple growing areas, but very little research has been done in Virginia on apple maturity or

response to different storage temperatures. In view of this fact it was decided to begin a study whereby basic information would be obtained on the physiological responses in storage of different maturities of Virginia apples. This information in turn could then be used for studies of a more technical nature.

In this experiment different maturity pickings of Staymared and Yorking apples were made during the harvest seasons of 1949 and 1950, and each picking was stored at 32°, 36°, and 40° F. to ascertain differences in physiological responses.

IV

REVIEW OF LITERATURE

Maturity of Fruit and Scald

Fisher (5) reported that there is a direct association between various physiological disorders of apples and their degree of maturity when picked. Of these, bitter pit and storage scald are associated with immaturity, whereas Jonathan spot, soggy breakdown, water core, and internal breakdown are associated with over maturity.

According to Fisher (5) storage scald is the most serious disorder of apples in storage. He describes scald as a surface browning or blackening that develops in 60 to 90 days after harvest in such early ripening varieties as Grimes Golden and in 100 to 150 days with later apple varieties.

Haller and Magness (9) found that picking the fruit at the proper maturity helped to prevent scald. They suggest that the possible storage life of York Imperial is determined almost entirely by the development of storage scald. Haller and Smith (10) observed that Stayman apples showed great variability in their susceptibility to scald, depending upon the source and other conditions. Kidd and West (13) in England reported that the less mature fruits lost more water in storage, and without control measures the earlier the apples were harvested the more susceptible the fruits were to surface scald.

According to Davis and Blair (4), maturity at the time of harvest appeared to be the most important factor in apple scald with the McIntosh and Fameuse varieties. Christopher (3) made a study of the effect of delayed harvest upon storage scald development with the Rhode Island Greening.

and Cortland varieties, and found with the Cortland the time of harvest appeared to be the only factor involved. Delaying the harvest of the Rhode Island Greening apples until late September resulted in larger apples, less scald, and very little breakdown.

Smock (18) reports that immature apples are likely to shrivel in storage, and be susceptible to storage disorders such as scald and bitter pit. He also observed that apples too mature when picked are likely to have a short storage life and break down prematurely.

Smock and Southwick (20) made an extensive investigation of the effect of maturity on storage scald over seven seasons. The fruit was picked at weekly intervals and stored at 40° F. The Rhode Island Greening and Cortland varieties were used in the test. They report that scald became less severe as the picking date was delayed. However, delayed picking hardly seems to be the solution to control scald, because the fruit may become overmature and then be subject to internal breakdown.

Brooks and others (1) found that scald increased in intensity up to 66° F. Above this temperature it decreased, and no scald could be produced at 77° F. In studies of scald on apples stored at 30°, 32°, 34°, 36°, and 40° F., Plagge and others (17) observed that scald increased with increase of temperature.

Temperature of Storage

In a study with the Stayman and York Imperial varieties from the

Potomac River Valley, using storage temperatures of 32° and 36° F., Haller and Lutz (7) found that the apples were distinctly softer and riper after storage at 36° F. as compared to the 32° F. stored apples. Rather large differences in the amount of scald were apparent in apples from the two temperatures, but these differences were not consistently greater at either temperature. The data for all three seasons (1935, 1936, 1937) indicate that 32° F. was preferable to 36° F. for storage for Stayman apples. The York Imperial variety also showed less scald and was firmer at 32° F. than when stored at 36° F.

Research by Magness and others (15) has shown that when apples are stored at 40° F., the rate of ripening is about double that at 32° F., and at 60° F. the rate is about three times that at 40° F.

According to Hukill and Smith (12) apples exposed to a temperature fluctuating from 30° to 34° F. will keep just as long as if stored at a uniform temperature of 32° F.

Haller and his associates (8) made a study of different maturity pickings of 16 apple varieties over three seasons of production at the Arlington Experimental Farm, Arlington, Virginia, and stored at temperatures of 32°, 36°, and 70° F. Their results show that with the Stayman variety at 70° F. some lots soften to as low as eight pounds pressure. When held at 32° to 36° F. practically all the lots tested between 11 and 12 pounds at the end of the storage period (April 15), and showed little or no further softening after one week at 70° F. For the York Imperial variety they found the softening rate was not very uniform. In some lots at 70° F. the pressures tended to level off at about 15 to 14 pounds, and

in several instances the York Imperial increased in firmness during ripening.

Firmness of Fruit

Hinton (11) studied the rate of softening after picking of apple fruits at the Long Ashton Station, England, and found the rate of softening was greater in the late harvested fruits. Haller and others (8) made an investigation of maturity of fruit and reported that each stage of ripeness during the storage of the fruit was represented by a fairly definite range of firmness.

Smock and Neubert (19) observed that the softening in apple fruits is accompanied by a change from insoluble to soluble pectin. Haller (6) describes the softening of apples after harvest as being associated with the hydrolysis of the insoluble cell wall cementing material, protopectin, to soluble pectin.

Morris (16) observed a considerable increase in the pressure test of Rome Beauty apples from Wenatchee, Washington. These apples were held in cold storage from harvest till March 27, and then in common storage at a temperature of about 43° to 45° F. Tests were made on several sizes of fruit on April 8 and May 18. The firmness increased about two pounds on May 18 over the tests of April 8.

Water Core

Water core, as described by Brooks and others (2), is a nonparasitic disorder characterized by a glassy or watery appearance of the flesh. This physiological disorder is particularly bad in regions of intense heat and sunlight. High temperature at the time the apples are approach-

ing maturity is especially favorable to the development of the disorder. Water core apples have a high sap concentration, and the water core condition is apparently the result of sap exudation under pressure.

Bitter Pit

Smock and Neubert (19) describe bitter pit, a physiological disorder, as being characterized by the development of small brown spots or streaks in the flesh of the apple, particularly just beneath the skin. They report that the exact cause of the disease is not known, but all the evidence points to its being caused by some maladjustment in the normal water relation of the fruit. They present the hypothesis that any treatment which accentuates the "pulling power" of the leaves for water (because of their advantage in osmotic concentration) at the expense of the fruit will increase the susceptibility of the fruit to bitter pit in storage. Osmotic pressures were checked on each quarter of individual apples by the workers and it was found that the areas of lowest osmotic pressure were the most susceptible to bitter pit. As a protection against rapid development of bitter pit in storage they recommend prompt storage after harvest at a temperature of 32° - 34° F.

Brown Core

Smock and Neubert (19) report that brown core, a physiological disorder, is characterized by a premature browning of the flesh around the core. They state that brown core may actually have different causes in different varieties, but in most varieties it is a true low temperature disorder. These authors recommend a storage temperature of 36° or 40° F. as a means of avoiding brown core rather than storage at 32° F.

Internal Breakdown

According to Brooks, and his associates (1), internal breakdown is a nonparasitic disorder associated with large and overripe apples. It is characterized by a breaking down and browning of the interior of the apple. The skin usually retains its normal appearance, but is sometimes slightly duller and darker and in the later stages of the disease frequently cracks outward. The authors state that internal breakdown is a condition that characterizes the end of life of the apple, and is particularly common on apples harvested overmature.

Decay

In the Staymared variety most of the decay was due to blue mold Fungus, Penicillum expansum. In the Yorking variety, bitter rot fungus Glomerella cingulata, was the cause of most of the decay.

V

EXPERIMENTAL PROCEDURE

Varieties Used and Method of Harvest

The Staymared and Yorking apple varieties were used in this study. All the apples in these tests were procured from the Carat Orchards (Occanneechi Orchards) at Boones Mill, Virginia, in the Roanoke apple growing area. Experiment station personnel harvested the fruit and placed it directly into boxes of one bushel capacity. Care was taken to avoid bruising and only fruit 2½ - 3¼ inches in diameter was used. One-half pound of mineral oil paper was distributed as evenly as possible throughout each box. Prior to harvest the trees to be harvested were selected for uniformity of fruit and all pickings were made from these trees. The number of trees used in the test was kept to a minimum in order to avoid differences in the fruit due to soil variation, and other factors.

Location and Time of Storage

In the 1949 tests, the apples were stored the day harvested in the Roanoke Ice and Cold Storage for about one month at approximately 34° to 35° F., until completion of the refrigerated storage at Blacksburg, Virginia, at which time the different treatments were begun. In 1950 the apples were stored in their respective treatments on the harvest date in the refrigerated storage at Blacksburg, Virginia.

Maturity Pickings

Two maturity pickings were made in 1949. One picking was made on September 19, 1949, which was before commercial harvesting was begun, and

the second picking was made on October 4, 1949, which coincided with the commercial harvest for these varieties.

In 1950 three maturity pickings were made. One picking was made on September 25, approximately just before commercial harvesting should have begun as determined by U.S.D.A. recommendations on days from full bloom. The second picking was made on October 3, and the third picking was made on October 12, 1950.

Size of Lot and Storage Temperature

One box of each variety and of each picking was stored at 32°, 36° and 40° F. Apple samples from each lot were ripened at 70° F., and shelf life was determined. Tests were made on ten to twenty apples of this lot immediately after harvest, and at weekly intervals for at least three weeks, in order to determine the keeping quality and condition of the fruit at the beginning of the experiment.

Ripening Test

After the initial tests on all the lots of fruit in 1949 and 1950, representative samples were removed at various intervals from each experimental lot and placed in 70° F. for ripening and testing.

In the ripening tests ten apples from each lot were checked upon removal from storage, or within one day thereafter, and at approximately seven and fourteen days.

In the initial and subsequent ripening tests before and after storage the following factors were checked: surface color, ground color, firmness, soluble solids, dessert quality, and disorders such as scald, shrivel, bitter pit, water core, and decay.

Firmness

The firmness in pounds pressure of the fruit was determined by use of the Magness-Taylor pressure tester with a plunger seven-sixteenths of an inch in diameter and having a penetration of five-sixteenths of an inch. One puncture was made on the unblushed side of each apple after a thin slice of the apple was removed.

Ground Color

Ground color (the green to yellow skin color) was determined by using the California State Department of Agriculture Standard Color Chart for Maturity of Bartlett Pears. Of the several available fruit ground color charts, this color chart appeared to be most useful for the determination of ground color of the apple varieties studied in this experiment.

Soluble Solids

The percentage of soluble solids was checked by taking the juice from each apple sample, and testing it with a Bausch and Lomb juice refractometer.

Surface Color

Surface color (the per cent of red coloration) was estimated for each picking at harvest time.

Scald

The amount of scald on each apple was rated as slight, moderate, or severe. An apple was rated as having slight scald when one-quarter or less of the entire surface was covered with scald, moderate when more than one-quarter but less than one-half was affected, and severe when more than one-half of the apple was covered with scald.

Shriveling

The amount of shriveling was estimated as slight, moderate, or severe. The apple was rated as having slight shriveling when the apple skin would wrinkle when pressed between one's fingers, moderate when the apple had small wrinkles without applying pressure to it, and severe when deep wrinkles were evident.

Dessert Quality

Dessert quality of the fruit was judged by two samplers tasting each test lot and rating it as very poor, poor, fair, or good. This method is subject to personal error, but no more accurate rapid means of evaluating dessert quality was available.

Storage Life

Storage life of the fruit was determined as follows: For the Yorking variety the length of storage life of the fruit was considered terminated when the average of the sample tested was 13.75 pounds pressure or lower, or when the fruit developed decay, scald, and other disorders in sufficient quantity to make it unfit for marketing even though the fruit was firmer than 13.75 pounds pressure. For the Staymared variety the length of storage life was considered terminated when the average of the sample tested was 11 pounds pressure or lower, or when the fruit had developed scald, decay, or other disorders in sufficient quantity to make it unfit for marketing even though it was firmer than 11 pounds pressure. Actually, under good storage conditions, fruit testing the above pressures may remain at 32° F. in good condition for a considerable period, but it should be taken from the storage at these minimum pressures in order to withstand the

higher temperatures in marketing channels, and still reach the consumer in at least fair condition.

Shelf Life Studies

The shelf life studies in this experiment were made by removing a sample of fruit from the various temperatures and holding each sample at 70° F. This temperature was used in order to have a somewhat comparable condition to the condition of retail outlets and the home of the consumer. At 7 and 14 day intervals after removal from storage, physiological changes were checked, such as firmness, soluble solids, ground color, scald, decay, and other disorders.

VI

PRESENTATION OF RESULTS

Staymared Apples 1949-1950 and 1950-1951

1949-1950

The test results of all the Staymared apple pickings, and storage at different temperatures for the two seasons, 1949-1950 and 1950-1951, are presented in Tables 1 through 6. The changes in pounds pressure are shown graphically in Figures 1 through 5. The horizontal line across Figures 1 through 5, at 11 pounds pressure designates the end of normal storage life for the Staymared variety for this experiment.

Storage at 32° F.

Table 1 (1949-1950) shows the test data of the first and second picking at harvest, after storage at 32° F., and during ripening at 70° F. The initial data are presented in order that a comparison of shelf life of the fruit at harvest time can be made with fruit after it has been removed from the different storage treatments. At the beginning of the experiment the apples of the first picking, which were slightly immature and picked on September 19, 1949, had a pressure test reading of 17.5 pounds as compared with 15.8 pounds for the second picking, which was judged a more optimum picking for longest storage life. The second picking was made on October 4, 1949. After 164 days in storage the first picking had dropped to 11.1 pounds pressure whereas the pressure for the second picking was 11.7 pounds.

In all the tests made the first picking had more total scald than the second picking. After 231 days of storage the first picking showed 100

TABLE 1. STAYMARED APPLES, 1949-1950.
Tests of First and Second Pickings at Harvest, after Storage at 32° F., and during Ripening at 70° F.
First Picking September 19, 1949, Surface Color 88%.
Second Picking October 4, 1949, Surface Color 94%.

Picking	Days at 32° F.	Days at 70° F.	Ground Color	Pounds Pressure	% Soluble Solids	% Scald				% Decay	Quality **	Shrivel *
						S. *	M. *	Se. *	Total			
INITIAL DATA												
1	0	0	2.2	17.5	10.1	0	0	0	0	0	P	0
2	0	0	2.8	15.8	10.4	0	0	0	0	0	F	0
1	0	7	2.5	16.5	11.8	0	0	0	0	0	P	0
2	0	7	3.2	14.9	12.0	0	0	0	0	0	F	0
1	0	14	2.7	14.6	12.1	0	0	0	0	0	P-F	0
2	0	14	3.3	12.4	12.6	0	0	0	0	0	F-G	0
AFTER STORAGE AT 32° F.												
1	164	0	3.4	11.1	12.9	30	60	0	90	0	F-G	0
2	149	0	3.9	11.7	13.5	0	0	0	0	0	G	0
1	164	7	3.4	9.2	13.0	60	20	10	90	0	P-F	0
2	149	7	4.0	9.7	13.4	20	0	0	20	0	F	0
1	164	14	3.6	8.2	12.5	20	40	30	90	30	P-F	0
2	149	14	4.0	8.4	12.7	20	10	0	30	20	P-F	0
1	231	0	3.6	10.1	11.7	0	20	80	100	2	F	S.
2	216	0	3.9	10.1	11.9	30	40	10	80	0	F	0
1	231	7	3.9	9.0	12.2	10	20	60	90	20	P-F	M.
2	216	7	4.0	8.9	12.7	40	30	10	80	10	P-F	S.
1	231	14	3.9	7.8	12.2	0	40	60	100	28	VP-P	M.
2	216	14	4.0	7.8	12.5	20	40	30	90	9	P	S.-M.

* S. is slight, M. is moderate, Se. is severe.
** VP is very poor, P is poor, F is fair, G is good.

per cent scald of which 80 per cent was rated as severe, and the second picking, after 216 days of storage had 80 per cent total scald, of which only 10 per cent was rated as severe.

Decay was more severe in the first picking than in the second picking. In general the second picking was higher in dessert quality, and developed a smaller amount of shriveling than the first picking.

The ground color was slightly higher in the second picking, but the differences do not appear to be significant.

The per cent soluble solids was always higher in the apples of the second picking.

Storage at 36° F.

The results of tests of the first and second picking after storage at 36° F. and during ripening at 70° F. are presented in Table 2. At the end of 163 and 148 days of storage for pickings one and two respectively, both pickings had past their storage life as judged by firmness of the fruit. Considerable scald was apparent throughout the tests after storage at 36° F. and in all instances the first picking had a higher total amount of scald as well as higher percentages of moderate and severe scald.

The quality of fruit of the second picking was equal to or slightly better in all the lots tested. The amount of shriveling was higher in the first picking as compared to the second picking. However, at this temperature of storage, decay was more pronounced in the second picking, except in one test lot, than it was in the first picking.

Storage at 40° F.

The results of tests of the first and second picking at harvest, after

TABLE 2. STAYMARED APPLES, 1949-1950.
Tests of First and Second Pickings at Harvest, after Storage at 36° F., and during Ripening at 70° F.
First Picking September 19, 1949. Second Picking October 4, 1949.

Picking	Days at 36° F.	Days at 70° F.	Ground Color	Pounds Pressure	% Soluble Solids	% Scald				% Decay	Quality **	Shrivel *
						S. *	M. *	Se. *	Total			
INITIAL DATA												
1	0	0	2.2	17.5	10.1	0	0	0	0	0	P	0
2	0	0	2.8	15.8	10.4	0	0	0	0	0	F	0
AFTER STORAGE AT 36° F.												
1	163	0	3.2	10.8	11.8	20	20	30	70	0	F	0
2	148	0	4.0	9.8	12.3	20	0	0	20	0	F	0
1	163	7	3.5	9.2	12.2	20	50	30	100	0	P-F	0
2	148	7	4.0	9.1	12.4	40	10	10	60	0	P-F	0
1	231	0	3.8	8.9	12.1	0	20	80	100	15	P-F	M.
2	216	0	3.9	9.0	13.0	50	10	20	80	0	P-F	S.
1	231	7	4.0	8.3	12.4	0	20	80	100	10	P-F	M.-Se.
2	216	7	4.0	8.2	12.7	40	40	10	90	20	P-F	S.-M.
1	231	14	Insufficient sample			16	0	84	100	33	VP	M.-Se.
2	216	14	4.0	7.4	12.8	30	40	0	70	68	P	S.-M.

*S. is slight, M. is moderate, Se. is severe.
**VP is very poor, P is poor, F is fair, G is good.

storage at 40° F., and during ripening at 70° F., are presented in Table 3. The firmness in pounds pressure dropped sharply until it reached approximately eight pounds, and then there was very little change in firmness throughout the remainder of the experiment. Considerable scald developed in all test lots, but there were differences in the amount and severity of scald in the first and second picking. For example, after 163 days at 40° F. the first picking developed 100 per cent scald of which 20 per cent was slight, 40 per cent moderate, and 40 per cent severe. For the second picking, after 148 days at 40° F., only 50 per cent of the apples had developed scald, and it was only slight scald.

There are some differences in quality of fruit, the amount of shriveling, and ground color, but these did not appear to be of any significance at this temperature. The per cent of soluble solids was always higher in the apples of the second picking. This was true in apples stored at 32°, 36°, or 40° F.

Storage Life of Staymared, Stored at 32°, 36°, and 40° F., 1949-1950

The changes in firmness of the Staymared apples as influenced by storage temperatures of the first picking for 1949 are presented in Figure 1. As the temperature increased the storage life decreased. The length of storage life for the 32°, 36° , and 40° F. lots was six months, four months, and three months respectively.

Figure 2 shows the changes in firmness of Staymared apples as influenced by storage temperatures for the second picking. The storage life of the 40° F. lot, as indicated by the firmness in pounds pressure, was only two months. At a storage temperature of 36° F. the storage life had increased approximately two weeks, whereas the storage life of the 32° F.

TABLE 3. STAYMARED APPLES, 1949-1950.
Tests of First and Second Pickings at Harvest, after Storage at 40° F., and during Ripening at 70° F. First Picking September 19, 1949. Second Picking October 4, 1949.

Picking	Days at 40° F.	Days at 70° F.	Ground Color	Pounds Pressure	% Soluble Solids	% Scald				% Decay	Quality **	Shrivel *
						S. *	M. *	Se. *	Total			
INITIAL DATA												
1	0	0	2.2	17.5	10.1	0	0	0	0	0	P	0
2	0	0	2.8	15.8	10.4	0	0	0	0	0	F	0
AFTER STORAGE AT 40° F.												
1	163	0	3.8	8.3	12.3	20	40	40	100	0	P-F	0
2	148	0	3.8	8.9	13.2	50	0	0	50	0	P-F	0
1	163	7	4.0	8.2	12.2	0	30	70	100	5	P	0
2	148	7	4.0	9.1	12.7	70	10	0	80	5	P	0
1	163	15	4.0	8.2	12.3	0	40	60	100	20	P-F	0
2	148	15	4.0	7.0	12.5	50	25	25	100	45	P	0
1	200	0	3.6	8.7	11.4	20	20	60	100	7	P-F	S.-M.
2	185	0	3.9	8.2	12.5	60	0	0	60	4	P-F	S.-M.
1	200	7	3.8	7.9	11.8	20	10	60	90	3	P-F	S.-M.
2	85	7	4.0	8.3	12.7	30	30	30	90	0	P-F	S.-M.
1	200	13	4.0	8.0	11.9	10	0	90	100	42	P-F	S.-M.
2	185	13	4.0	8.1	12.1	20	40	30	90	36	P-F	S.

* S. is slight, M. is moderate, Se. is severe.
** VP is very poor, P is poor, F is fair, G is good.

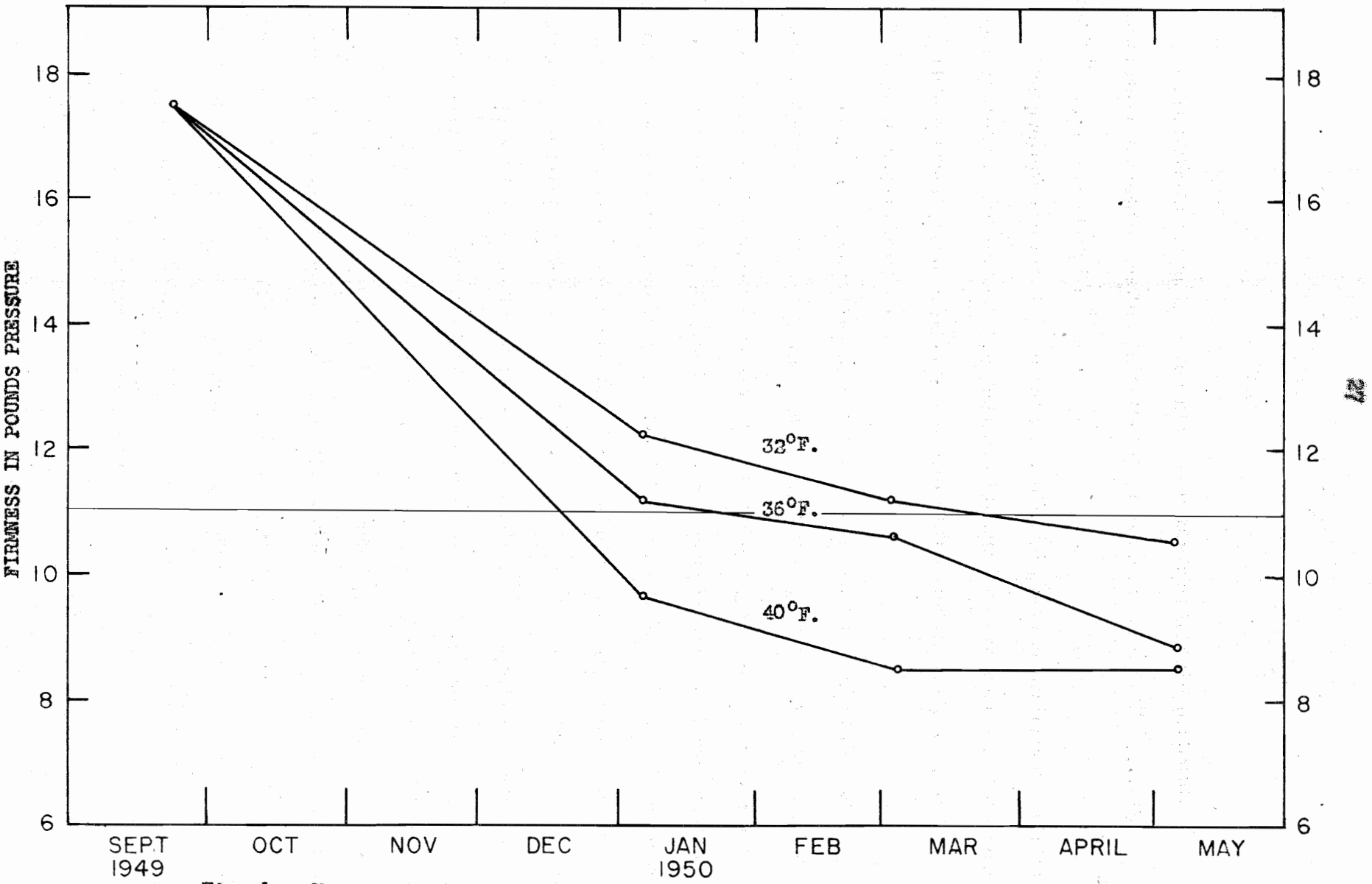

Fig. 1. Changes in Firmness of Staymared Apples as Influenced by Storage Temperatures. First Picking, Harvested September 19,1949.

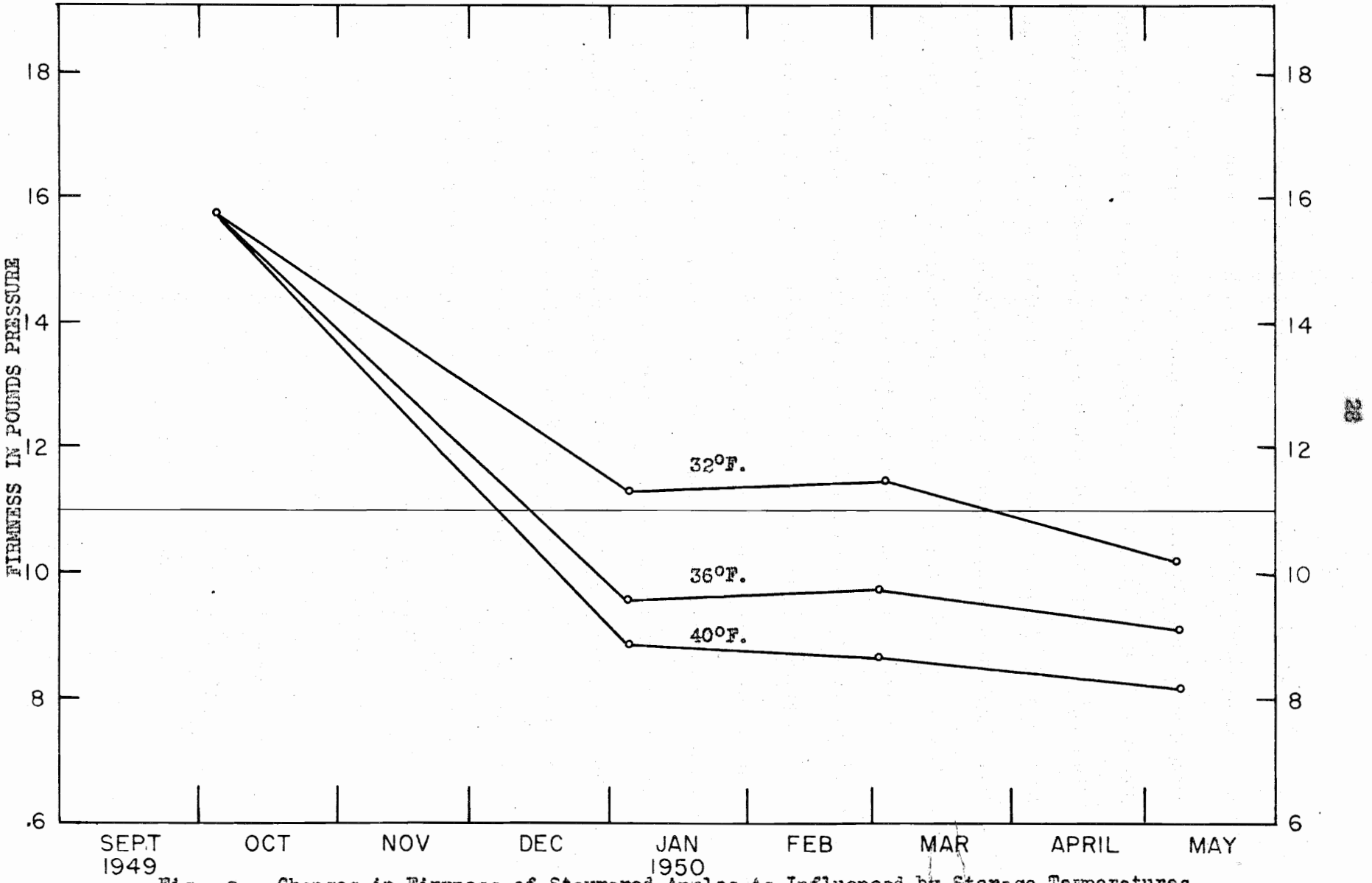

Fig. 2. Changes in Firmness of Staymared Apples As Influenced by Storage Temperatures. Second Picking, Harvested October 4,1949.

lot was more than double either the 36° or 40° F. sample.

1950-1951

Storage at 32° F.

Table 4 shows the test data of the first, second, and third picking at harvest, after storage at 32° F., and during ripening at 70° F. for 1950-1951. Some water core was present at harvest time in the second and third pickings, but it did not cause any decay in storage. This disease was reduced or disappeared in storage. There was only a little difference between the firmness of the three pickings on a given test date.

In all tests the first picking had the highest per cent of scald, and except for one test lot, the second picking developed more scald in storage and after ripening than the third picking.

Storage at 36° F.

The results of storage of the three pickings of Staymared at 36° F. at harvest, after storage at 36° F. and during ripening at 70° F. are presented in Table 5. At the first test of the fruit after storage, all the samples had dropped below 11 pounds pressure, which for this experiment is taken as the end of storage life of the fruit. Water core was present in the second and third pickings at harvest, but in storage it decreased in fruit of the third picking, and disappeared in apples of the second picking.

There was considerable difference in the amount of scald for the different samples. After 195 days at 36° F. the first picking had developed 80 per cent total scald. Of this 30 per cent was slight, 15 per cent moderate, and 35 per cent was severe. The second picking, after 186 days at 36° F. had developed only 55 per cent scald and it was all judged as slight in quantity.

TABLE 4. STAYMARED APPLES, 1950-1951.
Tests of First, Second, and Third Picking at Harvest, after Storage at 32° F., and during Ripening at 70° F.
First Picking September 25, 1950, Surface Color 80%.
Second Picking October 3, 1950, Surface Color 96%.
Third Picking October 12, 1950, Surface Color 95%.

Picking	Days at 36° F.	Days at 70° F.	Ground Color	Pounds Pressure	% Soluble Solids	% Scald				% Decay	Quality **	% Water Core
						S. *	M. *	Se. *	Total			
INITIAL DATA												
1	0	0	2.2	15.4	10.3	0	0	0	0	0	P-F	0
2	0	0	2.8	14.2	11.1	0	0	0	0	0	F-G	10
3	0	0	2.4	14.8	12.0	0	0	0	0	0	F	20
1	0	9	2.6	10.7	12.5	0	0	0	0	0	P-F	0
2	0	9	2.8	10.0	12.8	0	0	0	0	0	F-G	0
3	0	7	4.0	11.7	12.5	0	0	0	0	0	F-G	0
1	0	19	3.7	8.0	13.4	0	0	0	0	0	P-F	0
2	0	16	4.0	9.3	12.7	0	0	0	0	0	F-G	0
3	0	13	3.9	8.8	12.7	0	0	0	0	0	F-G	0
AFTER STORAGE AT 32° F.												
1	123	0	2.8	12.7	13.0	20	0	0	20	1	F-G	0
2	114	0	3.0	12.3	12.8	10	0	0	10	1	F-G	0
3	105	0	3.4	12.7	13.0	0	0	0	0	1	F-G	0
1	123	7	3.0	10.4	13.0	50	0	0	50	0	F-G	0
2	114	7	3.2	10.0	12.7	30	0	0	30	0	F	0
3	105	7	3.5	10.0	13.1	0	0	0	0	0	F-G	10
1	123	14	3.3	8.4	12.9	70	0	10	80	0	P-F	0
2	114	14	3.5	9.0	12.8	0	10	0	10	0	P-F	0
3	105	14	3.2	8.0	12.8	70	0	0	70	0	P-F	0
1	195	1	2.9	10.5	13.5	60	20	20	100	0	F	0
2	186	1	3.2	10.2	12.8	50	0	0	50	0	F	0
3	177	1	3.4	10.8	13.0	30	0	0	30	0	F-G	0

* S. is slight, M. is moderate, Se. is severe.
** P is poor, F. is fair, G is good. The letter is underlined when most of the apples were in that quality group.

TABLE 5. STAYMARED APPLES, 1950-1951.
Tests of First, Second, and Third Picking at Harvest, after Storage at 36° F., and during Ripening at 70° F. First Picking September 25, 1950, Second Picking October 3, 1950, and Third Picking October 12, 1950.

Picking	Days at 36° F.	Days at 70° F.	Ground Color	Pounds Pressure	% Soluble Solids	% Scald				% Decay	Quality **	% Water Core
						S. *	M. *	Se. *	Total			
INITIAL DATA												
1	0	0	2.2	15.4	10.3	0	0	0	0	0	P-F	0
2	0	0	2.8	14.2	11.1	0	0	0	0	0	F-G	10
3	0	0	2.4	14.8	12.0	0	0	0	0	0	F	20
AFTER STORAGE AT 36° F.												
1	195	1	3.2	9.5	12.8	30	15	35	80	5	P-F	0
2	186	1	3.3	9.4	12.9	55	0	0	55	3	F	0
3	177	1	3.7	9.2	13.1	15	0	0	15	3	F-G	10
1	195	7	3.5	8.2	13.0	10	40	50	100	20	P	0
2	186	7	3.9	8.8	13.0	10	20	0	30	0	P-F	0
3	177	7	4.0	9.6	12.6	10	10	0	20	5	F	0

* S. is slight, M. is moderate, Se. is severe.
** P is poor, F is fair, G is good. The letter is underlined when most of the apples were in that quality group.

The third picking, after 177 days of storage at 36° F., had only 15 per cent slight scald.

Storage at 40° F.

Results of the three Staymared pickings at harvest, after storage at 40° F. and during ripening, are presented in Table 6. These lots had a short storage life. At the end of 107 to 125 days at 40° F. the apples were soft, 8.3 to 9.2 pounds pressure.

In all the tests the first picking had the highest total amount of scald, with the second picking having less, and the third picking having the least scald present.

As much as ten per cent decay was found in the first picking after 125 days at 40° F. and seven days at 70° F. Decay was present in the other samples tested, but it was not consistently higher in any particular lot of fruit. Water core was present in some of the samples, and it was still present in the third picking after 107 days of storage at 40° F.

The third picking was consistently higher in quality after storage at 40° F. than either the first or second picking.

Storage Life of Staymared at 32°, 36°, and 40° F., 1950-1951

Figure 3 shows the changes in firmness of the first picking in 1950 of Staymared apples as influenced by storage temperatures. Unlike the experiments of 1949, this test shows considerable difference between storage at 40° F. and 36° F. storage. The 36° F. lot had a storage life of five months, as compared to approximately two and one-half months for the 40° F. sample. The 32° F. lot was still in good condition after about six months of storage, as shown by Figure 3.

TABLE 6. STAYMARED APPLES, 1950-1951.
Tests of First, Second and Third Picking at Harvest, after Storage at 40° F., and During Ripening at 70° F.
First Picking September 25, 1950, Second Picking October 3, 1950, and Third Picking October 12, 1950.

Picking	Days at 40° F.	Days at 70° F.	Ground Color	Pounds Pressure	% Soluble Solids	% Scald				% Decay	Quality **	% Water Core
						S. *	M. *	Se. *	Total			
INITIAL DATA												
1	0	0	2.2	15.4	10.3	0	0	0	0	0	P-F	0
2	0	0	2.8	14.2	11.1	0	0	0	0	0	F-G	10
3	0	0	2.4	14.8	12.0	0	0	0	0	0	F	20
AFTER STORAGE AT 40° F.												
1	125	0	3.0	8.3	12.4	80	0	0	80	2	P-F	0
2	116	0	3.2	8.6	12.5	70	0	0	70	1	F	0
3	107	0	3.2	9.2	12.8	50	0	0	50	3	F-G	20
1	125	7	3.2	7.6	12.1	80	0	0	80	10	P	0
2	116	7	3.6	8.8	12.6	40	0	0	40	0	P-F	0
3	107	7	3.4	8.1	12.9	30	0	0	30	5	P-F	0

* S. is slight, M. is moderate, Se. is severe.
** P is poor, F is fair, G is good. The letter is underlined when most of the apples were in that quality group.

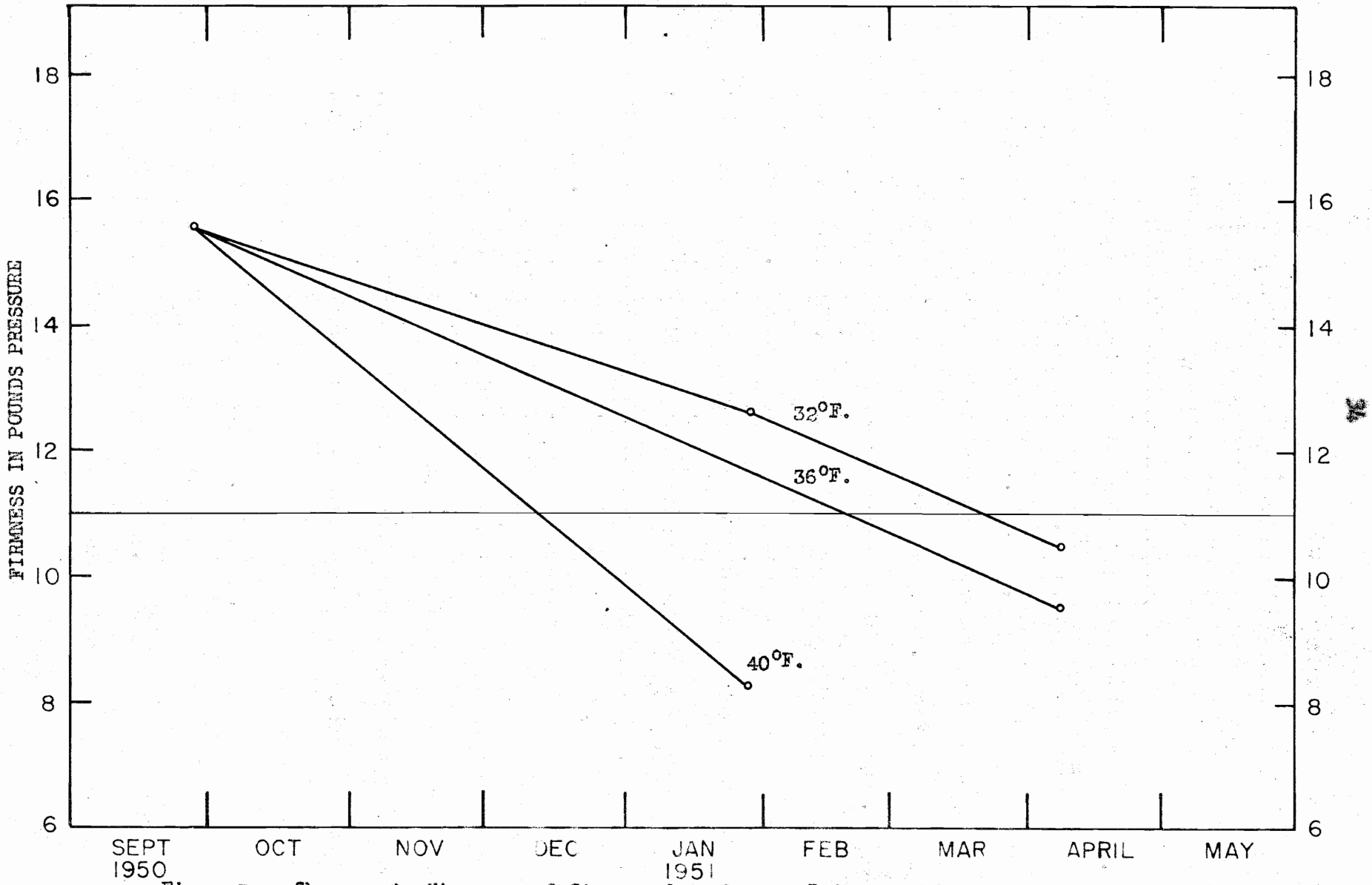

Fig. 3. Changes in Firmness of Staymared Apples as Influenced by Storage Temperatures. First Picking, Harvested September 25, 1950.

The changes in firmness of the second picking of Staymared apples as influenced by temperatures are shown in Figure 4. The storage life of the 32° F. sample was between five and five and one-half months, as compared to four months for the 36° F. lot, and only two months for the 40° F. test lot.

Figure 5 shows the changes in firmness of Staymared apples, as influenced by storage temperatures, of the third picking made in 1950. The storage life of the 40° F. sample was approximately two and one-half months, as compared to four months for the 36° F. lot, and five and one-half months for the 32° F. sample.

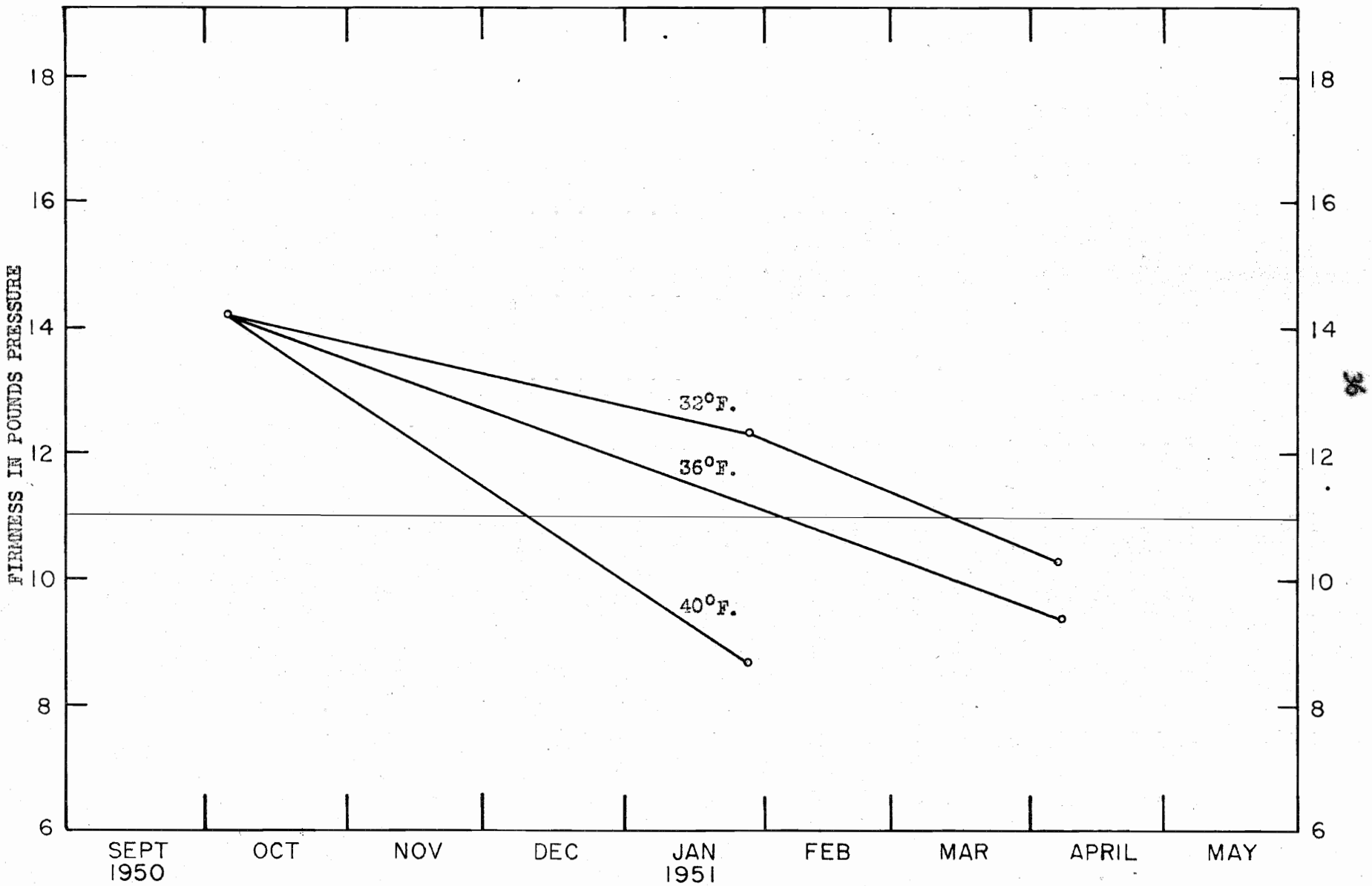

Fig. 4. Changes in Firmness of Staymared Apples as Influenced by Storage Temperatures. Second Picking, Harvested October 3, 1950.

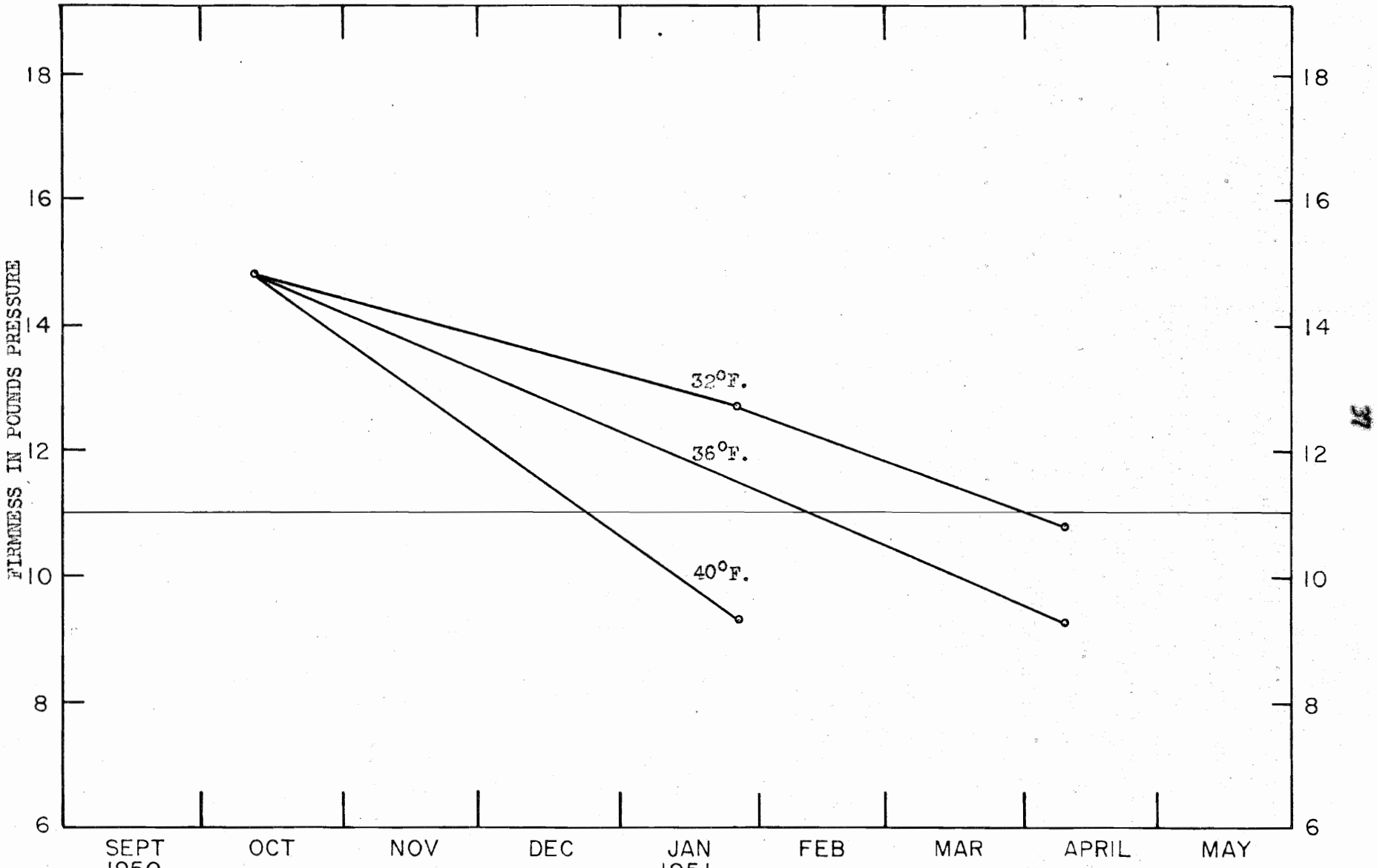

Fig. 5. Changes in Firmness of Staymared Apples as Influenced by Storage Temperatures. Third Picking, Harvested October 12, 1950.

Yorking Apples 1949-1950 and 1950-1951

1949-1950

The results of all the pickings, stored at different temperatures for the two seasons (1949-1950 and 1950-1951) are presented in Tables 7 through 12. The changes in pounds pressure are shown graphically in Figures 6 through 10. The horizontal line across Figures 8, 9, and 10, at 13.75 pounds pressure, indicates the end of normal storage life of fruit for this experiment. In Figures 6 and 7 no line was drawn, because some of the test lots had to be discontinued because of excessive decay before they reached 13.75 pounds pressure.

Storage at 32° F.

Table 7 shows the test data of the first and second pickings at harvest, after storage at 32° F., and during ripening at 70° F. Considerable scald developed after a short time in storage in both lots, but in all the tests made the first picking had a higher total amount as well as a higher percentage of moderate and severe scald.

Decay was more severe in the first picking than it was in the second picking.

The ground color was consistently higher in the second picking.

The soluble solids and quality were as high or higher in the second picking.

Storage at 36° F.

The results of tests of the first and second pickings at harvest, after storage at 36° F., and during ripening at 70° F. are shown in Table 8. There is considerable difference in the results of this variety

TABLE 7. YORKING APPLES, 1949-1950.
Tests of First and Second Pickings at Harvest, after Storage at 32° F., and during Ripening at 70° F.
First Picking September 19, 1949, Surface Color 80%.
Second Picking October 4, 1949, Surface Color 90%.

Picking	Days at 32° F.	Days at 70° F.	Ground Color	Pounds Pressure	% Soluble Solids	% Scald				% Decay	Quality **
						S. *	M. *	Se. *	Total		
INITIAL DATA											
1	0	0	2.2	18.0	10.4	0	0	0	0	0	P
2	0	0	3.0	17.0	10.7	0	0	0	0	0	P
1	0	7	2.7	16.7	11.5	0	0	0	0	0	P
2	0	7	3.4	18.0	11.8	0	0	0	0	0	F
1	0	14	2.8	15.0	12.6	0	0	0	0	0	P
2	0	14	3.5	15.6	13.9	0	0	0	0	0	F-G
AFTER STORAGE AT 32° F.											
1	106	0	2.7	15.6	12.8	40	30	0	70	0	F-G
2	90	0	3.7	15.1	13.2	10	0	0	10	0	G
1	106	8	2.9	15.8	12.9	32	32	36	100	0	F
2	90	8	3.6	14.4	13.9	10	5	0	15	0	G
1	106	15	3.5	13.8	12.8	30	50	20	100	50	P-F
2	90	15	3.9	14.2	13.5	10	10	0	20	0	P-F
1	200	0	3.7	16.2	13.4	60	20	10	90	0	F-G
2	184	0	4.0	15.4	13.4	40	0	0	40	3	F-G
1	200	7	3.8	15.6	13.4	20	20	60	100	60	F
2	184	7	4.0	14.3	13.9	40	10	40	90	45	F-G
1	231	0	3.6	14.2	12.9	30	10	60	100	0	F-G
2	216	0	3.8	13.6	13.7	20	40	40	100	0	F-G
1	231	7	3.8	15.0	14.1	20	10	70	100	0	F
2	216	7	No apples were left for test.								

* S. is slight, M. is moderate, Se. is severe.
** P is poor, F is fair, G is good.

TABLE 8. YORKING APPLES, 1949-1950.
Tests of First and Second Pickings at Harvest, after Storage at 36° F., and during Ripening at 70° F.
First Picking September 19, 1949. Second Picking October 4, 1949.

Picking	Days at 36° F.	Days at 70° F.	Ground Color	Pounds Pressure	% Soluble Solids	% Scald				% Decay	Quality **
						S. *	M. *	Se. *	Total		
INITIAL DATA											
1	0	0	2.2	18.0	10.4	0	0	0	0	0	P
2	0	0	3.0	17.0	10.7	0	0	0	0	0	P
AFTER STORAGE AT 36° F.											
1	163	0	3.2	14.0	12.0	20	20	60	100	0	P
2	147	0	3.8	15.5	12.8	30	0	0	30	0	P-F
1	163	7	No test (100% rot)			0	10	90	100	100	P
2	147	7	4.0	13.9	14.3	20	20	40	80	40	F
1	200	0	3.6	13.6	12.0	10	20	70	100	40	P-F
2	184	0	4.0	14.6	13.9	30	30	10	70	20	F-G
1	200	7	No test (100% rot)			0	40	60	100	88	—
2	184	7	4.0	13.8	14.2	50	25	25	100	66	F

* S. is slight, M. is moderate, Se. is severe.
** P is poor, F is fair, G is good.

at this temperature. For example, after 163 days in storage at 36° F. the first picking had developed 100 per cent scald of which 60 per cent was severe, whereas in the second picking, after 147 days at 36° F., only 30 per cent total scald was found.

Decay was more serious in all the lots of the first picking than in the second picking. After 163 days at 36° F. and seven days at 70° F. the first picking was 100 per cent decayed. The second picking had only 40 per cent decay after 147 days at 36° F. and seven days at 70° F.

The fruit quality was consistently better in the second picking.

Storage at 40° F.

The 40° F. lot of Yorking apples in 1949 had a short storage life due to excessive decay (Table 9). In all the tests, scald and decay were more severe in the first picking than in the second picking. After only 107 days at 40° F. the first picking had developed 100 per cent scald, as compared to 20 per cent scald for the second picking after 91 days in 40° F. storage.

Storage Life of Yorking Stored at 32°, 36°, and 40° F. 1949-1950

The changes in firmness of the first picking of Yorking apples as influenced by storage temperatures in 1949-1950 are shown in Figure 6. These lots of fruit did not ripen uniformly, and the 36° and 40° F. lots had to be discontinued because of excessive decay before the termination of the experiment. After approximately three and one-half months of storage the 32° F. lot began to increase in pounds pressure until a considerable increase was found when checked at about five and one-half months in storage. After this time a decline was found in pounds pressure until the end of the

TABLE 9. YORKING APPLES, 1949-1950.
Tests of First and Second Pickings at Harvest, after Storage at 40° F., and during Ripening at 70° F.
First Picking September 19, 1949. Second Picking October 4, 1949.

Picking	Days at 40° F.	Days at 70° F.	Ground Color	Pounds Pressure	% Soluble Solids	% Scald				% Decay	Quality **
						S. *	M. *	Se. *	Total		
INITIAL DATA											
1	0	0	2.2	18.0	10.4	0	0	0	0	0	P
2	0	0	3.0	17.0	10.7	0	0	0	0	0	P
AFTER STORAGE AT 40° F.											
1	107	0	2.8	14.8	12.4	40	30	30	100	10	P-F
2	91	0	3.6	14.8	11.2	20	0	0	20	0	F
1	163	0	3.8	14.7	13.4	0	50	50	100	100	P-F
2	148	0	3.9	13.8	12.7	0	50	50	100	50	P-F
1	163	7	No apples were left to test.								
2	148	7	3.9	14.2	13.4	0	60	40	100	65	P-F

* S. is slight, M. is moderate, Se. is severe.
** P is poor, F is fair, G is good.

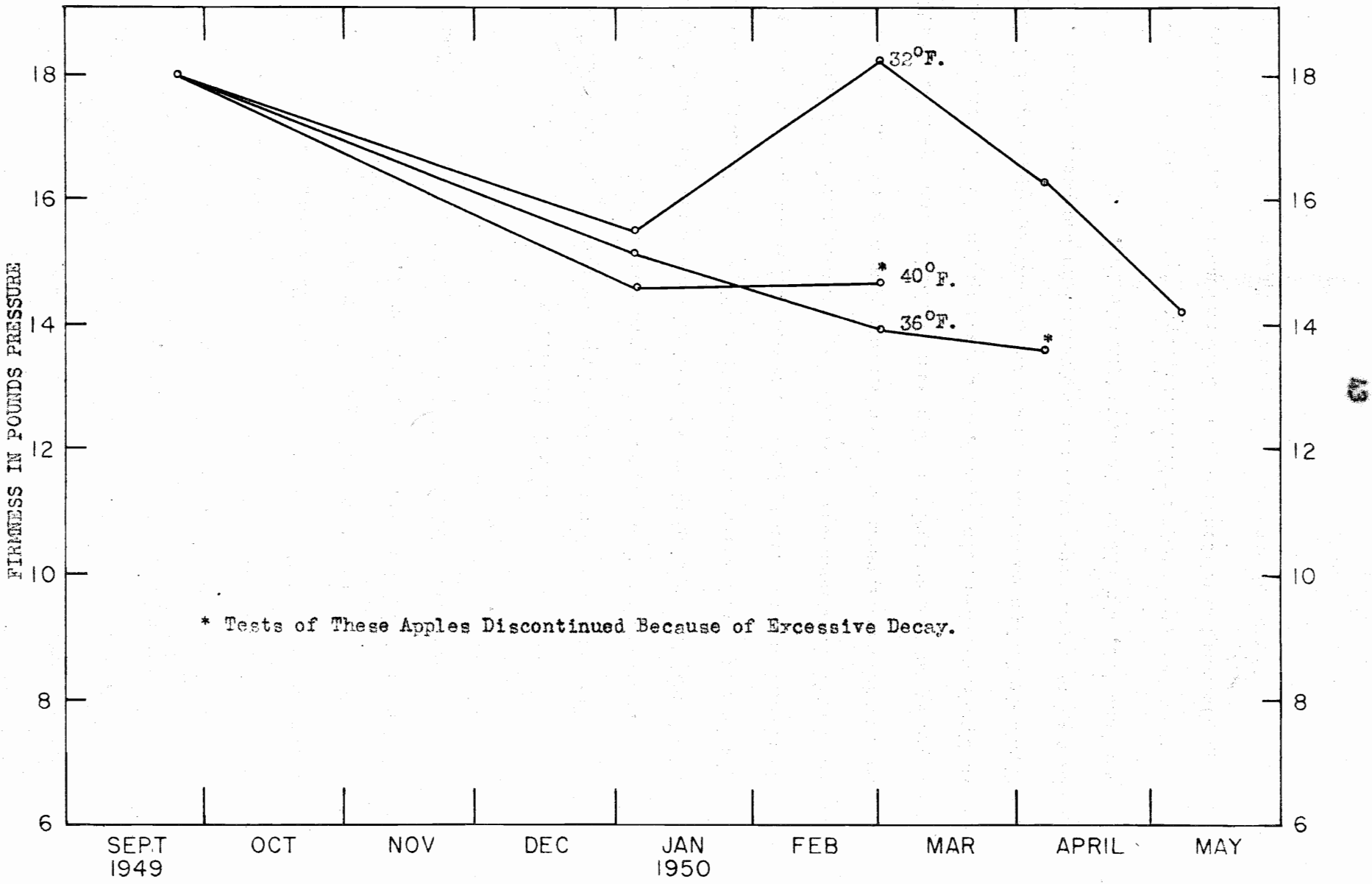

Fig. 6. Changes in Firmness of Yorking Apples as Influenced by Storage Temperatures. First Picking, Harvested September 19, 1949.

experiment. The storage life of the 36° and 40° F. was determined by the amount of decay rather than by the firmness of the fruit.

Figure 7 shows that the results in firmness for the second picking of the Yorking variety are similar to those of the first picking (1949-1950). The 36° and 40° F. lots were discontinued because of excessive decay. The 32° F. lot showed an increase in firmness after approximately five months in storage.

The second picking was about one pound softer when harvested than the first picking. However, the second picking was firmer after storage at 36° F. The rate of softening was approximately the same for the 40° F. lots of both pickings. At 32° F. the first picking was about one pound firmer than the second picking at the end of the experiment.

1950-1951

Storage at 32° F.

The results of tests of Yorking apples of the first, second, and third pickings at harvest, after storage at 32° F., and during ripening at 70° F. in 1950-1951 are presented in Table 10. In all the tests made, scald was more severe in the first picking than in either the second or third picking. Decay and bitter pit were more abundant in the second picking than in either the first or third picking. Some of the test lots were still increasing in soluble solids at the end of the experiment. This particular lot of Yorking apples ripened with fair uniformity, since the ground color, quality of fruit, and pounds pressure followed along the same pattern throughout the test.

Storage at 36° F.

Table 11 presents the data for the tests of first, second, and third

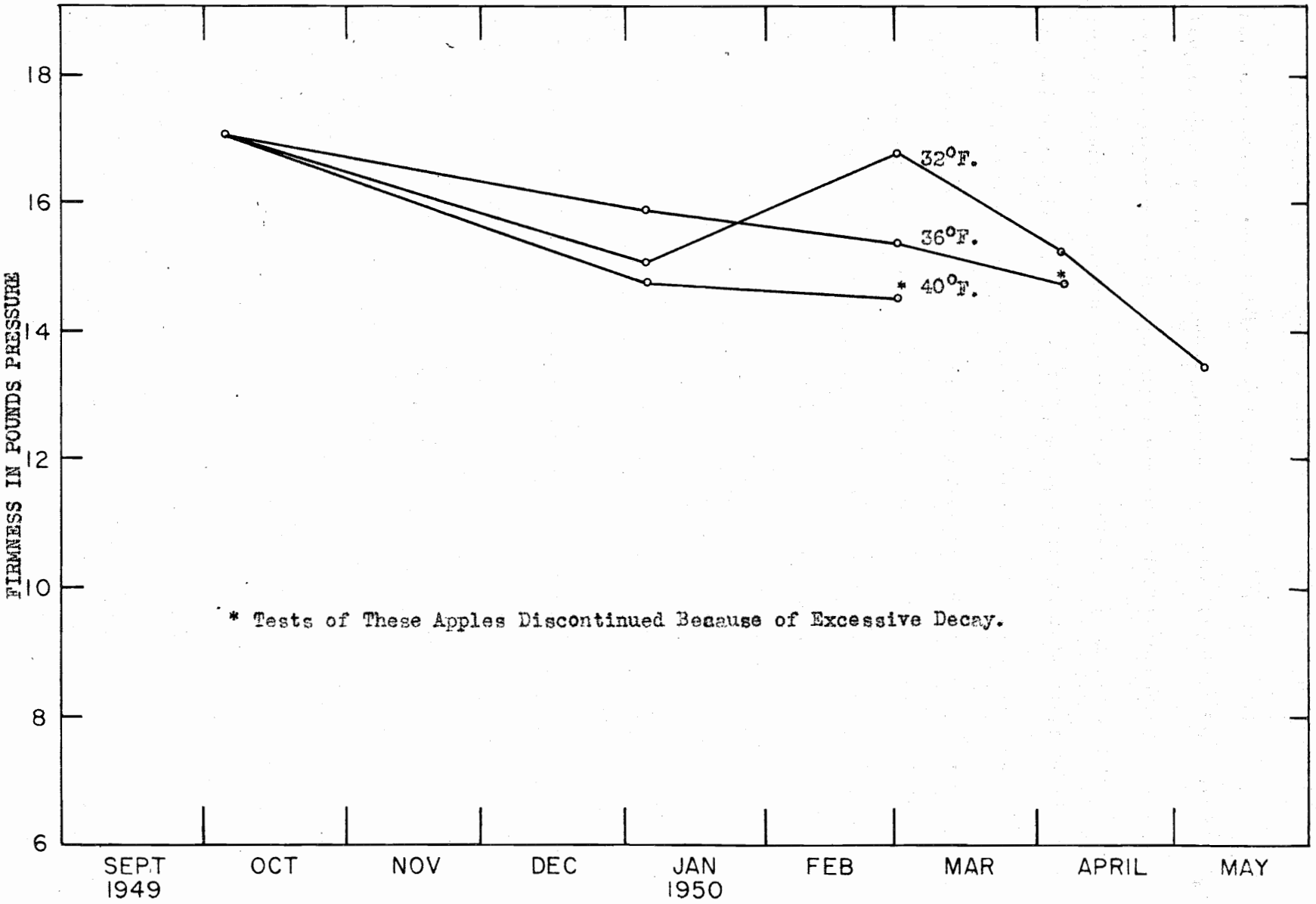

Fig. 7. Changes in Firmness of Yorking Apples as Influenced by Storage Temperatures. Second Picking, Harvested October 4, 1949.

TABLE 10. YORKING APPLES, 1950-1951.
Tests of First, Second, and Third Picking at Harvest, after Storage at 32° F., and during Ripening at 70° F.
First Picking September 25, 1950, Surface Color 71%.
Second Picking October 3, 1950, Surface Color 72%.
Third Picking October 12, 1950, Surface Color 83%.

Picking	Days at 32° F.	Days at 70° F.	Ground Color	Pounds Pressure	% Soluble Solids	% Scald				% Decay	Quality **	% Bitter Pit
						S. *	M. *	Se. *	Total			
INITIAL DATA												
1	0	0	2.3	15.3	8.8	0	0	0	0	0	P	0
2	0	0	2.5	16.7	9.1	0	0	0	0	0	P	0
3	0	0	2.1	14.6	9.4	0	0	0	0	0	P	0
1	0	9	2.1	15.3	10.0	0	0	0	0	0	P-F	0
2	0	9	2.6	15.6	10.0	0	0	0	0	0	P	0
3	0	7	3.7	15.9	10.3	0	0	0	0	0	F	0
1	0	19	2.9	11.7	10.6	0	0	0	0	0	P	0
2	0	16	3.5	13.0	10.0	0	0	0	0	0	P-F	0
3	0	13	2.8	12.0	10.8	0	0	0	0	0	F	0
AFTER STORAGE AT 32° F.												
1	123	0	2.6	15.0	10.7	30	0	0	30	0	P-F	0
2	114	0	3.0	14.6	10.4	30	0	0	30	0	P-F	20
3	105	0	3.0	14.7	11.5	20	0	0	20	1	P-F	10
1	123	7	2.9	14.0	10.5	70	10	0	80	0	P-F	0
2	114	7	3.2	13.1	10.6	40	0	0	40	0	P-F	20
3	105	7	3.2	13.7	11.0	10	0	0	10	5	P-F	10
1	123	14	3.2	12.0	11.0	60	20	0	80	0	P-F	0
2	114	14	3.4	12.8	10.5	60	0	0	60	20	P-F	20
3	105	14	3.3	12.6	10.5	40	0	0	40	0	P-F	10
1	195	1	3.2	13.6	11.2	40	10	20	70	0	P-F	0
2	186	1	3.4	13.5	10.8	50	0	0	50	0	P-F	20
3	177	1	3.1	12.4	11.0	40	0	0	40	0	P-F	20

* S. is slight, M. is moderate, Se. is severe.
** P is poor, F is fair, G is good. The letter is underlined when most of the apples were in that quality group.

TABLE 11. YORKING APPLES, 1950-1951.
Tests of First, Second, and Third Picking at Harvest, after Storage at 36° F., and during Ripening at 70° F. First Picking September 25, 1950, Second Picking October 3, 1950, and Third Picking October 12, 1950.

Picking	Days at 36° F.	Days at 70° F.	Ground Color	Pounds Pressure	% Soluble Solids	% Scald				% Decay	Quality **	% Brown Core
						S. *	M. *	Se. *	Total			
INITIAL DATA												
1	0	0	2.3	15.3	8.8	0	0	0	0	0	P	0
2	0	0	2.5	16.7	9.1	0	0	0	0	0	P	0
3	0	0	2.1	14.6	9.4	0	0	0	0	0	P	0
AFTER STORAGE AT 36° F.												
1	195	1	3.2	12.9	10.7	55	10	10	75	1	P-F	30
2	186	1	3.3	12.7	10.5	50	10	5	65	5	P-F	10
3	177	1	3.3	11.8	10.7	40	5	0	45	3	P-F	0
1	195	7	3.4	10.8	10.2	20	80	0	100	0	P-F	100
2	186	7	3.6	10.8	10.4	50	40	10	100	0	P-F	70
3	177	7	3.6	11.0	10.5	60	40	0	100	0	P-F	40

* S. is slight, M. is moderate, Se. is severe.
** P is poor, F is fair, G is good. The letter is underlined when most of the apples were in that quality group.

pickings at harvest, after storage at 36° F., and during ripening at 70° F. for the Yorking variety (1950-1951). Brown core was more severe in the first picking than in either the second or third picking. After storage, the third picking was consistently higher in fruit quality. Scald was generally more severe in the earlier harvested fruits.

Storage at 40° F.

Table 12 shows the test data of the first, second, and third pickings at harvest, after storage at 40° F., and during ripening at 70° F. of the Yorking variety (1950-1951). After storage at 40° F. for approximately three and one-half to four months all the lots had past the end of normal storage life as determined by pounds pressure. Considerable decay was found, but only slight differences were apparent in the three test lots.

Internal breakdown was found in these lots, with more being found in the first and second pickings than in the third picking.

Scald development was different in this lot, compared to all the other lots tested. The third picking had twice as much scald as the second and first pickings at the first test after storage, but after seven days at 70° F. the first picking developed more total scald than either the third or second picking.

Storage Life of Yorking Stored at 32°, 36°, and 40° F. 1950-1951

The changes in firmness of Yorking apples as influenced by storage temperatures for the first picking (1950-1951) are presented in Figure 8. After one and one-half months in storage the 40° F. lot had reached the minimum pounds pressure for length of storage life. The 36° F. lot had a

TABLE 12. YORKING APPLES, 1950-1951.
Tests of First, Second, and Third Picking at Harvest, after Storage at 40° F., and during Ripening at 70° F. First Picking September 25, 1950, Second Picking October 3, 1950, and Third Picking October 12, 1950.

Picking	Days at 32° F.	Days at 70° F.	Ground Color	Pounds Pressure	% Soluble Solids	% Scald				% Decay	Quality **	% Internal Breakdown
						S. *	M. *	Se. *	Total			
INITIAL DATA												
1	0	0	2.3	15.3	8.8	0	0	0	0	0	P	0
2	0	0	2.5	16.7	9.1	0	0	0	0	0	P	0
3	0	0	2.1	14.6	9.4	0	0	0	0	0	P	0
AFTER STORAGE AT 40° F.												
1	125	0	2.8	11.2	10.3	50	0	0	50	2	P	0
2	116	0	3.2	11.6	10.5	50	0	0	50	1	P-F	0
3	107	0	3.2	11.1	10.6	100	0	0	100	4	P-F	0
1	125	7	3.1	10.2	10.0	70	20	0	90	30	P	60
2	116	7	3.2	10.8	9.9	60	20	0	80	30	P	60
3	107	7	3.2	10.4	10.9	60	10	0	70	30	P-F	20

* S. is slight, M. is moderate, Se. is severe.
** P is poor, F is fair, G is good.

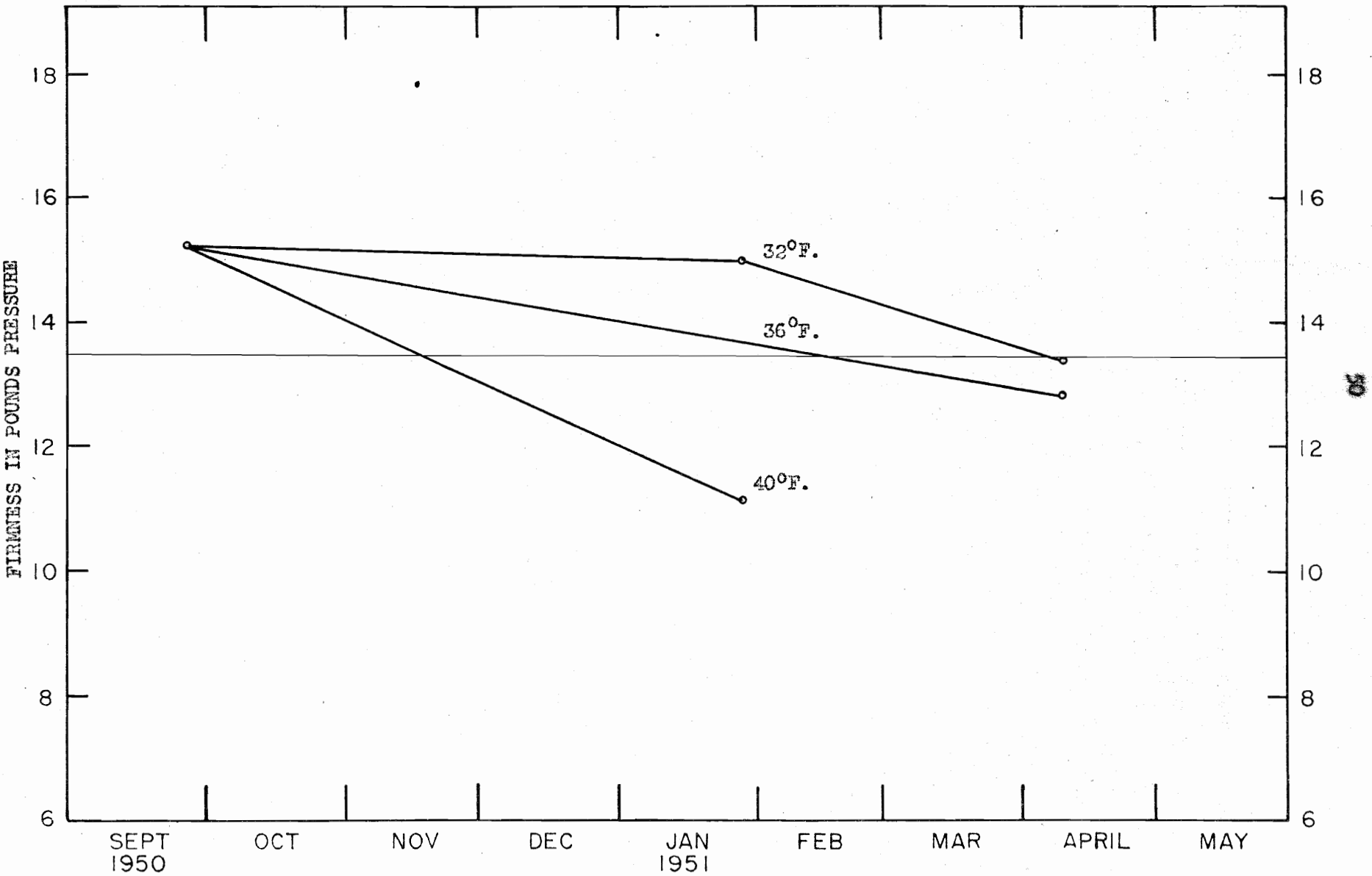

Fig. 8. Changes in Firmness of Yorking Apples as Influenced by Storage Temperatures. First Picking, Harvested September 25, 1950.

storage life of approximately four and one-half months, whereas about six and one-half months were required for the 32° F. lot to reach the end of storage life.

The changes in firmness of Yorking apples as influenced by storage temperatures for the second picking (1950-1951) are presented in Figure 9. In this lot of apples the maximum length of storage life varied considerably between the 40° and 36° F. storage. The storage life of the 40° F. sample was only two months, compared with five months for the 36° F. lot, and six months for the 32° F. sample of fruit.

Figure 10 shows the changes in firmness of Yorking apples as influenced by storage temperatures for the third picking (1950-1951). The 40° F. lot had a storage life of only one month, compared to two months for the 36° F. sample, and approximately four and one-half months for the 32° F. lot.

The second picking was firmer than either the first or third picking at the beginning of the experiment. The third picking softened faster at all temperatures than either the first or second picking. The rate of softening for the first and second pickings was approximately the same.

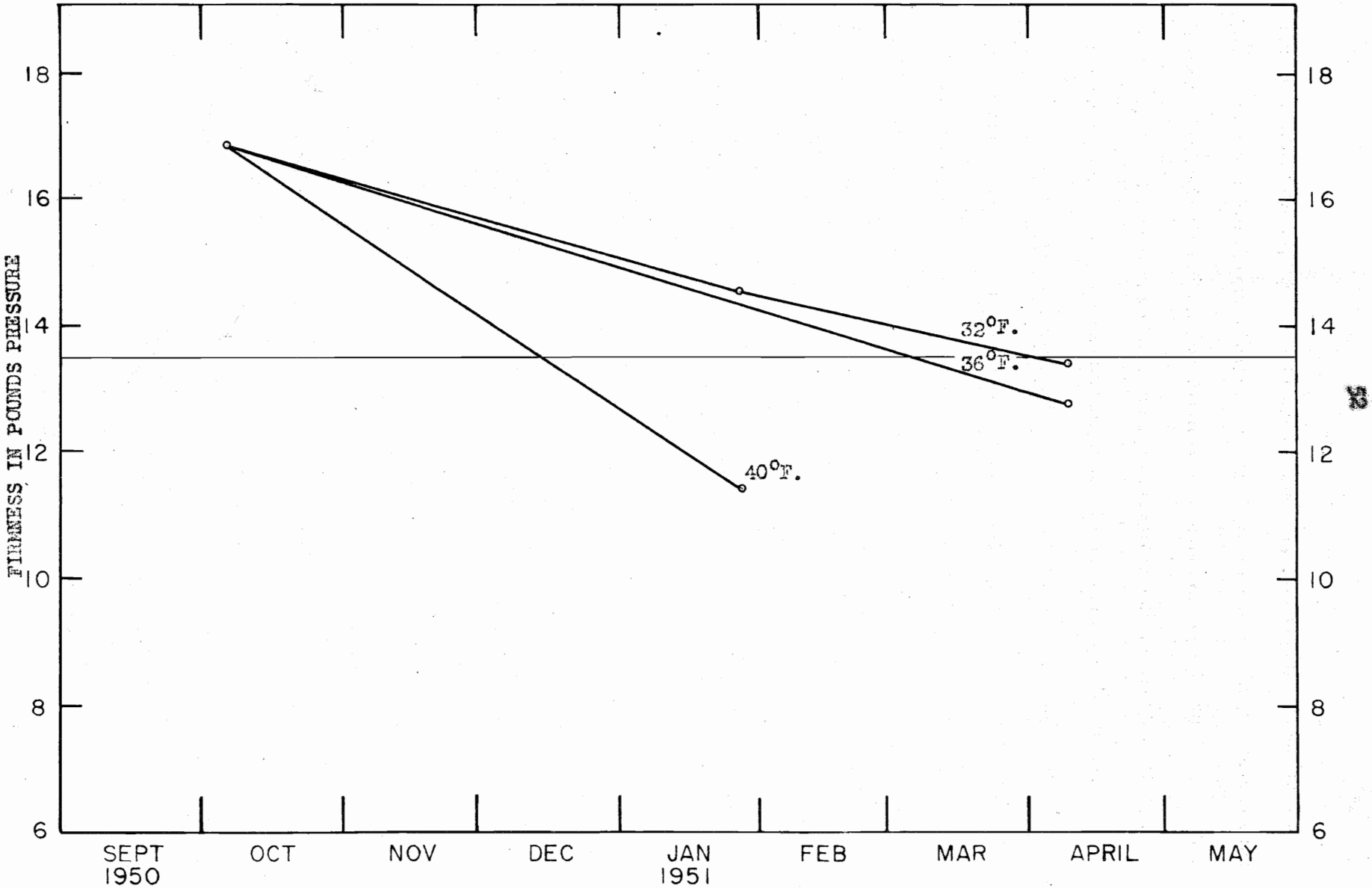

Fig. 9. Changes in Firmness of Yorking Apples as Influenced by Storage Temperatures. Second Picking, Harvested October 3, 1950.

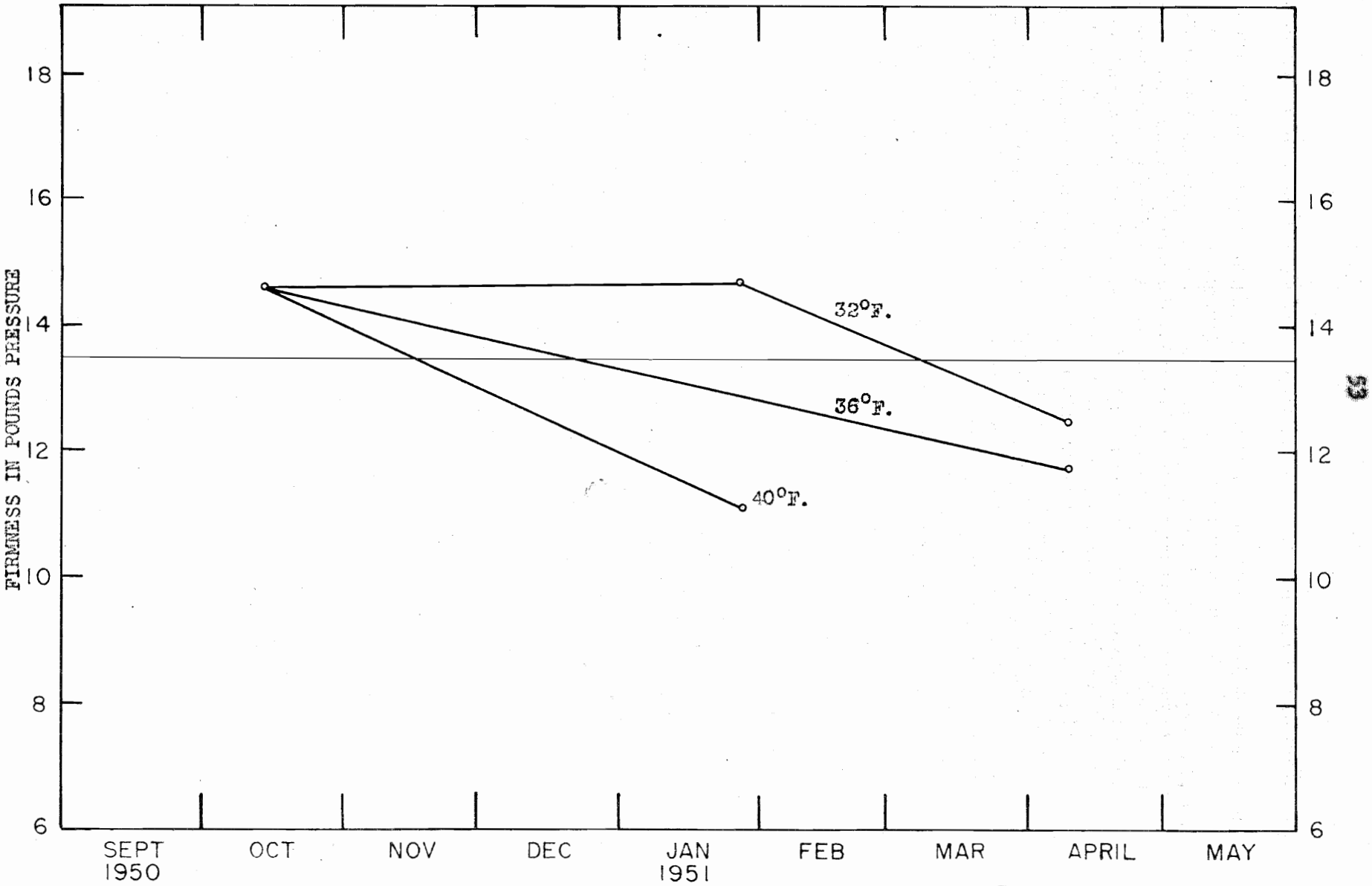

Fig. 10. Changes in Firmness of Yorking Apples as Influenced by Storage Temperatures. Third Picking, Harvested October 12, 1950.

VII

DISCUSSION OF RESULTS

In general the results found in this experiment on Staymared and Yorking apples in 1949-1951 are in agreement with those of earlier investigations by others on apple storage experiments of this nature.

Ground color increased most rapidly when the apples were stored at 40° F., followed by 36° F., and least rapidly at 32° F. The change from green to yellow, a decrease of chlorophyll (19), and an increase of quercetin (yellow pigment), is speeded up at the higher temperatures.

Normally the soluble solids of the fruit would be expected to increase for a short period after harvest, due to the hydrolysis of starch. This increase would then be followed by a gradual decline during the remainder of the life of the fruit (19). This decrease is due to the fact that all the starch in the fruit has been hydrolyzed, and there is a net loss of sugar due to respiration.

The soluble solids data in this experiment varied considerably. In some treatments the percentage of soluble solids decreased as was expected, but in other lots the soluble solids were still high or increasing slightly at the end of the experiment. Reasons for the high soluble solids level at the end of storage life may be: A water loss of five per cent or more which would cause a relative increase in soluble solids, late hydrolysis of starch to sugar, or the hydrolysis of disaccharides into monosaccharides resulting in an increase in soluble solids concentration.

Scald development was more severe in the earlier pickings of both varieties, and it developed at a faster rate at the higher temperatures.

Scald is the result of an accumulation of certain unknown gases which the apple generates in its life processes (2). Since physical and chemical changes are increased with an increase in temperature, it is plausible that an increased production and accumulations of a sufficient concentration of these scald producing gases would be reached sooner at the higher temperatures.

The quality of fruit of the earlier pickings was in general inferior to the quality of the pickings made at a later date. This is partly due to the fact that the later picked fruits have a higher sugar content when they are harvested. Smock (19) reports that sugar content is an important factor in dessert quality. However, factors such as firmness, bruising, water content, and other factors are also important.

The firmness of the fruit decreased as the fruit ripened in storage. The rate of decrease in pounds pressure was more pronounced at the higher temperatures of 40° and 36° F. than at 32° F. storage. In the 1949-1950 tests, however, a definite increase was found at the 32° F. temperature, after approximately five months in storage of the Yorking variety for both pickings. Haller and others (8) found this same response with the York Imperial variety, but they offered no explanation as to why this result was found. Morris (16) observed an increase in pounds pressure after storage with the Rome Beauty apple, and attributes the difference in the pressure test to the wilting of the fruit. Wilting or shriveling of the fruit may increase apparent firmness by producing a spongy apple and could be one of the possible explanations for this increase in pressure. But, if this were so, an increase should also have been found at the other temperatures of

the experiment. This did not occur at 36° and 40° F.

Another possible explanation lies in the change of protopectin into soluble pectin. It has been stated that the decrease in firmness is associated with the hydrolysis of the insoluble cell wall cementing material, protopectin, to soluble pectin (6). Heinze (21) in 1943, in a study of the curing process of sweet potatoes found at a temperature of 50-53° F. that the protopectin increased while the soluble pectin decreased. This storage synthesis of protopectin continued in the roots as long as they remained alive and sound. If this is true for apples it would help explain the increase in firmness. Here again the same results should have been found at the other temperatures, unless this response is due to some peculiar enzymatic reaction of the Yorking variety at a temperature of 32° F.

VIII

SUMMARY

The maximum storage life for two maturity pickings in 1949, and three maturity pickings in 1950, of both Staymared and Yorking apples was greatest at 32° F., less at 36° F., and least at 40° F.

The average storage life of all the pickings of the Staymared variety for 1949-1950 and 1950-1951, as judged by length of time required to reach 11 pounds pressure, was 2.4, 3.9, and 5.6 months for the 40°, 36°, and 32° F. lots respectively.

The average storage life of all the pickings of the Yorking variety for 1949-1950 and 1950-1951, as judged by length of time required to reach 13.75 pounds pressure, or excessive breakdown or decay, was 3.0, 4.8, and 6.4 months for the 40°, 36°, and 32° F. lots respectively. These results show that temperatures above 32° F., which may be found in Virginia storages at the start of the season and during the season, may considerably reduce the storage life of the fruit.

The Yorking apples did not ripen very uniformly. With the 1949-1950 tests the Yorking lots which were held at 40° F. and 36° F. had to be discontinued at the end of approximately five months because of excessive decay. At 32° F., in 1949-1950, the Yorking apples decreased in firmness for approximately three and one-half months, and then at about five and one-half months of storage a definite increase in pounds pressure was found.

Scald was more severe, with a very few exceptions, in the lots of the earliest picking of both Staymared and Yorking varieties. The practice of early picking of some varieties, combined with the higher temperatures found in some Virginia storages, constitutes a definite scald problem.

The change of ground color from green to yellow increased most rapidly at 40° F., followed by 36° F., and least rapidly at 32° F.

In general the soluble solids increased after harvest and in storage for a few months, and after this a gradual decline was evident. However, this result was not consistent, and in some of the test lots the soluble solids were still high or increasing slightly at the termination of the experiment.

Decay was generally more severe in the earlier harvested lots of both varieties.

The amount of shriveling was greater in the earlier harvested fruits of both varieties.

Water core was more abundant in the second and third pickings, as compared with the first picking of the Staymared variety in the 1950-1951 tests. However, this disorder usually decreased or disappeared in storage, and did not cause any breakdown in any of the lots of fruit.

Brown core and internal breakdown were found to be more severe in the earlier pickings of the Yorking variety. Brown core was not found in the Staymared variety, and internal breakdown seldom occurred.

Considering all the results of this experiment, early harvesting of the Staymared and Yorking varieties is not desirable for maximum storage life of the fruit. If the fruit is picked too early it has not developed

the surface color and quality of fruit harvested at a later more optimum time. Also early picked fruit is more susceptible to storage scald.

IX

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X

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XI

BIOGRAPHICAL SKETCH

George Robertson Williams was born in Comanche, Texas, December 30, 1919. The early part of his life was spent on a farm near Comanche. He attended Texas A. and M. College from 1938 to 1941, after which time he worked for the U.S. Public Health Service for approximately one year. From 1943 until 1946 he served in the U.S. Air Force in the United States and in the European Theater of Operations. After separation from the service he returned to Texas A. and M. College and received the B.S. degree in June of 1947. Following graduation he worked in the Rio Grande Valley of Texas in citrus fruit and vegetable research at Substation No. 15, of the Texas Agricultural Experiment Station. Since September 1949 he has been an assistant at the Virginia Agricultural Experiment Station while a graduate student.