EFFECTS OF DROP-DELAYING SPRAYS ON THE POSTHARVEST PHYSIOLOGY OF APPLES

By

George Morton Kessler

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

Department of Horticulture

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The effects of preharvest sprays of growth regulators upon the ripening of apple fruit has been a subject of interest to both professional horticulturists and growers ever since such sprays were first successfully used to delay apple drop in 1939. This investigation was undertaken with the purpose of more clearly establishing, by chemical analysis and physical observations, the physiological responses of apples to such sprays.

McIntosh and Northern Spy apple trees in Michigan orchards were sprayed prior to harvest with drop delaying sprays of naphthaleneacetic acid (NAA), 2-methyl-4-chlorophenoxyacetic acid (Toloxy) and 2,4,5-trichlorophenoxypropionic acid (2,4,5TP or Color-set). The physiological responses of the fruit to these growth regulators during three consecutive years (1949, 1950 and 1951) was measured at harvest and after storage at temperatures of 32° F. The fruit was also observed in 1950 after a 70° F storage period.

The fruit samples were harvested at random from the test trees once during the normal commercial harvest period. An early harvest of McIntosh fruit was also made in 1949.

Samples of the edible portions of the apple fruit were taken at harvest or after storage and frozen for later chemical analysis. Total sugars in the water extract of the fruit tissue was determined by the Munson-Walker method and expressed as percent invert sugar. Total nitrogen was determined by the Kjeldahl method and results expressed as percent protein. Soluble solids were measured with the Abbé refractometer and expressed as percent sugars. The moisture content of the apple tissue was found with the Braybender moisture tester. Total acids were determined by titration of the water extract with 0.1 N NaOH and expressed as ml of 0.1 N NaOH per 10 gm of fresh tissue. All chemical analyses were reported on a fresh weight basis. Respiration determinations were made upon samples of approximately 10 fruit. Respiration rates were measured by using the method of Claypool and Keefer, in which CO_2, evolving from the apples, was collected in a solution containing $NaHCO_3$ and Brom Thymol Blue indicator. The color changes caused by varying amounts of CO_2 was then measured with an Evelyn Colorimeter.

The results of this investigation show that NAA and Toloxy did not markedly influence the physiology of the fruit. Sprays of 2,4,5-TP significantly affected McIntosh apples in one of the two years in which this material was tested. Applications of 2,4,5-TP to McIntosh trees 28 days before harvest were of greater effect on the fruit than the applications made 17 days before harvest. The sprays of 2,4,5-TP in 1951 caused the fruit to be softer at harvest and caused a significant reduction in the soluble solids, acid content and firmness of the fruit during the subsequent storage period. These effects from 2,4,5-TP were not observed on McIntosh in 1950 or on Northern Spy in either of the two years in which this material was used. The evidence suggests that the higher temperatures occurring during the period of application of 2,4,5-TP in 1951 than in 1950 may have been a contributing cause for the different results obtained for McIntosh apples in these two years. There were no significant effects upon the respiration rates of the fruit attributable to the growth regulator sprays during the one year in which respiration was measured.

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I. INTRODUCTION

Fruit drop from apple trees is a natural phenomenon which may or may not be detrimental to the economic yield from the orchard. When natural drop occurs early in the season it is referred to as the June drop. This is frequently beneficial because it may be a thinning process essential to the production of fruit of proper size and quality. Loss of fruit from the tree may occur later in the season and preceding harvest and result in a greatly reduced yield of marketable fruit. This latter phenomenon occurs because of the early development of the abscission zone at the junction of the pedicel of the fruit and the peduncle of the fruit cluster. Some varieties of fruit, McIntosh apple for an example, tend to exhibit premature drop as the harvest season is approached because of certain inherent characteristics (44). The amount of premature drop may be also greatly affected by certain growing conditions such as climate and nutrition. It is a problem which is always a serious hazard to the financial returns of an orchardist. Considerable relief to this problem has resulted from the discovery that certain growth regulators will delay fruit abscission at harvest-time.

The use of these materials to prevent the preharvest drop of fruit may adversely affect the ripening rates and storage life of the fruit. In addition, if the harvest of the apple is delayed considerably beyond the time of normal harvest by the use of these materials, it is known that the life of such fruit in storage will be appreciably shortened. Treated fruit picked at the regular time may also exhibit abnormal behavior. For example, it has been shown that preharvest sprays of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) hastened the ripening of attached fruits of certain varieties of apple. Whether or not preharvest sprays hasten ripening and thereby shorten the storage life of fall and winter varieties of apple is not clear, because conflicting results have been reported by various workers. Further investigations concerning the effects of the various growth substances upon the physiological behavior of the fruit after harvest seemed desirable.

A study was therefore undertaken with the purpose of determining the effects of certain growth regulating substances on the storage behavior and chemical composition of McIntosh and Northern Spy apples.

II. REVIEW OF LITERATURE

Our knowledge of plant growth substances dates back at least to Darwin in 1881 (14). At that time, the phototropic bending of seedlings of *Phalaris canariensis* which had been exposed to unilateral light was observed by Darwin. He suggested that "some influence is transmitted from the upper to the lower part, causing the latter to bend". This was followed by a series of classical works dealing with various aspects of phototropism, but it was not until 1910 that Fitting (19) hypothesized, for the first time, the presence of a hormone in plants. He suggested that the swelling of the gynostemium of the orchid flower results from the activity of a naturally occurring growth substance in orchid pollen. Fitting called this substance a "hormone".

A hormone is described by Boysen-Jensen (11) as a chemical substance produced in the cells of one part of an organism and carried to distant parts, where only minute quantities are capable of exerting a profound effect upon growth in some way other than by direct nutritive means.

The existence of plant hormones has been accepted since about 1928, due to evidence or tests developed by Went (65) and others. However, it was not until 1942 that the presence of hormones in higher plants was absolutely verified by chemical methods. At that time, Haagen-Smit *et al* (27) isolated beta-indoleacetic acid from corn meal and by biological tests proved it to be a true plant hormone. Although there is strong evidence pointing to the existence of other plant hormones, the isolation of others has not been verified.

While work proceeded with the natural plant hormones, it was reported in 1935 (67) that a number of synthetic growth regulators exhibit growth effects on plants very much like those of natural hormones. Because of this similarity synthetic growth regulators are often called "hormones".

Practical applications of the fundamental knowledge of plant hormones and synthetic growth regulators were probably initiated by the discovery in 1934 (60) that natural plant auxin has a root-promoting effect. Many other applications followed, such as setting of tomato fruits parthenocarpically (36), control of potato sprouting in storage (26), chemical weed control (43) and delaying the blossoming of fruit (66).

The discovery by LaRue in 1936 (38) that a plant auxin will inhibit the abscission of Coleus leaf petioles is of particular interest to the study reported in this paper. It was shortly thereafter that Gardner and Marth (21) reported that the drop of holly leaves and berries could be delayed with synthetic hormones. Gardner, Marth and Batjer (22) used growth regulating substances to delay the harvest drop of apples for the first time in 1939 and this has since become a standard practice in the production of apples and pears.

This paper is concerned with the effects of synthetic growth regulating materials on apple fruits, and it is therefore of interest to consider the effects of both synthetic and naturally occurring ethylene on the physiological behavior of fruits. The growth regulating properties of ethylene were already quite well known before results with drop delaying sprays were reported. Denny (16) demonstrated in 1934 that ethylene evolved in the incomplete combustion of kerosene was responsible for the change in skin color of lemons from green to yellow, during the curing process. Other effects were noted and according to Gane (20), an atmosphere containing ethylene caused the climacteric rise in the respiration rate of bananas to occur earlier than normal. Pear fruits also exhibit a climacteric rise and, as reported by Hansen and Hartman (32), react in a similar manner upon exposure to ethylene. Smock (51) found that pre-climacteric apples exposed to the emanations from post-climacteric apples show a premature climacteric rise in respiration. Gane (20) had previously demonstrated the production of ethylene by apple fruits and the ripening effect observed by Smock may have been due to ethylene given off by the riper fruits. Substances other than ethylene in the apple emanations were probably also involved.

Growth regulating substances other than ethylene often affect the physiological behavior of fruits. Some hasten the ripening of fruits while still attached to the tree. For example, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) used to set the fruit of fig (10), caused the fruit to ripen much earlier than those which had set naturally. Attached peaches have been shown to ripen earlier than normal after spraying with 2,4,5-T (42, 48, 64), although the treated fruits were sometimes distorted and ripened unevenly (64). Workers (33) at Beltsville, Maryland, found that 2,4,5-T, sprayed on Rome Beauty apple trees in August, hastened the maturing of the fruit by as much as one month. They report that the same material also caused a number of summer varieties of apple to mature from 9 to 13 days earlier than normal. The maturity of Delicious apples was also advanced before harvest as measured by pressure tests. Pears sprayed with naphthaleneacetic acid (NAA) yielded a larger number of soft fruits at harvest than unsprayed trees (8). It has been observed that preharvest sprays of the butyl ester of 2,4-dichlorophenoxyacetic acid (2,4-D) applied to Stayman apple trees resulted in fruits which were softer and showed more watercore than on trees which were unsprayed (34). Similar effects were not observed for the 2,4-D acid, the sodium salt of 2,4-D, or the triethanolamine salt of 2,4-D used in the same work. 2,4,5-trichlorophenoxypropionic acid (2,4,5-TP) is reported to have advanced the maturity of attached fruits of McIntosh, Delicious, Winesap, and several summer varieties of apple (9, 17, 35, 61). Conversely, sprays containing a combination of maleic hydrazide with NAA applied to Duchess, Wealthy and McIntosh trees (53), resulted in fruits which were firmer at harvest than those from trees sprayed with either NAA or 2,4,5-TP alone. California workers (63) report that applications of beta-naphthoxypropionic acid to the Black Corinth grape vines advanced the ripening of the grapes by two weeks in one of the two years in which it was tested.

Another important physiological response to growth regulators is the increased development of red skin color of attached apples. Most workers reporting this effect from the use of preharvest sprays of NAA and 2,4,5-T have found that the increased red color was associated with an advanced stage of maturity (6, 8, 33). Apple growers have recognized this dual effect and sometimes use NAA to improve fruit color, even though the delayed harvest which may accompany this practice means a shorter storage life of the fruit. Hoffman and Edgerton (35) report that stop-drop sprays of 2,4,5-TP have increased the amount of red color on Early McIntosh, Wealthy, McIntosh and Northern Spy fruits. However, there is insufficient evidence concerning the effects of this material on the maturity of apples to permit one to conclude that color is affected independently.

Evidence presented by some workers indicates that preharvest sprays may also influence the storage life of fruits. Gerhardt and Allmendinger (23) report that the keeping quality of Bartlett pears sprayed with 10 ppm of NAA before harvest was not impaired when the fruit was harvested within the normal harvest period. However, a delayed harvest, made possible by the treatment, resulted in more rapid ripening in storage. In another study with the Bartlett pear, Batjer _et al_ (8) found that a preharvest spray of 10 ppm NAA hastened the ripening of the fruit on the tree as well as during storage when it was picked during the normal harvest period. The reasons for the differences in the results of these two studies are not clear. Spraying of Bartlett pears with 2,4,5-T (48) two weeks to one month before harvest is reported to have resulted in softer fruit after storage than was the case with unsprayed trees. More recently, sprays of 75 ppm of 2,4,5-TP on the Bartlett variety in the pink stage of blossom development, are reported to have resulted in considerably more breakdown in storage than with fruits of control trees. Other workers (25), who applied 100 ppm of this material to Bartlett pears at the pink stage, found no effect on ground color and firmness in storage. The difference in time of application of the 2,4,5-TP could have been the reason for some of the differences in the results reported.

Until recently, NAA was the most generally used growth regulating substance to delay preharvest drop of apples, and a number of storage studies have been made following the use of this material. Batjer and Moon (7), at Beltsville, Maryland, concluded that the storage life of Jonathan, Delicious and Rome Beauty apples was unimpaired by stop-drop sprays of NAA. Gerhardt and Allmendinger (23), at Wenatchee, Washington, using both physical and chemical tests, observed that NAA shortened the storage life of Delicious harvested 31 days after spray treatment, but found no effect upon the stored fruit harvested 15 days after treatment. Christopher and Pieniazek (12) reported that preharvest applications of NAA did not influence the ripening of McIntosh in storage and Haller (29) found the same to be true for Jonathan, Delicious, Rome Beauty, Stayman, Winesap and York. Conversely, Smock and Gross (54, 55) concluded, as a result of respiration and firmness studies after harvest, that NAA increased the rate of ripening of Wealthy, McIntosh and Golden Delicious. Since the methods used by the various workers were quite similar, geographical and varietal differences may have been responsible, in some instances, for the variability in results.

Another material which has been used with some success as a spray to delay the harvest drop of apple is 2-methyl-4-chlorophenoxypropionic acid (Toloxy) (45). Smock and Gross (55) stored Toloxy-treated Wealthy and McIntosh apples and observed that the Toloxy caused an earlier occurrence of the climacteric rise in respiration of Wealthy fruits stored at 74° F and was of no effect on the McIntosh stored at 33° F. Wealthy was not observed at 33° F and McIntosh was not tested at 74° F in this work.

The influence of preharvest sprays of 2,4,5-TP on the firmness of apples during storage has been studied (15). McIntosh, Starking and Baldwin were not found to be affected significantly, but Golden Delicious treated with 2,4,5-TP was two pounds softer, by pressure tests, than the check in January.

A question which has arisen in connection with studies of preharvest sprays on apple fruits is whether or not the effects observed in storage are directly caused by the growth regulators. Investigations on this problem have been few, and one difficulty in such studies is that the normal fruit drop may be delayed by the growth regulator sprays and fruit which are ordinarily lost from the tree may be harvested as part of the test sample. Comparable fruit for the untreated trees is not available and a good comparison cannot be made. Smock (correspondence, August 31, 1951) attempted to solve this problem by taking fruit samples before any appreciable drop had occurred from unsprayed trees. One objection to this approach, at least with McIntosh apple, is that fruit picked before the drop of normal fruit has begun may be immature and therefore unsatisfactory for storage in some seasons. Furthermore, as pointed out by Batjer (4), a delay in harvest of even a few days, made possible by sprays of growth regulators, may result in more mature fruit with a longer storage life. This is a noteworthy observation because there is a tendency for growers to pick McIntosh at an immature stage when "stop-drop" sprays are not used.

Christopher and Pieniazek (12) attempted to obtain comparable samples by taping the check fruit to the trees in order to prevent its natural drop. In discussing this investigation, Vyvyan (62) states that although taping prevented the fruit from falling it did not necessarily prevent the formation of an abscission zone. Development of the abscission zone would alter the physiology of the fruit considerably so that it would not be comparable to fruit in which abscission had been prevented by applying NAA.

The concentrations of the different growth substances used by the various workers for preharvest sprays on apple were variable. The concentrations of NAA varied from 5 to 500 ppm, but 10 ppm was the most common employed. Smock and Gross (55) found in their work with Golden Delicious that they were able to increase the acceleration effect on the climacteric rise in the respiration rate of the fruit after harvest, by progressively increasing the concentration of NAA in the applied spray from 100 to 500 ppm. Toloxy was utilized at 20 ppm in the studies which were reviewed. The butyl ester of 2,4-D at 10 ppm, and 10 and 50 ppm of 2,4-D acid and the sodium salt of 2,4-D were used in the one work reviewed dealing with this group of chemicals. Concentrations of 10 and 20 ppm of 2,4,5-TP have been used, with the higher concentration being most commonly employed. Generally, concentration was not a variable where results on the effects of preharvest sprays on maturity and storage life were not in agreement.

Storage studies of fruits treated with growth regulators after harvest should also be considered. Treatment of preclimacteric peach, apricot, pear and apple fruits after harvest with 2,4-D has been reported to have had no effect on ripening (24). On the other hand, other workers (31, 46) found that postharvest treatment with 2,4-D hastened the ripening of apples and pears. This contradictory evidence was obtained with similar methods and concentrations of materials even though the fruit was grown in comparable regions. The reasons for the discrepencies are not evident.

Michigan workers (41) wrapped four varieties of apples in oiled papers which had been previously sprayed with the methyl ester of NAA, sprayed other fruit with a mixture of the same hormone and 10 percent geon, and compared them with untreated fruit for differences in respiration rate for periods of 67 hours to 10 days. They found the CO_2 evolved by both treated samples of fruit was less than from the controls. However, when another worker (58) repeated this work, it was found that the respiration and softening rates and development of ground color of preclimacteric Baldwin apples were increased by treatment with the methyl ester of NAA. It was also found that post climacteric fruit of the same varieties were not affected by the growth regulator treatment. The two groups of workers may have obtained unlike results because of differences in the physiological age of the fruit at the time of treatment.

The evidence available indicates that the ripening behavior of many different fruits may be influenced by treatment with growth regulating substances. The fruits affected include the fig, apple, peach, pear and grape. This physiological effect on fruits will vary with the chemical used. Maleic hydrazide, for example, was reported to have counteracted the ripening effect of NAA and 2,4,5-TP on apple fruits, when it was sprayed on the trees in combination with NAA or 2,4,5-TP (53). The response of fruits to growth substances varies also with variety. The summer varieties of apple, such as Oldenburg (Duchess) and Williams respond to NAA sprays by ripening very much more rapidly than normally, while later maturing varieties like Delicious and Rome Beauty may not show any signs of advanced ripening. It has been generally found that the extended delay in the harvest of fruits, made possible by the use of preharvest sprays, tends to shorten the storage life of such fruit. Furthermore, the effects of such sprays on fruit of the later maturing varieties of apple, picked during or soon after the normal harvest period, are not specific or consistent.

III. FIELD AND STORAGE PROCEDURES

The studies in 1949 and 1951 were conducted with fruit grown at the Graham Experiment Station, Grand Rapids, Michigan; and in 1950 with fruit grown in the Palmer orchard, Mason, Michigan. Treatments were applied each year to the varieties McIntosh and Northern Spy. McIntosh, a representative fall-winter variety widely grown in Michigan, is commonly sprayed commercially to control preharvest fruit drop. Northern Spy is a typical winter variety grown in Michigan, which is sometimes treated with preharvest sprays to hold the fruit on the tree beyond the normal harvest period in order to increase the amount of red color.

Mature trees, bearing medium to heavy crops of clean fruit, showing vigorous growth and healthy foliage, were selected for these tests. Groups of trees were chosen for uniformity of crop and from these, plots of four trees were selected at random for each treatment. Only three trees were used for the McIntosh check plot in 1949.

The chemical names, commercial names and sources of the growth regulators used as preharvest sprays in this investigation are given in Table 1.

NAA was used at concentrations of 10 and 20 ppm in 1949 and 1950 and 20 ppm in 1951. The 10 ppm concentration

TABLE 1

MATERIALS USED AS PREHARVEST SPRAYS IN 1949, 1950 AND 1951 AND THE COMMERCIAL SOURCES FROM WHICH THEY WERE OBTAINED

Chemical name	Commercial name	Source
Naphthaleneacetic acid	1949: Fruit Fix	Haviland Products Co. Grand Rapids, Michigan
	1950: Shell Endrop	Shell Oil Co., Inc. New York, New York
	1951: Parmone	E. L. Dupont DeNemours & Co. Wilmington, Delaware
2-methyl-4-chlorophenoxy-acetic acid	Toloxy	Dow Chemical Co. Midland, Michigan
2,4,5-trichlorophenoxy-propionic acid	Color-set 1004	Dow Chemical Co. Midland, Michigan

was not used in 1951 because 20 ppm frequently showed better drop control than the weaker concentration (from unpublished data). Chemically pure Toloxy was dissolved in alcohol and water solutions of this were applied at concentrations of 20 and 30 ppm in 1949, and since the higher concentration did not seem to offer any advantage in the control of preharvest drop, only the 20 ppm concentration was applied in 1951. 2,4,5-TP in the form of "Color-set 1004" was used at the commercially recommended concentration of 20 ppm in 1950 and 1951. One pint of summer oil was added to each 100 gallons of hormone spray solution in 1949, but not in 1950 or 1951.

The differences in dates of applications for the different years and varieties are listed in Table 2. In 1949, two sprays were applied for all treatments except Toloxy at 30 ppm, which was applied only once. All treated blocks received one spray in 1950.

In 1951, a single spray was applied for the NAA treatment and one for the Toloxy. The three treatments of 2,4,5-TP differed in time and frequency of spray applications. The first treatment ("A"), as shown in Table 2, was the earliest spray; the second ("B") was a later spray which coincided with the NAA and Toloxy treatments; and the third treatment ("C") consisted of two applications which corresponded to a combination of the previous two treatments as to the date of spraying.

The sprays were applied each year with standard high

TABLE 2

DATES OF SPRAY APPLICATIONS, HARVESTS, AND OBSERVATIONS OF COLOR AND FIRMNESS

Date	Spray application		First harvest		Second harvest		Observations	
	1st.	2nd.	Date	Days after bloom	Date	Days after bloom	Ground color	Firmness
				McIntosh				
1949	Aug. 30	Sept. 8	Sept. 8	124	Sept. 14	130	Jan. 19-26	Feb. 1-8
1950 70° stor.	-	Sept. 16	-	-	Sept. 27	132	Oct. 1-4 Oct. 14-16	
32° stor.	-	Sept. 16	-	-	Sept. 27	132	Oct. 7-9 Jan. 15-17	
1951	Aug. 30[a]	Sept. 11	-	-	Sept. 28	129	Oct. 3-5 Jan. 2-10 Mar. 11-14	
				Northern Spy				
1949	Sept. 24	Oct. 1	-	-	Oct. 11	156	Oct. 24-26 Jan. 29 Feb. 3	Oct. 24-26 Feb. 9-11
1950 70° stor.	-	Oct. 13	-	-	Oct. 25	153	Nov. 3-5 Jan. 15-17	
32° stor.	-	Oct. 13	-	-	Oct. 25	153	Oct. 28-Nov. 2 Feb. 8-12	
1951	Oct. 1[a]	Oct. 12	-	-	Oct. 18	164	Oct. 22-25 Feb. 7-8 Apr. 10-13	

[a]2,4,5-TP treatment only

pressure equipment employing a single nozzle gun. Spraying was done in the late morning under clear weather conditions, when there was little air movement. The maximum and minimum temperatures occurring on the days spray applications were made are given in Table 3.

The fruit samples in 1949 were taken at random around the outside of the entire tree while in 1950 and 1951 random samples were picked only from the lower periphery of the trees. The sampling dates are listed in Table 2. The trees of each treatment were sampled once for each variety with the exception of McIntosh which was picked at two dates in 1949. The fruit picked September 8 had received one spray of growth regulator while that picked September 14 had been given two applications. One-half to one field crate of fruit was harvested from each tree for pre-storage study and for storage tests.

The test fruit in 1949 and 1950 were stored with other varieties of apples, pears and miscellaneous vegetables. Storage temperatures fluctuated between 31° and 36° F and relative humidity of the storage room was approximately 86 percent. The cold storage room utilized in 1951 contained only apples and was maintained at temperatures between 30° and 34° F and at a relative humidity of about 88 percent. Some McIntosh fruit were frozen when storage temperature dropped to about 26° F for approximately 18 hours on one occasion in 1951. One lot of treated and check fruit was stored in a laboratory room in which the

TABLE 3

MAXIMUM AND MINIMUM TEMPERATURES ON DAYS WHEN TREATMENTS WERE APPLIED

Variety	Year	Application	Maximum (degrees F.)	Minimum (degrees F.)
McIntosh	1949	1st	73	53
		2nd	63	45
	1950	one	59	46
	1951	1st	81	66
		2nd	80	51
Northern Spy	1949	1st	58	38
		2nd	72	42
	1950	one	58	39
	1951	1st	71	52
		2nd	58	33

temperature averaged about 70° F throughout the test period in 1950. This fruit was held in cold storage during the observation period to minimize further changes in the fruit for the duration of this period.

IV. CHEMICAL AND PHYSICAL DETERMINATIONS

A. Chemical Determinations

Tissue samples were prepared for chemical analysis from the fruit tested for firmness by cutting three wedges which altogether comprised about one-third of the entire fruit. Ten fruits in 1949 and twenty in 1950 and 1951 were used for each replication. The sampled tissue included the edible flesh and skin but not the carpels or seeds. The segments or wedges were further cut into one-half to one inch pieces and then packed and sealed in No. 1 tin cans (1949) or in Plasticine bags in 1950. The sealed samples, weighing approximately 300 gm in 1949 or 450 gm in 1950, were frozen at -20° F and stored at 0° F for analysis at a later date. Samples were not preserved in 1951 since the fresh material was analyzed immediately following the physical determinations.

Sugars are represented by the total reducible substances in the acid-hydrolyzed water extract of the fruit tissue samples in 1949 and 1950. They were determined by preparing the extract according to the official method of the A.O.A.C. (1) and completing the determination by the Munson Walker Method (2), with the minor modifications described below.

The frozen tissue was finely ground with a household distilled water, stirred and allowed to stand for 10 minutes. A 20-minute extraction period fitted more efficiently into the analysis routine in 1950. A more uniform extraction was made in a shorter period of time in 1951 by first blending the sample of fresh tissue with a small amount of distilled water in a standard size Waring Blendor for about three minutes. This was then made up to a volume of 250 ml with distilled water and a 25 ml aliquot was used for analysis.

The acidity determinations were made each year from the water extracts by titration with 0.1N NaOH using phenolphthalein as the indicator. The results are expressed as milliliters of 0.1N NaOH required to neutralize the total acids extracted from 10 gm of apple tissue.

The determinations of total nitrogen were made from duplicate 10-gm samples taken from the frozen apple tissue. The stoppered glass weighing bottles containing the samples were weighed on an analytical balance and the standard Kjeldahl procedure (3) for determining total nitrogen was followed.

The protein content was calculated from the total nitrogen of the fruit tissue and the results are expressed as percent protein on a fresh weight basis.

The percent moisture was determined with the Braybender moisture tester. Duplicate samples of frozen ground fruit tissue were weighed in small metal trays at 32° F on a torsion balance. The trays were then placed in the moisture tester at 70° C for about 12 hours and the moisture content was read directly.

B. Physical Observations

The "Ground color chart for McIntosh apples" (59) was used for estimating the shade of ground color of the skin. The chart colors range from yellow to a deep green with No. 1 representing the yellow and No. 5, the deep green. One lot of 20 fruits was used for color observations at harvest and during storage for each sample. The values are presented as average ratings for each sample.

Flesh firmness was determined with a Magness-Taylor type pressure tester with a 7/16 inch plunger. Samples of 10 fruits in 1949 and 20 fruits in 1950 and 1951 were used. Readings were made in pounds required to force the plunger of the tester into the apple flesh, free of skin, to a depth of 5/16 inch, according to the directions given by Haller (28). The fruit was first prepared by paring the skin and a small amount of flesh from the fruit so as to expose a flat area of flesh approximately 2 mm in diameter. Three tests were made on each fruit, one on the blushed side, a second on the unblushed side, and a third test one-half the distance between the other two. Fruit without a blushed side were tested at positions equi-distant from each other. All tests were made half-way between the cavity and basin. The average values for 60 readings from each sample are tabulated in the results.

C. Respiration Methods

The respiration rates of treated and untreated fruits were determined by the method described by Claypool and Keefer (13) for measurement of the carbon dioxide evolved. The principles involved in this method are described by the originators as follows:

> Briefly, the method of analysis consists in passing a known volume of CO_2 free air (not essential) over a weighed portion of plant material to be tested and then equilibrating this air sample with a dilute solution of sodium bi-carbonate containing an appropriate indicator. The solution is then placed in the Evelyn Colorimeter and the per cent transmission is determined. By comparing this per cent transmission with a previously established curve of per cent CO_2 vs per cent transmission, the per cent CO_2 in the gas may be obtained.

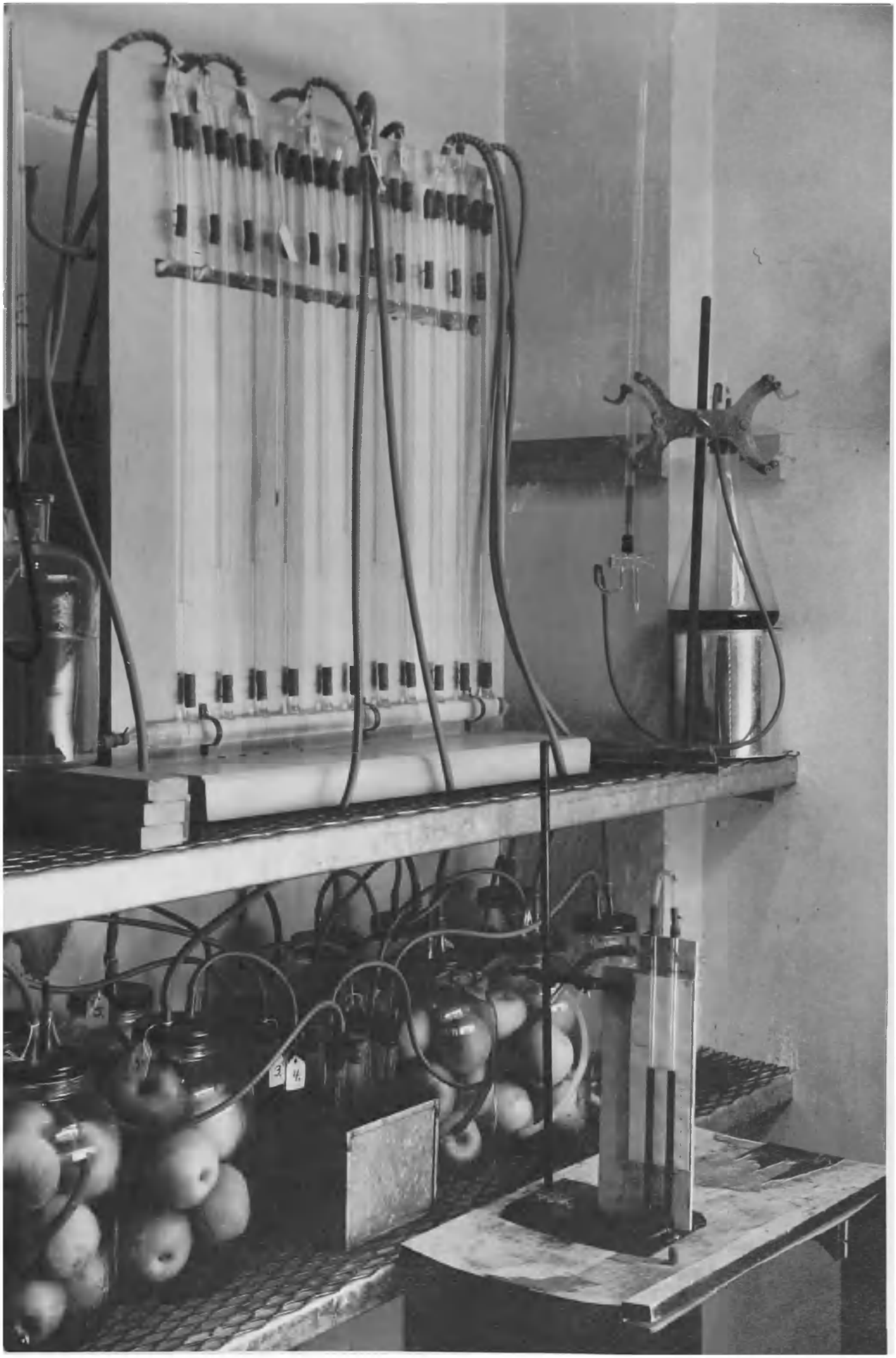
This method was modified according to the recommendations of Claypool (correspondence, August 11, 1949), by replacing the air-scrubbing tower with a set blank determination. Other changes in the apparatus were of a minor nature. The respirometer is illustrated in Figure I.

A curve for mg of CO_2 based on the percent of light transmission of the Evelyn Colorimeter, using a No. 620 filter, was established by absorbing mixtures of known quantities of nitrogen and CO_2 and using bromthymol blue as the indicator.

The manometers, used as flowmeters in the respirometer and for establishing the CO_2 curve, were calibrated by water displacement.

The respirometer was placed in an insulated room in which the temperature was maintained between 70° and 73° F.

Figure I. A portion of the respiration apparatus in operation, showing the respiration chambers in the lower half of the photograph and the flowmeters in the upper half. The air pump, air manifold and barostat tower are hidden from view.



type grinder at 0° F. It was weighed into 20-gm samples at 32° F, then frozen again and held at 0° F until the chemical analysis was made. Water extraction was accomplished by utilizing a 200 ml jar fitted with a standard Waring Blendor cutting assembly, in which blending with distilled water was done for four minutes. The subsequent steps of analysis were made according to standard procedures. The cupric oxide precipitate was filtered with a Selas crucible instead of a Gooch crucible with asbestos. The results are expressed as percent invert sugars on a fresh weight basis.

The soluble solids content (expressed as percent sugar) of the juice of fresh tissue was determined in 1951 in lieu of sugars. Approximately 25 gm of fresh fruit tissue was taken from the 20 apples representing each replicate. Each sample was prepared by removing a thin slice of flesh and skin from the blushed side and another from the unblushed side of each fruit, as in sampling for sugar analysis. The juice from these slices was extracted with a small, hand-operated mechanical press and tested with an Abbé Refractometer.

The acidity of the water extract of the fruit tissue was determined by titration with 0.1N NaOH. Samples weighing 10 gm were taken in duplicate from the ground-frozen tissue in 1949 and 1950. In the former year the weighed sample was diluted with approximately 200 ml of boiled

In order to provide a more constant temperature for the equilibration of CO_2 in the sodium bicarbonate indicator solution, the absorption tubes were kept partly immersed in a distilled water bath. Although there was no means of temperature control, the temperature of the water bath held at 60° F rather consistently.

Outside air which was saturated with moisture by bubbling through water was pushed through the respirometer with a Quincy paint sprayer type compressor powered by a one hp motor.

Pickle jars of one gallon capacity holding 9 to 12 fruits served as respiration chambers. The solutions were held in matched pyrex tubes for the absorption of CO_2 and the colorimeter readings. The tubes were filled with 20 ml of alkali and indicator from a burette, which was refilled by siphoning from a stock bottle.

The fruit samples were placed in the respiration chambers for 24 hours prior to testing for CO_2 evolved, to allow the temperature of the fruit to equilibrate with that of the respiration room. A series of 10 fruit samples plus an empty chamber which served as a blank were tested simultaneously in the respirometer. The CO_2 evolved in respiration was absorbed in the indicator-sodium bicarbonate solutions for 10 minutes. One complete operation required approximately $1\frac{1}{2}$ hours and included three to five checks on rate of air flow through each respiration chamber. Each time that CO_2 absorption for a series of 10 samples was completed the absorption tubes, still in the water bath, were taken into a room held at about 70° F for the colorimeter readings. These readings generally were made within 15 minutes after CO_2 absorption for a series of samples was completed. The results are expressed as mg of CO_2 per kg of fresh fruit per hour.

V. RESULTS

Experiments were conducted in 1949, 1950 and 1951 in which McIntosh and Northern Spy apple trees were treated with preharvest sprays of several growth regulating substances. The results of these tests, as measured by chemical determinations and physical observations, are reported below.

A. McIntosh

Apples of the McIntosh variety were harvested twice in 1949 from treated and untreated trees and stored for approximately four months at 32° F. At the conclusion of the storage period the apples were analyzed for sugars, acids, moisture, ground color and firmness, and the resulting data for growth regulator treatments and harvest dates are summarized in Table 4 (See Appendix Tables 12 and 13 for more detailed data).

There were no significant differences in the chemical composition or firmness of the fruit for treatments (including the check) and harvest dates. The ground color, when observed after storage, was very significantly more yellow for the fruit of the second picking than for the fruit of the first picking. However, no significant differences in ground color occurred between treatments and the check for

TABLE 4

MEAN CHEMICAL COMPOSITION, GROUND COLOR, AND FLESH FIRMNESS OF McINTOSH APPLES HARVESTED SEPTEMBER 8 AND 14, 1949

(Observed after storage at 32° F for more than four months)

Treatment	Harvest period	Invert sugars (%)	Acids (ml .1N NaOH)	Moisture (%)	Color rating	Firmness (lbs.)
Check	1st	9.20	5.4	86.5	4.0	8.6
	2nd	9.30	5.5	86.5	3.3	8.6
	Mean	9.24	5.5	86.5	3.7	8.6
NAA 10 ppm	1st	8.71	5.0	86.7	3.9	9.1
	2nd	9.03	4.9	86.1	3.2	8.6
	Mean	8.87	4.9	86.4	3.6	8.9
NAA 20 ppm	1st	8.62	5.4	86.9	3.7	8.6
	2nd	8.82	4.7	86.6	3.3	8.4
	Mean	8.72	5.1	86.8	3.5	8.5
Toloxy 20 ppm	1st	9.20	5.3	85.9	3.7	10.1
	2nd	9.34	5.0	86.2	3.3	8.8
	Mean	9.28	5.1	86.1	3.5	9.5
Toloxy 30 ppm	1st	8.96	5.5	86.3	4.0	9.2
	2nd	9.30	5.0	85.9	3.5	9.1
	Mean	9.18	5.1	86.0	3.6	9.1
Harvest means	1st	8.94	5.3	86.5	3.9	9.1
	2nd	9.16	5.0	86.3	3.3	8.7
Observed F values:						
Between treatments means		2.56	0.65	1.39	2.2	1.92
Between harvest means		2.20	0.54	1.16	27.7**	2.50

fruit harvested at the same date.

All samples of the second picking were slightly higher in sugars than those of the first picking when analyzed at the conclusion of the storage period. At this time, however all lots of fruit of the first harvest which received a growth regulator spray, except Toloxy at 20 ppm, were slightly lower in sugars than were the untreated fruit. The fruit from the second picking that received NAA were also slightly lower than the untreated lot at the end of the storage period.

The moisture content of the fruit showed small but insignificant differences. No trend for either treatments or harvest dates was evident.

At the conclusion of the storage period, the titratable acidity for fruit receiving the growth regulator sprays was slightly less for the second than for the first harvest. However, the untreated fruit contained approximately the same percent of acids for both harvest dates.

The treated fruits of the second harvest were also somewhat softer than those of the first harvest, when tested immediately after storage at 32° F. The fruits of the first harvest treated with Toloxy at 20 ppm were more firm than the other fruit harvested at the same time.

McIntosh was harvested once in 1950. Chemical composition, ground color, and firmness were determined at harvest, after ten days of storage at 70° F, and after three months of storage at 32° F. The data obtained from these tests are summarized in Table 5. As in the previous year, there were no significant differences at the conclusion of the cold storage period in the sugar content, moisture content, ground color, or firmness of the fruit (See also Appendix Tables 14 - 16). However, when the fruit was analyzed immediately after storage at 32° F, those treated with Toloxy at 20 ppm were significantly higher in acids than the untreated fruit or those receiving 20 ppm of NAA. This difference did not occur at the time of harvest or after holding the fruit for ten days at 70° F. Likewise, there were no significant differences between treatments in the other determinations at these two sampling dates.

The sugar content of the McIntosh fruit in 1950 showed little change during storage (Figure II). Although the sprays of growth regulators appeared to influence the sugar content of the fruit in 1949, the apples treated with such sprays in 1950 did not show, at the end of the 32° F storage period, a decrease in sugars as compared with the untreated fruit.

Increases in ground color and decreases in flesh firmness were rather marked and consistent for all lots of fruit during the storage periods at both high and low temperatures (Figures III and IV). The acidity of the fruit also decreased during storage. The moisture and sugars contents of the apples, as shown in Figure II, did not change appreciably between harvest and the end of the storage periods at 32° or 70° F.

TABLE 5

MEAN CHEMICAL COMPOSITION, GROUND COLOR, AND FLESH FIRMNESS OF McINTOSH APPLES HARVESTED SEPTEMBER 27, 1950

(Observed at harvest, 10 days after storage at 70° F, and after some three months of storage at 32° F)

Treatment	Time	Invert sugars (%)	Acids (ml .1N NaOH)	Moisture (%)	Color rating	Firmness (lbs.)
Check	Harvest	9.90	8.0	85.6	3.4	14.0
	Stored 70° F	9.98	6.7	85.6	2.1	9.5
	Stored 32° F	9.85	5.0	86.1	2.6	9.1
NAA 10 ppm	Harvest	9.96	9.1	85.4	3.6	14.0
	Stored 70° F	9.89	7.0	85.7	2.0	9.0
	Stored 32° F	10.11	6.6	85.9	2.8	9.3
NAA 20 ppm	Harvest	9.50	7.6	85.5	3.4	13.8
	Stored 70° F	9.92	6.5	85.7	1.9	8.9
	Stored 32° F	9.75	4.9	86.7	2.7	9.5
Toloxy 20 ppm	Harvest	9.98	9.3	85.2	3.4	14.5
	Stored 70° F	9.77	7.1	85.4	2.1	9.5
	Stored 32° F	10.18	7.9	85.7	2.5	9.0
2,4,5-TP	Harvest	9.58	8.5	85.8	3.4	13.6
	Stored 70° F	9.71	7.1	85.7	1.8	8.9
	Stored 32° F	9.99	6.7	86.5	2.5	9.0
Observed F values:						
Between treatments						
Harvest		0.91	1.51	1.16	0.62	1.62
Stored 70° F		0.18	0.74	0.58	0.68	2.44
Stored 32° F		0.93	3.21*	2.16	0.70	0.51
L.S.D. between treatments:						
Stored 32° F						
5% level		--	2.2	--	--	--

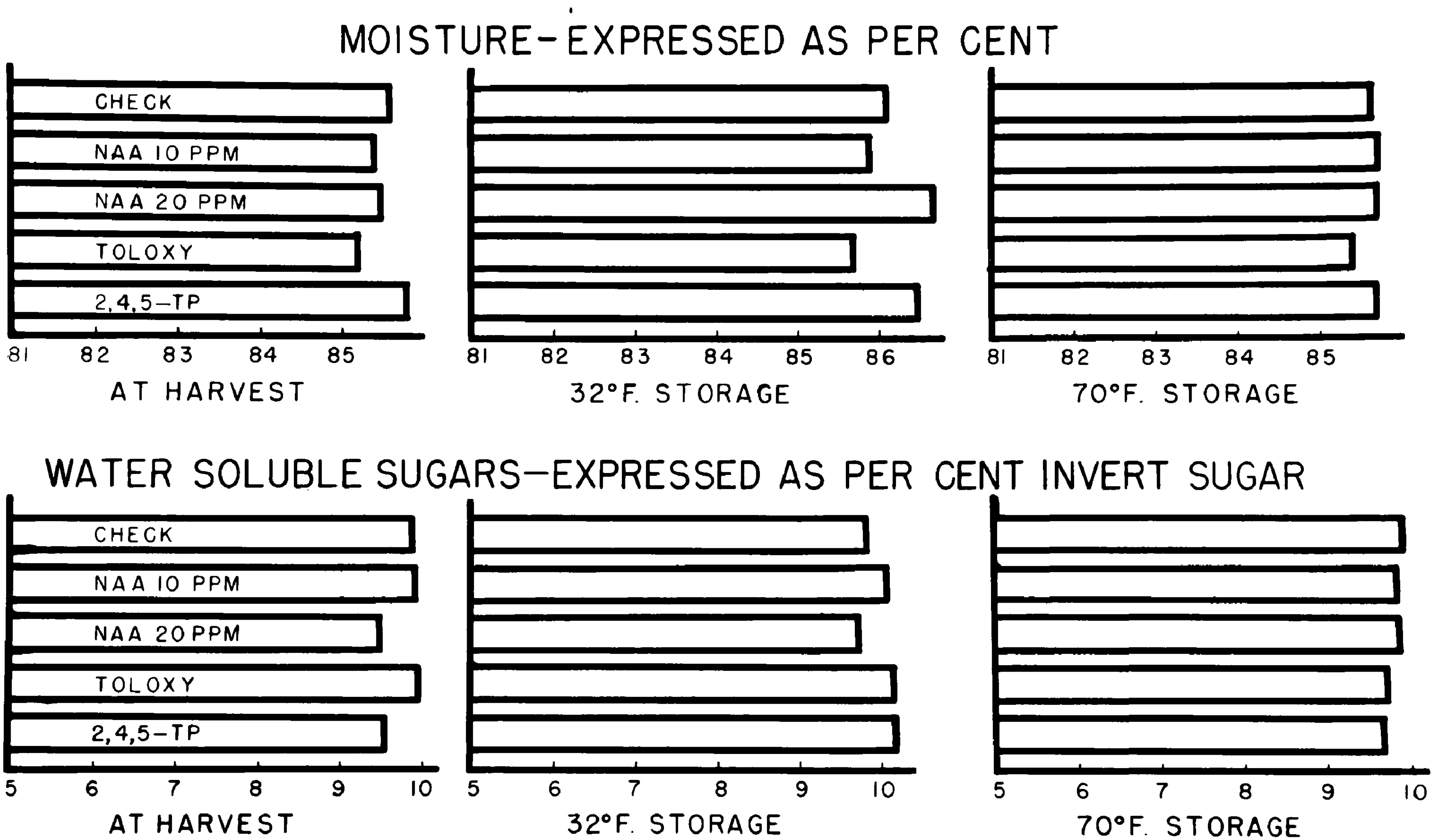


Figure II. Moisture and carbohydrate contents of McIntosh apples harvested September 27, 1950. (Observed at harvest, 10 days after storage at 70° F and after three months of storage at 32° F.)

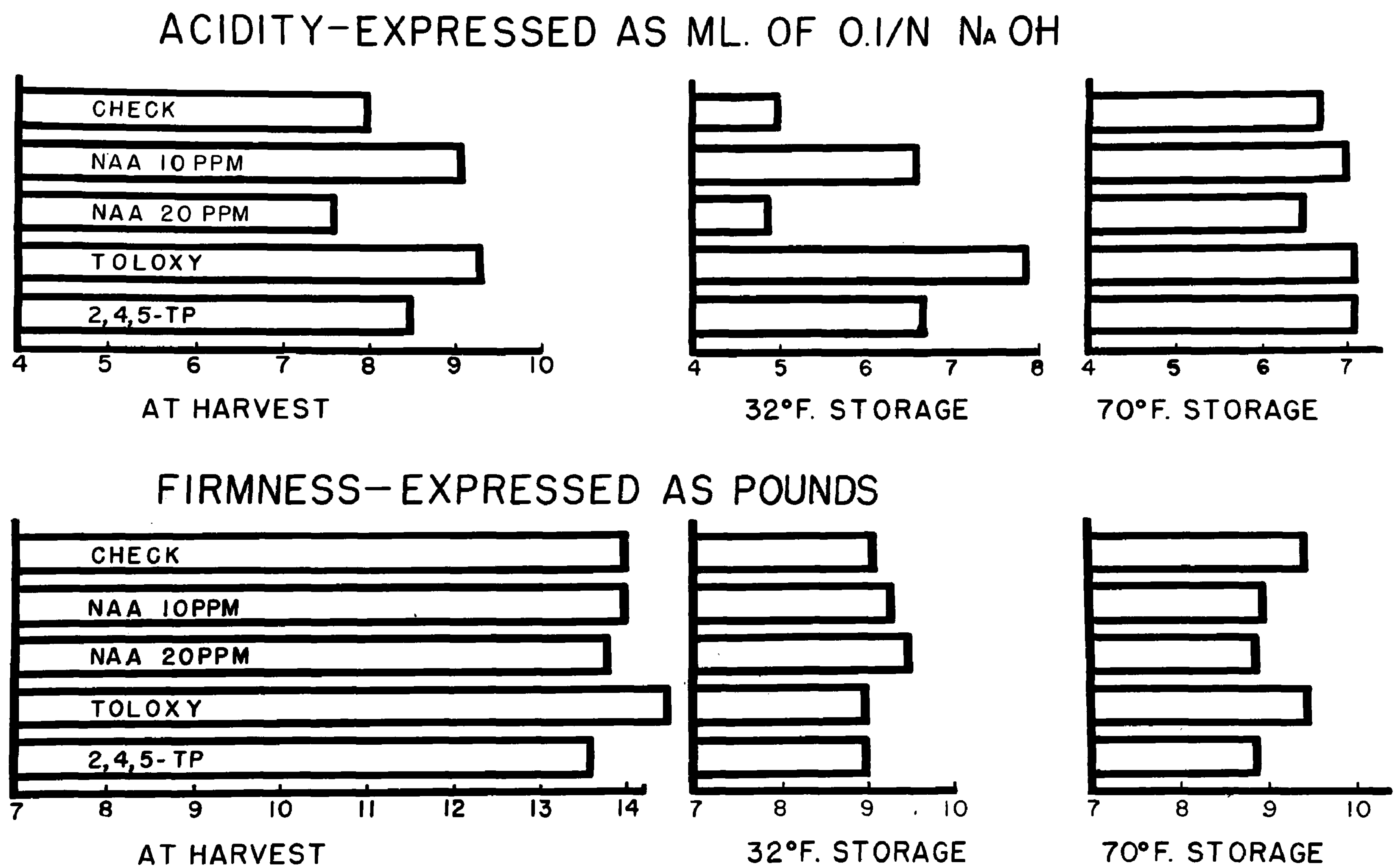


Figure III. Acid content and firmness of McIntosh apples harvested September 27, 1950. (Observed at harvest, 10 days after storage at 70° F and after three months of storage at 32° F.)

Figure IV. Ground color of McIntosh apples harvested September 27, 1950. (Observed at harvest, 10 days after storage at 70° F and after three months of storage at 32° F.)

During 1951, the concluding year of this study, McIntosh apples were harvested at one date. A severe windstorm which removed one-third to two-thirds of the crop occurred prior to sampling of the fruit. The fruit were observed for ground color and firmness at harvest. They were then examined in January and March for color and firmness and were also analyzed for soluble solids (expressed as sugars) and titratable acidity. The data for the two storage periods were combined for statistical analysis. The results obtained in 1951 for McIntosh, as summarized in Tables 6 and 7 (See also Appendix Tables 17 - 19), show some striking differences between treatments in soluble solids, titratable acidity and the firmness of the fruit. The largest and most consistent effects occurred for the fruit treated with 2,4,5-TP, although this same growth regulator did not exert any significant influence upon McIntosh fruit during the preceding year. The soluble solids content (expressed as sugars) of fruit treated with 2,4,5-TP was significantly lower, after storage, than those of the check. Applications of 2,4,5-TP on September 11 (2,4,5-TP "B") showed less effect from the treatment than those sprayed on August 30 (2,4,5-TP "A") or those treated August 30 and September 11 (2,4,5-TP "C"). The NAA and Toloxy-treated fruit were also somewhat lower in sugars than the check in January and March.

Less acid was found in the after-storage analysis of McIntosh apples treated in 1951 with 2,4,5-TP than those

TABLE 6

MEAN GROUND COLOR AND FIRMNESS OF McINTOSH APPLES HARVESTED SEPTEMBER 28, 1951

(Observed at harvest)

Treatment	Color rating	Firmness (lbs.)
Check	4.0	11.5
NAA 20 ppm	4.0	11.2
Toloxy 20 ppm	4.0	10.7
2,4,5-TP "A" (applied Aug. 30)	3.8	9.5
2,4,5-TP "B" (applied Sept. 11)	4.1	9.9
2,4,5-TP "C" (applied Aug. 30 and Sept. 11)	3.8	8.7
L.S.D. between treatments:		
5% level	-	0.9
1% level	-	1.3

TABLE 7

MEAN CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF McINTOSH APPLES HARVESTED SEPTEMBER 28, 1951

(Observed in January and March after storage at 32° F)

Treatment	Time	Sugars[a] (%)	Acids (ml .1N NaOH)	Color rating	Firmness (lbs.)
Check	Jan.	12.0	7.0	3.2	8.9
	March	12.2	4.5	3.1	8.2
	Mean	12.1	5.9	3.1	8.6
NAA 20 ppm	Jan.	11.8	6.4	3.4	9.1
	March	11.7	4.4	3.0	8.1
	Mean	11.7	5.4	3.2	8.6
Toloxy 20 ppm	Jan.	11.7	6.3	3.3	8.9
	March	11.5	4.2	3.1	8.1
	Mean	11.6	5.3	3.2	8.5
2,4,5-TP "A" (applied Aug. 30)	Jan.	11.3	5.4	3.3	8.0
	March	11.1	3.7	3.1	7.7
	Mean	11.2	4.5	3.2	7.8
2,4,5-TP "B" (applied Sept. 11)	Jan.	11.5	5.8	3.3	8.9
	March	11.3	4.0	3.2	7.8
	Mean	11.4	4.9	3.2	8.3
2,4,5-TP "C" (applied Aug. 30 and Sept. 11)	Jan.	11.3	5.5	2.7	8.2
	March	11.4	3.9	2.9	7.3
	Mean	11.3	4.7	2.8	7.8
Storage periods	Jan.	11.6	6.1	3.2	8.7
	March	11.5	4.1	3.0	7.9
Observed F. values:					
Between treatments		5.00**	6.24**	2.30	3.83**
Between storage periods		0.17	182.52**	2.10	26.40**
L.S.D. between treatments:					
5% level		0.6	0.7	--	0.8
1% level		0.8	1.0	--	1.0

[a]Soluble solids expressed as sugars

not treated. This difference was highly significant. However, the 2,4,5-TP "B" treatment had less effect than either the "A" or "C" treatments. The acid content, after storage, of the apples of the 2,4,5-TP "A" treatment was lower than those treated with NAA and Toloxy. The fruit of the 2,4,5-TP "C" treatment were significantly less acid than those treated with NAA. The NAA- and Toloxy-treated samples were also slightly lower in acidity than the check, but not enough so as to be statistically significant. The 2,4,5-TP "A" samples had the least amount of acidity and the untreated samples the greatest amount of acidity as shown in Figure V.

The effects of the various treatments on firmness and ground color of McIntosh apples in 1951 are illustrated in Figure VI. The use of preharvest sprays of 2,4,5-TP resulted in fruit, at harvest, that were less firm than the check fruit and those treated with NAA. This difference in firmness was highly significant. This effect was not observed for 2,4,5-TP on McIntosh during the preceding year. The samples of the 2,4,5-TP "C" treatment were also less firm at harvest than the Toloxy-treated fruit at a highly significant level, while those of the "A" and "B" treatments were less firm at the five percent level. Although the fruit of 2,4,5-TP "A" and "C" treatments were slightly more yellow in ground color at harvest than fruit of the check, NAA, and Toloxy treatments, the differences were not significant.

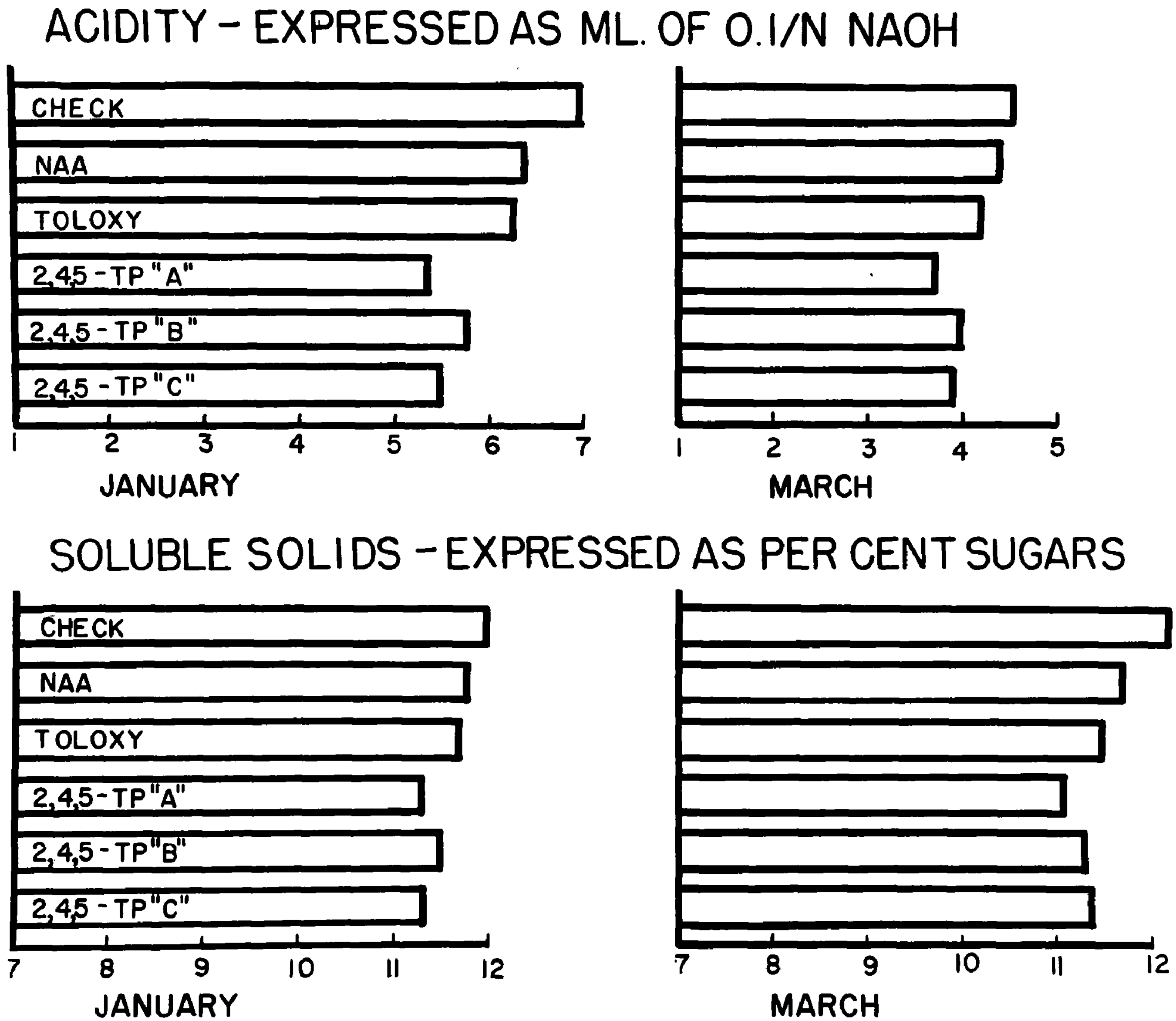


Figure V. Acid and soluble solids contents of McIntosh apples harvested September 28, 1951. (Observed in January and March after storage at 32° F.)

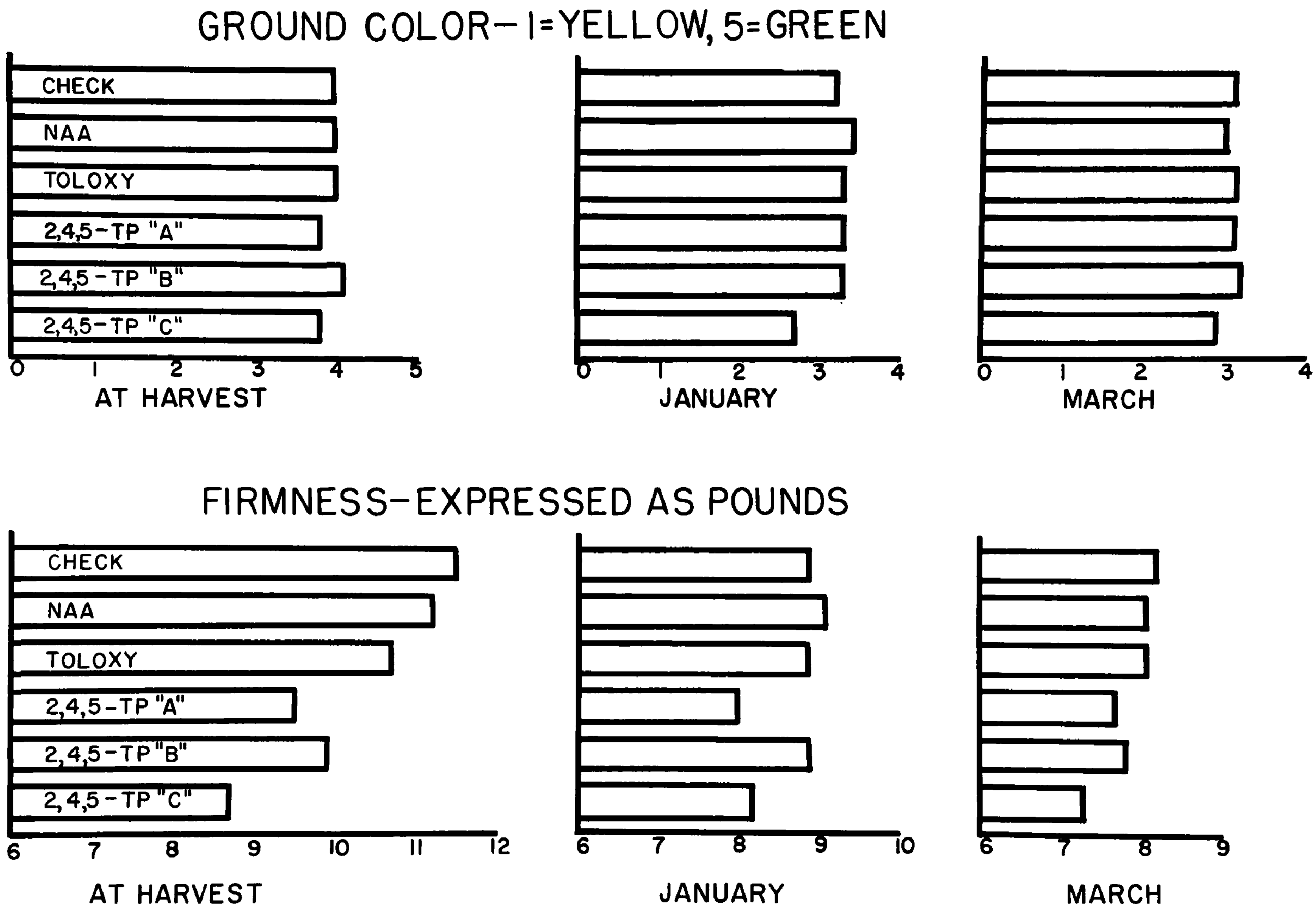


Figure VI. Ground color and firmness of McIntosh apples harvested September 28, 1951. (Observed in January and March after storage at 32° F.)

In 1951, as shown in Figure VI, the fruit of the 2,4,5-TP "A" and "C" treatments were significantly less firm after storage than those of either the check or the NAA treatment. All lots of apples treated with 2,4,5-TP were also slightly less firm, when removed from storage, than those treated with Toloxy. The fruit of all treatments, including the check, were significantly less firm in March than in January.

Figure VI illustrates that the growth regulators did not effect the ground color of McIntosh apples at harvest or when the fruit was observed in January and March. This was also observed in the studies of the previous two years.

B. Northern Spy

Northern Spy trees were treated with sprays of growth regulators in the same manner as McIntosh in 1949 and similar determinations and observations of the fruit were made at harvest and after three months of storage at 32° F. This variety was picked only once in 1949.

The 1949 data for this variety are presented in Table 8 (See also Appendix Tables 20 and 21). No significant differences were observed between treatments at harvest or after storage. However, the sugar content of the fruit decreased slightly during storage for all fruit. Differences in acidity were either too small or too inconsistent to indicate any effects from the treatments. Protein content at harvest was somewhat greater for fruit treated with

TABLE 8

MEAN CHEMICAL COMPOSITION, GROUND COLOR, AND FLESH FIRMNESS OF NORTHERN SPY APPLES HARVESTED OCTOBER 10-12, 1949

(Observed at harvest and again three months later)

Treatment	Time	Invert sugars (%)	Acids (ml .1N NaOH)	Protein (%)	Moisture (%)	Color rating	Firmness (lbs.)
Check	Harvest	11.92	7.4	0.23	83.9	2.7	18.3
	Stored	11.28	7.1	0.24	84.0	2.3	14.0
NAA 10 ppm	Harvest	12.11	7.0	0.27	--	2.2	18.8
	Stored	11.45	7.3	0.23	83.4	2.0	14.4
NAA 20 ppm	Harvest	11.23	7.6	0.27	84.5	2.6	18.9
	Stored	10.60	7.3	0.26	84.3	1.9	13.7
Toloxy 20 ppm	Harvest	11.81	7.3	0.25	83.7	2.2	18.4
	Stored	11.14	7.6	0.23	83.7	1.9	14.0
Toloxy 30 ppm	Harvest	11.72	7.6	0.28	83.8	2.3	18.1
	Stored	10.98	8.0	0.26	83.7	2.1	13.8
Observed F values:							
Between treatments							
Harvest		1.65	0.65	1.36	2.80	1.31	0.39
Stored		1.45	0.88	0.00	1.45	2.68	0.27

growth regulators than for the check fruit. The protein content of all sprayed fruit decreased slightly during the storage period.

None of the preharvest spray treatments appeared to influence the ground color or firmness of the fruit when examined either at harvest or after storage. All apples of this variety seemed to soften equally and showed a similar increase in ground color during storage in 1949.

In 1950, Northern Spy trees were given the same growth regulator treatments as McIntosh. The fruit was harvested once and observed at harvest, after ten days of storage at 70° F, and again after three months at 32° F. The 1950 data which are presented in Table 9 show no significant effects from the sprays of growth regulators at either the high or low storage temperatures (See Figure VII and also Appendix Tables 22 - 24).

All Northern Spy fruits were slightly softer, less acid, and had somewhat more ground color after storage at 32° and 70° F than at harvest (Figures VIII and IX). The treated fruit were slightly more firm than the check fruit at harvest and after storage at both temperatures.

The Northern Spy trees received the same differential treatments of preharvest sprays as McIntosh in 1951. Soluble solids and titratable acidity determinations and color and firmness observations were made at harvest and in February and April on fruit stored at 32° F. The signifi-

TABLE 9

MEAN CHEMICAL COMPOSITION, GROUND COLOR, AND FLESH FIRMNESS OF NORTHERN SPY APPLES HARVESTED OCTOBER 25, 1950

(Observed at harvest, after storage for 10 days at 70° F, and after three months at 32° F)

Treatment	Time	Invert sugars (%)	Acids (ml .1N NaOH)	Moisture (%)	Color rating	Firmness (lbs.)
Check	Harvest	10.36	10.0	84.7	2.6	14.4
	Stored 70° F	10.56	7.7	85.3	1.7	11.3
	Stored 32° F	10.06	7.3	85.3	1.5	10.3
NAA 10 ppm	Harvest	10.74	10.5	84.9	2.3	15.0
	Stored 70° F	10.67	8.1	84.7	1.5	12.7
	Stored 32° F	10.63	7.8	85.1	1.3	11.3
NAA 20 ppm	Harvest	10.42	10.6	84.5	2.4	14.9
	Stored 70° F	10.59	8.1	85.0	1.6	12.3
	Stored 32° F	10.36	7.4	85.0	1.4	11.2
Toloxy 20 ppm	Harvest	10.49	9.6	84.9	2.4	14.6
	Stored 70° F	10.84	7.8	84.9	1.7	12.1
	Stored 32° F	10.89	6.8	85.4	1.4	10.9
2,4,5-TP	Harvest	10.33	10.4	84.8	2.5	15.0
	Stored 70° F	10.74	8.0	84.9	1.7	12.4
	Stored 32° F	10.21	8.2	85.2	1.4	11.2
Observed F values:						
Between treatments						
Harvest		0.69	1.32	1.00	0.42	0.50
Stored 70° F		0.38	0.70	0.46	1.50	1.73
Stored 32° F		1.00	1.78	0.50	0.67	0.61

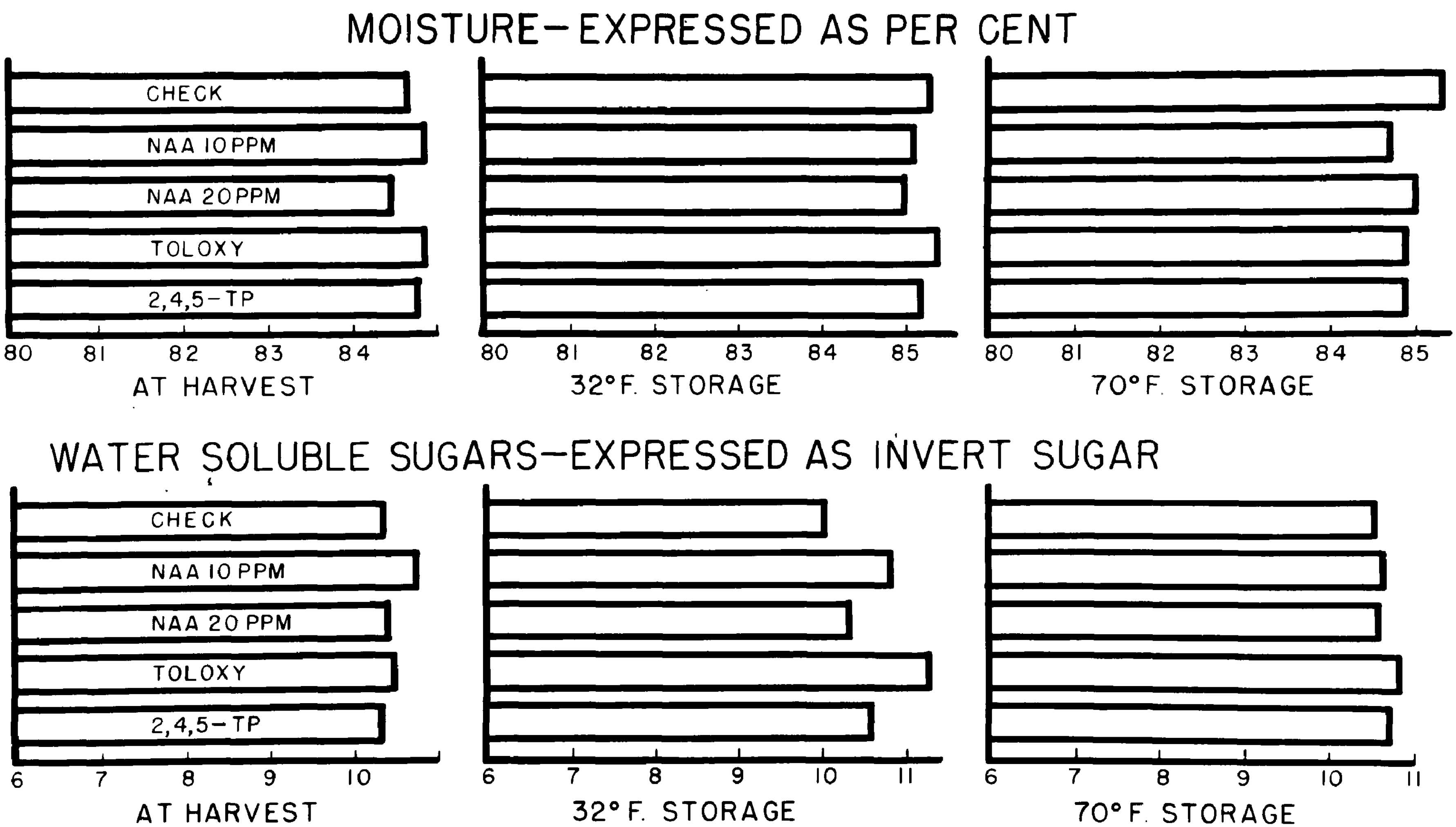


Figure VII. Moisture and carbohydrate contents of Northern Spy apples harvested October 25, 1950. (Observed at harvest, 10 days after storage at 70° F and after three months of storage at 32° F.)

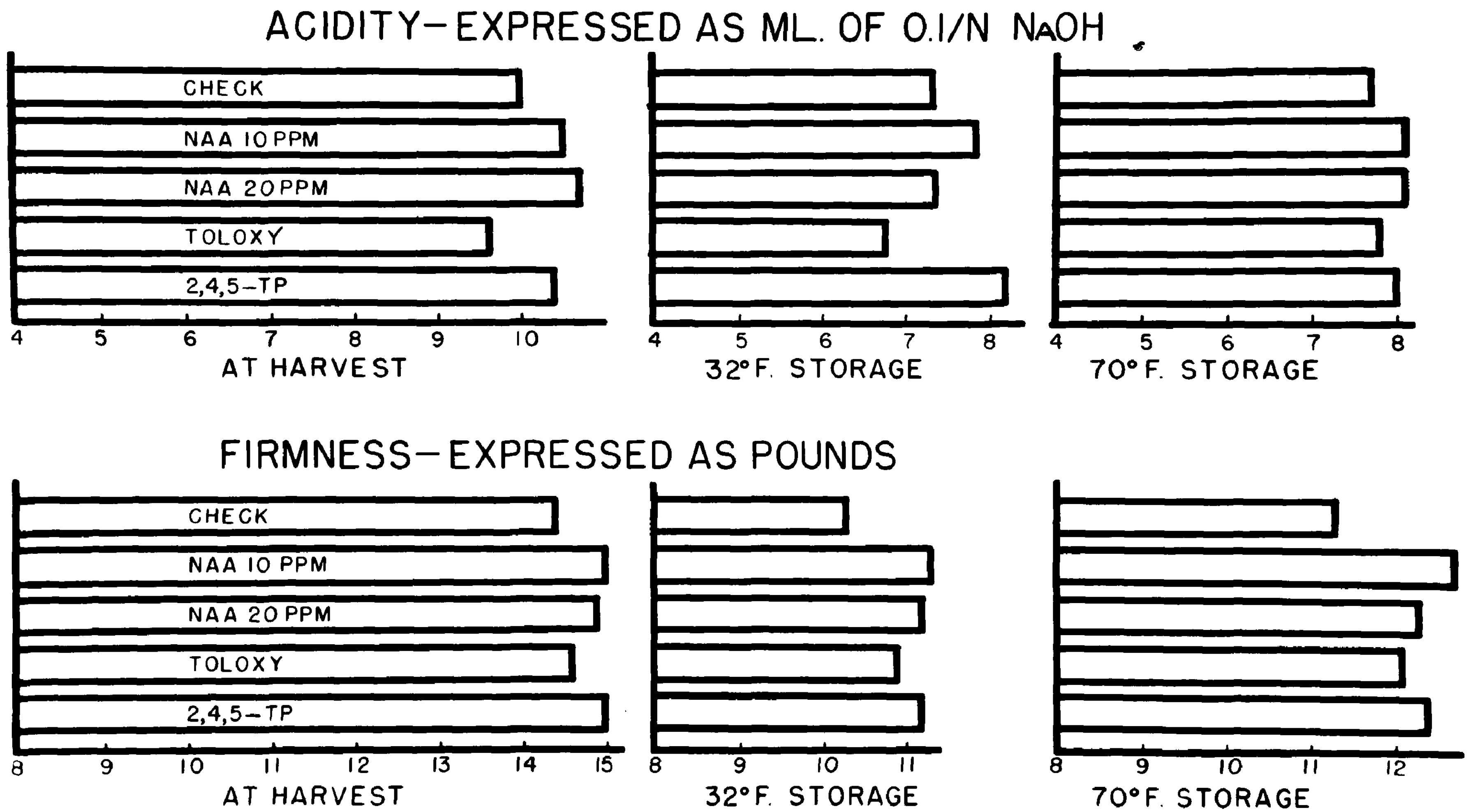


Figure VIII. Acid content and firmness of Northern Spy apples harvested October 25, 1950. (Observed at harvest, 10 days after storage at 70° F and after three months of storage at 32° F.)

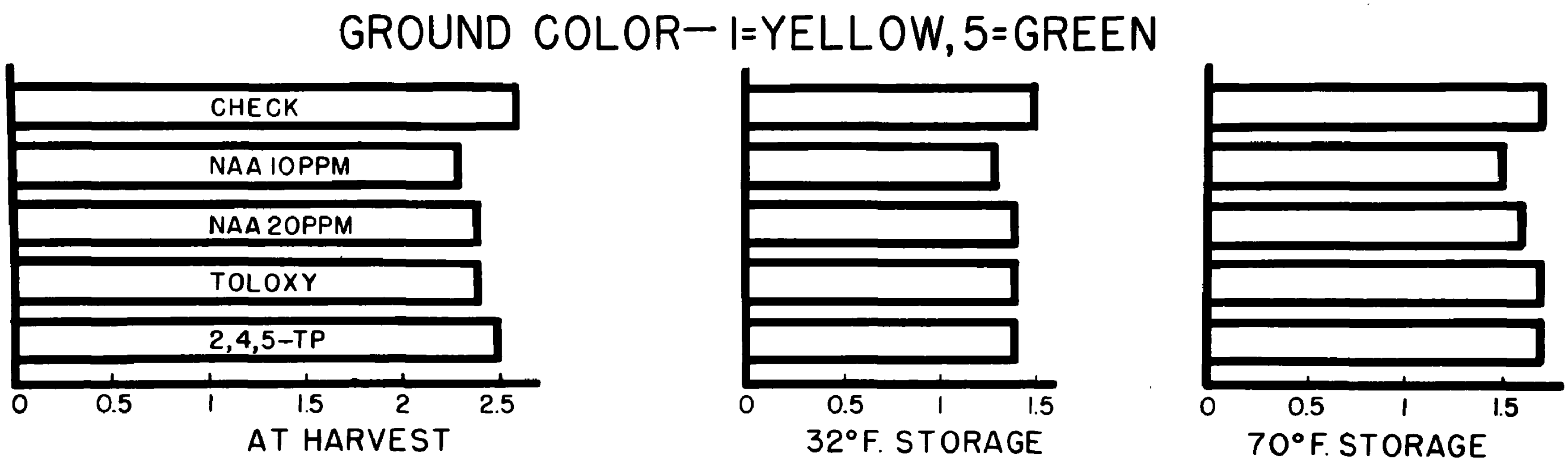


Figure IX. Ground color of Northern Spy apples harvested October 25, 1950. (Observed at harvest, 10 days after storage at 70° F and after three months of storage at 32° F.)

cant differences between treatments obtained with McIntosh fruit in 1951 were not observed with Northern Spy during the same year, as shown in Tables 10 and 11 and Appendix Tables 25 - 27. Only the fruit treated with Toloxy were significantly different from the check in any respect. When analyzed in February and April the Toloxy-treated fruit were significantly less acid than the check.

The Northern Spy fruit became lower in sugars and acids and less firm between February and April in amounts that were highly significant.

The various treatments in 1951 had no significant effects, as shown in Figures X and XI, upon Northern Spy apples at harvest time. However, the fruit treated with 2,4,5-TP were highest in sugars at harvest and were second lowest after storage in April. The check was the lowest in sugars in April. The check fruit showed slightly more ground color and slightly softer flesh, at the time of harvest, than the treated fruit, but these differences decreased during the storage period.

C. Respiration

Respiration determinations were made with McIntosh and Northern Spy apples harvested in 1951 from treated and untreated trees. The McIntosh were tested soon after harvest (October 1-8) and after storage at 32° F (January 19-30). Similar determinations were made with Northern Spy fruit from October 25 to November 4, and from February 19-28.

TABLE 10

MEAN CHEMICAL COMPOSITION, GROUND COLOR, AND FIRMNESS OF NORTHERN SPY APPLES HARVESTED OCTOBER 18, 1951

(Observed at harvest)

Treatment	Sugars[a] (%)	Acids (ml .1N NaOH)	Color rating	Firmness (lbs.)
Check	13.4	9.7	2.5	14.0
NAA 20 ppm	13.8	11.3	2.9	14.7
Toloxy 20 ppm	13.4	10.7	2.8	14.4
2,4,5-TP "A" (applied Oct. 1)	14.2	11.5	2.7	14.1
2,4,5-TP "B" (applied Oct. 12)	14.1	9.8	2.8	14.9
2,4,5-TP "C" (applied Oct. 1 and Oct. 12)	13.8	12.0	2.7	14.7
Observed F values:	1.14	1.15	1.42	0.47

[a]Soluble solids expressed as sugars

TABLE 11

MEAN CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF NORTHERN SPY APPLES HARVESTED OCTOBER 18, 1951

(Observed in February and April after storage at 32° F)

Treatment	Time	Sugars[a] (%)	Acids (ml .1N NaOH)	Color rating	Firmness (lbs.)
Check	Feb.	13.7	8.1	1.9	12.1
	April	13.0	7.2	1.8	11.1
	Mean	13.4	7.5	1.9	11.7
NAA 20 ppm	Feb.	13.8	7.9	2.1	12.2
	April	13.4	7.4	2.2	11.0
	Mean	13.6	7.7	2.2	11.6
Toloxy 20 ppm	Feb.	13.7	7.4	2.0	11.8
	April	13.3	6.5	1.9	11.3
	Mean	13.6	7.0	2.0	11.5
2,4,5-TP "A" (applied Oct. 1)	Feb.	13.6	8.2	2.1	12.2
	April	13.1	7.4	1.9	10.9
	Mean	13.4	7.8	2.0	11.5
2,4,5-TP "B" (applied Oct. 11)	Feb.	13.6	8.1	2.2	12.3
	April	13.6	6.5	1.8	11.5
	Mean	13.6	7.3	2.0	12.0
2,4,5-TP "C" (applied Oct. 1 and Oct. 11)	Feb.	14.0	8.1	1.9	12.0
	April	13.6	7.0	1.7	11.4
	Mean	13.8	7.5	1.8	11.7
Storage periods	Feb.	13.7	8.0	2.0	12.1
	April	13.3	7.0	1.9	11.2
Observed F values:					
Between treatments		1.00	2.66**	1.40	4.89**
Between storage periods		8.68**	37.69**	3.00	24.63**
Treatment x storage period		--	1.00	--	0.79
L.S.D. between treatments:					
5% level		--	0.7	--	0.9
1% level		--	1.0	--	1.2

[a]Soluble solids expressed as sugars

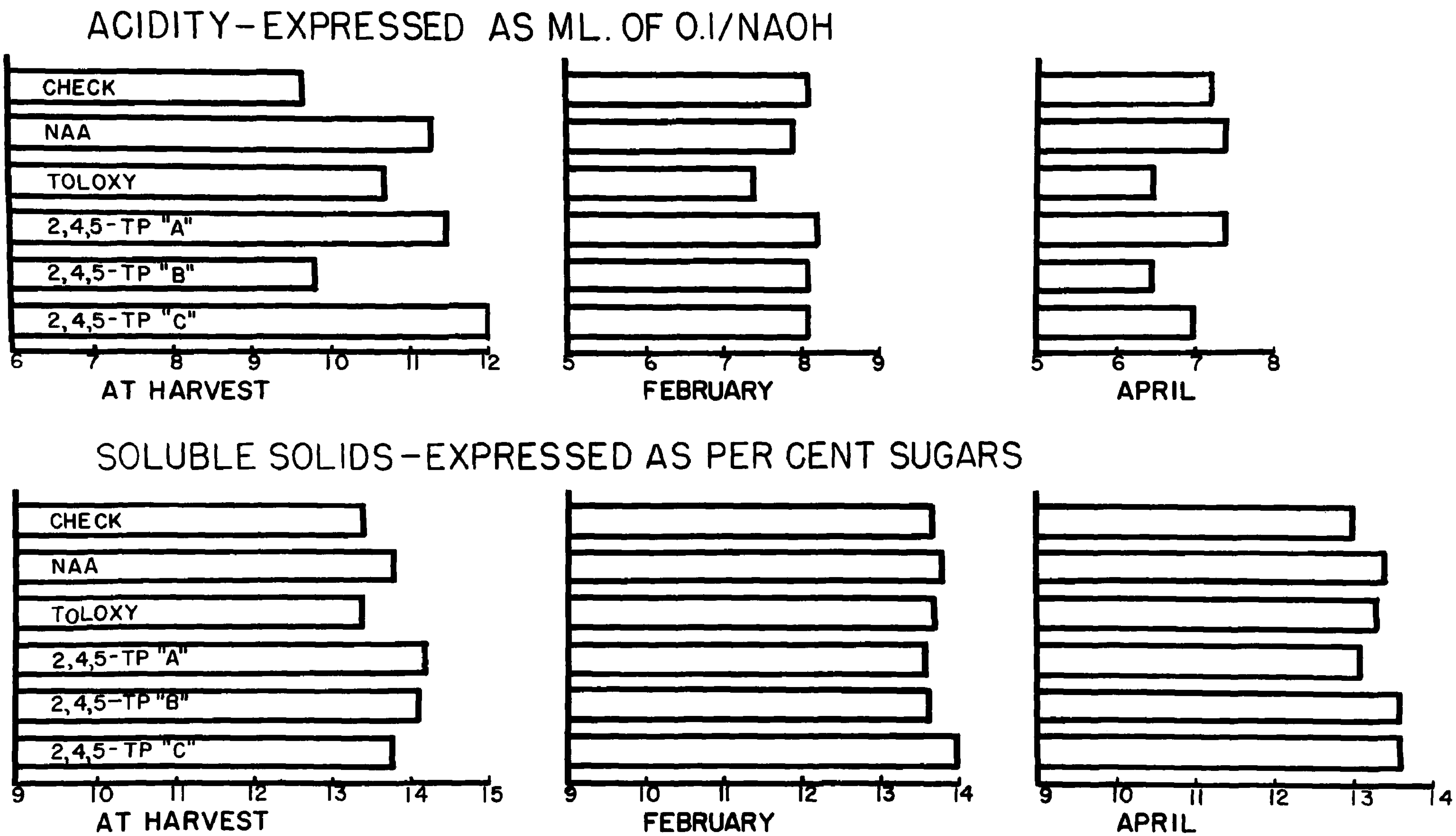


Figure X. Acid (as 0.1 N NaOH) and soluble solids (as sugars) present in Northern Spy apples harvested October 18, 1951. (Observed at harvest and in February and April after storage at 32° F.)

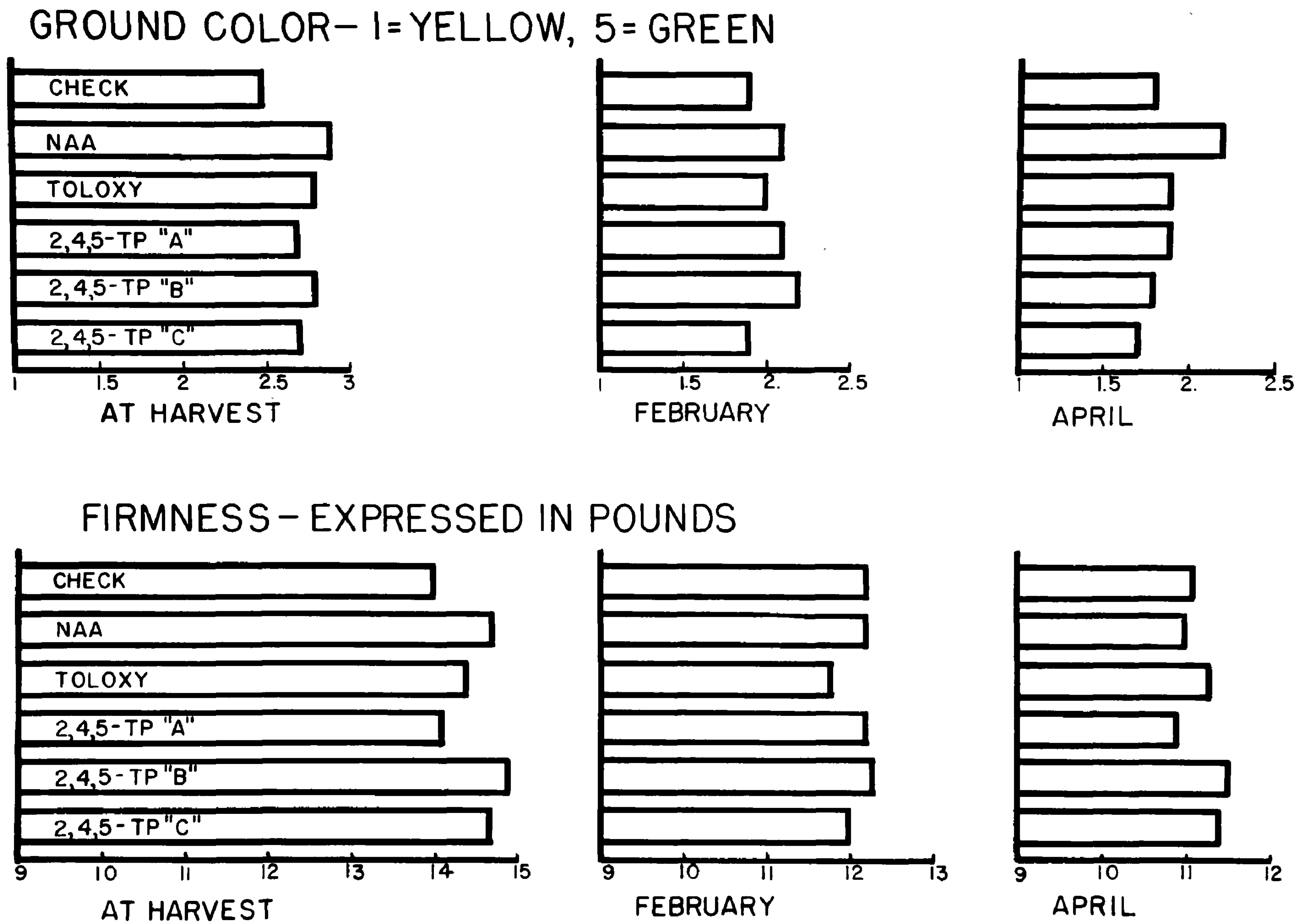


Figure XI. Ground color and firmness of Northern Spy apples harvested October 18, 1951. (Observed at harvest and in February and April after storage at 32° F.)

The respiration curves in Figure XII are plotted from typical data and illustrate the amount of variability that generally occurred between replicates. The detailed data for these respiration studies are presented in Appendix Tables 16 and 17. The general levels of respiration, as measured by CO_2 production, were similar for all treatments at harvest and again after storage. This similarity was found for each variety, although the two varieties had different levels of respiration. The respiration rates did not show differences that could be attributed to pre-harvest applications of growth regulator materials.

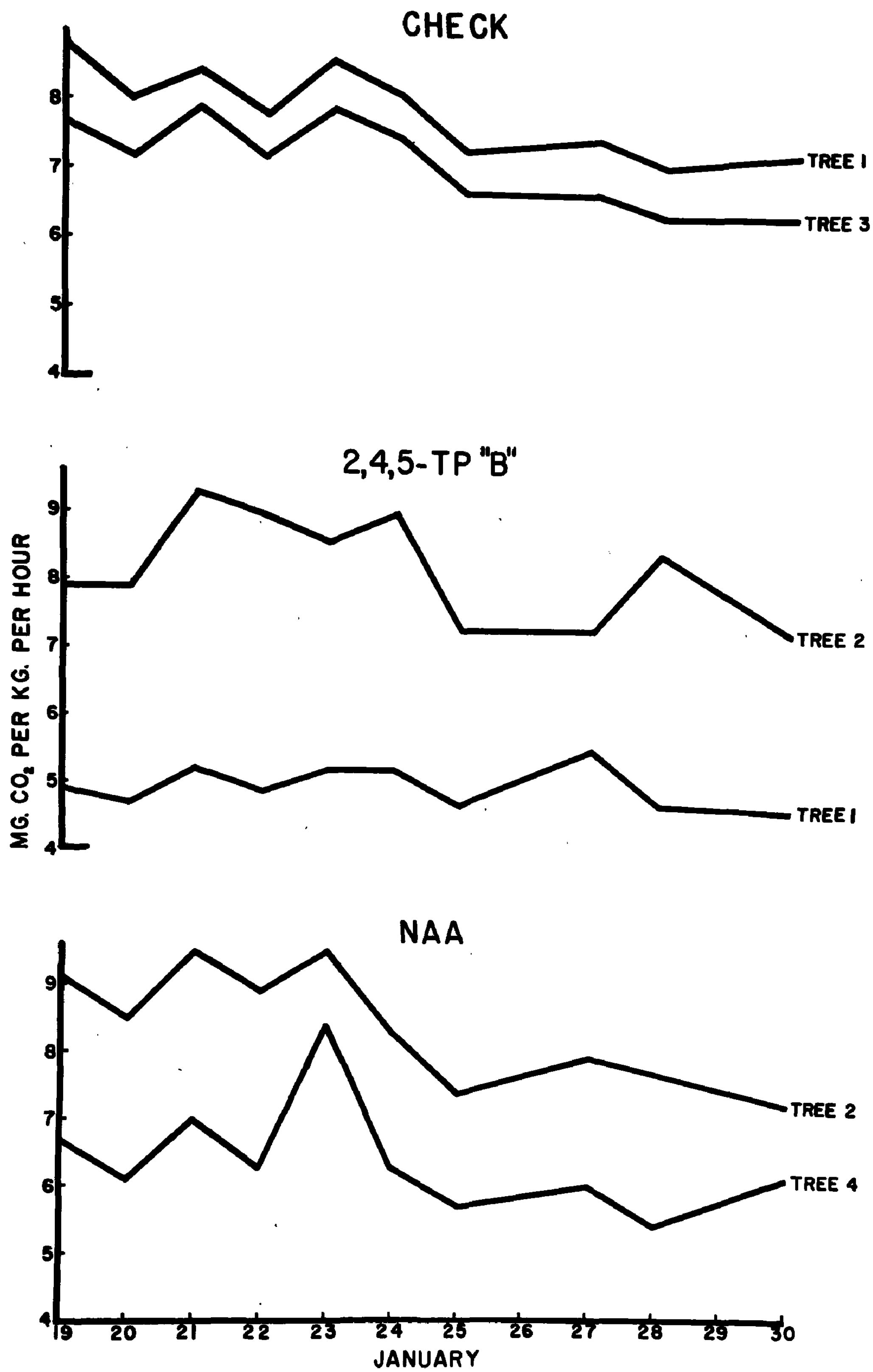


Figure XII. The respiration rates of McIntosh apples from untreated trees and those sprayed with 2,4,5-trichlorophenoxypropionic and naphthaleneacetic acids, and harvested September 28, 1951. (Fruit observed in January after storage at 32° F.)

VI. DISCUSSION

The results of this investigation show that preharvest stop-drop sprays applied to McIntosh and Northern Spy apple trees over a period of three years in Michigan orchards had a variable effect upon the physiology of the harvested fruits.

The differences noted in most instances cannot be attributed to the materials employed because of the variable results obtained. However, in 1951 2,4,5-TP affected the post-harvest physiology of the McIntosh fruit more than NAA or Toloxy.

Preharvest sprays of NAA had no apparent effects upon the chemical composition, ground color or firmness of harvested McIntosh and Northern Spy apples during the three years of this study. However, this material may have advanced the ripening of McIntosh fruit in storage in 1951. This is indicated by the observation that the soluble solids content was slightly lower for the NAA-treated fruit than for untreated fruit (See Table 7). These results are in general agreement with those of a number of other workers. Batjer and Moon (7) reported no effect upon Jonathan, Rome Beauty and Delicious apples during storage, as measured by firmness and the occurrence of storage disorders. Christopher and Pieniazek (12) also found that NAA sprays did not affect firmness, taste, and breakdown of McIntosh fruits in storage. Haller (29) reported no influence on the firmness at harvest, during storage or on the amount of decay, breakdown, and scald during cold storage of a number of apple varieties, including Jonathan and Delicious. The agreement of the results of the studies reported in this paper with those cited above are due probably, at least in part, to the harvesting of the experimental fruit at the normal harvesting dates or shortly thereafter.

The absence of post-harvest effects of NAA sprays applied before harvest is apparently contrary to the findings of Smock and Gross (54). These workers observed that applications of preharvest sprays containing 10 ppm of NAA applied to individual limbs of McIntosh trees caused the fruit to soften 0.5 pound more than the check fruit, in 32° F storage. They also reported that NAA sprays increased the respiration of McIntosh fruit at 74° F, when harvested five or eight days after treatment. A shorter storage life for the fruit is implied since an increased rate of ripening is usually associated with an increased rate of respiration of apple fruit (39). The same workers later reported that preharvest sprays of NAA did not increase the respiration rate of McIntosh apples. However, the fruit of this study were harvested two days after spraying and were stored 58 days at 33° F. Also, the respiration measurements were made at 33° F rather than at 74° F, as in the previous study. It was their opinion that the lack of response to NAA was due to the low temperature at which respiration was measured and to the short interval between treatment and harvest.

McIntosh and Northern Spy fruits also failed to exhibit marked post-harvest effects following the use of drop-delaying sprays of Toloxy during the three years of this investigation. However, Toloxy applications at 20 ppm in 1949, may have had a slight effect on McIntosh fruit. This was indicated by the greater decrease in firmness of the fruit between the first and second pickings for this treatment than was found for other treatments and the check (See Table 4). Furthermore, a tendency toward advanced ripening in storage of McIntosh fruit from the Toloxy treatment was indicated in 1951 by the fact that the acid and soluble solids contents of the fruit were somewhat lower after storage than was found for the check. This trend, however, was not supported by the other chemical and physical changes of the fruit in 1949 and 1951 or by the data obtained in 1950. These results are similar to those of Smock and Gross (55) who observed that the respiration rate of McIntosh fruit was not measurably influenced by limb sprays of Toloxy applied two days before harvest. Their respiration measurements were made at 33° F after a storage period of 58 days at 33° F. However, they attribute the absence of an effect to the low temperature at which respiration was measured and to the short interval of time between spraying and harvesting. This is the same explanation they offered for the lack of response obtained with NAA in the same experiment.

The results obtained in 1951 with McIntosh show that preharvest sprays of 2,4,5-TP caused significant reductions in the firmness of the fruit on the tree and significant reductions in soluble solids and acid contents of McIntosh fruit during storage at 32° F. Applications of this material in 1951 to trees of this variety 28 days before harvest (2,4,5-TP "A") seemed to be more effective in reducing the soluble solids and acid contents and firmness of the fruit than applications made 17 days before harvest (2,4,5-TP "B"). However, 2,4,5-TP did not induce the changes in the fruit of McIntosh in 1950 and significant changes in the fruit did not result from the application of this material to Northern Spy in either 1950 or 1951.

These observations indicate that 20 ppm of 2,4,5-TP, applied as a preharvest spray, may advance the ripening of McIntosh fruit slightly in some seasons and thereby shorten the storage life of the fruit.

The different results in 1950 and 1951 obtained with sprays of 2,4,5-TP on McIntosh may have been due to the seasonal differences in temperature occurring on the days of growth regulator treatments. By reference to Table 3 it may be seen that the maximum temperature on the day the McIntosh trees were sprayed in 1951 was 21 to 22 degrees higher than it was in 1950. The higher temperature in 1951 may have been partly responsible for the influence of 2,4,5-TP observed on McIntosh fruits that year.

Smock and Gross (54) have frequently observed that climatic variations in the growing season contribute to the magnitude of the effect of "stop-drop" sprays in advancing the respiration and softening of apple fruits after harvest. Edgerton and Hoffman (17) state that the extremely hot weather which prevailed during the course of one of their experiments with 2,4,5-TP may have contributed to the advanced ripening and increased red color which they observed with McIntosh fruit.

Reports indicate that temperatures at the time of and soon after the application of preharvest sprays influence the effectiveness of the sprays in controlling apple drop. Batjer (5) observed less drop of fruit from Delicious and Winesap trees sprayed with NAA when they were treated at mid-day with prevailing temperatures of 80-84° F than when they were treated in the morning at temperatures of 63-64° F. He suggested that more of the active growth substance was absorbed at the higher temperature than at the lower temperature.

Overholser et al (47) reported similar results and Vyvyan (62), reviewing the previous two reports, pointed out that the greater drop-control obtained with sprays applied at the higher temperatures may have been due to more rapid drying, less run-off and, therefore, a greater deposition and absorption of the growth regulator by the tree. Mitchell et al (45) point out that the unusually effective drop-control which they obtained on McIntosh with Toloxy in 1949 may have been influenced by the unusually warm weather which prevailed before and several days after the first of two applications of this material. However, Roberts and Struckmeyer (49) reported very good drop control with NAA on Fameuse and Northern Spy apples which were treated at the low temperature of 43° F following heavy frost. The results of the experiments reported here lend some support to the hypothesis that high temperatures on the day "stop-drop" sprays are applied may hasten the ripening rate and other physiological changes of apple fruit. Although the temperatures at the time of application are probably of considerable influence, further investigation is needed before its true effects may be established.

Other factors than temperature may be important. For example, there is evidence indicating that the occurrence of rainfall soon after preharvest sprays are applied reduces the control of apple drop with such sprays. Southwick (56) states that drop-control on McIntosh was reduced appreciably by rain that fell before applications of NAA had dried completely. Overholser et al (47) simulated rainfall by spraying Delicious apple trees with water soon after treatment with preharvest applications of NAA. They found that water applied within two hours after a NAA spray, reduced the drop-delaying effect of this material. Some loss of the growth regulator before it was absorbed by the tree, when rainfall followed shortly after the spray, was probably responsible for the reduced drop control. Rainfall probably also modifies other physiological effects upon the fruit resulting from the application of preharvest sprays to apple trees.

The results of these experiments show other noteworthy trends in the physiological behavior of the fruit. The McIntosh fruit from the second picking in 1949 were measurably less acid, softer, and had developed more sugars and ground color in storage than those of the first picking (Table 4). These observations are in agreement with those reported by Magness and Diehl (39) who found that as apples mature on the tree, they contain increasingly more sugar, develop more ground color and become less acid and less firm. The differences between fruits attributable to variation in maturity at harvest would be expected to persist after storage, and this was true in the 1949 studies of this investigation. These observed differences could have been due also to the fact that the fruit of the first picking received only one application of the growth regulator sprays, whereas the fruit of the second picking received two sprays. Although there seems to be some doubt in regard to the value of a second application of NAA in delaying apple harvest drop (6, 47), benefit may be expected when the first application is made considerably in advance of maturity (6). It might therefore be desirable under such circumstances, to use two applications of NAA even though the storage life of the fruit may be shortened.

The McIntosh and Northern Spy fruit of all treatments, including the check in 1950 and 1951, were generally less acid, softer, and more yellow in color after the longest period in storage than either at harvest or upon earlier observation in storage (See Tables 6, 7, 9, 10 and 11). The reason is not evident for the increase in acidity of Northern Spy fruit after storage, following sprays of 10 ppm of NAA or 20 and 30 ppm of Toloxy in 1950 and 1951 (See Table 8).

An expected reduction in the sugar content of Northern Spy fruit during storage occurred in 1949 (See Table 8), but the sugars of both McIntosh and Northern Spy apples showed slight fluctuations during storage in 1950 and 1951. The sugar content of most fruit samples increased during the ten days of storage at 70° F in 1950, while most of those apples that were held for three months at 32° F decreased in sugars during storage. This upward trend in sugars at 70° F may have resulted from the conversion of starch to sugar which occurs in the maturing apple fruit on the tree and which sometimes continues for a short period after harvest. On the other hand, the decrease in sugar content of most of the fruit in 1950 during the three months of storage at 32° F probably resulted from the utilization of carbohydrates in respiration during this extended period of storage. The fruit which decreased in sugar content at 70° and increased at 32° F may have been harvested at a different stage in the starch-sugar cycle described above.

The soluble solids content of all McIntosh fruit harvested in 1951 showed only small changes during the storage period from January to March. There was, however, a slight downward trend in sugar or soluble solid content which would be expected due to the loss of carbohydrates in respiration toward the end of the storage period. Analysis of all Northern Spy fruit at harvest and in February indicated no consistent changes in the sugar content during storage. However, all lots of Northern Spy fruit, except those receiving the 2,4,5-TP "B" treatment, were lower in soluble solids in April than in February. Again, this would be expected toward the end of the storage period due to carbohydrate utilization in respiration. The absence of change in soluble solids of the fruit from the "B" treatment in storage may have been due to faulty sampling of material for analysis.

The protein analyses for Northern Spy apples in 1949 at harvest show that all treated fruit were slightly higher in total nitrogenous substances than the checks (Table 8). Although the differences are small, it is conceivable that the growth regulator sprays were responsible for the slightly increased amounts of nitrogenous materials in the fruit. A similar effect has been reported by Sell et al (50) for the stems of bean plants treated with 2,4-D. The apple fruit may be comparable to the bean stem because the edible flesh of the apple is modified toral or stem tissue (37). It is therefore possible that the response of apples to NAA and Toloxy was similar to the response of bean stems to 2,4-D. Toloxy is somewhat similar in chemical structure to 2,4-D. It should be pointed out, however, that Sell et al (50) found a considerable reduction in the carbohydrate content of the bean stems following treatment with 2,4-D, and that this was not true for the Northern Spy apples treated with Toloxy and analyzed for protein content in the investigation reported in this paper (See Tables 8, 9, 10).

The use of summer oil in combination with NAA as a preharvest spray was reported by Haller (29) to have caused apple fruits to be less firm at harvest than those treated with NAA alone. Oil was used in combination with NAA and Toloxy in the 1949 studies of this investigation, but there was no evidence to support Haller's findings. The data in Tables 4 and 8 show there were no significant effects from any of the spray combinations employed.

The samples of fruit from all spray treatments in 1950 were stored at temperatures of 70° and 32° F in order to determine if fruit treated with growth regulating materials would react differently at temperatures which might prevail in a retail store than at temperatures commonly used for commercial cold storage of apples. The storage temperatures had no influence upon the response of the fruit to the preharvest sprays (Tables 5 and 6).

One of the difficulties in comparing the results of this study with those of others has been the lack of a suitable and universal maturity index for determining the optimum time for harvesting apples. Haller (30) states that the number of days from bloom is the most reliable index for picking apples to obtain optimum maturity. He points out, however, that fertilizer practices, climatic conditions, and size of crop may influence the lapse of time between bloom and optimum maturity for any one variety. Other indices such as changes in seed color, chemical composition, firmness, and ground color were found to be unreliable. The variability reported for these maturity indices was attributed to differences in season and geographical location. Smock (52) attempted to determine the most desirable index of maturity for picking McIntosh apples in New York. He tested the various standard methods as well as the rates of respiration of the fruit and concluded that the best time to pick McIntosh under New York conditions is "just at or just following the beginning of the climacteric rise in respiration" of the fruit. He qualified this conclusion by stating that the respiration index is practical only for experimental workers and that ground color is the most useful measure of maturity for McIntosh fruit for the grower.

In the three years of this study, the fruit were harvested generally within the normal commercial harvest period, soon after the drop of normal, fully developed fruit had begun. However, the sampling time for McIntosh in 1951 was a few days later than in 1949 and 1950 in relation to the beginning of natural drop. It may be noted from the data that the ground color of the check fruit at harvest time varied only slightly during the three years of this study for both varieties; the color ratings ranged from 3.5 to 4 for McIntosh and from 2.5 to 2.7 for Northern Spy. The firmness of the check fruit varied, however, from 11 to 14 pounds for McIntosh and from 14 to 18.5 pounds for Northern Spy. The number of days from bloom to harvest was uniform for McIntosh, ranging from 129 to 132 days, whereas Northern Spy was less uniform, ranging from 156 to 164 days from bloom to harvest. The measurement of the respiration of the fruit recommended by Smock might have provided a more accurate maturity index than that which was used. It was, however, not practical under the experimental conditions encountered in these studies.

The respiration data obtained were of little value in determining the effects upon the fruit sprayed with growth regulators due to the sizable differences which frequently occurred between replicates. These fluctuations may have been due to the methods employed as well as to the biological differences existing between fruit of the replicate trees within a treatment. The random picking of fruit from the trees may have given samples which were at different stages in the respiration cycle. The samples of 9 to 14 fruit, from which respiration determinations were made, may have been too small. Furthermore, the difference in size between fruit within each sample probably added to the variation noted in the respiration rates.

Even if the variations between replications were disregarded, average curves representing the data would still not indicate any definite effects attributable to the preharvest treatments. Climacteric peaks in respiration were not apparent for the fruit immediately after harvest as expected, either because the test periods were of too short a duration or because the fruit was in a postclimacteric condition. The distinctly downward trend in respiration of the Northern Spy apples at harvest seems to indicate a postclimacteric condition (Appendix Table 16). The daily fluctuations in respiration exhibited by each sample could have been caused by factors such as the 3° F temperature fluctuation in the room where the determinations were made. The almost straight line curves shown in Figure XII for the respiration rates of McIntosh apples after cold storage, would be expected for fruit held and tested under these conditions.

VII. SUMMARY

McIntosh and Northern Spy apple trees were sprayed prior to harvest with drop delaying sprays of naphthalene-acetic acid (NAA), 2-methyl-4-chlorophenoxyacetic acid (Toloxy) and 2,4,5-trichlorophenoxypropionic acid (2,4,5-TP). The physiological responses of the fruit to these sprays at harvest and after storage at 70° and 32° F were measured by chemical analyses of the edible portions of the fruit for moisture, sugars, soluble solids, protein and acid contents. Determinations of skin ground color, flesh firmness and respiration rates of the fruit were also made.

The fruit samples were harvested at random from the test trees once during the normal commercial harvest period. An early harvest of McIntosh fruit was also made in 1949.

The results of this investigation show that NAA and Toloxy did not markedly influence the physiology of the fruit. However, sprays of 2,4,5-TP significantly affected McIntosh apples in one of the two years in which this material was tested. Applications of 2,4,5-TP to McIntosh trees 28 days before harvest were of greater effect on the fruit than the applications made 17 days before harvest. The sprays of 2,4,5-TP in 1951 caused the fruit to be softer at harvest and caused a significant reduction in the soluble solids, acid content and firmness of the fruit during the subsequent storage period. These effects from 2,4,5-TP were not observed on McIntosh in 1950 or on Northern Spy in either of the two years in which this material was used. The evidence suggests that the higher temperatures occurring on the day of application of 2,4,5-TP in 1951 than in 1950 may have contributed to the differences obtained for McIntosh apples in these two years.

The lack of response of the fruit to treatment with growth regulators in 1950 was not due to the temperature at which the fruit was held following harvest, since both varieties were observed after storage at 32° and 70° F. Likewise, varying the number of applications of preharvest sprays and dates of harvest had no effect in the 1949 tests with McIntosh. In this test, the fruit was harvested early in the usual harvest period following a single application of growth regulators, and again at a later date after a second treatment.

The rates of respiration of the McIntosh and Northern Spy apples treated in 1951 were determined by CO_2 evolution soon after harvest and at the conclusion of an extended storage period. Variations in the respiration rates between replications of test fruit were great and differences in respiration due to treatments of growth regulators were not observed.

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APPENDIX

TABLE 12

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF McINTOSH APPLES HARVESTED SEPTEMBER 8, 1949

(Observed after cold storage in January, 1950)

Treatment	Repli-cation	Invert sugars (%)	Acids (ml .1N NaOH)	Moisture (%)	Color rating	Firmness (lbs.)
Check	1	8.87	4.7	87.3	4.1	9.1
	2	8.95	6.3	86.5	4.0	8.1
	3	9.83	5.3	85.8	3.9	8.7
	Mean	9.20	5.4	86.5	4.0	8.6
NAA 10 ppm	1	8.58	4.1	87.0	4.3	9.1
	2	9.19	5.0	86.9	3.8	9.2
	3	8.96	4.8	87.0	3.8	9.0
	4	8.12	6.1	85.8	3.7	9.1
	Mean	8.71	5.0	86.7	3.9	9.1
NAA 20 ppm	1	8.41	5.8	87.0	4.1	8.6
	2	8.97	3.4	87.3	3.9	8.6
	3	8.56	6.2	87.0	3.6	8.4
	4	8.56	6.5	86.2	3.1	8.7
	Mean	8.62	5.4	86.9	3.7	8.6
Toloxy 20 ppm	1	--	--	--	--	12.9
	2	7.92	4.6	87.1	3.9	8.5
	3	10.06	4.9	84.9	3.8	10.0
	4	9.62	6.4	85.7	3.4	9.0
	Mean	9.20	5.3	85.9	3.7	10.1
Toloxy 30 ppm	1	8.58	5.1	86.6	4.1	9.0
	2	9.34	5.8	86.0	3.9	9.3
	3	--	--	--	--	--
	4	--	--	--	--	--
	Mean	8.96	5.5	86.3	4.0	9.2

TABLE 13

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF McINTOSH APPLES HARVESTED SEPTEMBER 14, 1949

(Observed after cold storage in January, 1950)

Treatment	Repli-cation	Invert sugars (%)	Acids (ml .1N NaOH)	Moisture (%)	Color rating	Firmness (lbs.)
Check	1	8.90	4.8	87.0	3.9	8.9
	2	8.98	5.3	86.9	3.1	8.5
	3	9.91	6.4	85.7	2.9	8.5
	Mean	9.30	5.5	86.5	3.3	8.6
NAA 10 ppm	1	8.83	3.6	86.4	3.4	9.1
	2	8.86	5.2	86.3	3.4	8.1
	3	8.83	5.0	86.3	2.9	8.6
	4	9.61	5.7	85.6	3.2	8.7
	Mean	9.03	4.9	86.1	3.2	8.6
NAA 20 ppm	1	8.84	5.3	86.5	3.5	8.2
	2	8.80	3.4	87.0	3.7	8.4
	3	8.89	4.2	86.8	3.5	8.6
	4	8.73	6.1	86.4	2.6	8.5
	Mean	8.82	4.7	86.6	3.3	8.4
Toloxy 20 ppm	1	7.99	4.6	87.6	3.3	8.4
	2	9.80	4.6	87.0	3.4	8.4
	3	10.12	4.5	84.5	3.3	9.6
	4	9.43	6.3	85.7	3.2	8.9
	Mean	9.34	5.0	86.2	3.3	8.8
Toloxy 30 ppm	1	9.09	4.5	86.2	3.9	9.6
	2	9.59	5.4	85.1	3.3	8.9
	3	9.40	4.7	85.9	3.5	9.7
	4	9.11	5.3	86.3	3.1	8.2
	Mean	9.30	5.0	85.9	3.5	9.1

TABLE 14

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF McINTOSH APPLES HARVESTED SEPTEMBER 27, 1950

(Observed at harvest)

Treatment	Repli-cation	Invert sugars (%)	Acids (ml .1N NaOH)	Moisture (%)	Color rating	Firmness (lbs.)
Check	1	10.20	7.8	84.9	3.6	14.2
	2	10.01	7.4	85.4	3.1	14.8
	3	9.93	8.0	86.3	3.4	13.4
	4	9.47	8.8	85.9	3.6	13.6
	Mean	9.90	8.0	85.6	3.4	14.0
NAA 10 ppm	1	10.15	8.7	85.5	3.6	14.8
	2	9.64	10.6	85.1	3.2	14.3
	3	9.93[a]	9.4[a]	85.4[a]	3.7[a]	14.0
	4	10.11	7.8	85.4	4.0	12.9
	Mean	9.96	9.1	85.4	3.6	14.0
NAA 20 ppm	1	9.74	8.0	85.8	3.6	13.6
	2	9.42	4.9	85.7	3.3	13.8
	3	8.85	8.1	84.9	3.4	14.3
	4	9.98	9.5	85.4	3.3	13.6
	Mean	9.50	7.6	85.5	3.4	13.8
Toloxy 30 ppm	1	10.17	9.6	85.0	3.1	14.6
	2	9.50	9.7	85.2	3.3	14.8
	3	10.32	10.1	84.9	3.4	14.2
	4	9.93	7.8	85.5	3.7	14.4
	Mean	9.98	9.3	85.2	3.4	14.5
2,4,5-TP 20 ppm	1	9.74	9.2	85.6	3.2	13.2
	2	10.18	8.5	85.3	3.4	13.7
	3	9.76	8.2	86.2	3.6	13.9
	4	8.63	8.0	85.9	3.4	13.7
	Mean	9.58	8.5	85.8	3.4	13.6

[a]Calculated missing value

TABLE 15

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF McINTOSH APPLES HARVESTED SEPTEMBER 27, 1950

(Observed 10 days after storage at 70° F)

Treatment	Replication	Invert sugars (%)	Acids (ml .1N NaOH)	Moisture (%)	Color rating	Firmness (lbs.)
Check	1	10.56	6.8	85.1	2.2	9.8
	2	9.30	7.1	85.7	1.9	9.6
	3	10.02	6.3	85.7	2.1	9.1
	4	10.02	6.4	85.7	2.0	9.6
	Mean	9.98	6.7	85.6	2.1	9.5
NAA 10 ppm	1	9.91	6.6	85.8	2.0	9.6
	2	9.55	8.1	85.8	1.7	9.2
	3	10.01[a]	6.8[a]	85.7[a]	2.1[a]	8.9[a]
	4	10.08	6.4	85.5	2.3	8.2
	Mean	9.89	7.0	85.7	2.0	9.0
NAA 20 ppm	1	9.47	6.2	86.2	2.3	8.5
	2	10.30	6.0	85.5	1.7	8.9
	3	10.15	6.6	85.2	2.0	8.9
	4	9.76	7.3	85.7	1.5	9.2
	Mean	9.92	6.5	85.7	1.9	8.9
Toloxy 30 ppm	1	9.47	7.0	85.2	1.8	9.2
	2	9.47	7.9	85.3	2.3	9.8
	3	10.51	7.3	85.2	2.1	9.3
	4	9.62	6.3	85.8	2.2	9.5
	Mean	9.77	7.1	85.4	2.1	9.5
2,4,5-TP 20 ppm	1	10.37	7.2	85.5	1.8	8.6
	2	10.00	7.1	85.7	2.2	8.9
	3	9.78	6.4	86.2	1.8	9.1
	4	9.30	7.6	85.4	1.5	9.1
	Mean	9.71	7.1	85.7	1.8	8.9

[a]Calculated missing value

TABLE 16

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF McINTOSH APPLES HARVESTED SEPTEMBER 27, 1950

(Observed after some three months of storage at 32° F)

Treatment	Replication	Invert sugars (%)	Acids (ml .1N NaOH)	Moisture (%)	Color rating	Firmness (lbs.)
Check	1	10.20	4.7	85.6	2.7	9.3
	2	10.08	5.6	85.8	2.2	9.8
	3	9.79	5.1	86.6	2.7	8.4
	4	9.33	4.4	86.3	2.9	9.0
	Mean	9.85	5.0	86.1	2.6	9.1
NAA 10 ppm	1	9.86	8.1	85.7	2.8	9.5
	2	9.91	6.4	85.6	2.5	9.3
	3	10.17[a]	7.5[a]	86.1[a]	2.8[a]	9.2[a]
	4	10.49	4.3	86.2	3.2	9.2
	Mean	10.11	6.6	85.9	2.8	9.3
NAA 20 ppm	1	10.25	4.4	87.8	3.2	9.1
	2	9.28	4.8	86.5	2.6	9.1
	3	9.67	4.7	85.9	2.5	9.8
	4	9.81	5.7	86.7	2.4	9.9
	Mean	9.75	4.9	86.7	2.7	9.5
Toloxy 30 ppm	1	10.64	8.9	85.5	2.3	8.5
	2	10.06	8.2	85.0	2.3	10.0
	3	10.10	9.8	86.3	2.4	9.5
	4	9.93	4.5	86.1	3.1	8.1
	Mean	10.18	7.9	85.7	2.5	9.0
2,4,5-TP 20 ppm	1	9.67	8.2	86.2	2.4	8.5
	2	9.98	4.7	86.1	2.6	9.7
	3	10.46	8.5	86.9	2.6	8.5
	4	9.83	5.5	86.7	2.5	9.1
	Mean	9.99	6.7	86.5	2.5	9.0

[a]Calculated missing value

TABLE 17

GROUND COLOR AND FIRMNESS OF McINTOSH APPLES HARVESTED SEPTEMBER 28, 1951

(Observed at harvest)

Treatment	Replication	Color rating	Firmness (lbs.)
Check	1	4.0	10.7
	2	3.9	12.0
	3	3.9	11.9
	4	4.0	11.5
	Mean	4.0	11.5
NAA 20 ppm	1	4.0	11.1
	2	4.1	11.0
	3	4.0	11.2
	4	3.9	11.4
	Mean	4.0	11.2
Toloxy 20 ppm	1	4.0[a]	10.4[a]
	2	4.0	11.0
	3	4.1	10.5
	4	4.0	10.9
	Mean	4.0	10.7
2,4,5-TP "A" 20 ppm (applied Aug. 30)	1	4.0	9.5
	2	3.7	9.5
	3	3.8	9.3
	4	3.8	9.8
	Mean	3.8	9.5
2,4,5-TP "B" 20 ppm (applied Sept. 11)	1	4.1	9.8
	2	4.1	8.9
	3	4.0	11.0
	4	4.0	10.9
	Mean	4.1	9.9
2,4,5-TP "C" 20 ppm (applied Aug. 30 and Sept. 11)	1	3.6	9.1
	2	4.0	8.5
	3	3.9	9.0
	4	3.8	8.3
	Mean	3.8	8.7

[a]Calculated missing value

TABLE 18

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF McINTOSH APPLES HARVESTED SEPTEMBER 28, 1951

(Observed in January, 1952, after storage at 32° F)

Treatment	Replication	Sugars[b] (%)	Acids (ml .1N NaOH)	Color rating	Firmness (lbs.)
Check	1	11.5	6.2	3.3	9.3
	2	12.5	6.6	3.4	8.4
	3	11.5	6.6	2.9	9.0
	4	12.5	8.4	3.2	9.0
	Mean	12.0	7.0	3.2	8.9
NAA 20 ppm	1	11.0	6.4	3.1	9.0
	2	12.0	7.0	3.4	9.4
	3	12.0	6.6	3.3	9.0
	4	12.0	5.4	3.6	9.0
	Mean	11.8	6.4	3.4	9.1
Toloxy 20 ppm	1	11.7[a]	6.0[a]	3.1[a]	9.0[a]
	2	11.5	6.8	3.2	8.4
	3	11.5	5.8	3.3	9.3
	4	12.0	6.4	3.4	8.7
	Mean	11.7	6.3	3.3	8.9
2,4,5-TP "A" 20 ppm (applied Aug. 30)	1	11.0	5.2	3.2	8.1
	2	11.5	5.0	3.3	8.3
	3	11.0	5.4	3.2	7.7
	4	11.5	6.0	3.5	7.7
	Mean	11.3	5.4	3.3	8.0
2,4,5-TP "B" 20 ppm (applied Sept. 11)	1	11.5	5.8	3.4	8.9
	2	10.5	5.8	3.3	8.9
	3	12.0	5.2	3.1	8.2
	4	12.0	6.4	3.2	9.6
	Mean	11.5	5.8	3.3	8.9
2,4,5-TP "C" 20 ppm (applied Aug. 30 and Sept. 11)	1	11.5	5.2	2.0	8.4
	2	11.0	5.6	3.2	8.0
	3	11.5	6.0	3.0	8.5
	4	11.0	5.2	2.7	8.0
	Mean	11.3	5.5	2.7	8.2

[a]Calculated missing value
[b]Soluble solids expressed as sugars

TABLE 19

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF McINTOSH APPLES HARVESTED SEPTEMBER 28, 1951

(Observed in March, 1952, after storage at 32° F)

Treatment	Replication	Sugars[b] (%)	Acids (ml .1N NaOH)	Color rating	Firmness (lbs.)
Check	1	12.0	3.9	3.6	7.5
	2	12.5	4.4	3.1	8.9
	3	12.3[a]	4.5[a]	2.8	8.8
	4	12.0	5.0	2.8	7.5
	Mean	12.2	4.5	3.1	8.2
NAA 20 ppm	1	11.5	4.6	2.4	8.9
	2	11.8	4.4	3.3	7.5
	3	11.8	4.4	3.1	8.2
	4	11.8	4.2	3.2	7.8
	Mean	11.7	4.4	3.0	8.1
Toloxy 20 ppm	1	11.3[a]	3.9[a]	3.1[a]	8.0[a]
	2	12.0	3.8	3.1	7.6
	3	11.0	4.4	3.2	8.4
	4	11.5	4.6	3.1	8.4
	Mean	11.5	4.2	3.1	8.1
2,4,5-TP "A" 20 ppm (applied Aug. 30)	1	11.0	3.2	3.3	6.8
	2	11.3	3.9	3.3	8.3
	3	11.0	3.8	2.9	7.9
	4	11.0	3.7	3.0	7.6
	Mean	11.1	3.7	3.1	7.7
2,4,5-TP "B" 20 ppm (applied Sept. 11)	1	11.0	3.9	3.3	8.0
	2	10.5	3.3	3.2	6.6
	3	12.3	4.1	3.0	7.5
	4	11.5	4.52	3.1	8.9
	Mean	11.3	4.0	3.2	7.8
2,4,5-TP "C" 20 ppm (applied Aug. 30 and Sept. 11)	1	11.5	3.4	2.5	7.2
	2	11.0	4.4	3.7	7.7
	3	11.5	3.8	2.8	7.4
	4	11.5	4.1	2.4	6.9
	Mean	11.4	3.9	2.9	7.3

[a]Calculated missing value
[b]Soluble solids expressed as sugars

TABLE 20

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF NORTHERN SPY APPLES HARVESTED OCTOBER 10-12, 1949

(Observed at harvest)

Treatment	Repli-cation	Invert sugars (%)	Acids (ml .1N NaOH)	Protein (%)	Moisture (%)	Color rating	Firm-ness (lbs.)
Check	1	11.97	7.6	0.22	83.8	2.2	18.5
	2	11.74	6.6	0.23	84.3	2.4	16.6
	3	11.84	7.7	0.25	83.4	3.0	18.5
	4	12.14	7.7	0.23	84.1	3.1	19.7
	Mean	11.92	7.4	0.23	83.9	2.7	18.3
NAA 10 ppm	1	12.39	7.5	0.22	--	2.5	20.9
	2	10.92	7.2	0.31	--	1.7	17.2
	3	12.80	7.0	0.28	--	2.3	18.0[a]
	4	12.37[a]	6.4	0.27[a]	--	2.2	18.4
	Mean	12.11	7.0	0.27	--	2.2	18.8
NAA 20 ppm	1	11.53	8.1	0.24	84.2	2.0	18.4
	2	11.13	8.3	0.33	85.1	2.3	15.1
	3	11.20	7.2	0.27	84.1	2.7	21.5
	4	11.12	6.9	0.25	84.6	2.1	20.5[a]
	Mean	11.23	7.6	0.27	84.5	2.6	18.9
Toloxy 20 ppm	1	11.94	7.2	0.25	83.8	2.2	18.9
	2	11.47	7.8	0.22	83.9	2.2	18.6
	3	12.15	8.0	0.25	83.4	1.9	16.2
	4	11.67	6.2	0.28	83.5	2.4	19.9
	Mean	11.81	7.3	0.25	83.7	2.2	18.4
Toloxy 30 ppm	1	11.03	8.1	0.31	84.7	2.5	18.6
	2	10.97	8.1	0.28	84.6	1.7	16.8
	3	12.12	7.5	0.26	82.8	2.2	14.9
	4	12.77	6.5	0.28	83.1	2.7	21.9
	Mean	11.72	7.6	0.28	83.8	2.3	18.1

[a]Calculated missing value

TABLE 21

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF NORTHERN SPY APPLES HARVESTED OCTOBER 10-12, 1949

(Observed after three months of storage at 32° F)

Treatment	Replication	Invert sugars (%)	Acids (ml .1N NaOH)	Protein (%)	Moisture (%)	Color rating	Firmness (lbs.)
Check	1	11.22	7.5	0.19	83.9	1.8	14.0
	2	10.78	6.8	0.25	84.1	2.0	13.2
	3	10.85	7.2	0.26	84.5	2.6	13.8
	4	12.27	7.0	0.25	83.7	2.9	14.9
	Mean	11.28	7.1	0.24	84.0	2.3	14.0
NAA 10 ppm	1	12.15	6.7	0.20	82.5	2.5	15.5
	2	11.05	7.2	0.23	84.1	1.5	13.6
	3	11.65	7.0	0.23	83.8	2.1	14.6
	4	10.93	8.1	0.25	83.4	1.9	14.0
	Mean	11.45	7.3	0.23	83.4	2.0	14.4
NAA 20 ppm	1	10.63	7.6	0.25	84.3	1.9	14.0
	2	9.71	7.2	0.26	85.3	2.0	12.3
	3	11.15	7.0	0.28	83.6	1.9[a]	15.8
	4	10.90	7.4	0.24	84.1	1.9	12.7
	Mean	10.60	7.3	0.26	84.3	1.9	13.7
Toloxy 20 ppm	1	11.45	7.2	0.24	83.4	2.0	14.1
	2	11.33	8.1	0.20	83.6	1.8	13.9
	3	10.76	8.5	0.25	84.2	1.9	13.0
	4	11.03	6.6	0.22	83.7	2.0	15.0
	Mean	11.14	7.6	0.23	83.7	1.9	14.0
Toloxy 30 ppm	1	10.79	8.4	0.21	84.3	2.2	12.9
	2	10.68	8.7	0.21	84.0	1.7	13.7
	3	10.64	7.8	0.36	83.9	1.7	13.4
	4	11.79	7.0	0.27	82.4	2.7	15.3
	Mean	10.98	8.0	0.26	83.7	2.1	13.8

[a]Calculated missing value

TABLE 22

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF NORTHERN SPY APPLES HARVESTED OCTOBER 25, 1950

(Observed at harvest)

Treatment	Replication	Invert sugars (%)	Acids (ml .1N NaOH)	Moisture (%)	Color rating		Firmness (lbs.)
					b	c	
Check	1	10.49	9.88	84.6	3.3	2.8	13.5
	2	10.22	9.85	84.5	1.9	2.5[a]	14.6
	3	10.42	10.58	85.1	2.4	2.1	14.6
	4	10.30	9.68	84.8	2.9	2.5	14.7
	Mean	10.36	10.00	84.7	2.6	2.5	14.4
NAA 10 ppm	1	10.34	11.00	84.9	2.1	2.2	14.5
	2	11.65	11.60	84.5	2.7	2.3	16.9
	3	10.46	9.18	84.9	2.1	2.4	14.5
	4	10.52	10.05	85.3	2.1	1.7	14.1
	Mean	10.74	10.46	84.9	2.3	2.2	15.0
NAA 20 ppm	1	10.49	10.45	84.1	2.8	2.8	15.5
	2	10.35	10.28	84.5	2.1	2.4	15.4
	3	10.25	10.45	84.6	2.3	2.2	14.0
	4	10.59	11.05	84.7	2.3[a]	2.0	14.7
	Mean	10.42	10.56	84.5	2.4	2.4	14.9
Toloxy 20 ppm	1	10.94	9.55	85.0	2.3	2.5	15.1
	2	10.01	10.10	85.3	2.3	2.5	14.0
	3	9.98	9.85	84.8	2.8	2.5	14.6
	4	11.01	8.95	84.5	2.3	2.0	14.8
	Mean	10.49	9.61	84.9	2.4	2.4	14.6
2,4,5-TP 20 ppm	1	10.39	10.65	94.3	2.6	2.6	15.2
	2	10.34	9.65	85.3	2.8	2.2	14.3
	3	10.30	10.90	84.6	2.2	2.3	15.6
	4	10.30	10.40	84.9	2.2	2.4	14.8
	Mean	10.33	10.40	84.8	2.5	2.4	15.0

[a]Calculated missing value
[b]Color reading for fruit stored at 32° F
[c]Color reading for fruit stored at 70° F

TABLE 23

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF NORTHERN SPY APPLES HARVESTED OCTOBER 25, 1950

(Observed after storage for 10 days at 70° F)

Treatment	Repli-cation	Invert sugars (%)	Acids (ml .1N NaOH)	Moisture (%)	Color rating	Firmness (lbs.)
Check	1	10.79	7.78	85.7	1.8	10.7
	2	10.37[a]	7.52[a]	85.5[a]	1.7[a]	11.2[a]
	3	10.44	7.65	85.1	1.4	11.1
	4	10.64	7.75	85.0	1.8	12.1
	Mean	10.56	7.7	85.3	1.7	11.3
NAA 10 ppm	1	11.08	8.75	84.6	1.4	12.0
	2	11.03	8.25	84.0	1.6	13.4
	3	10.27	7.45	85.2	1.5	12.5
	4	10.30	7.88	85.0	1.4	12.8[a]
	Mean	10.67	8.1	84.7	1.5	12.7
NAA 20 ppm	1	10.76	8.05	84.8	1.7	12.0
	2	10.59	7.65	85.0	1.6	12.8
	3	10.44	8.65	85.0	1.6	12.0
	4	10.56	8.00	85.0	1.3	12.5
	Mean	10.59	8.1	85.0	1.6	12.3
Toloxy 20 ppm	1	11.82	7.90	84.6	1.6	13.5
	2	9.98	8.15	85.4	1.5	11.4
	3	10.64	7.90	85.5	1.8	11.5
	4	10.93	7.23	84.2	1.7	11.8
	Mean	10.84	7.8	84.9	1.7	12.1
2,4,5-TP 20 ppm	1	10.66	8.25	84.2	1.7	13.4
	2	10.47	7.30	85.3	1.5	11.5
	3	10.96	8.40	84.8	1.5	12.5
	4	10.88	8.05	85.3	1.5	12.3
	Mean	10.74	8.0	84.9	1.7	12.4

[a]Calculated missing value

TABLE 24

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF NORTHERN SPY APPLES HARVESTED OCTOBER 25, 1950

(Observed after storage for 3½ months at 32° F)

Treatment	Replication	Invert sugars (%)	Acids (ml .1N NaOH)	Moisture (%)	Color rating	Firmness (lbs.)
Check	1	9.72	7.05	86.0	2.0	9.0
	2	10.25	7.23	84.8	1.3	11.4
	3	9.47	7.95	85.2	1.3	10.9
	4	10.81	7.08	85.1	1.5	9.7
	Mean	10.06	7.33	85.3	1.5	10.3
NAA 10 ppm	1	10.34	8.45	84.9	1.3	11.2
	2	11.28	7.60	84.5	1.4	12.1
	3	10.25	8.20	85.3	1.3	11.1
	4	10.64	7.05	85.7	1.3	10.7
	Mean	10.63	7.83	85.1	1.3	11.3
NAA 20 ppm	1	10.06	9.18	85.0	1.6	10.5
	2	9.02	6.35	85.0	1.4	11.8
	3	11.50	7.55	85.3	1.3	10.6
	4	10.84	6.40	84.7	1.2	11.7
	Mean	10.36	7.37	85.0	1.4	11.2
Toloxy 20 ppm	1	10.81	6.80	84.9	1.4	11.3
	2	10.81	7.18	85.8	1.2	10.3
	3	10.86	6.75	85.5	1.6	10.8
	4	11.06	6.38	85.3	1.4	11.0
	Mean	10.89	6.78	85.4	1.4	10.9
2,4,5-TP 20 ppm	1	10.66	7.68	84.9	1.5	11.6
	2	10.25	8.58	85.3	1.4	10.9
	3	10.15	7.80	85.2	1.3	11.0
	4	9.76	8.73	85.3	1.3	11.1
	Mean	10.21	8.20	85.2	1.4	11.2

TABLE 25

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF NORTHERN SPY APPLES HARVESTED OCTOBER 18, 1951

(Observed at harvest)

Treatment	Repli- cation	Sugars[a] (%)	Acids (ml .1N NaOH)	Color rating	Firmness (lbs.)
Check	1	13.5	9.8	2.7	13.6
	2	14.0	9.4	2.4	13.8
	3	13.0	10.0	2.9	14.9
	4	13.0	9.6	1.9	13.6
	Mean	13.4	9.7	2.5	14.0
NAA 20 ppm	1	13.8	11.8	2.9	12.9
	2	13.5	10.2	2.6	15.2
	3	14.0	12.8	3.2	14.5
	4	14.0	10.2	2.8	16.0
	Mean	13.8	11.3	2.9	14.7
Toloxy 20 ppm	1	13.5	14.4	2.9	16.0
	2	13.5	11.2	2.9	13.7
	3	13.5	8.8	2.7	13.9
	4	13.0	8.4	2.6	13.9
	Mean	13.4	10.7	2.8	14.4
2,4,5-TP "A" 20 ppm (applied Oct. 1)	1	14.0	10.0	3.0	15.5
	2	15.8	14.0	2.6	14.8
	3	13.0	13.0	2.7	12.8
	4	13.8	9.0	2.5	13.3
	Mean	14.2	11.5	2.7	14.1
2,4,5-TP "B" 20 ppm (applied Oct. 12)	1	14.2	11.2	2.8	15.9
	2	13.5	9.4	2.8	15.5
	3	14.0	8.2	2.7	14.4
	4	14.5	10.2	2.9	13.8
	Mean	14.1	9.8	2.8	14.9
2,4,5-TP "C" 20 ppm (applied Oct. 1 and Oct. 12)	1	13.5	14.2	2.9	14.4
	2	14.0	10.2	3.0	14.7
	3	13.5	12.2	2.7	14.5
	4	14.0	11.2	2.3	15.1
	Mean	13.8	12.0	2.7	14.7

[a]Soluble solids expressed as sugars

TABLE 26

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF NORTHERN SPY APPLES HARVESTED OCTOBER 18, 1951

(Observed in February, 1952, after storage at 32° F)

Treatment	Replication	Sugars[a] (%)	Acids (ml .1N NaOH)	Color rating	Firmness (lbs.)
Check	1	13.0	8.2	2.3	12.1
	2	14.3	8.2	1.7	12.0
	3	13.5	7.6	2.1	11.9
	4	14.0	8.4	1.6	12.7
	Mean	13.7	8.1	1.9	12.2
NAA 20 ppm	1	14.0	7.8	2.0	11.4
	2	13.5	7.9	2.3	12.5
	3	13.8	7.9	1.9	12.4
	4	13.8	7.9	2.1	12.3
	Mean	13.8	7.9	2.1	12.2
Toloxy 20 ppm	1	13.8	7.8	2.2	11.8
	2	13.8	7.2	1.9	11.5
	3	14.0	8.0	2.0	13.1
	4	13.0	6.5	1.7	10.7
	Mean	13.7	7.4	2.0	11.8
2,4,5-TP "A" 20 ppm (applied Oct. 1)	1	14.0	8.9	1.9	12.6
	2	13.0	7.9	2.3	11.8
	3	13.8	8.1	2.1	12.9
	4	13.5	8.0	1.9	11.3
	Mean	13.6	8.2	2.1	12.2
2,4,5-TP "B" 20 ppm (applied Oct. 1 and Oct. 12)	1	14.0	8.0	1.8	12.7
	2	13.3	9.2	1.7	13.3
	3	13.0	7.5	2.8	12.1
	4	14.0	7.7	2.4	11.2
	Mean	13.6	8.1	2.2	12.3
2,4,5-TP "C" 20 ppm (applied Oct. 1 and Oct. 12)	1	13.5	8.6	2.3	11.9
	2	13.5	7.5	2.0	11.8
	3	14.5	8.0	2.2	11.3
	4	14.5	8.3	1.2	13.0
	Mean	14.0	8.1	1.9	12.0

[a]Soluble solids expressed as sugars

TABLE 27

CHEMICAL COMPOSITION, GROUND COLOR AND FIRMNESS OF NORTHERN SPY APPLES HARVESTED OCTOBER 18, 1951

(Observed in April, 1952, after storage at 32° F)

Treatment	Replication	Sugars[b] (%)	Acids (ml .1N NaOH)	Color rating	Firmness (lbs.)
Check	1	13.0	6.3	1.7	10.9
	2	13.5	7.2	1.8	11.2
	3	12.5	7.8	2.0	11.3
	4	13.0	6.6	1.6	11.1
	Mean	13.0	7.2	1.8	11.1
NAA 20 ppm	1	13.0	6.9	2.5	10.7
	2	13.4[a]	7.3[a]	2.0	11.3
	3	13.5	7.3	2.3	11.7
	4	13.5	8.2	2.1	10.3
	Mean	13.4	7.4	2.2	11.0
Toloxy 20 ppm	1	13.5	7.0	1.9	11.3
	2	13.0	7.1	1.8	11.6
	3	13.5	6.2	1.8	11.6
	4	13.0	5.8	1.8	11.1
	Mean	13.3	6.5	1.9	11.3
2,4,5-TP "A" 20 ppm (applied Oct. 1)	1	14.0	7.7	2.3	10.4
	2	13.0	6.6	1.8	10.9
	3	12.5	7.8	1.9	11.4
	4	13.0	7.5	1.5	11.0
	Mean	13.1	7.4	1.9	10.9
2,4,5-TP "B" 20 ppm (applied Oct. 12)	1	13.0	6.72	1.7	12.1
	2	14.3	6.8	1.5	11.8
	3	13.5	6.2	2.4	10.8
	4	13.5	6.4	1.6	11.4
	Mean	13.6	6.5	1.8	11.5
2,4,5-TP "C" 20 ppm (applied Oct. 1 and Oct. 12)	1	13.5	6.5	2.0	10.7
	2	13.0	6.4	1.7	11.6
	3	13.5	7.6	1.7	11.6
	4	14.3	7.32	1.5	11.8
	Mean	13.6	7.0	1.7	11.4

[a]Calculated missing value
[b]Soluble solids expressed as sugars

TABLE 28

RESPIRATION RATES AT 71° F FOR McINTOSH APPLES HARVESTED IN 1951

(Values expressed as mg. CO_2/kg./hr. for two replicate trees per treatment)

Date	Check		NAA		Toloxy		2,4,5-TP "A"		2,4,5-TP "B"	
	1	3	2	4	2	4	1	3	2	1
					At harvest					
Oct. 1	7.5	11.3	11.6	6.4	6.5	8.2	7.0	10.0	10.5	8.8
2	8.2	7.5	8.0	7.1	6.8	9.8	6.5	9.1	9.1	8.0
3	9.0	6.5	8.0	6.8	6.5	7.8	6.0	8.4	7.2	8.4
5	8.2	7.8	8.8	8.2	6.0	8.6	6.5	11.3	6.6	7.7
6	9.4	6.8	9.7	8.6	6.2	7.4	7.0	7.6	7.9	9.2
7	8.2	7.3	8.4	9.8	5.4	7.1	6.4	8.0	6.2	6.7
8	9.4	7.8	8.8	11.3	6.5	8.4	7.0	10.3	6.9	8.4
					After storage at 32° F					
	1	3	2	4	2	4	1	3	2	4
Jan. 19	8.8	7.7	9.1	6.7	7.7	7.7	8.3	7.8	4.9	7.9
20	8.0	7.2	8.5	6.1	7.2	7.4	7.8	7.3	4.7	7.9
21	8.4	7.9	9.5	7.0	8.2	7.9	7.9	7.8	5.2	9.3
22	7.8	7.2	8.9	6.3	8.0	8.3	7.6	8.0	4.9	9.0
23	8.6	7.9	9.5	8.4	8.4	7.7	7.8	7.3	5.2	8.6
24	8.1	7.5	8.3	6.3	7.2	7.7	7.8	7.1	5.2	9.0
25	7.3	6.7	7.4	5.7	6.7	7.0	7.1	6.5	4.7	7.3
27	7.5	6.7	7.9	6.0	7.0	7.0	8.1	6.8	5.5	7.3
28	7.1	6.4	7.7	5.4	6.5	6.7	7.2	6.4	4.7	8.4
30	7.3	6.4	7.2	6.1	6.2	6.7	6.9	6.4	4.6	7.2

TABLE 29

RESPIRATION RATES AT 71° F FOR NORTHERN SPY APPLES HARVESTED IN 1951

(Values expressed as mg. CO_2/kg./hr. for two replicate trees per treatment)

Date	Check		NAA		Toloxy		2,4,5-TP "A"		2,4,5-TP "B"	
	1	4	1	3	1	2	3	4	1	3
At harvest										
Oct. 25	8.7	7.4	10.0	9.9	11.8	8.7	9.0	9.6	12.4	9.2
26	9.5	6.4	8.7	9.2	9.0	8.5	8.4	13.6	13.4	8.6
27	8.5	6.4	9.1	9.0	8,6	7.4	8.8	9.0	10.7	8.0
28	9.1	6.7	10.3	9.0	9.6	9.1	9.0	9.6	11.7	8.8
29	7.7	5.6	7.6	7.8	8.4	7.1	7.3	7.8	10.2	7.1
31	7.4	5.9	8.5	7.8	8.6	7.4	7.5	8.2	11.4	7.1
Nov. 1	13.1	8.9	15.2	15.3	15.9	13.8	14.6	19.2	12.0	13.6
2	6.0	4.1	6.0	5.4	5.9	5.5	5.2	5.7	6.4	5.3
4	5.1	4.0	4.8	4.9	4.9	4.8	4.4	5.2	5.7	4.0
After storage at 32° F										
	1	3	1	4	1	2	2	4	1	3
Feb. 19	5.1	4.9	5.3	5.2	5.1	5.6	7.3	5.3	5.2	3.8
20	7.6	7.4	8.0	8.1	8.9	8.7	11.3	8.0	8.4	5.8
21	8.0	8.2	8.8	8.8	9.0	9.3	12.1	9.0	9.0	6.0
22	9.0	8.9	9.7	9.5	10.0	10.0	13.3	9.2	9.6	6.3
23	9.2	8.9	9.9	9.9	10.9	10.2	13.3	9.6	9.9	6.3
25	8.0	10.8	8.6	12.5	9.3	9.3	12.1	8.6	8.8	6.2
26	7.6	7.6	7.9	7.7	8.9	8.0	10.8	8.6	8.0	5.4
27	8.7	8.4	8.6	7.7	8.7	8.9	11.3	7.6	8.6	6.0
28	9.0	9.4	9.7	8.6	9.7	9.3	13.3	7.6	9.4	--