THE EFFECT OF VARIOUS POTASH FERTILIZERS ON THE FIRMNESS AND KEEPING QUALITY OF APPLES, PEACHES AND STRAWBERRIES

by

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Introduction

The contention that the use of nitrogen fertilizers injures the keeping quality of fruits has received widespread attention among growers and research workers in recent years. Many fruit commission men and brokers have held that nitrogen causes fruit to deteriorate rapidly in transit and in storage. These same people have often penalized, to a greater or less extent, growers who fertilize with nitrogen by giving them lower prices for their products.

In an attempt to alleviate this condition, the use of potassium fertilizers has been adopted to some extent by fruit growers, many strawberry growers, especially in Maryland, firmly believing that potash fertilization will produce berries having a brighter appearance and a superior shipping quality. The effect of potash, however, has been attributed chiefly to its influence as a counteractant in overcoming the supposedly deleterious effects of nitrogen fertilizers on keeping quality. In view of these contentions,

reliable evidence as to the value of potassium fertilizers in improving keeping quality of fruits is of the greatest importance.

Outline of Investigations

The present investigations were started in the spring of 1928 in an attempt to study the problem from two angles; first, to determine the firmness and storage quality of fruits taken from field plots fertilized with potash salts in various combinations with nitrogen and phosphorus in comparison with a standard nitrogen treatment, and second, to determine if any differences in chemical content or chemical changes occurred in such fruit and to correlate if possible any such differences with any differences in keeping quality. Four potassium fertilizers were applied in varying amounts and in various combinations with nitrogen and phosphorus to four varieties of apples in different orchards, two varieties of peaches in four orchards, and four varieties of strawberries, in cooperation with commercial growers in the fruit producing sections of Maryland. Samples of fruit were selected from the fertilized plots at harvest time in 1928, 1929, and 1930 and subjected to various shipping and storage tests.

As a measure of the shipping and keeping quality of strawberries the number of decayed and soft berries developing during the tests was recorded. Firmness and rate of ripening of apples and peaches were

measured by means of mechanical pressure testers. The prevalence of decay and scald in apple storage samples was also taken as an indication of keeping quality and as a further criterion the rate of change of certain chemical constituents of the fruit was studied.

In the presentation of the results, each year's work for each variety of each fruit is considered separately and conclusions for each fruit are drawn independently.

Review of Literature

Studies of the effect of potash fertilizer on the keeping quality of fruits are extremely limited in extent. McCue (25) in 1911 in connection with various fertilizer studies on peaches made the statement that the fruit from the potash treatment had a longer period of soundness than the fruit from the other treatments. Brown (4) in 1919 observed that during a warm season strawberry plants which received applications of sulfate of potash produced somewhat firmer berries. During a long cool picking season, however, no differences between plots were apparent.

Stuckey (31) presents some of the results of fertilizer tests on maturity and keeping quality of peaches in Georgia in which potash increased the yield considerably, but had no appreciabe effect on the time of maturity. However, it seemed to have a marked effect in improving the keeping quality of the peaches and

lessening the susceptibility to disease organisms.

In 1928 Cooper (8) reports that neither phosphorus nor potassium, when used with nitrogen, had any effect on keeping quality of Ben Davis apples in any way. Pressure tests of samples after being held in common and cold storage for three months showed as great a difference within lots as between treatments.

In another publication Cooper and Wiggans (9), as a result of three years pressure testing on Elberta peaches with a Magness and Taylor tester, state that no consistent differences in firmness of fruit from different fertilizer treatments, including potash, were observable, the same plots frequently representing both extemes in firmness in any one year. They attributed a great deal of this variation to error in sampling, finding it practically impossible to collect large samples of equally mature fruit from the different plots at the same time. The results of two years storage and shipping tests showed only inconsistent differences. Since records varied so much they concluded there was no difference in firmness or shipping quality of fruit from the different plots.

In a preliminary report on storage investigations conducted in Washington, Magness and Overly (23) report that there were no measurable differences in rate of softening of Jonathan apples in storage, as measured by the pressure test, which could be attributed to potash

fertilizer treatment, either alone or in combination with nitrogen and phosphorus. The amount of physiological breakdown at the end of the storage season was practically unaffected, with no statistically significant differences between the plots.

Wallace (32) in England presents data showing that the use of sulfate of potash on Grenadier apples markedly increased the number of decayed fruits in cold storage. Furthermore, at ordinary temperature, potassium deficient fruits showed considerably less breakdown than high potassium fruits, but in cold storage the reverse occurred. He states that "In these cases it appears that potassium deficient fruits have a longer period of senescence than the high potassium fruits, but that they are more susceptible to Low Temperature Breakdown." It should be noted here that reference is made to actual potassium deficiency; that is, under the conditions of the above experiments potassium has been a limiting factor to growth, a condition seldom found in this country. Grubb (12) previously reported increases in size of fruit and decrease in color resulting from potash fertilization, so that the effect of the fertilizer on keeping quality may possible be attributed to its influence on size and color. In general, smaller, well-colored apples keep better in storage than large, poorly-colored fruit.

Recently Kimbrough (18) observed that potash used in a complete fertilizer had no effect on the moisture or sugar content of strawberries. Rainfall appeared to be

the most important factor.

The literature includes no conclusive evidence that potassium fertilizers have improved the firmness or keeping quality of fruits in this country. On the other hand the data are entirely too meager from which to draw a definite conclusion that potash will not affect the keeping quality of fruit.

CHEMICAL METHODS

Apples

Sampling. Each apple sample for chemical analyses consisted of sections of flesh from twenty or more fruits, which had previously been used for pressure testing. Immediately after pressure testing of a given plot, in the field or in storage, thin sections of flesh were removed from each apple, dropped in a quantity of cold alcohol sufficient to give a final concentration of eighty per cent by volume, and weighed. Four samples of one-hundred grams each were prepared from each plot at a given time, two for carbohydrate analysis, and two for pectin studies. Different fruits were used for each duplicate. Immediately after weighing the carbohydrate samples were boiled gently for several minutes, but to avoid hydrolyzing the protopectin, the pectin samples were not heated.

Dry Matter. The alcohol was decanted from the insoluble residue of the carbohydrate samples and

aliquots were dried forty-eight hours at 70°, weighed, and then ground to pass a 60 mesh screen.

Reducing Sugar. An aliquot of the ground sample was placed in Soxhlet apparatus with eighty per cent alcohol and extracted for three hours. The alcoholic extract was freed from alcohol on a sand bath by means of an air blast, cleared with neutral lead acetate and deleaded with potassium oxalate. The reducing value was determined by the Bertrand-Walker-Munson method.

Total Sugars. The reducing powers of the cleared solution after acid hydrolysis with 2.5 per cent HCl for twenty-four hours at room temperature is reported as total sugars. Seven normal sodium hydroxide was used to neutralize the acid after hydrolysis.

Sucrose. The differences between total sugars and reducing sugars is recorded as sucrose.

Acid Hydrolyzable Material. The residue of the sugar extraction was refluxed for two and one-half hours with 2.5 per cent hydrochloric acid. After neutralization the reducing value of the solution was determined and is reported as acid hydrolyzable material.

Starch. An aliquot of the extracted residue was ground to pass a one-hundred mesh sieve, boiling water added, and the mixture maintained at 100°C for an hour. After cooling, saliva was added. An oven at 50°C. was used for incubation during digestion. After an hour, the material was removed and placed in a boiling

water bath for fifteen minutes. Upon cooling the digestion was repeated.

The liquid was cleared with seventy per cent alcohol, freed from alcohol, and hydrolyzed with 2.5 per cent HCl under a reflux condenser for two and one-half hours. The reducing power of the solution is reported as starch.

Titratable Acidity. At the time of chemical sampling sections of the flesh were minced in a small grinder, and the juice was pressed out through muslin. Titratable acidity is given as the number of cc of .1 N NaOH required to neutralize 10 cc of the expressed juice. Phenolphthalein was used as the indicator.

Actual Acidity. Ph of the expressed juice was determined directly by means of a Youden hydrogen ion apparatus.

Potassium. Potassium was determined by precipitation with sodium cobalt nitrate in alcoholic solution. An aliquot of the sample was ashed with sulfuric acid in a muffle furnace, taken up with water, acidified with acetic acid, and treated with 5 cc of a twenty-five per cent solution of sodium cobalt nitrate, in the presence of sufficient alcohol to make a twenty-five per cent solution. The solution was cooled to 6 - 8°C, allowed to stand for one and one-half/to two hours and filtered on an asbestos pad. The precipate was taken up with hot

water and titrated immediately with potassium permanganate solution. Though difficulty was experienced in obtaining very close checks on duplicates with this method, determinations on a known solution checked within two per cent of the calculated amounts.

Pectic Substances The alcohol was decanted from the pectin samples and the insoluble residue dried at 80°C and ground to pass a forty-mesh sieve. Half of the residue was used for soluble pectin determination and half for total pectin.

Soluble Pectin. Five hundred cc of water was added to one portion and the mixture shaken in a mechanical shaker for an hour at 20°C. At the end of the hour it was filtered immediately, the filtration requiring less than thirty minutes. Heating to facilitate filtration as practiced by Nightingale, et al (26) was found to increase the soluble pectin yield about fifty per cent, indicating hydrolysis of protopectin.

Aliquots of the filtrate were used to determine soluble pectin as calcium pectate, according to the Carre' and Haynes method (6).

Total Pectic Material. The other portion of the ground residue was refluxed in water for thirty minutes and filtered with suction. The material was then refluxed with 1/30 N HCl for another thirty minute period, and filtered. The latter procedure was repeated twice, when hydrolysis had continued for two hours.

Further hydrolysis with 1/30 N HCl failed to produce appreciable amounts of pectin. The filtrates were combined, neutralized with Na OH and treated according to the Carre' and Haynes method for determining pectin.

Peaches

The same procedure followed with apples was used with peaches with few exceptions. Pressure tested fruit was used for all samples, sections of the flesh from thirty to forty-five fruits composing one one-hundred gram sample. Since only one carbohydrate sample per treatment was taken, only uniform and comparable fruits were used. The samples were taken to compare the effect of treatment on chemical composition, rather than rate of chemical change.

Because of the impracticability of separating skin from flesh, especially in the earlier stages of ripening, the skin was included with the flesh in all the samples.

Strawberries

Berries used in the storage tests were also used in preparing samples. Quarter sections of twenty or more berries, sufficient to make one-hundred grams, were treated in a manner similar to that used in preserving apple tissues.

In grinding the residue, reducing all seeds to a sixty mesh size was found impractical; consequently

some of the residue was larger, though all would pass through a twenty mesh sieve.

I. APPLE STUDIES

Four varieties of apples were included in the plans of experiments laid out in the spring of 1928 -- Williams at Berlin, Stayman Winesap at Salisbury, Rome Beauty at Frederick, and York Imperial at Tonoloway, Hancock. Because of crop failures and the small amounts of fruit available for testing, the results of the Williams tests are not included.

STAYMAN WINESAP ORCHARD AT SALISBURY .

Description of Plots. An eighteen-year old Stayman orchard near Salisbury, owned by W. F. Allen Company, was divided into plots in the spring of 1928. The soil, a Sassafras loamy sand, (30) was cultivated and cover-cropped annually. The trees received a moderate pruning and ten pounds of nitrate of soda each year; consequently they were making a fairly vigorous growth (table 1).

Eighteen adjoining rows of fifteen trees each received treatment as shown in the plan of the experiment in table 2. Four potash carriers were used: muriate of potash, sulfate of potash, sulfate of potash magnesia, and kainit (20 per cent). The kainit was formerly called double manure salts, or manure salts. Fertilizer was applied in the latter part of March each year, at the

TABLE I.

Growth And Yield Records On Apple Fertilizer Experiments - Season of 1930.

(Terminal Growth And Yields were Estimated For Each Tree.)

Fertilizer Treatment	Stayman Winesap			Rome Beauty			York Imperial		
	Terminal Growth in Inches	Trunk Incremant in mm.	Yield in Bushels	Terminal Growth in Inches	Trunk Incremant in mm.	Yield in Bushels	Terminal Growth in Inches	Trunk Incremant in mm.	Yield in Bushels
$NaNO_3$ only	4.30 ± .44	36.92 ± 1.32	2.49	2.56 ± .14	15.33 ± .64	1.82			
N-KCl single	4.55 ± .46	36.36 ± 2.24	3.67	4.00 ± .16	17.00 ± .96	2.17	4.50 ± .24	21.12 ± 1.72	16.33
N-K_2SO_4 single	4.10 ± .58	40.20 ± 1.98	3.31	3.07 ± .20	16.53 ± .83	1.67	3.50 ± .16	17.00 ± .658	11.73
N-$K_2Mg(SO_4)_2$ single	5.67 ± .53	38.24 ± 1.82	4.02	3.14 ± .21	14.38 ± 1.23	1.54	3.33 ± .15	20.21 ± 1.19	11.45
N-Kainit	4.07 ± .55	35.83 ± 1.18	3.55	2.60 ± .15	13.13 ± 1.10	1.79	3.75 ± .20	19.42 ± 1.77	10.82
N-KCl. double	5.35 ± .43	39.36 ± 1.51	3.73	2.73 ± .12	12.67 ± .84	1.66	3.75 ± .18	23.27 ± 1.58	13.75
N-P-KCl	6.20 ± .62	35.22 ± 2.11	4.12	3.23 ± .15	15.83 ± 2.01	1.87	3.33 ± .12	19.83 ± .98	15.22
$NaNO_3$	6.62 ± .54	34.62 ± 1.90	3.75						

Nitrate of soda - Stayman ten pounds; Rome five pounds; and York eight pounds per tree.

Superphosphate - ten pounds per tree.

Potash single - five pounds muriate of potash or its equivalent.

TABLE 2.

Outline of Fertilizer Treatments in Stayman Winesap Orchard at Salisbury. Single Application = Five Pounds Muriate of Potash or Its Equivalent in Potash.

Row.	Treatment.	Amount.
1	Muriate of potash	half
2	Sulphate of potash	half
3	Sulphate of potash magnesium	half
4	Kainit	half
5	Nitrate of soda only	
6	Muriate of potash	single
7	Muriate of potash plus lime	single
8	Sulphate of potash	single
9	Sulphate of potash magnesium	single
10	Kainit	single
11	Nitrate of soda only	
12	Muriate of potash only	
13	Muriate of potash	double
14	Sulphate of potash	double
15	Sulphate of potash magnesia	double
16	Kainit	double
17	Complete with muriate	
18	Nitrate of soda only	

All plots except 12 received nitrate of soda as a basic treatment.

Superphosphate was applied at the rate of ten pounds per tree on row 17.

rate of five pounds of muriate of potash per tree or its equivalent in potash in three other potash carriers (table 3). All plots except row 13 received nitrate of soda each year as a basic treatment.

Investigations Conducted in 1928

Sampling and Testing. One to three bushels of fruit comparable at the outset, were selected from the various plots. Only apples of the same size and maturity, covered with like amounts of blush and from trees bearing average crops, were included in the sample. All persons engaged in sampling, usually two or three, assisted in selecting the fruit from any particular treatment. In this way the error of the individual was reduced to a minimum.

In 1928 one bushel of fruit was selected from each of the fertilizer treatments on October 2 and placed immediately in cold storage at 32°F in Salisbury. The following day the samples were pressure tested with a Magness and Taylor (24) pressure tester, having a plunger of 7/16 inches in diameter. Three punches were made in each of fifteen apples from each bushel. A piece of skin about 1/2 inch in diameter was cut from the cheek of the apple for each test. When the plunger had penetrated the flesh to a depth of 5/16 inches, electrical contact in the pressure tester caused a light to flash. The pressure exerted on the apple was measured in pounds.

TABLE 3.

Rate of Application of Fertilizer Materials in Pounds Per Apple Tree.

	Half	Single	Double	Percent K_2O
Muriate of potash (KCl)	2.5	5.0	10.0	51.3
Sulfate of potash (K_2SO_4)	2.6	5.3	10.5	49.0
Sulfate of potash magnesia ($Mg(KSO_4)_2$) *	4.6	9.3	18.7	27.5
Kainit	5.9	11.9	23.9	21.5
Superphosphate		10.0		

Note. -- The amounts of nitrate of soda per tree varied with different orchards depending on their age.

* Not a definite chemical compound, but used for convenience to designate the potash salt, termed sulfate of potash magnesia.

At approximately monthly intervals during storage the samples were pressure tested in the same manner. This same general procedure was followed in all experiments with apples.

Oiled paper was not mixed with the fruit, and during storage the number of decayed and scalded apples which developed were recorded as a further measure of the keeping quality.

Results. The data of the pressure tests and summary of the inspection counts are presented in table 4. Except for the N-P-KCl treatment, no sample was significantly firmer or softer at time of picking than the sodium nitrate plots. This sample was softer at time of picking, but in the succeeding pressure test, December 8, it was no longer less firm. Probable errors were determined on the basis of the forty-five individual punches.

At the end of the storage test on March 15 one of the three plots receiving nitrate of soda only was the least firm and another was the firmest. With this variability in these triplicates, it would be impossible to say that any of the potash fertilizers had affected the keeping quality as far as the firmness of the fruit was concerned.

Decay and scald counts were quite variable and showed no marked differences between potash treatments and the nitrogen checks at the end of the storage season.

TABLE 4.

Pressure Test and Storage Counts of Stayman Winesap Apples Taken from Fertilizer Plots at Salisbury. (Picked Oct. 2, 1928, and Held in Cold Storage at 32°F.)

Fertilizer Treatment *	Pressure Tests in Pounds				Storage Counts		
	Oct. 3, 1928	Dec. 8, 1928	Feb. 1, 1929	March 15, 1929	Percent Sound	Percent Decay	Percent Scald
$NaNo_3$ only	16.75 ± .168	12.73 ± .055	11.18 ± .064	9.88 ± .063	73.1	2.7	24.2
$NaNo_3$ only	17.00 ± .146	13.62 ± .126	11.91 ± .084	10.50 ± .109	55.2	3.6	41.2
$NaNo_3$ only	17.13 ± .159	14.58 ± .134	12.85 ± .105	11.64 ± .122	78.0	3.3	18.7
N-KCl half	16.40 ± .185	13.14 ± .089	11.81 ± .090	10.89 ± .078	59.5	2.4	38.1
N-K_2SO_4 half	16.30 ± .180	12.23 ± .100	11.21 ± .078	10.72 ± .089	43.9	0.0	56.1
N-$Mg(KSO_4)_2$ half	16.33 ± .159	12.62 ± .063	11.61 ± .096	10.77 ± .067	67.8	2.8	29.4
N-Kainit half	16.51 ± .168	13.32 ± .084	11.34 ± .096	10.76 ± .063	62.3	0.0	37.7
N-KCl single	16.39 ± .162	13.00 ± .071	11.66 ± .085	10.62 ± .071	82.6	5.5	11.9
N-KCl single	17.57 ± .168	13.81 ± .126	12.31 ± .114	11.82 ± .126	80.4	1.4	18.2
N-K_2SO_4 single	17.02 ± .131	12.29 ± .122	11.67 ± .084	10.91 ± .055	72.9	1.0	26.1
N-$Mg(KSO_4)_2$ single	18.04 ± .168	13.04 ± .063	11.73 ± .084	11.60 ± .084	71.5	0.0	28.5
N-Kainit single	13.73 ± .193	12.60 ± .084	12.56 ± .095	11.12 ± .100	75.8	1.3	22.9
N-KCl double	17.35 ± .188	13.16 ± .118	12.08 ± .138	10.85 ± .089	53.0	6.2	40.8
N-K_2SO_4 double	17.54 ± .174	12.44 ± .095	11.68 ± .090	11.38 ± .044	61.0	4.4	34.6
N-$Mg(KSO_4)_2$ double	16.71 ± .165	12.34 ± .095	11.71 ± .085	11.08 ± .071	65.9	0.0	34.1
N-Kainit double	16.55 ± .182	13.15 ± .134	12.63 ± .096	11.44 ± .063	71.5	3.3	25.2
N-P-KCl	15.73 ± .153	13.14 ± .100	11.55 ± .106	10.16 ± .105	66.8	3.5	29.7
N-KCl lime	17.54 ± .146	13.42 ± .114	12.32 ± .100	10.84 ± .078	56.1	2.7	41.2

* Nitrate of soda - ten pounds per tree.
Superphosphate - ten pounds per tree.
Potash single - five pounds muriate or equivalent.

Summary for 1928. The firmness and keeping quality of Stayman apples has not been improved by application of potash fertilizers.

Experiments Conducted in 1929

In 1929 the trees bore a very light crop and the fruit was unusually large. No differences among the fertilizer treatments in the vigor of the trees were noticeable.

Sampling and Testing. On September 30, 1929 samples of one bushel each were selected from eight of the Stayman plots, including two plots receiving sodium nitrate only, four potassium fertilizer treatments in single amounts, one complete fertilizer, and one double muriate of potash treatment.

Fifteen apples were pressure tested from each bushel at time of picking and at monthly intervals to March 18, 1930, during cold storage in Salisbury. Because of the low yields, one bushel of uniform fruit was the largest sample obtainable from each treatment, and since the fruit was unusually large, there were not enough apples remaining after the final pressure test to provide a fair sample for decay and scald counts. Hence the latter were omitted.

Results. Pressure test averages of the fruit during storage are presented in table 5. The results were very uniform and no significant differences appeared

TABLE 5.

Pressure Tests of Stayman Winesap Apples From Fertilizer Plots at Salisbury.

(Picked Sept. 28, 1929, and Held in Storage at 32° F.)

Fertilizer Treatment. **	Average Pressure Test in Pounds.					
	Sept.28, 1929	Nov.2, 1929	Dec.14, 1929	Jan.14, 1930	Feb.15, 1930	March 18, 1930
$NaNo_3$	16.56 ± .134	14.68 ± .119	12.53 ± .125	11.42 ± .074	11.79 ± .098	9.00 ± .090
N-KCl single	16.36 ± .108	15.65 ± .140	13.45 ± .141	11.84 ± .188	11.38 ± .125	9.76 ± .097
					12.11 ± .106*	9.22 ± .072*
$N-K_2SO_4$ single	16.37 ± .209	15.93 ± .210	14.18 ± .114	12.07 ± .096	11.95 ± .123	9.18 ± .095
					11.63 ± .042*	9.39 ± .086*
$N-Mg(KSO_4)_2$ single	17.13 ± .168	16.19 ± .141	13.96 ± .171	12.93 ± .180	12.39 ± .126	10.11 ± .084
					11.79 ± .089*	10.13 ± .088*
N-Kainit single	16.33 ± .127	15.57 ± .247	13.03 ± .158	11.23 ± .165	11.48 ± .104	9.22 ± .068
$NaNo_3$	16.61 ± .137	16.10 ± .182	13.72 ± .207	11.35 ± .084	11.57 ± .128	9.10 ± .075
N-KCl double	16.35 ± .128	16.52 ± .136	13.18 ± .132	11.93 ± .108	11.86 ± .056	9.50 ± .091
N-P-KCl	17.16 ± .088	15.72 ± .257	13.83 ± .246	11.80 ± .151	11.94 ± .120	9.38 ± .072
						9.46 ± .102

* A duplicate test was made on these samples.

** Nitrate of soda - ten pounds per tree.
Superphosphate - ten pounds per tree.
Potash single - five pounds muriate or equivalent.

between treatments either at time of picking or during storage with one exception. In two of the final three tests the sulfate of potash magnesia fruit was significantly firmer than fruit from either of the nitrate only plots and in each of the other three tests the sample was slightly firmer. Pairing the two treatments on each date, Student's Method gives odds of 475:1 that the difference in favor of sulfate of potash magnesia treatment was not due to error in pressure testing, or variability in the sample. There is a possibility that this effect of treatment was in reality due to error in sampling. This point will be discussed later.

Summary for 1929. Sulfate of potash magnesia was the only potash treatment which gave any indication of improvement in the firmness and keeping quality of the fruit.

Investigations Conducted in 1930.

The yield in the Stayman orchard was again light in 1930, averaging less than four bushels per tree. The dry season did not affect the size of the fruit markedly. No differences between treatment in the vigor of the trees were apparent.

Sampling and Testing. Two bushels of extremely uniform apples were selected from eight plots on September 30, 1930. These plots included the usual six potassium treatments (table 6) used in peach studies, and two plots

receiving nitrate of soda only. Immediately after picking the samples were pressure tested with a Magness and Taylor tester, fifteen apples per bushel, and then placed in cold storage at Salisbury. At monthly intervals the samples were pressure tested, and when necessary, inspected for decayed and scalded fruit.

Results. Table 6 shows the results of the pressure tests and inspections. Because of the larger samples a different method of statistical analysis of the data has been applied.

In all previous work when only one bushel of fruit was selected from each treatment there was no method of estimating the error due to sampling. Once the sample was obtained, there was no trouble in finding the variability of that particular lot of fruit, but no comparison could be made between that sample and the fruit remaining on the tree, other than the picker's own judgment. Unquestionable if a person, after picking one sample, should select another sample immediately afterwards from the same trees, the two samples would not be exactly comparable. It was to evaluate this error that three bushels of fruit were taken from each plot in 1930. Each bushel was treated as an individual sample and probable errors were based on the average of fifteen apples from each bushel rather than on the individual punch as heretofore. In that way the error of sampling, the error of pressure

TABLE 6.

Pressure Tests and Storage Counts of Stayman Winesap Apples from Fertilizer Plots at Salisbury. (Picked Sept. 30, 1930 and Held in Cold Storage at 32°F.)

Fertilizer Treatment. *	Pressure Tests in Pounds					Storage Counts		
	Sept. 30, 1930	Nov.10, 1930	Dec.14, 1930	Jan.26, 1931	March 2, 1931	Percent Sound	Percent Decay	Percent Scald
$NaNo_3$	19.12	17.23	14.71	12.95	12.43	42.7	4.2	53.1
N-KCl single	18.80	17.64	15.65	13.21	12.54	48.3	0.0	51.7
N-K_2SO_4single	19.32	18.51	15.26	13.06	12.98	39.7	0.0	60.3
N-Mg$(KSO_4)_2$ single	19.66	17.95	15.94	13.67	13.45	45.0	0.0	55.0
N-Kainit single	19.28	17.45	15.73	13.41	13.29	52.6	1.4	46.0
$NaNo_3$ only	19. 04	17.63	15.61	13.10	12.70	50.0	0.0	50.0
N-KCl double	19.34	17.76	15.95	13.34	13.21	62.7	1.7	35.6
N-P-KCl	19.43	17.76	16.07	12.98	12.60	43.8	1.4	54.8

Difference required for 30:1 odds = 5.37 pounds.

* Nitrate of soda - ten pounds per tree.
Superphosphate - ten pounds per tree.
Potash single - five pounds muriate of potash or its equivalent.

testing, the variability of the fruit -- in fact all possible sources of error were included in determining the reliability of the results.

The method employed was to treat all the pressure test averages of a single variety during the entire storage period as a population and determine the variance of each average. By means of simultaneous equations the correlated variance due to treatment, date of testing, etc. was removed from this item, leaving only the uncorrelated variance which was desired. From this value the average standard deviation of a single bushel average was determined by taking the square root, and since no correlation between the three bushels from one treatment and the three bushels from another could be expected, the usual formula $\sigma_{a-b} = \sqrt{\sigma_a^2 + \sigma_b^2}$ for determining the standard deviation of the difference was applied. This deviation is then applicable to the difference between any two bushel averages from any two treatments at a particular date.

Since small numbers are involved, two or three items in each comparison, Student's method is employed here, for in determining odds by Student's allowances are made for small numbers. Where N=3, z must equal 2.65 in order that odds may be 30:1. Substituting this value in the formula $z = \frac{\text{Difference}}{\sigma \text{ Difference}}$, and knowing the standard deviation of the difference from above, the difference

which must be present between plot averages for significance in each of the three varieties has been determined. In the Yorks for example the standard deviation is .577. The difference equals 2.65 x .577 = 1.53, which represents the smallest difference between treatments on a single date which can be given significance.

Using the same procedure, the standard deviation based on the individual apple, thereby eliminating the sampling error, has been determined for Yorks. That value substituted in Student's equation requires only a difference of 0.101 pounds to give significance. Consideration of the actual data would eliminate the latter method of calculation as a means of interpreting significance of differences.

Because only two-bushel samples were obtained from the Stayman plots in 1930, the error was correspondingly increased, and a difference between treatments of 5.37 pounds had to be established before odds of 30:1 were obtained by Student's method. None of the four potassium salts in single amounts influenced the firmness of the fruit to that extent at picking time (table 6). The same is true of the double muriate and complete treatments.

Sulfate of potash magnesia fruit, was the firmest sample of the lot throughout the storage test, and the odds were 6:1 that the difference in firmness of .54 pounds at picking time between it and the nitrate of soda

only fruit was not due to chance. However, the odds by Student's Method that the sample was firmer throughout the entire storage period were 832:1. Considering the results obtained the previous year and the results in other orchards during the same year, with regards to this treatment, which will be presented later, the 6:1 odds that the difference was due to treatment and not error in sampling appear more logical.

Inspection counts of the same fruit (table 6) show that the six potash treatments studied have not affected the prevalence of scalded or decayed fruit. All potash treatments averaged about fifty per cent scalded fruit, and the nitrate only fruit was fifty-three per cent scalded.

Summary for 1930. Sulfate of potash magnesia was the only potash treatment studied which gave any indication of increase in firmness and decrease in rate of ripening of the fruit.

Discussion of Stayman Studies

In the first year of the experiments on Stayman apples no evidence resulted to show that the fertilizer applied had any influence whatsoever on the trees or on the fruit. This was not surprising since apple trees are much slower to respond to fertilizer treatments than many other horticultural crops.

In the second year a distinct influence of sulfate of potash magnesia on the firmness of the fruit was noted, though at the time its importance was questioned because of the great variability involved in studies of this nature. Even with probable errors based on the individual pressure test punch, the differences between the sulfate of potash magnesia sample and the nitrate only fruit was not significant at picking time.

When the influence was again noted in 1930 and an effort was made to evaluate the error in sampling, it was possible to more fully appreciate the significance of the effect of the treatment. The fruit from the magnesia treatment was unquestionably firmer than the sample from the nitrate only plot, and the odds were distinctly in favor of this difference being due to treatment. However, from a commercial standpoint the benefits of the treatment were not important. The amount of scald and decay was not affected appreciably, and a difference in firmness of seven per cent is too small to be considered, from a practical standpoint.

Of the five other potash treatments studied in 1929 and 1930 tests, none gave the slightest indication of having affected the firmness or keeping quality.

General Summary of Stayman Studies

In this Stayman orchard where four different potassium fertilizers were used in varying amounts and

combinations, one treatment, magnesia sulfate of potash increased the firmness of the fruit during the second and third year of the experiment to a slight extent, and also improved the keeping quality as measured by a pressure tester, but not as measured by development of decay and scald. The three other potash fertilizers studied -- muriate of potash, sulfate of potash, and kainit -- were ineffective. A complete fertilizer with muriate of potash likewise had no influence on the keeping quality.

ROME BEAUTY ORCHARD AT FREDERICK

Description of Plots. A fourteen year old Rome orchard, owned by E. D. McCain near Frederick in Frederick County, was included in the studies in 1928. The trees were on an Upshur gravelly loam, (19), cultivated and cover cropped. Each tree received five pounds of nitrate of soda annually, and a moderate pruning. The terminal growth was comparatively short, averaging three inches in 1930 (table 1) principally because of the lack of rainfall in 1929 and 1930. The trees suffered severely from the two dry seasons, and some failed to recover.

Eight rows of twenty-eight trees each were divided into sixteen plots as shown in table 7, receiving the same treatments and the same amounts as the Stayman experiments. The Rome trees were interplanted with Grimes in the row. Peach tree fillers between the first four rows of the experiment were removed early in 1929. Fertilizer

TABLE 7.

Outline of Fertilizer Treatments in Rome Beauty Orchard at Frederick. Single Application= Five Pounds Muriate of Potash Or its Equivalent.

Row.	Trees 1 - 13	Amount.
1	Muriate of potash	half
2	Sulphate of potash	half
3	Sulphate of potash magnesia	half
4	Kainit	half
5	Complete with muriate	
6	Muriate of potash plus lime	
7	Nitrate of soda only	
8	Superphosphate	

Row.	Trees 14 - 28	Amount.
1	Muriate of potash	single
2	Sulphate of potash	single
3	Sulphate of potash magnesia	single
4	Kainit	single
5	Muriate of potash	double
6	Sulphate of potash	double
7	Sulphate of potash magnesia	double
8	Kainit	double

All plots received five pounds of nitrate of soda as a basic treatment.

Superphosphate was applied at the rate of ten pounds per tree.

TABLE 8.

Pressure Tests and Storage Counts of Rome Beauty Apples from Fertilizer Plots at Frederick.

(Picked Oct. 13, 1928 and Held in Cold Storage at 32°F.)

Fertilizer Treatment. *	Pressure Tests in Pounds					Storage Counts		
	Oct.15, 1928	Dec.14,1928	Jan.18, 1929	March 2, 1929	April 6, 1929	Percent Sound	Percent Decay	Percent Scald
$NaNo_3$ only	17.65 ± .123	13.33 ± .118	11.13 ± .095	11.11 ± .079	11.01 ± .077	67.3	2.5	30.2
N-KCl half	16.95 ± .127	11.91 ± .071	10.80 ± .063	10.64 ± .071	9.96 ± .071	68.8	1.7	29.5
N-K_2SO_4 half	17.17 ± .138	12.51 ± .067	9.99 ± .055	10.42 ± .064	11.32 ± .071	86.6	1.5	13.9
N-$K_2Mg(SO_4)_2$ half	16.84 ± .104	11.82 ± .089	10.16 ± .063	10.54 ± .077	10.25 ± .071	95.9	0.5	3.6
N-Kainit half	16.30 ± .138	12.00 ± .100	10.51 ± .078	10.51 ± .045	10.35 ± .077	83.9	1.2	14.9
N-KCl single	17.10 ± .152	12.24 ± .100	10.25 ± .100	10.39 ± .077	10.07 ± .063	98.2	1.1	0.7
N-K_2SO_4 single	16.84 ± .104	11.82 ± .089	10.16 ± .063	10.53 ± .077	10.25 ± .071	88.4	1.6	10.0
N-$K_2Mg(SO_4)_2$ single	17.17 ± .141	13.10 ± .063	11.15 ± .089	10.55 ± .088	10.61 ± .072	94.0	1.0	5.0
N-Kainit single	17.61 ± .127	12.48 ± .100	10.68 ± .078	11.16 ± .071	10.96 ± .055	68.3	4.3	27.4
N-KCl double	17.13 ± .100	12.53 ± .063	10.78 ± .071	10.89 ± .084	11.25 ± .084	70.5	1.2	28.3
N-K_2SO_4 double	17.22 ± .168	12.93 ± .088	10.12 ± .071	10.84 ± .083	10.42 ± .084	89.3	2.1	8.6
N-$K_2Mg(SO_4)_2$ double	17.28 ± .131	12.88 ± .071	10.87 ± .100	10.40 ± .055	10.74 ± .084	92.8	1.1	6.1
N-Kainit double	17.65 ± .128	13.17 ± .089	11.26 ± .063	11.22 ± .071	11.01 ± .077	87.9	0.0	12.1
N-P-KCl	17.70 ± .088	13.49 ± .055	11.13 ± .105	11.00 ± .071	11.11 ± .095	61.8	2.2	36.0
N-KCl lime	17.60 ± .134	12.57 ± .084	11.23 ± .082	10.85 ± .077	11.35 ± .064	79.3	4.8	15.9
N-P	17.27 ± .134	12.84 ± .084	11.43 ± .095	11.52 ± .095	10.93 ± .094	52.8	7.0	40.2

* Nitrate of soda - five pounds per tree.
Superphosphate - ten pounds per tree.
Potash single - five pounds of muriate of potash or equivalent.

applications were made each year about the first of April, depending upon the earliness of the season.

Investigations Conducted in 1928

The average yield in 1928 was four bushels per tree. No difference between plots in the appearance of the trees were observable at time of harvesting.

Sampling and Testing. On October 13, 1928 two bushels of uniform fruit were selected from each of the plots. These were pressure tested October 15, and placed in cold storage in Hagerstown, twenty-five miles distant. Pressure tests with a Magness and Taylor tester and inspection counts were made at approximately monthly intervals during storage until April 6, 1929.

Results. In table 8 are presented the results of this test. The samples were remarkably uniform in size, color, and maturity and hence the probable errors of the averages, based on the forty-five individual punches, were extremely small. The fruit softened rapidly in storage to January 18, decreasing from an average test of all plots of 20.5 pounds to 14.7 pounds, but on April 6, three months later, the average of all plots was still 14.7 pounds.

Throughout the storage season the fruit from the nitrogen plot was among the firmest samples and thus no benefit in increased firmness could be ascribed to the use of potash fertilizers. Several potash treatments,

including the muriate in single and half amounts, were significantly softer at the end of the storage test; but as mentioned previously, the values of the probable errors as determined in this table were not all-inclusive, and in addition the differences were not large enough to be considered commercially important.

The results of decay and scald counts (table 8) showed the development of decay during storage to be unaffected by treatment, but scald had been distinctly reduced on the sulfate of potash magnesium and the sulfate of potash treatments, compared with nitrogen only, to an extent greater than three times the probable errors of the differences. The nitrate only plot showed 30.2 per cent scald and all the $Mg(KSO_4)_2$ and K_2SO_4 plots only 4.9 per cent and 10.8 per cent respectively. The average of all muriate plots was 19.5 per cent and kainit 18.1 per cent, but these last two fertilizers were not significantly lower than nitrate only.

Summary for 1928 The first year's tests on Rome indicate that the potash treatments have not increased the firmness of the fruit, though fruit from two of the fertilizer treatments showed less scald in storage.

Investigations Conducted in 1929

The Rome orchard experienced an almost complete crop failure in 1929 and no samples were taken for storage studies.

Investigations Conducted in 1930

Although the trees set a fair crop in the spring of 1930, the season was so dry that much of the fruit was too small to be worth harvesting in the fall. The trees wilted badly and lost a great many leaves. Though the apples used in the storage tests lacked color and size, the fruit ripened slowly in storage and kept much better than the fruit used two years previously.

Chemical studies and respiration determinations were made on samples of fruit from this orchard in this year, in addition to the usual pressure tests and storage studies, as further measures of keeping quality.

Pressure Tests and Storage Studies.

Sampling and Testing. Three bushels of two and one-fourth inch apples, the largest fruit on any of the plots, were selected from six potassium treatments and the nitrogen only plot on October 18, 1930. The fruit was pressure tested immediately with a Magness and Taylor pressure tester, and hauled to Washington where it was placed in cold storage at 32°F. Pressure tests were made at monthly intervals during storage. On the date of the last pressure test, April 14, no scalded or decayed fruit was evident in any of the samples.

Results. Table 9 shows the results of the pressure tests. In these samples a difference of at least 1.59 pounds must be present between plot averages before odds

TABLE 9.

Pressure Tests of Rome Beauty Apples from Fertilizer Plots at Frederick.

(Picked Oct. 17, 1930 and Held in Cold Storage at 32°F.)

Fertilizer Treatment. *	Pressure Tests in Pounds.					
	Oct. 18, 1930	Nov. 25, 1930	Jan. 6, 1931	Feb. 7, 1931	March 9, 1931	April 14, 1931
$NaNo_3$ only	22.66	19.59	17.44	14.69	15.09	15.99
N-KCl single	22.49	19.46	16.15	14.21	14.64	15.28
N-K_2SO_4 single	23.98	20.82	16.98	16.11	15.33	15.71
N-$Mg(KSO_4)_2$ single	25.85**	22.94	18.63	18.13	17.42	15.94
N-Kainit	23.86	20.48	17.10	16.30	15.60	16.18
N-PKCl	22.87	19.71	16.56	15.63	15.32	16.20
N-KCl double	22.08	19.72	16.33	15.12	14.12	15.09

Difference required for 30:1 odds = 1.59 pounds.

* Nitrate of soda - five pounds per tree.
Superphosphate - ten pounds per tree.
Potash single - five pounds of muriate of potash or its equivalent.

** Two-bushel sample.

of 30:1 are obtained by Student's method. Only one treatment, sulfate of potash magnesia, had affected the firmness of the fruit to that extent at picking time, it being 3.2 pounds firmer than the nitrate only sample. In the final test on April 14 the sample was still two pounds firmer than the nitrogen check, showing that the treatment had increased the firmness and improved the keeping quality of the fruit markedly. None of the other potassium salts affected the pressure test averages appreciably.

The fruit at time of picking averaged five pounds greater in firmness than the 1928 samples. Whether this difference was due entirely to the smaller size of the fruit or whether lack of moisture had an influence can only be surmised, but unquestionably the keeping quality was greatly improved.

Respiration Studies.

Measurement of the products of respiration has long been considered a reliable way of measuring the rate of metabolism taking place in fruit in storage. Though the CO_2 measurement represents only a summary of the metabolic processes, it furnishes a valuable index to the rate at which certain changes are taking place. Numerous investigators have studies the relation between respiration, rate of softening , and keeping quality. Kidd and West (16) found an inverse relationship between rate of respiration, nitrogen content of the fruits and keeping quality,

rate of respiration, and the poorer the keeping quality. In a study of the rate of senescence in the apple, Kidd (17) observed that a mature apple had a respiratory activity of about 1/10 that of the young apple fruit. About the time that apples are normally gathered the respiratory activity was found to be at a minimum, and then as full maturity was reached a second maximum was attained followed by a falling off in activity corresponding to the initiation of senescence. The final values attained at the end of the life of the apple were about equal to the original minimum, or about half of the rate of the second maximum. Magness, et. al. (22) notes a close correlation between rate of respiration and rate of softening of apples at different temperatures. In another publication, Magness and Burroughs (20) observed that respiration was greatest early in the storage life of the apple, the rate decreasing as senescence approaches.

Methods. As part of the 1930 studies, duplicate samples, each of fifteen pounds, from the nitrate only, muriate, and complete plots of the Rome orchard were removed from cold storage in the latter part of January and placed in five-gallon glass jars for respiration studies. The apparatus, shown in figure 1 was similar to that described by Harding (14). The jars were held at a constant temperature of 15°C. in a 9' x 3' x 3' chamber with thermostatic control. A hot plate served as a heating element, and an electric fan produced the necessary

Figure 1. Section of respiration outfit, showing design and arrangement of apparatus.

air circulation. Air flow through the jars was regulated with water manometers at approximately five liters per hour. Soda lime was used to remove the carbon dioxide from the air as it entered the jars, and normal NaOH to absorb the CO_2 respired. Barium hydroxide served as a check on the efficiency of both absorbents. The double titration method as used by Gore (11) was employed to determine the amount of CO_2, phenolphthalein and methyl orange being the indicators used. Titrations were made daily on each variety for a period of three weeks.

Results. The data of the Rome studies are presented in table 10. Despite the use of a mercury trap in the system to maintain a constant air pressure in the apparatus, variation in the city water pressure produced changes in the average daily flow. Since there was at all times an accumulation of CO_2 in the jars, daily changes in the air flow affected the CO_2 determinations appreciably. Each jar was affected to the same degree, however, resulting in a definite correlation from day to day. For this reason Student's method was employed in determining the reliability of the differences.

The Rome samples respired at approximately the same rate, regardless of treatment (table 10). In all comparisons the odds according to Student's method were less than 21:1 and in addition the differences of 0.06 and 0.18 milligrams CO_2 per kilogram hour were so small as to be negligible.

TABLE 10.

Respiration at 15° C. of Rome Beauty Apples from Fertilizer Plots at Frederick. Picked Oct. 17, 1930 and Held in Cold Storage to January 27.

(Average length of run 10 hours)

Date	Mgms. CO_2 produced per Kilogram hour					
	$NaNO_3$		N-KCl		N-P-KCl	
	I	II	I	II	I	II
Jan. 27	8.44	8.39	8.95	8.48	7.83	9.16
Jan. 28	8.98	8.50	7.12	9.00	7.71	8.42
Jan. 30	9.97	9.54	10.03	9.86	9.15	--
Jan. 30	9.96	10.13	11.23	9.87	9.52	9.13
Jan. 31	9.78	9.30	10.46	9.67	8.73	9.06
Feb. 1	11.93	11.67	11.50	11.58	10.92	10.91
Feb. 2	10.61	10.33	10.76	--	9.65	9.81
Feb. 3	12.21	12.25	12.55	--	12.36	11.45
Feb. 4	9.77	9.97	9.53	--	10.00	9.70
Feb. 5	8.84	9.00	9.22	9.13	8.44	9.02
Feb. 6	9.82	10.12	10.14	9.85	9.74	9.62
Feb. 7	11.15	10.56	10.25	10.79	9.98	10.82
Feb. 8	9.92	9.69	10.01	10.61	10.25	10.29
Feb. 9	9.45	--	9.22	--	9.48	9.47
Feb. 10	10.14	10.48	9.78	10.37	10.30	10.65
Feb. 11	10.08	10.39	10.55	10.80	10.11	9.82
Feb. 12	9.54	9.31	9.17	9.26	9.93	9.36
Feb. 13	9.79	10.14	9.93	9.42	9.98	9.85
Feb. 14	9.39	9.66	9.44	--	9.75	9.48
Feb. 15	9.78	8.92	9.04	9.03	9.66	--
Feb. 16	9.44	8.94	8.80	9.27	9.44	9.75
Average	9.95	9.86	9.87	9.81	9.66	9.78
	9.90		9.84		9.72	

Difference between $NaNO_3$ and N-KCl = .06 Odds 1:1

Difference between $NaNO_3$ and N-P-KCl = .18 Odds 20:1

Chemical Studies.

During the storage season of 1930-1931, chemical analyses of the pressure tested fruits from three of the Rome plots were made to determine what effect potash fertilizer treatments might have on the normal rate of change taking place with certain of the chemical constituents, and to ascertain if the chemical analyses could be correlated with the results of storage studies.

Results. The data of the Rome analyses are presented in table 11. Pectin changes were closely correlated with changes in firmness as shown graphically in figure 2. The muriate fruit, having less dry weight, was uniformly lower in protopectin on a fresh weight basis. The soluble pectin content, however, was practically identical for all the plots on date of picking, and remained so until January 6. From then on the pectin content of the nitrate fruit increased but slightly compared with the two potash plots.

An interesting relation is evident in this data, although whether it could be ascribed to treatment is questionable. There appeared to be an almost perfect correlation between firmness of the fruit, moisture content, and protopectin content. The complete plot had the firmest fruit, which in turn had the least moisture and the most protopectin. The muriate fruit represented the other extreme, with nitrate only fruit occupying a median position. On a dry weight basis, however, the

Figure 2. Pectic constituents and pressure tests of Rome apples during storage.

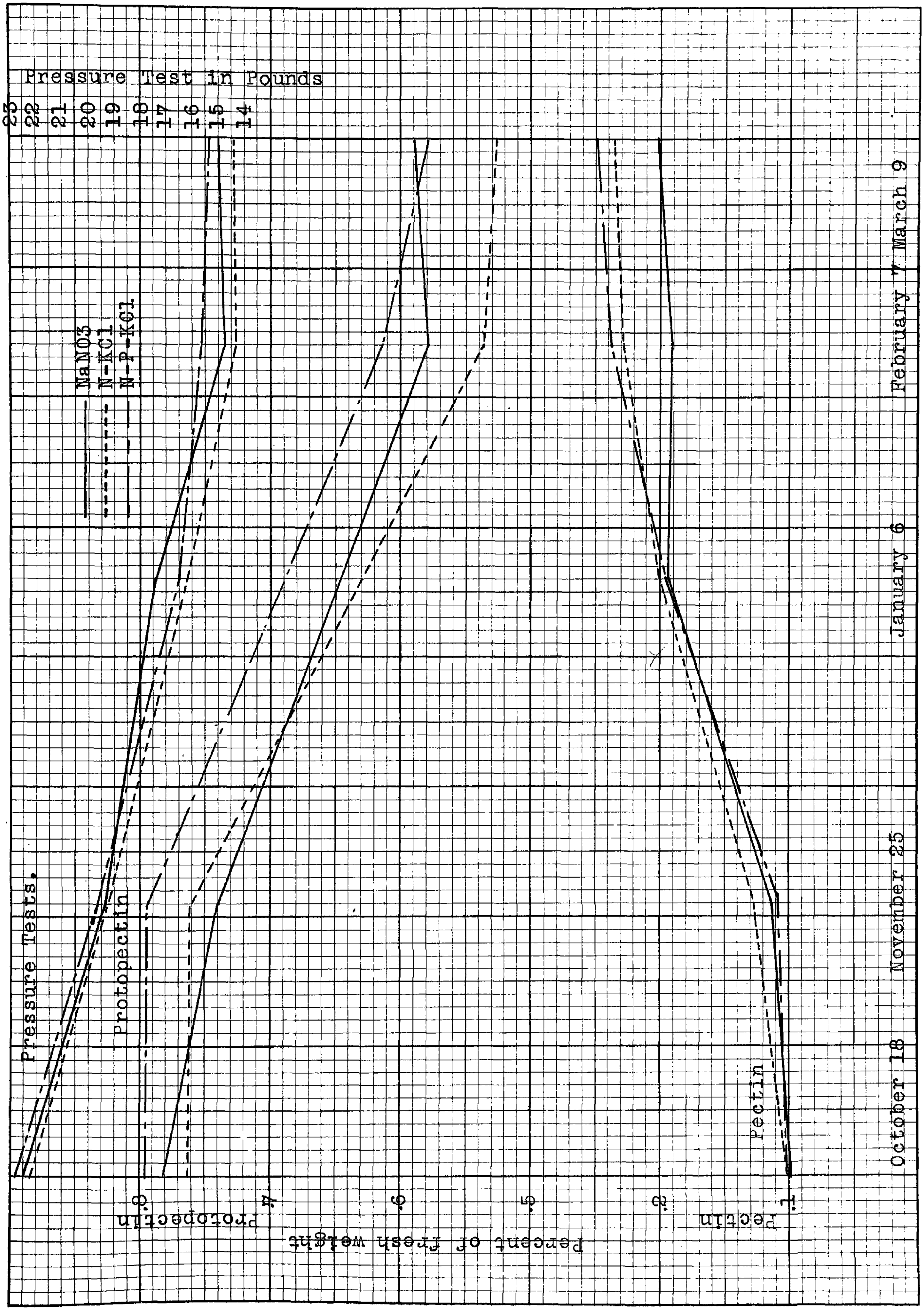


TABLE 11.

Analysis of Rome Apples from Fertilizer Plots at Frederick During 1930 Storage Tests.

(Results with the exception of pectin and acidity expressed as percentage dry weight.)

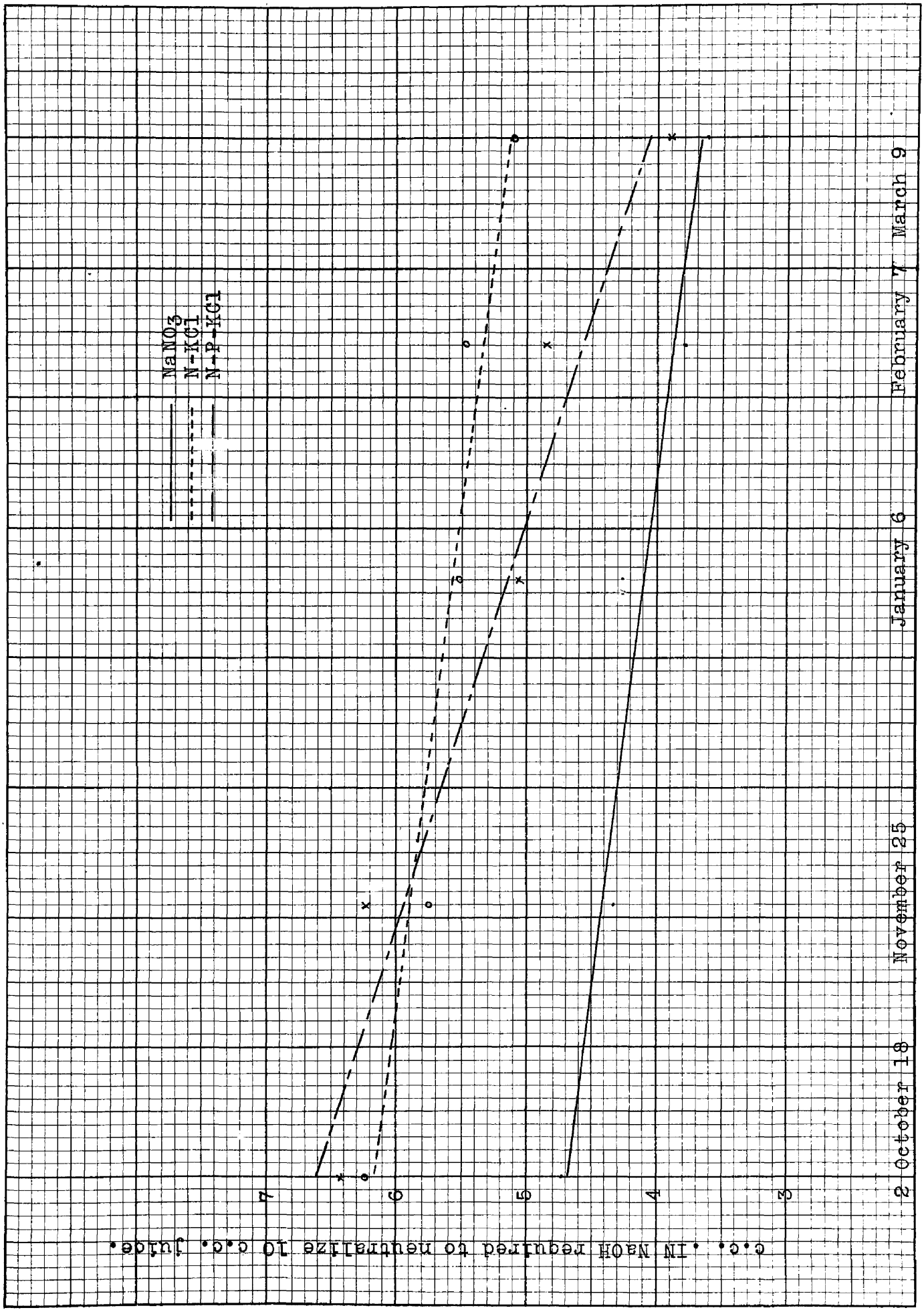
Date of Sampling	Fertilizer Treatment	Pressure test. lbs.	Soluble Pectin	Proto-Pectin	Total Pectic Material	Dry Weight	Reducing Sugars	Sucrose	Total Sugars	Hydrolyzable material	Starch	Titratable Acidity*	Ph	Potassium
Oct. 18 1930	$NaNo_3$	22.66	.098	.784	.872	19.10	52.53	13.75	66.28	9.85	2.70	3.67	3.79	.160
	N-KCl	22.49	.100	.764	.864	18.11	53.49	14.01	67.50	9.43	1.92	4.86	3.78	.175
	N-P-KCl	22.87	.102	.798	.900	19.62	51.49	15.18	66.67	10.16	3.34	4.99	3.69	.165
Nov. 25 1930	$NaNo_3$	19.59	.118	.742	.860	18.75	53.02	15.14	68.16	7.81	1.10	4.32	3.64	.190***
	N-KCl	19.46	.130	.766	.896	18.10	53.30	15.95	69.25	7.80	.95	5.75	3.62	.233***
	N-P-KCl	19.71	.113	.795	.908	19.63	48.69	16.56	65.25	7.78	1.26	6.27	3.56	.192***
Jan. 6 1931	$NaNo_3$	17.44	.196	.572	.768**	18.17	55.93	14.08	70.01	6.95	.60	4.27	3.78	
	N-KCl	16.15	.203	.529	.732**	17.50	55.97	13.23	69.20	7.21	.74	5.56	3.74	
	N-P-KCl	16.56	.198	.654	.852**	19.00	55.50	13.21	68.71	7.39	.47	5.05	3.76	
Feb. 7 1931	$NaNo_3$	14.69	.194	.582	.776	18.71	52.59	14.45	67.44	5.38	.45	3.79	3.74	
	N-KCl	14.21	.232	.540	.772	17.72	53.78	14.29	68.07	5.71	.51	5.45	3.68	
	N-P-KCl	15.63	.238	.614	.852	19.78	53.34	13.38	66.72	5.81	.51	4.87	3.66	
March 9 1931	$NaNo_3$	15.07	.205	.591	.796	18.23	56.14	12.91	69.05	6.24	.--	3.64	3.88	
	N-KCl	14.64	.237	.527	.764	17.74	54.99	13.30	68.29	6.38	--	5.09	3.61	
	N-P-KCl	15.32	.250	.582	.832	19.08	54.78	12.31	67.09	6.61	--	3.91	3.85	

* cc. in Na OH required to neutralize 10 cc. of juice. Normality on Oct. 18 unknown.
** Total pectic material determined on carbohydrate sample.
*** August 1, 1930.

differences between treatments in protopectin content practically disappeared. The slight, though consistent differences in firmness, may therefore be partially attributed to moisture content. Whether this in turn was due to fertilizer treatment is doubtful. The season of 1930 was extremely abnormal as regards rainfall, and this particular experiment suffered more severely from lack of moisture than any other orchard. Factors other than treatment which are difficult to evaluate and which in normal seasons can be disregarded must therefore be taken into consideration.

The figures on titratable acidity (table 11) show wide differences between plots, the nitrate only fruit having had considerably less acid than fruit from either the muriate or complete plots. The straight lines of closest fit to the date are presented in figure 3. The nitrate only and muriate samples decreased in acidity at practically the same rate, the lines being parallel; but the complete plot, with the most acid at picking time lost acid at more than twice the rate of the other plots. One month more in storage possibly would have brought its acidity to a point lower than the nitrate plot. This rapid loss of acid was apparently independent of other chemical changes, for there was no corresponding increase in respiration rate, pectin changes, or sugar changes. Furthermore, the low acid content of the nitrate only fruit did not influence the rate of change taking place

Figure 3. Total acidity of Rome apples during storage with straight lines of closest fit.



in other chemical constituents. A possible explanation of this lies in the Ph determinations as presented in table 11. Though there were wide differences in titratable acidity, the hydrogen-ion concentration was but slightly affected, with the nitrate only fruit having a consistently higher Ph than the other samples.

Rome apples contained little starch at time of picking (table 11) consequently the changes in sugar content during storage were slight. Sucrose was slowly but constantly hydrolyzed to reducing sugar. No doubt sampling and analytical errors involved masked any of the small differences in rate of change which might have been present. The acid hydrolyzable material which presumably is associated more closely with cell wall material and firmness than the other carbohydrate constituents was practically identical for all three treatments.

Summary for 1930.

1. The firmness of the fruit in 1930 was affected only by the sulfate of potash magnesia treatment, where a decided increase in firmness and keeping quality was noted. Muriate of potash, sulfate of potash, kainit, and complete fertilizer treatments had no effect on the keeping quality of the fruit.

2. Muriate of potash, used in combination with nitrogen, or nitrogen and phosphorus, applied to Rome apple trees, did not affect the rate of respiration of the

fruit in storage.

3. Pectic constituents of fruit were practically unaffected by muriate of potash applications.

4. The potash treatments produced fruit having the greatest acid content, but the complete fertilizer sample lost acid at double the rate of the other two samples.

5. Potassium content of the fruit was almost identical for all three treatments.

6. No differences in carbohydrate content or carbohydrate changes could be attributed to treatment.

Discussion of Rome Studies

In these Rome experiments no differences in the firmness of the samples of fruit taken in 1928 could be attributed to fertilizer treatments. With one or two exceptions, all pressure test averages fell within a comparatively narrow range at all dates in this first year of the experiment. The significant part of that year's results lay in the storage counts, which showed that the fruit from the sulfate of potash and sulfate of potash magnesia plots had less scald than the nitrate only fruit, beyond the limits of error. While the reliability of the probable error may be questioned, where such small numbers are involved, the differences were quite large.

In the third year of this experiment occurred the

only effect of treatment on the firmness of apples great enough to be considered important in any of the experiments. Sulfate of potash magnesia fruit was distinctly firmer than the fruit from any of the other six treatments sampled, at time of picking and at all dates during storage. None of the other potash treatments appeared to have any appreciable influence on firmness of the fruit. Just what relation the extremely dry weather may have had in accentuating the effect of the fertilizer cannot be judged, but it should be remembered that the fruit used in the samples was abnormally small in size and poor in color.

General Summary of Rome Studies

1. The first year's treatment produced no differences in the firmness of the fruit. The samples from the sulfate of potash and magnesia sulfate of potash plots had significantly less scald in storage than fruit from the plot receiving nitrate of soda only.

2. The third year of treatment, the magnesia sulfate of potash treatment produced fruit which was decidedly firmer than the nitrogen check fruit, both at time of picking and seven months later in cold storage.

3. The results of pressure test determinations were closely correlated with the results of the chemical studies. Except for a more rapid loss of acid in the complete fertilizer sample, differences in the rate of change of the other chemical constituents studied were negligible.

YORK IMPERIAL ORCHARD AT HANCOCK

Description of Experiment. The York orchard used in this experiment was owned by the American Fruit Growers, Incorporated, and was situated on the east side of Tonoloway ridge, near Hancock in Washington County. The land was in blue grass sod for the most part, with occasional patches of alfalfa. The soil was classified as Hagerstown clay loam (5). Limestone outcroppings were frequent. The orchard was twenty-eight years old when the experiment was begun in 1928. An application of eight pounds of nitrate of soda was given each tree annually during the experiment.

The rows of trees ran perpendicular to the ridge. Twenty rows of sixteen trees each were given treatments as shown in a plan of the experiment in table 12. Fertilizer was applied about April 1, each year at the rate of five pounds of muriate of potash or its equivalent in the single applications. The plots receiving nitrate of soda only were included in an adjoining nitrogen fertilizer experiment begun in 1926.

Investigations Conducted in 1928

As indicated by their age, the trees in this experiment were large, and the average yield of seven bushels per tree borne in 1928 was by no means a heavy crop. As far as could be determined by careful observation during the summer and at harvesting time, the fertilizer treatments had no effect on the growth or general vigor of the trees.

TABLE 12.

Outline of Fertilizer Treatments in York Imperial Orchard at Hancock.

Single Application = Five Pounds of Muriate of Potash or Its Equivalent.

Row.	Treatment.	Amount.
1	Complete with sulphate of potash	double
2	Superphosphate	
3	Complete with muriate of potash	double
4	Muriate of potash plus lime	single
5	Complete with muriate of potash	single
6	Complete with sulphate of potash	single
7	Complete with sulphate of potash magnesia	single
8	Complete with kainit	single
9 - 24	Nitrogen fertilizer experiment	
25	Muriate of potash	double
26	Sulphate of potash	double
27	Sulphate of potash magnesia	double
28	Kainit	double
29	Muriate of potash	single
30	Sulphate of potash	single
31	Sulphate of potash magnesia	single
32	Kainit	single
33	Muriate of potash	half
34	Sulphate of potash	half
35	Sulphate of potash magnesia	half
36	Kainit	half

All trees received eight pounts of nitrate of soda as a basic treatment.

Superphosphate was applied at the rate of ten pounds per tree.

Pressure Tests and Storage Studies

Sampling and Testing. On October 11, 1928, samples of one bushel each were selected in the usual manner from each plot. After pressure testing with a Magness tester, the fruit was placed in cold storage in Hagerstown. At four later dates, the final one April 6, pressure tests and inspections were made.

Results. The results of the pressure test work and inspections are presented in table 13. York apples showed more variability in firmness than Stayman or Rome, as evident by the size of the probable errors based on individual punches. The two samples from the nitrogen only treatment duplicates represented with but two exceptions the firmest and the softest samples at time of picking. The fruit from the half applications of muriate of potash was appreciably firmer than the nitrogen check, but in the second pressure test on December 15, the difference had disappeared.

Throughout the storage test no consistent differences appeared in favor of any potash treatment, and in the final pressure test on April 6, there was no evidence that any treatment had improved the keeping quality.

No single potassium salt had lessened scald consistently; and the total average of all potassium plots on April 6 was 71:8 per cent scalded fruit, while the fruit of the nitrate only plots had 69:8 per cent scald.

TABLE 13.

Pressure Tests and Storage Counts of York Imperial Apples from Fertilizer Plots at Hancock.

(Picked Oct. 12, 1928 and Held in Cold Storage at 32°F.)

Fertilizer Treatment. *	Pressure Tests in Pounds.					Storage Counts		
	Oct.11, 1928	Dec. 15, 1928	Jan.19, 1929	March 1, 1929	April 6, 1929	Percent Sound	Percent Decay	Percent Scald
$NaNo_3$	21.35 ± .301	20.20 ± .100	18.42 ± .259	17.00 ± .247	14.91 ± .117	24.1	3.8	72.1
$NaNo_3$	19.12 ± .205	17.88 ± .105	16.70 ± .134	15.39 ± .095	14.40 ± .102	28.6	3.9	67.5
N-KCl half	23.25 ± .288	19.04 ± .132	16.99 ± .201	15.89 ± .174	15.09 ± .145	36.0	2.9	61.1
N-K_2SO_4 half	19.99 ± .238	18.01 ± .152	15.46 ± .194	15.87 ± .159	14.66 ± .164	12.8	2.0	85.2
N-$Mg(KSO_4)_2$ half	20.79 ± .159	18.88 ± .142	16.77 ± .225	16.56 ± .145	14.90 ± .159	44.3	0.0	55.7
N-KCl single	20.68 ± .278	18.83 ± .156	17.10 ± .205	15.14 ± .168	13.61 ± .171	26.9	0.0	73.1
N-K_2SO_4 single	21.02 ± .374	18.61 ± .115	15.80 ± .139	15.16 ± .089	14.61 ± .138	48.1	0.9	51.0
N-KCl double	19.95 ± .265	18.12 ± .156	17.09 ± .142	15.48 ± .135	----	14.2	2.7	83.1
N-K_2SO_4 double	19.65 ± .227	17.40 ± .149	17.05 ± .165	16.39 ± .193	14.96 ± .201	30.6	3.8	65.5
N-$Mg(KSO_4)_2$ double	21.07 ± .224	17.50 ± .153	16.48 ± .174	14.54 ± .114	----	17.5	0.0	82.5
N-Kainit double	19.42 ± .300	17.32 ± .119	16.68 ± .115	15.14 ± .168	13.61 ± .171	25.2	3.7	71.1
N-P-KCl	20.79 ± .268	20.27 ± .152	19.01 ± .224	16.29 ± .182	14.53 ± .131	39.4	2.2	58.4
N-P-K_2SO_4	20.14 ± .261	18.43 ± .162	16.81 ± .193	17.08 ± .185	14.87 ± .312	13.7	3.9	82.4
N-P-$Mg(KSO_4)_2$	20.11 ± .225	19.54 ± .138	17.37 ± .123	16.40 ± .182	14.24 ± .123	54.7	1.7	43.6
N-P-Kainit	18.18 ± .379	17.03 ± .127	16.33 ± .164	15.46 ± .162	13.86 ± .123	44.1	0.8	55.1
KCl lime	19.48 ± .217	19.17 ± .174	17.67 ± .295	16.39 ± .142	----	9.0	1.3	89.7
Phosphate only	20.68 ± .246	17.28 ± .174	16.21 ± .149	14.01 ± .156	13.88 ± .100	34.7	6.7	58.6

* Nitrate of soda - eight pounds per tree.
Superphosphate - ten pounds per tree.
Potash single - five pounds muriate of potash or equivalent.

Summary for 1928. Firmness and keeping quality of York apples was not affected appreciably in this year by application of various potash fertilizers.

Investigations Conducted in 1929

Sampling and Testing. The crop on the York orchard was very light in 1929 and as a result the one-bushel samples obtained from each of ten plots were not as uniform as usual. The fruit was picked on October 16, pressure tested immediately, and then placed in cold storage in Hagerstown. Pressure tests were made at monthly intervals during storage until March 30, 1930.

Results. Pressure test averages for these samples are presented in table 14. Since only one bushel was obtained from each plot, it was impossible to evaluate the sampling error. Disregarding this error, and considering only the error due to variability within each sample and to pressure testing, none of the fruit from the eight potassium plots sampled were significantly firmer or softer than the nitrate only sample on consecutive dates.

Nevertheless, the sulfate of potash magnesia treatments, both single and double, were firmer than the nitrogen check plot in practically every test. The average difference for all dates between the sulfate of potash magnesia double sample and the nitrate only samples was 0.78 pounds in favor of the former, with odds greater than 9999:1. With the single magnesia treatment the average difference was 0.75 pounds, with odds of 65:1 that

TABLE 14.

Pressure Tests of York Imperial Apples from Fertilizer Plots at Hancock. (Picked Oct. 5, 1929 (and Held in Cold Storage at 32°F.)

Fertilizer Treatment.*	Pressure Tests in Pounds.					
	Oct. 6, 1929	Nov.8, 1929	Dec.6, 1929	Jan.10, 1930	Feb.22, 1930	March 30, 1930
$NaNo_3$	21.96 ± .232	21.61 ± .211	20.26 ± .179	19.26 ± .192	17.76 ± .239	17.82 ± .144
N-KCl lime	20.16 ± .202	20.21 ± .187	19.53 ± .152	18.60 ± .176	15.96 ± .148	18.12 ± .168
N-P-KCl	21.10 ± .187	20.52 ± .159	20.50 ± .177	19.20 ± .152	16.76 ± .168	17.82 ± .148
N-P-KCl	21.37 ± .182	19.67 ± .191	19.99 ± .146	18.96 ± .115	16.79 ± .153	17.87 ± .162
N-KCl double	21.41 ± .209	20.32 ± .189	18.82 ± .197	18.70 ± .159	17.18 ± .187	16.43 ± .156
N-$Mg(KSO_4)_2$ double	22.69 ± .206	21.99 ± .177	21.70 ± .232	19.67 ± .148	18.62 ± .262	18.77 ± .133
N-KCl single	22.20 ± .214	20.81 ± .226	21.18 ± .185	19.64 ± .206	17.43 ± .210	18.68 ± .134
N-K_2SO_4 single	21.52 ± .147	22.26 ± .238	20.20 ± .184	18.81 ± .215	18.57 ± .224	17.75 ± .136
N-$Mg(KSO_4)_2$ single	23.76 ± .268	21.77 ± .290	21.36 ± .263	19.06 ± .131	19.04 ± .259	18.27 ± .154
N-Kainit single	24.25 ± .286	22.75 ± .324	21.72 ± .238	19.91 ± .147	18.21 ± .172	17.93 ± .182

* Nitrate of soda - eight pounds per tree.
Superphosphate - ten pounds per tree.
Potash single - five pounds of muriate of potash or equivalent.

it was not due to chance. These odds prove definitely that the fruit from these treatments was firmer than that from the nitrogen only treatment, though not necessarily due to treatment. When later results are considered, however, the data becomes more significant.

Summary for 1929. Sulfate of potash magnesia treatment was the only treatment which appeared to increase the firmness and improve the keeping quality of the fruit.

Investigations Conducted in 1930

In 1930 the trees yielded an average of fourteen bushels per tree. The crop was scattered though, certain limbs bearing fruit to the point of breaking while adjacent limbs were bare of fruit. This condition made it difficult to obtain comparable samples. During the summer the trees in the experiment were irrigated at intervals, and hence suffered little from lack of rainfall.

Chemical studies and respiration determinations were made in addition to pressure tests in the 1930 studies in this orchard.

Pressure Tests and Storage Studies.

Sampling and Testing. Three bushels of apples were selected from the usual seven treatments on October 16. Only one bushel was obtained from the sulfate of potash magnesia treatment and two from the kainit plot. The samples were pressure tested with a Magness and Taylor tester immediately and then placed in cold storage in

Hagerstown. Four pressure tests were made during storage, and also a final inspection.

Results. The results of the test are presented in table 15. According to the error value based on the bushel average, a difference of 1:53 pounds must be established between plot averages before it may be considered significant. Again the sulfate of potash magnesia treatement produced the only sample significantly firmer than the nitrate only fruit, the difference being 1.85 pounds. Since only one bushel of fruit constituted the former sample, the error should be correspondingly increased. The difference, however, was evident to the final pressure test, distinctly in favor of the potash treatment. None of the other three potassium salts appeared to have affected the firmness to an appreciable extent.

Inspection counts made on the final two pressure test dates showed no differences among treatments in the amount of decay. The sulfate of potash magnesia sample, however, had only 19 per cent scald compared with 39 per cent scald on the nitrate only fruit. The double muriate sample on the other hand had 72.6 per cent scald; and all of the other four potash treatments had distinctly more scald than the nitrate only sample.

Respiration Studies.

On February 20th, 1930, duplicate samples of York apples from the nitrate only, muriate of potash, and

TABLE 15.

Pressure Tests and Storage Counts of York Imperial Apples from Fertilizer Plots at Hancock

(Picked Oct. 15, 1930 and Held in Cold Storage at 32°F.)

Fertilizer Treatment. ***	Pressure Tests in Pounds						Storage Counts		
	Oct.16, 1930	Nov.29,1930	Jan.8,1931	Feb.10,1931	March 7,1931	April 20,1931	Percent Sound	Percent Decay	Percent Scald
$NaNo_3$	21.65	19.57	16.94	16.19	15.85	14.87	57.0	0.4	32.6
N-KCl single	20.63	19.83	16.32	16.01	14.98	14.74	53.3	0.9	45.8
N-K_2SO_4 single	22.33	21.11	17.07	15.92	16.46	15.13	58.9	1.9	39.2
N-$Mg(KSO_4)_2$ single	23.50*	21.08	17.41	—	17.31	15.40	78.9	2.1	19.0
N-Kainit single	22.76**	21.04	17.97	16.81	16.80	15.66	53.9	0.0	46.1
N-KCl double	21.69	19.72	16.21	15.44	15.88	15.44	26.9	0.5	72.6
N-P-KCl	22.03	20.24	16.16	16.01	15.71	15.62	52.7	0.5	46.8

Difference required for 30:1 odds = 1.53 pounds.

* 1 bushel
** 2 bushels

*** Nitrate of soda - eight pounds per tree.
Superphosphate - ten pounds per tree.
Potash single - five pounds muriate of potash or equivalent

complete plots, which had been held in cold storage, were placed in the respiration chambers at 15°C. The same procedure used with the Rome samples, previously described, was employed with this fruit.

Results. The data for the CO_2 determinations are presented in table 16. They show that the nitrate only fruit respired the most rapidly with the odds greater than 9999:1 that the differences between it and the muriate fruit was not due to chance. The odds between the muriate and complete samples are 17:1 in favor of the former so that the nitrate plot respired at a significantly faster rate than either of the potash treatments. Two views may be taken of this difference; one that because the nitrate fruit was respiring more rapidly, it was breaking down at a faster rate and catabolic changes were accelerated, or on the other hand that the nitrate fruit had not yet, on the date the tests were begun -- February 18, -- reached the point in its storage life where the approach of senescence would retard respiration.

While the first viewpoint appears the most logical, contemporary studies indicate that the nitrogen only fruit did not exhibit the poorest keeping quality. Pressure tests of the fruit upon removal from the respiration chambers showed the nitrogen only fruit to have been the firmest, testing 14.05 pounds, compared with the muriate and complete samples which tested 13.58 and 13.16 pounds respectively. Chemical studies which will be considered later likewise favored the nitrate only fruit, in regards

TABLE 16.

Respiration at 15°C. of York Imperial Apples from Fertilizer Plots at Hancock. Picked Oct. 15, 1930 and Held in Cold Storage to Feb. 20, 1931.

(Average length of run - 24 hours)

Date	Mgms. CO_2 per kilogram hour					
	$NaNo_3$		N-KCl		N-P-KCl	
	I	II	I	II	I	II
Feb. 21	7.83	8.58	7.72	7.31	7.34	6.89
Feb. 22	8.45	8.99	7.67	6.99	7.11	7.35
Feb. 23	7.93	8.67	7.35	7.68	7.24	7.04
Feb. 24	7.87	8.59	7.22	7.12	7.33	7.26
Feb. 25	7.56	8.32	6.97	7.10	6.66	6.94
Feb. 26	7.56	8.00	6.95	7.27	--	6.56
Feb. 27	7.67	7.99	7.05	6.60	7.01	6.64
Feb. 28	7.67	7.99	7.05	6.60	7.01	6.64
March 1	7.67	7.99	7.05	6.60	7.01	6.64
March 2	7.67	7.99	7.05	6.60	7.01	6.64
March 3	7.98	7.74	6.89	7.09	6.29	6.48
March 4	7.67	8.58	7.29	7.13	7.09	6.93
March 5	7.60	8.03	6.65	6.68	7.11	6.34
March 6	7.30	7.60	6.39	6.49	6.27	6.33
March 7	7.24	7.67	6.25	6.46	6.55	6.58
March 8	7.10	7.69	6.28	6.37	6.49	6.26
March 9	6.91	7.49	5.95	6.31	6.38	6.40
Average	7.63	8.11	6.93	6.85	6.87	6.70
	7.87		6.89		6.78	

Difference between $NaNo_3$ and N-KCl = .98 mgs. Odds 9999:1

Difference between N-KCl and N-P-KCl = .11 mgs. Odds 17:1

to keeping quality.

Chemical Studies:

During the storage season of 1930-1931 chemical analyses of the pressure-tested fruits from three of the plots in the York Orchard were made. Methods of analyses were the same as those previously described with Rome apples.

Results. In table 17 are presented the results of the chemical analyses of the fruit from the nitrate only, muriate of potash, and complete with muriate treatments. As shown more clearly in figure 4, pectin changes were closely correlated with changes in firmness. The same relation has previously been reported by Haller (13) who found the rate of softening at different temperatures to be proportional to the rate of conversion of insoluble pectic substances into soluble form. The curves in figure 4 show that the greatest drop in firmness in any one period, -- November 29 to January 8 -- was accompanied by the greatest increase in soluble pectin. Insoluble protopectin likewise showed the greatest decrease in the same period. It would seem, therefore, that pectin changes are a reliable indication of ripening, and an important factor in keeping quality. The curves for the three plots parallel each other closely and there is no indication that fertilizer treatments have affected the amounts of the pectic constituents of the fruit. The close correlation of pectin changes with pressure tests

Figure 4. Pressure test and pectic constituents of York apples in storage.

TABLE 17.

Analysis of York Apples from Fertilizer Plots at Hancock During 1930 Storage Tests.

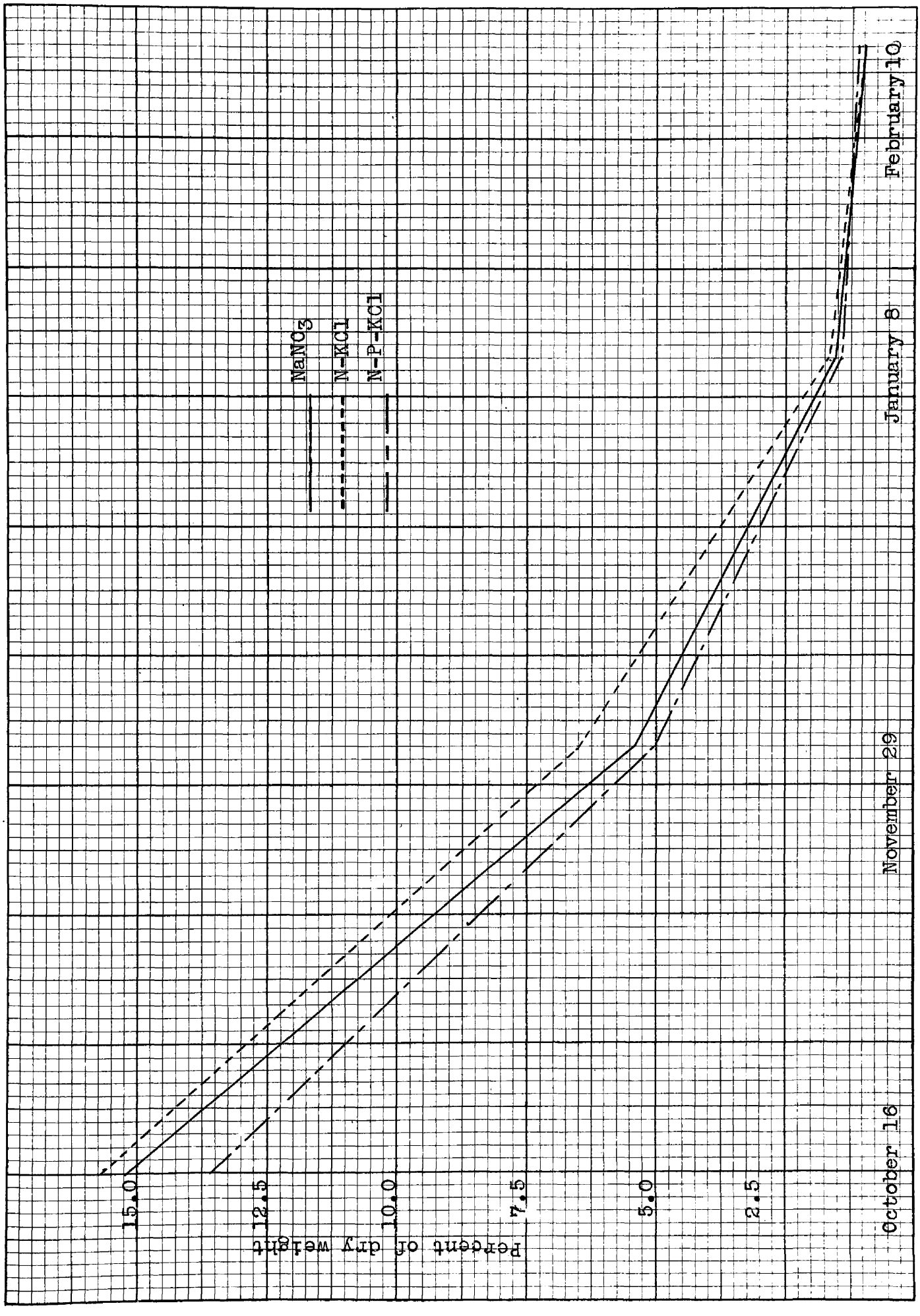
(Results with the exception of pectin and acidity expressed as percentage dry weight.)

Date of Sampling	Fertilizer Treatment	Pressure test lbs.	Soluble Pectin	Proto-Pectin	Total Pectic Material	Dry Weight	Reducing Sugars	Sucrose	Total Sugars	Hydrolyzable Material	Starch	Titratable Acidity *	Ph	Potassium
Oct. 16 1930	$NaNo_3$	21.65	.049	.803	.852	18.26	40.52	13.05	53.57	24.35	15.19	8.80	3.20	.205
	N-KCl	20.63	.042	.762	.804	18.67	36.73	12.39	49.12	25.00	15.86	8.20	3.17	.194
	N-P-KCl	22.03	.049	.755	.804	18.02	42.88	14.65	57.53	23.47	13.67	8.36	3.27	.190
Nov. 29 1930	$NaNo_3$	19.57	.060	.760	.820	18.79	44.42	20.01	65.43	13.91	5.42	9.98	3.25	.254**
	N-KCl	19.83	.047	.765	.812	18.87	43.85	21.63	65.48	13.78	6.54	9.94	3.25	.234
	N-P-KCl	20.24	.051	.745	.796	18.05	47.52	18.48	66.00	12.96	5.06	9.58	3.18	.257
Jan. 8 1931	$NaNo_3$	16.94	.152	.636	.788	19.01	49.47	20.35	69.82	8.50	1.65	8.91	3.42	
	N-KCl	16.32	.130	.670	.800	18.88	48.13	20.32	68.45	8.08	1.64	8.56	3.45	
	N-P-KCl	16.16	.139	.637	.776	18.21	49.72	19.03	68.75	8.25	1.42	8.61	3.39	
Feb. 10 1931	$NaNo_3$	16.19	.178	.562	.740	18.44	50.77	18.13	68.90	6.57	.86	8.62	3.54	
	N-KCl	16.01	.166	.574	.740	18.24	51.21	17.97	69.18	6.73	.83	8.36	3.56	
	N-P-KCl	16.01	.176	.580	.756	18.39	50.85	17.74	68.59	6.85	1.09	8.38	3.52	
March 7 1931	$NaNo_3$	15.85	.209	.575	.784	18.85	50.96	17.17	68.13	6.42	--	8.48	3.49	
	N-KCl	14.98	.199	.609	.808	19.00	51.94	17.97	69.91	6.18	--	7.57	3.51	
	N-P-KCl	15.71	.211	.601	.812	19.11	51.93	16.45	68.38	6.22	--	7.98	3.52	

* cc. .1 N NaOH required to neutralize 10 cc. juice.

** August 1, 1930.

Figure 5 Starch in York Apples during storage.



adds additional evidence that the keeping quality was not influenced by the fertilizer treatments.

The chemical constituent showing the greatest change during storage was starch, which decreased from fifteen per cent to one and one-half per cent in less than three months (figure 5). The fruit from muriate and nitrogen only plots had slightly more starch at time of picking than the fruit from complete fertilizer plot, but the rate of loss was almost in direct proportion to the amounts present, so that on January 8 the differences were negligible.

As the starch content decreased, sugar, especially sucrose, increased and when starch had practically disappeared, the sucrose content began to decrease. Reducing sugars, however, continued to increase to the final sampling on March 7. It will be remembered that the nitrate fruit had the greatest respiration rate, approximately twelve per cent greater than either of the other samples. But in spite of this greater loss of dry material, the sugar content on a dry weight basis was practically unaffected.

Acidity determinations of the expressed juice show the nitrate only fruit to have had slightly more titratable acid content, which was in keeping with the slightly greater firmness. During storage the acidity of the fruit decreased. Ph likewise increased, but the differences

between treatments were small and inconsistent.

Potassium content of the fruit was unaffected by treatment. This is contrary to what Wallace (31) found in England, but his experiments were conducted on a soil which was markedly deficient in available potassium, and the trees showed effects of such lack of potash.

Summary for 1930.

1. Sulfate of potash magnesia treatment again increased the firmness of the York apples markedly at the time of picking, and during storage. None of the other three potash salts were effective.

2. The magnesia treatment appeared to reduce the amount of scald, and the double muriate of potash treatment on the other hand had the greatest amount of scald.

3. The fruit from the York plot receiving nitrate of soda respired at a distinctly faster rate than either the muriate of potash or complete fertilizer samples.

4. The changes in pectic constituents during storage fully corroborate the pressure test studies, in that no differences ascribable to muriate of potash treatment were evident.

5. Potassium content was identical for all three samples, and sugar loss and starch changes were not influenced by the muriate of potash or superphosphate treatments.

Discussion of York Studies.

The results in the storage tests of fruit from the York orchard were very similar to those obtained with the Stayman and Rome varieties. Potash fertilizer treatments had no effect upon any of the factors studied in the first year of application. In the second year, samples from both the single and double applications of sulfate of potash magnesia were firmer than the fruit from the nitrate only treatment, and in the third year the same effect was evident. Muriate of potash, sulfate of potash, and kainit in single amounts and muriate of potash with superphosphate again did not affect the firmness or the rate of ripening of the fruit in any year.

From a commercial standpoint the effect of the magnesia treatment on the fruit was not important in either 1929 or 1930. The two-pound difference in firmness in the latter year in favor of the potash treatment, though significant at time of picking, diminished during storage to a point at the end of the storage period where it was no longer significant. Further mention of this point is made in the general discussion.

General Summary of York Studies.

1. In this York Experiment only one treatment, sulfate of potash magnesia, had any appreciable influence on the firmness or the keeping quality of the fruit.

2. Applications of muriate of potash, sulfate of

potash, and kainit were ineffective on the firmness or keeping quality.

3. The sulfate of potash magnesia treatment increased the firmness of the fruit to a small degree during the second and third years of the experiment, and the effect was still noticeable at the end of the usual storage period. The amount of scald was also lessened somewhat in the third year by the treatment.

4. Muriate of potash treatments, in combination with nitrogen and nitrogen and phosphorus, compared with nitrogen only, had no influence on the keeping quality of the fruit, as measured by chemical changes during storage.

YORK AND STAYMAN APPLES FROM STATE COLLEGE, PENNSYLVANIA

Through the courtesy of Dr. R. D. Anthony of the Pennsylvania State College, samples of fruit were obtained from the old York and Stayman fertilizer experiments at State College, in 1929. The orchard was approximately thirty years old and was on a clay loam soil of limestone origin. The fruit was picked on October 19 by Dr. Anthony as a random sample, representative of the apples on each particular treatment. Consequently a great deal of variation in size and color was evident within a sample and between samples. Records were taken of the average size of the fruit and the amount of color present for each treatment. From picking time until October 27, the fruit was held in cold storage at State College, then

the fruit was hauled to Arlington, Virginia by truck and placed at 32°F. Pressure tests were made on October 28, December 5, January 15, February 18, March 27, and April 26.

York Variety. The data for four of the York plots are given in table 18. Potassium in combination with nitrogen or with nitrogen and phosphorus has shown neither a significant nor consistent effect on the firmness of the fruit. Small differences occurred among the various tests. The maximum difference between two treatments was 1.41 pounds which was found on October 28. At the end of storage the largest difference was 0.28 pound. The potash plots had more scalded and wilted apples on April 26, the date of inspection, but on the other hand these samples had less color. Since fruit which lacks color is more apt to scald and wilt, the interpretation of the results is difficult.

Stayman Variety. Two bushels of Stayman apples from trees receiving the same treatments as the York samples were included in these tests and in addition a bushel each from P-KCl and P-K_2SO_4 treatments. The latter two samples, from trees lacking nitrogen, were small and very highly colored (table 19). They were much firmer than the other samples, at time of picking and during storage, and showed practically no scald or decay. The fruit from the sulfate plot , with smaller apples, was slightly firmer (0.78 pounds) than fruit from the muriate plot, but had considerably more

TABLE 18.

Pressure Tests and Storage Counts of York Apples from Fertilizer Plots at State College, Pa.

(Picked Oct. 19, 1929 and Held in Cold Storage at 32°F at Arlington, Va.)

Fertilizer Treatment	Size	Percent Color	Pressure Tests in Pounds						Storage Counts			
			Oct.28, 1929	Dec.5, 1929	Jan.15, 1930	Feb.18, 1930	March 27,1930	April 26,1930	Percent Sound	Percent Decay	Percent Scald	Wilt
$NaNo_3$	$2\frac{3}{4}$ - 3"	68.5	25.14*	22.07	20.17	20.57	19.21	18.76	83.1	5.9	1.5	9.5
N-KCl	$2\frac{3}{4}$"	57.6	23.75	22.35	20.45	20.58	19.54	19.04	67.4	4.1	2.9	15.6
N-P	$2\frac{3}{4}$"	62.0	24.10	22.37	20.22	20.05	19.25	18.90	82.1	3.1	0.7	14.1
N-P-KCl	$2\frac{3}{4}$ - 3"	44.7	23.73	21.26	19.93	19.54	18.46	18.94	68.1	8.2	4.6	19.1
		* P.E.M	± .258	± .337	± .158	± .302	± .215	± .835				

TABLE 19.

Pressure Tests and Storage Counts of Stayman Apples from Fertilizer Plots at State College, Pa.

(Picked Oct. 19, 1929 and Held in Cold Storage at Arlington, Va.)

Fertilizer Treatment	Pressure Tests in Pounds.					Storage Counts			
	Size	Percent Color	Oct. 28, 1929	Dec. 5, 1929	Jan. 15, 1930	Feb. 18, 1930	Percent Sound	Percent Decay	Percent Scald	Percent Wilt
$NaNo_3$	$2\frac{3}{4}$-3"	58.6	18.83	15.87	13.40	13.62	53.8	1.3	19.1	25.8
N-KCl	$2\frac{3}{4}$"	60.0	18.97	14.96	12.87	13.67	58.3	1.3	9.6	30.8
N-P	3"	56.2	17.53	15.77	11.46	12.62	56.7	3.3	20.0	25.0
N-P-KCl	3-$3\frac{1}{4}$"	55.8	17.35	14.80	12.15	12.80	27.4	0.0	55.3	17.3
P-KCl	$2\frac{1}{2}$-$2\frac{3}{4}$"	85.3	22.00	16.26	13.20	14.67	89.6	0.0	1.0	9.4
$P-K_2SO_4$	$2\frac{1}{2}$"	83.3	22.78	16.89	13.28	15.21	75.0	1.9	1.7	22.4
		P.E.M	±.095	±.222	±.084	±.257				

wilted apples at the end of the test. Of the other treatments, muriate of potash with nitrogen had the least scald, but also the most highly colored fruit. The complete plot with the largest fruit and the least color, had over fifty per cent scald compared to N-P with twenty per cent scald. The firmness of the fruit was unaffected by the potash treatments. In the final test, February 18, the potash fruit averaged 13.67 and 12.80 against 13.62 and 12.62 pounds respectively for the no-potash treatments.

Discussion

The advisability of taking samples of fruit of uniform color, size, and maturity in order to study the effect of fertilizer treatments on keeping quality was well emphasized in these results. It is a matter of common knowledge that small, well-colored apples, in general, will be firmer and will keep better than large, poorly-colored fruit. Where fertilizer or other cultural treatments affect the size and color of the fruit markedly one may reasonably expect that the firmness and keeping quality will also be affected.

That is the situation which existed in the samples of fruit from State College. The variables of size and color, which were practically impossible to evaluate, had such a great influence on the keeping quality that any possible direct influence of fertilizer treatment could not

be detected. The practical method in studies of this nature is to eliminate these variables by selecting only uniform fruit from the fertilizer treatments.

Summary of Results. Random samples of fruit from York and Stayman fertilizer experiments at State College, Pennsylvania failed to show any evidence of a direct effect of potash treatment during storage in rate of ripening, wilting, or development of scald and decay.

General Discussion of Apple Results

Only one treatment, sulfate of potash magnesia, has affected the firmness or keeping quality of the fruit to any extent, compared with nitrogen only. In every sample of every variety taken from this treatment during the past two years, the fruit was firmer than the nitrogen check at time of picking. While the differences in each case were not significant, the consistency with which they appear adds immensely to their validity. By Student's method the odds were 2400 to 1 against these differences at time of picking due to chance alone.

From a commercial standpoint, the differences were important in only one orchard, the Rome experiments. Here a consistent difference of two to three pounds in favor of the magnesium sulfate of potash treatment over the nitrate only was maintained throughout the storage period. On April 14, 1930, thirty Rome apples from each of the two treatments was removed from cold storage and

held at room temperature to determine how the samples would hold up under market conditions. Ten days later the nitrate only fruit had over fifty per cent scald while the potash samples had less than five per cent scald. Size and color factors, of course, were eliminated in these tests. A similar test on the York fruit in 1930 showed no benefits for this potash treatment, for although less scald was evident on the sulfate of potash magnesia sample, more apples were decayed; so that each treatment had practically the same number of sound fruits ten days after removal from storage.

That these differences were due directly or indirectly to magnesium and not to potassium, was evidenced by the fact that the potassium sulfate fertilizer containing the same ingredients with the exception of magnesium, as the sulfate of potash, magnesia fertilizer, failed to show any appreciable effect on firmness or keeping quality of the fruit. Fletcher (10) reports that ten pounds of magnesium sulfate applied to York Imperial trees at Tonoloway, Hancock, produced foliage of a deeper green color, though the color of the fruit was not affected. In two Elberta peach experiments at Berlin and Mount Airy, to be discussed later under peaches, the sulfate of potash magnesia double treatment was observed to have the densest and greenest foliage of any plots, with a slight delay in maturity of the fruit in 1929. The first year of the experiment, and during the dry season

of 1930, this effect was not noticeable. In the more vigorous Belle and Elberta orchards at Salisbury and Hancock also, no differences due to this treatment were observable. In the case of apple trees no potash treatment appeared to effect the vigor of the trees in any orchard, though because of the inherent variability of trees within plots, minor differences would not be readily noticeable.

That the extremely dry season of 1930 and lack of rain in western Maryland in 1929 limited the possible effects of fertilizers was unquestionable, for moisture was a limiting factor in growth. Also growers reported that nitrate of soda, a very soluble fertilizer, applied in the spring of 1930, remained on the surface of the ground until fall of the same year. Under normal conditions, therefore, one might expect the differences observed to be amplified.

As far as the chemical studies are concerned, it appeared that firmness and keeping quality of fruits were not associated closely with any particular chemical constituent, except pectic substances. While the York nitrate only fruit respired the most rapidly, acid and sugar changes were not correspondingly increased and starch hydrolysis was not hastened, on a dry weight basis. All constituents appeared to be lost at a proportional rate.

With Rome apples, no difference between treatments were found in respiration rate, though in the chemical

studies it was found that the complete fruit lost acid at twice the rate of either the nitrate only or the muriate samples. Furthermore, the nitrate only sample had considerably less acid than either the muriate or the complete samples. Neither of these conditions was correlated with firmness, but the nitrate only fruit had more scald in 1928 and again in 1930 than the magnesia sulfate of potash treatment. Since scalded fruit presents an unattractive appearance to the prospective buyer, and is much more susceptible to decay organisms, than sound fruit, this factor is of importance in measuring keeping quality.

It appears that the chief factors concerned with firmness and keeping quality of apples were the pectic constituents. The gradual change of protopectin, the substance cementing the cell walls together, to soluble pectin, was closely associated with a decrease in firmness in the fruit, and within a variety the proportion of protopectin to pectin was a fair measure of keeping quality.

General Conclusions

Applications of potash fertilizers do not affect the firmness or keeping quality of apples in Maryland to an extent great enough to be considered important commercially. There is a positive indication that sulfate of potash magnesia treatment increases the firmness of fruit to a certain degree, and in one year in one variety under very

abnormal moisture relations, the effect was very marked. This treatment likewise appears to lessen the development of scald in storage, though further verification of this point is necessary.

A higher rate of respiration of apples from different fertilizer treatments is not necessarily associated with poorer keeping quality. The same is true of acid changes.

Carbohydrate content of apples and carbohydrate changes in storage, as well as pectin changes, are not influenced by applications of muriate of potash used in combination with nitrogen and phosphorus.

General Summary

1. The investigations included York, Rome, and Stayman varieties on three different soil types.

2. Four different potassium fertilizers were used: muriate of potash, sulfate of potash, sulfate of potash magnesia and kainit, in varying amounts and in combination with superphosphate.

3. The effect of fertilizers on the firmness of the fruit at time of picking and the rate of softening during cold storage was measured by means of a Magness and Taylor pressure tester.

4. All fruit used in storage studies was uniform in size, maturity, and color. The method of selection corresponded to "spot-picking" as practiced by many careful growers.

5. The development of decay and scald in storage was also used as an index to keeping quality.

6. Muriate of potash, sulfate of potash, and kainit did not affect the firmness of the fruit or the rate of softening in any variety or test.

7. Fruit from the sulfate of potash treatments in the Rome orchard had less scald than the no-potash treatment in the first year's study. In no other instance was the development of scald and decay affected by the muriate, sulfate, or kainit treatment.

8. The sulfate of potash magnesia treatments in the second and third years of all experiments produced firmer fruit than the no-potash treatment. The effect remained noticeable to the end of the storage season. Only one variety, Rome, under very abnormal moisture relations, was affected to a degree considered to be commercially important. Scald on the York and Rome fruits, but not on Stayman, was also decreased by the treatment, but this result needs further study to arrive at definite conclusions.

9. Rate of change in the pectic constituents of Rome and York apples was not affected by applications of muriate of potash, alone or in combination with superphosphate.

10. Muriate treatments likewise did not affect carbohydrate content or rate of change in starch and sugar constituents.

11. A twelve per cent greater respiration rate in a York sample was not accompanied by poorer keeping quality

of the fruit, as measured by other means.

12. The amount of acid or rate of loss of acid in Rome apples did not influence the rate of ripening as measured by firmness, respiration, changes in pectic constituents, carbohydrates, and starch, and development of decay and scald.

13. The potassium content of Rome and York fruit was not affected by applications of muriate of potash.

14. Random samples of fruit from York and Stayman fertilizer experiments at State College, Pennsylvania, failed to show any evidence of a direct effect of potash treatment during storage in rate of ripening, wilting or development of scald and decay.

15. Three annual applications of four potassium fertilizers had no measurable effect on the general vigor of trees of any variety.

II. PEACH STUDIES

In cooperation with the owners of four peach orchards in different sections of the state, a series of fertilizer experiments was laid out in the spring of 1928. A Belle of Georgia orchard at Salisbury and an Elberta orchard at Berlin were selected as representative of the Eastern Shore, and in western Maryland an Elberta orchard near Hancock and an Elberta orchard near Mount Airy were used. These locations represent widely different soil types and climatic conditions.

In 1928, 1929, and 1930 samples of fruit were taken from the various fertilizer plots at harvest time for studies on firmness and keeping quality, as measured by a mechanical pressure tester and the development of decay. In 1930 additional studies on the changes taking place in the pectin constituents were made on Salisbury Belle and Berlin Elberta samples, as a further measure of keeping quality.

ELBERTA ORCHARD AT MOUNT AIRY

Description of Plots. An Elberta orchard at Mount Airy, in Frederick County, owned by W. Walker, which consisted of eight rows of fifty-four trees each, was divided into twenty-four plots, three plots in each row. The trees were six years old in 1928, were pruned moderately, and were given one and one-half pounds of sodium nitrate annually. The soil type was classified as Manor loam (19). The system of soil management used was cultivation and cover crops, though the seasons of 1929 and 1930 were too dry for a cover crop to catch. Bean leaves from a canning factory were plowed under in 1930 at the rate of twelve tons per acre. The dry weather affected the size of fruit and terminal growth to some extent, especially in 1930. While it was not the purpose of this experiment to determine the effect of potassium fertilizers on growth and yield, supplementary records were taken each year of yield, average terminal growth, and trunk circumference. The 1930 data for seven of the plots are pre-

TABLE 20.

1930 Growth and Yield Measurements on Peach Fertilizer Experiments.

Treatment	Belle - Salisbury			Elberta - Berlin			Elberta - Mt. Airy			Elberta - Hancock		
	Terminal Growth. In.	Trunk Increment. mm.	Yield Bu.	Terminal Growth. In.	Trunk Increment. mm.	Yield Bu.	Terminal Growth. In.	Trunk Increment. mm.	Yield Bu.	Terminal Growth. In.	Trunk Increment. mm.	Yield Bu.
$NaNo_3$	8.20 ± .27	34.60 ± 2.16	2.20	5.38 ± .23	32.85 ± 1.38	.40	6.62 ± .236	48.00 ± .509	1.10	---	----	
N-KCl single	8.50 ± .43	31.87 ± 1.07	4.12	5.20 ± .11	27.80 ± 1.72	.31	6.16 ± .294	49.86 ± .546	1.31	2.00 ± .14	27.50 ± 1.10	.22
N-K_2SO_4 single	6.44 ± .27	36.88 ± 1.46	3.94	5.24 ± .14	29.23 ± 1.23	.24	6.56 ± .297	52.77 ± .474	1.06	2.20 ± .09	29.00 ± 1.60	.21
N-$K_2MG(SO_4)_2$ single	6.87 ± .27	32.08 ± 1.41	4.23	5.21 ± .15	29.36 ± .90	.34	5.36 ± .352	51.19 ± .706	1.07	2.43 ± .18	28.79 ± 1.19	.19
N-Kainit single	7.93 ± .47	33.92 ± 1.86	3.62	5.57 ± .18	33.18 ± 2.01	.33	6.08 ± .216	54.10 ± .477	.57	1.93 ± .14	28.71 ± 1.62	.26
N-KCl double	9.30 ± .49	33.79 ± 1.98	3.14	5.50 ± .16	34.71 ± 1.24	.32	6.64 ± .286	52.66 ± .627	1.88	2.38 ± .40	23.69 ± 1.17	.20
N-P-KCl	8.67 ± .41	34.67 ± 1.54	4.12	5.92 ± .17	36.42 ± 1.48	.06	6.58 ± .301	48.26 ± .435	.75	2.13 ± .18	28.60 ± 1.13	.41
$NaNo_3$				5.54 ± .15	36.38 ± 1.48	.15						

sented in table 20. An idea of the vigor and uniformity of the trees thus can be obtained.

A plan of the experiment is given in table 22. Four potassium salts were used: muriate of potash, sulfate of potash, sulfate of potash magnesia, and kainit (20 percent K_2O), applied at the rate of three pounds of muriate salt, or its equivalent in potash in the other carriers per bearing tree. Half and double amounts of this single application

TABLE 21

Rate of Application of Fertilizer Materials in Pounds Per Peach Tree.

Fertilizer	Half	Single	Double	Per Cent K_2O
Muriate of Potash (KCl)	1.5	3.0	6.0	51.3
Sulfate of Potash (K_2SO_4)	1.6	3.1	6.3	49.0
Magnesia Sulfate of Potash ($Mg(KSO_4)_2$)	2.8	5.6	11.2	27.5
Kainit	3.6	7.2	14.3	21.5
Superphosphate			6.0	

Note: The amounts of nitrate of soda per tree varied with different orchards, depending on their age.

also were used, the double application of kainit amounting to fourteen pounds per tree. All plots received nitrate of soda except row I, in which muriate and sulfate of potash

TABLE 22.

Outline of Fertilizer Treatments in Elberta Orchard at Mt.Airy.

Single Application = Three Pounds of Potash or Its Equivalent.

Row.	Trees 1-16.	Trees 17-33.	Trees 34 - 54.
1	KCL double	K_2SO_4 double	
2	N-KCl half	N-KCl single	N-KCl double
3	N-K_2SO_4 half	N-K_2SO_4 single	N-K_2SO_4 double
4	$NaNo_3$ only	$NaNo_3$ only	$NaNo_3$ only
5	N-$Mg(KSO_4)_2$ half	N-$Mg(KSO_4)_2$ single	N-$Mg(KSO_4)_2$ double
6	N-Kainit half	N-Kainit single	N-Kainit double
7	N-P-K_2SO_4 single	N-P-KCl single	N-P-$Mg(KSO_4)_2$ single
8	N-P-Kainit single	N-P-KCl lime single	N-P- lime single

Trees in all rows except number one received 1 $\frac{1}{2}$ pounds of nitrate of soda.

Phosphate was applied at the rate of six pounds per tree.

were used alone. The fertilizer was applied each year, 1928, 1929, 1930, about two weeks before blooming time.

It was in this orchard that Auchter and Schrader in 1928 reported increases in growth and yield from the use of muriate of potash and acid phosphate (2).

Investigations Conducted in 1928

This first year of the experiment the trees were making about eight inches terminal growth and yielded about five bushels of fruit per tree. Fertilizer treatments appeared to have no influence on either growth or yield.

The firmness of the ripe fruit was measured by means of a corn pressure tester and the keeping quality by counting the number of decayed fruits developing during the storage or shipping test. Bushel samples were taken from each plot and hauled by truck to College Park, where they were held at 60° - 70°F for a number of days.

Sampling. The samples were selected in such a way that fruits from all the plots were on a comparable basis of maturity, size, and color at the outset, since random sampling of ripe and green fruit as found on peach trees at any time during harvest was obviously impracticable as a means of obtaining comparable samples, due to the fact that peaches do not ripen uniformly on all trees within a given treatment or among fertilizer treatments. Therefore samples of shipping ripe fruit were selected from each plot just as the grower would pick and grade them for commercial purposes. Thus, all the fruit used in

a single storage test was of the same degree of maturity, of similar size and shape, similar ground color, covered with like amounts of blush, and was from trees with normal or average amounts of crop. In this way extraneous factors which would affect firmness and keeping quality were eliminated, and the direct effect of the fertilizer treatment on keeping quality could be studied.

Though the ideal method of sampling would have been to divide all the fruit of a plot into various sizes, take samples from each size, and record the percentage of the crop falling into each size, the time and facilities available made this impracticable. Consequently tests were conducted on a single size representing the average fruit of the treatment. Inasmuch as no differences in size or color of fruit were observable among the plots, except in cases noted, a selected sample, although limited to a certain size, constituted a representative sample as well.

Pressure Testing. The pressure tester used in 1928 was the Magoon and Culpepper corn tester, manufactured by J. Chatillon Company, of New York. It consisted of a hollow metal tube, inside of which was suspended a plunger on a spring. The instrument was used in a vertical position. A 1/32 inch needle plunger penetrated the flesh as far as the collar would permit, and the force required for puncture was registered in grams. Ten tests were made on each peach at definite points, through the skin. When the peach ripened the resistance of the flesh

alone to the needle was barely sufficient to register and because of this fact the tester proved unsatisfactory. As the peach ripened the skin became an increasingly important factor, compared with the flesh, in determining the firmness of the fruit, and the measurement was chiefly the resistance of the skin to puncture, rather than the firmness of the fruit. In addition a wide variation in individual adjacent punctures on the same peach existed, indicating a lack of reliability. In succeeding years, another pressure tester, which will be described later, was used.

Results. As previously mentioned, a bushel of uniform fruit was selected from each treatment on September 1, 1928, and hauled to College Park by truck, a distance of forty-five miles, where the samples were held at prevailing temperatures. On September 5, the same samples were inspected for decayed fruit, and were pressure tested with the corn tester. The results are shown in table 23.

The percentages of sound fruit (table 23) were fairly uniform among treatments. The per cent of the fruit unaccounted for represented the decayed peaches. The samples were too small to say that any of the narrow differences in number of sound fruits were significant.

Summary for 1928. No differences were evident in the data this year to show that potash fertilizers had affected the keeping quality of Elberta peaches. However, samples from each plot were small and the results of pressure tests were unsatisfactory.

TABLE 23.

Pressure Tests and Storage Counts of Elberta Peaches from Fertilizer Plots at Mt. Airy.* (Pressure Tests made with Corn Tester - #16 needle plunger.)

Fertilizer Treatment.**	Percent Sound	Pressure Test. gms.
$NaNo_3$	83.9	239.9
$NaNo_3$	78.2	227.1
N-KCl single	93.0	244.1
N-K_2SO_4 single	95.4	229.4
N-$Mg(KSO_4)_2$ single	91.3	239.2
N-Kainit single	93.4	234.4
N-KCl double	95.6	264.1
N-K_2SO_4 double	93.4	265.9
N-$Mg(KSO_4)_2$ double	89.4	253.9
N-Kainit double	95.8	260.0
N-P-KCl	92.0	256.5
N-P-K_2SO_4	89.9	241.8
N-P-$Mg(KSO_4)_2$	88.9	224.4
N-P-Kainit	90.3	230.7
N-KCl plus lime	88.0	259.4

* Picked Sept. 1 - Hauled by truck forty-five miles.
Inspected and tested Sept. 5.

** Nitrate of soda -- one and one-half pounds per tree.
Superphosphate -- six pounds per tree.
Potash single -- three pounds Muriate of Potash or equivalent.

Investigations Conducted in 1929

Rainfall was below normal in western Maryland during the summer of 1929, and the fruit was slightly smaller than would usually be expected. The crop averaged approximately three bushels of fruit per tree. The plots receiving muriate of potash and sulfate of potash only, ripened their fruit two or three days earlier than the other plots which had received nitrogen. The sulfate of potash magnesia double plot appeared to ripen a day or two later than the nitrate treatment and the foliage had a darker appearance and was somewhat thicker. The adjoining plot which received fourteen pounds of kainit per tree appeared to be injured by the treatment. The branches bore fewer leaves, and the foliage was considerably less dense and of a lighter color. However, this treatment bore a normal crop in 1929 and again in 1930. Terminal growth also was not decreased by the treatment.

Pressure Tests and Storage Studies.

Sampling. The same method of sampling used the previous year was employed again, except that three bushels of fruit were taken from each treatment, and the number of treatments sampled was reduced to eleven (table 24). The samples were picked August 23, and held six days in open shed until they had reached a soft-ripe condition.

Pressure Testing. Since the needle pressure tester had proved inadequate, it was thought that a pressure tester

having a larger plunger would be more satisfactory and reliable for several reasons: (1) a greater area of the peach surface would be involved, lessening variation, (2) less emphasis would be placed on the resiliency of the skin rather than upon the ability of the flesh to support the skin, and (3) the larger plunger would more nearly simulate conditions of bruising met in shipping and handling. Hence, a pressure tester having a 3/16 inch plunger and registering the pressure in pounds was used in all peach studies in 1929, and 1930. This tester was developed at the New Jersey Experiment Station in 1929 and is called the Blake peach tester (3).

At daily intervals the samples, held in open sheds, were pressure tested, thirty peaches from each bushel, and six tests per peach at equal intervals on the circumference, midway between stem/end and apex. Fifteen thousand punches was the maximum number required to be made in a single day in any of the experiments.

All pressure tests were made with unpeeled peaches. However, in the second sampling of Elbertas at Berlin in 1929, tests were made at picking and during storage on both peeled and unpeeled fruit from five treatments (three bushels per treatment) to determine the effect of removal of the skin upon the results of pressure tests. On each occasion thirty fruits taken at random from each bushel were pressure tested with the skin removed. The data presented in table 25 are the results of over 10,000 punches on 1,800

TABLE 24.

Pressure Tests of Elberta Peaches from Fertilizer Treatments at Mt. Airy.

(Picked Aug. 23, 1929 and Held in an Open Shed. Blake Peach Tester.)

Fertilizer Treatment. ***	Pressure Tests in Pounds.					
	Aug. 23	Aug. 25	Aug. 26	Aug. 27	Aug. 28	Aug. 29
$NaNo_3$ only	9.18	8.26	7.43	6.26	4.72	4.09
KCl only	8.34	6.23	5.07	4.11	3.38	3.02
K_2SO_4 only	8.58	7.65	6.01	5.37	3.81	3.50
N-KCl single	9.11	8.20	7.34	6.62	4.99	4.10
N-K_2SO_4 single	9.03	7.87	7.12	6.03	4.78	3.98
N-$Mg(KSO_4)_2$ single	8.72	7.54	6.73	5.13	4.08	3.36
N-Kainit single	9.09	7.99	6.88	5.38	4.15	3.70
N-P-KCl	9.18	8.09	7.12	6.84	4.63	4.03
N-P-Kainit	8.48	7.21	6.45	4.42	3.58	3.28
N-KCl double	9.27	8.20	7.60	5.89	4.84	--
N-Kainit double	8.86*	7.63	6.46	5.38	3.97	3.95
N-P-KCl **	9.05	6.96	6.13	4.96	4.96	4.05

* One bushel.

** Sample taken from trees which had received treatment for seven years.

*** Nitrate of soda - one and one-half pounds per tree.
Superphosphate - six pounds per tree.
Potash single - three pounds muriate of potash or equivalent.

TABLE 25.

Effect of Skin Removal on Pressure Test of Elberta Peaches from Fertilizer Plots at Berlin.

(Picked Aug. 9. Averages of three Bushels per Plot - Blake Peach Tester.)

Fertilizer Treatment.	Pressure Tests in Pounds.						
	August 9		August 12			August 9-12	August 9-12
	Unpeeled 3/16" plunger	Peeled* 3/16" plunger	Unpeeled 3/16" plunger	Peeled 5/16" plunger	Peeled calculated to 3/16" plunger	Difference Unpeeled	Difference Peeled
$NaNo_3$	8.62	5.45	7.53	7.75	4.81	1.09	.64
Kainit	8.05	4.83	6.09	4.89	3.04	1.96	1.79
N-P-KCl	8.33	5.12	6.08	5.91	3.67	2.25	1.45
N-P-K_2SO_4	8.40	5.26	8.69	10.07	6.23	-.29	-.97
N-P-$Mg(KSO_4)_2$	8.42	5.14	6.57	6.31	3.92	1.85	1.22

* Different peaches from same sample.

Figure 6. Pressure tests of Elberta samples from fertilizer plots at Mt. Airy during storage at prevailing temperatures.

peaches. The fruit was too soft on August 12 to use the 3/16 inch plunger on the peeled samples, so a 5/16 inch plunger was substituted. In assembling the data the 5/16 inch plunger tests were converted to a 3/16 inch basis. The correlation coefficient between the change in firmness as measured by pressure tests of peeled fruit and change in firmness as measured by pressure tests on unpeeled fruit during the three-day storage period was + 0.96. Since the skin factor becomes more important as the fruit becomes ripe as shown by Blake (3) the difference in the case of the peeled fruit may be greater, which would tend to increase the correlation. This high degree of correlation between different tests of different fruits of the same samples shows: (1) that peeled or unpeeled fruits are equally reliable in showing the effect of fertility treatments and (2) that the pressure tester, employing the number of peaches mentioned for a given test from any plot (90 peaches) is a safe measure of the firmness of a given lot of fruit.

Results. The averages of the pressure tests during the storage period are presented in table 24 and graphically in figure 6. The effect of the various fertilizers upon the firmness of the fruit is shown in the pressure test averages on the date of picking, August 23. Only in one or two cases was the fruit from any one plot appreciably firmer or softer than the fruit from any other plot. One instance was the greater ripeness of the fruit from the two

plots which did not receive nitrogen, the muriate and sulfate of potash only treatments. These samples tested more than a half pound less than the nitrate of soda only sample. As stated before, these plots ripened earlier than the other treatments and the tendency of the picker was to select a riper sample from them. This was an error in sampling which entered in every time fruit was in different stages of ripeness on different plots, and was practically unavoidable where sampling was done on a large scale in a limited time. Consequently a great deal, if not all, of the variability which exists in the firmness of the samples from the different treatments, at picking time, must be attributed largely to sampling error. Also where the samples appeared uniform in color, size, and maturity as far as could be judged by external appearance, a difference of at least a pound of firmness between two samples must be present before one could be considered significantly firmer than the other, because of the variability in the firmness of the fruit within a sample.

In studying the factor of keeping quality, one might assume that all samples were of the same degree of ripeness in the beginning of the storage test, since they were selected with that purpose in view; then by comparing the firmness of the samples at later dates, one could study the rate of ripening and the keeping quality as affected by fertilizer treatment. Obviously such a procedure would not be justified, for as shown in figure 6, the initial

firmness of a sample had a marked effect on the keeping quality and subsequent firmness, for a definite correlation existed between the pressure tests at time of picking and at the end of the storage test. By means of regression this influence of initial firmness was removed from the final pressure tests, and in table 26 are given the differences between treatments at the end of the storage tests, with the plot receiving nitrate of soda only as 0.

The results fully justified the method of interpretation. Though the fruit from the plots receiving muriate and sulfate only were softer at picking time and at the end of the storage test, the data in table 26 shows that the fruit ripened at almost identically the same rate as that from the nitrate of soda plot. This can also be seen in figure 6. All the other treatments studied show the same results -- the effect of the fertilizer treatments on the keeping quality has been negligible.

Data for a sample of fruit from a complete fertilizer plot in an adjoining nitrogen fertilizer experiment which had received treatment for seven years are included in table 24. At time of picking this sample was 0.13 pounds less firm than the nitrate of soda only sample, and in the final test the difference was only 0.04 pounds, indicating no effect of potash or superphosphate.

Summary for 1929. No postive indication that potash had improved the keeping quality or increased the firmness of Elberta peaches was evident in the 1929 studies.

TABLE 26.

Effect of Fertilizers on the Keeping Quality of Peaches in 1929 Showing Differences Between Firmness of Fruit from Various Plots at End of Storage Tests, Computed on the Basis of Nitrogen only as Zero. (Blake Peach Tester.)

Fertilizer Treatment.	Elberta Variety				Belle Variety	
	Mt. Airy	Hancock	Berlin	Berlin	Salisbury	Salisbury
	Aug. 23-28	Aug. 22-28	Aug. 7-11	Aug. 9-13	Aug. 3-5	Aug. 5-7
	(4.74)*	(4.42)*	(6.62)*	(5.33)*	(3.65)*	(4.73)*
$NaNo_3$	.00	.00	-.08	-.25	.00	.00
$NaNo_3$			-.31	+.25		
$NaNo_3$			+.40			
N-KCl single	+.34	-.16	-2.25	-.05	+.85	+.21
N-K_2SO_4 single	+.30	+.05	+.14	+.63	+.02	+.24
N-$Mg(KSO_4)_2$ single	+.09	-.26	-1.94	-1.10	+.44	+.38
N-Kainit single	-.29	-.53	-.05	+1.25	-.83	-.02
N-KCl double	-.01	-.28	+.61	+1.75	+.22	.21
N-K_2SO_4 double			+.35	+.43		
N-$Mg(KSO_4)_2$ double			+.66	+2.20		
N-Kainit double	-.31	-.74				
N-PKCl single	-.09	-.35	-.47		+.74	-.11
N-P-K_2SO_4 single			+.43			
N-$Mg(KSO_4)_2$ single			-.80			
N-P-Kainit single	-.03	-.37	-.57	+2.42		
KCl double	+.02					
K_2SO_4 double	+.05					

* Figures in parenthesis represent actual pressure test averages.

although larger samples (three bushels per plot) than in 1928 were used and firmness was measured with a Blake peach tester.

Investigations Conducted in 1930

The season of 1930 was extremely dry and the lack of moisture was reflected in the shorter terminal growth and the size of the peaches, though the crop was light, averaging about a bushel per tree (table 20). Except for the two plots which did not receive nitrate of soda, no treatment affected the vigor of the trees or the stage of maturity of the fruit. Nitrate of soda again caused the fruit to ripen later, whether applied alone or in various combinations with potash and super phosphate.

Sampling and Testing. A very uniform sample of three bushels per plot was selected on August 30 from seven of the treatments (table 27). These were placed in an open shed and held until September 3, for daily pressure testing with the Blake peach tester, as in the previous year.

Results. The daily pressure test averages are presented in table 27. The samples from the various treatments were remarkably uniform in firmness at time of picking. The largest difference between the nitrate of soda only plot and any one of the six potash plots was less than 0.3 pounds. At the end of the storage test (table 28), after removal of the effect of the initial firmness, no potash treatment was significantly firmer than nitrate only.

TABLE 28.

Effect of Fertilizers on the Keeping Quality of Peaches in 1930

Showing Differences between Firmness of Fruit from Various Plots at end of Storage Tests, Computed on the Basis of Nitrogen Only Treatment as Zero. Blake Peach Tester.

Fertilizer Treatment	Elberta Variety			Belle Variety	
	Mt. Airy Aug.30 - Sept.2	Hancock Aug. 27 - 29	Berlin Aug. 16 - 20	Salisbury Aug. 14 - 16	Salisbury Aug. 13 - 17
$NaNo_3$	0.00 (3.69)*	0.00 (2.94)	0.00 (5.62)	0.00 (2.35)	0.00 (2.81)
N-KCl single	-.29	-.27	-.12	+.56	+.17
$N\text{-}K_2SO_4$ single	-.29	-.24		+.30	+.23
$N\text{-}Mg(KSO_4)_2$ single	+.53	-.36	-.13	+.76	+.18
N-Kainit single	-.19	-.08	-.05	+1.44	+.35
N-KCl double	-.27	-.37	+.63	+1.19	-.01
N-P-KCl	+.06	+.58	--	+.41	+.27

* Figures in parenthesis represent actual pressure test averages.

TABLE 27

Pressure Tests of Elberta Peaches From Fertilizer Plots at Mount Airy

(Picked 8/30/30 and Held at Prevailing Temperatures)
(Blake Peach Tester Used)

Fertilizer Treatment*	Pressure Tests in Pounds				
	Aug. 30	Aug. 31	Sept. 1	Sept. 2	Sept 3
$NaNO_3$	7.53	6.29	4.62	3.69	2.12
N-KCl single	7.50	6.28	4.61	3.38	2.28
N-K_2SO_4single	7.37	5.98	4.44	3.20	2.29
N-Mg $(KSO_4)_2$ single	7.58	6.92	5.61	4.16	2.80
N-Kainit	7.72	6.68	4.92	3.66	2.59
N-KCl double	7.27	6.73	6.08	3.71	2.68
N-P-KCl	7.83 **	6.90	5.98	4.00	2.71

* Nitrate of soda — 1-1/2 pounds per tree.
Superphosphate — 6 pounds per tree.
Potash single -- 3 pounds muriate of potash or equivalent
** One bushel sample.

Summary for 1930

As in 1928 and 1929 the fruit used in storage studies in 1930 failed to show any benefit from the use of potash fertilizer. Differences were small and not significant in every case.

Summary of Mount Airy Experiment

Storage tests conducted for three years show that potash fertilizers have not affected the firmness or keeping quality of Elberta peaches grown near Mount Airy.

Elberta Orchard at Hancock

Description of Plots. Fertilizer treatments were applied in the spring of 1928 to a six year old Elberta orchard near Hancock owned by M. W. Fulton. The soil type was Upshur gravelly loam(5). The land was cultivated each year and a rye cover crop was sown in late summer. The trees were relatively small because of heavy pruning received. During 1928 terminal growths as long as seventy-two inches were recorded, but the extremely dry seasons of 1929 and 1930 reduced the average terminal growth to less than three inches. Each tree received an annual application of two pounds of nitrate of soda during the experiment. Growth and yield records for 1930 are presented in table 20.

The peach trees were fillers for apple trees and, since only the full peach rows received treatment, plots were separated from each other by buffer rows. Nineteen treatments were included in this experiment as shown in table 29, each plot consisting of fifteen trees. The standard amounts of fertilizer as presented in table 21 were applied per tree. Trees receiving nitrate of soda only were located on both sides of the experiment.

Investigations Conducted in 1928

The first year of the experiment the trees made a very vigorous growth and yielded on the average one bushel per tree. The fertilizer treatments had no effect on the size of the crop or the vigor of the trees.

Sampling and Testing. On August 29 a bushel of

TABLE 29.

Outline of Fertilizer Treatments in Elberta Orchard at Hancock.

Single Application = Three Pounds of Muriate of Potash or Its Equivalent.

Row.	Plot.	Treatment.	Amount.
1	1	Muriate of potash	half
3	2	Sulfate of potash	half
5	3	Sulfate of potash magnesia	half
7	4	Kainit	half
9	5	Muriate of potash	single
11	6	Sulfate of potash	single
13	7	Sulfate of potash magnesia	single
15	8	Kainit	single
17	9	Muriate of potash	double
19	10	Sulfate of potash	double
21	11	Sulfate of potash magnesia	double
23	12	Kainit	double
25	13	Complete with muriate	single
27	14	Complete with sulfate	single
29	15	Complete with sulfate magnesia	single
31	16	Complete with kainit	single
33	17	Muriate of potash plus lime	single
35	18	Superphosphate only	
37	19	Complete with muriate plus lime	single

All trees received two pounds nitrate of soda as a basic treatment.

Superphosphate was ap lied at the rate of six pounds per tree.

uniform fruit was selected from each of fifteen plots (table 30), and hauled to College Park by truck, a distance of one-hundred miles. The fruit was held in a cool room until September 5, when a count was made of the number of peaches which had decayed. Pressure tests with the corn tester were also made, ten punctures on each of twenty peaches from each bushel.

Results. The data of the inspection and pressure tests are presented in table 30. None of the four

TABLE 30

Pressure Tests and Storage Counts of Elberta Peaches From Fertilizer Plots at Hancock.*

(Pressure Tests Made With Corn Tester, #16 Needle Plunger)

Fertilizer Treatment **	Per Cent Sound	Pressure Test gms.
$NaNO_3$	79.7	315.3
$NaNO_3$	82.4	304.4
N-KCl single	81.7	307.0
N-K_2SO_4 single	77.2	324.6
N-Mg $(KSO_4)_2$ single	85.7	329.5
N-Kainit single	85.1	303.7
N-KCl double	84.4	301.9
N-K_2SO_4 double	78.2	330.5
N-Mg $(KSO_4)_2$ double	85.5	299.7
N-Kainit	87.2	268.8
N-P-KCl	85.6	305.0
N-P-K_2SO_4	75.3	281.6
N-P-Mg $(KSO_4)_2$	86.6	285.9
N-P-Kainit	87.7	301.1
N-KCl + Lime	85.8	312.8

*Picked August 29 -- Shipped by express 100 miles. Held at prevailing temperature. Inspected and tested September 3.

**Nitrate of soda, 2 pounds per tree. Superphosphate, 6 pounds per tree. Potash single, 3 pounds muriate of potash or equivalent.

potassium salts in single or double applications or with phosphorus appeared to have influenced the susceptibility of the fruit to decay organisms. The percentages of sound fruits for all plots fell within a narrow range of twelve percent, with the nitrate only plots occupying a median position. Considering the small size of the samples this uniformity was remarkable.

The pressure test averages (table 30) show but little variability, with no potassium fertilizer treatment consistently firmer or softer than the nitrate only.

Summary for 1928. The results of these tests indicated that potash fertilizers applied for the first time in 1928 had not affected the shipping or keeping quality of Elberta peaches as determined by the development of decay during storage and by measurements of firmness with a needle plunger.

Investigations Conducted in 1929

The summer of 1929 was extremely dry in the Hancock region and the trees and fruit suffered severely. The trees were bearing their heaviest crop, averaging between two and three bushels per tree. The peaches were extremely small, however, and numbered about three hundred per bushel. The fertilizer treatments had no effect on the stage of maturity of the fruit on the trees or on the vigor of the trees.

Sampling and Testing. On August 22 two bushels of carefully selected, shipping-ripe fruit were taken from each of nine plots (table 31). These plots included the four potassium salts in single amounts, one nitrate only, and the muriate and kainit salts in double amounts and in complete fertilizers. The fruit was pressure tested immediately with a Blake peach tester, forty peaches from each bushel. It was then hauled sixty miles to Mount Airy by truck, where it was held in an open shed and pressure tested daily until August 29.

Results. The daily pressure test averages for each sample are presented in table 31. At time of picking the fruit from all plots was of the same degree of firmness. None of the differences in pressure tests between treatments were large enough to be considered significant. The maximum difference was only 0.83 pounds. The average of all plots receiving potash was 9.40 pounds compared with nitrate of soda only, 9.50 pounds. However the effect of differences in initial firmness on the rate of ripening was again evident; the softer samples at time of picking testing the least at the end of the storage test. In table 26 are presented the pressure test averages of August 28, after removal of this correlation. The figures in this table, which represent the actual effect the fertilizer treatments have had on the keeping quality of the fruit, are all negative with one exception -- the K_2SO_4 treatment which had a value of +0.05 pounds. This indicates that the effect

TABLE 31.

Pressure Tests of Elberta Peaches from Fertilizer Plots at Hancock.

(Picked Aug.22, 1929 and Held in Open Shed at Mt.Airy. Blake Peach Tester.)

Fertilizer Treatment. *	Pressure Tests in Pounds.						
	Aug. 22	Aug. 24	Aug. 25	Aug. 26	Aug. 27	Aug. 28	Aug. 29
$NaNo_3$	9.50	9.25	8.21	6.51	5.42	4.42	--
N-KCl single	8.86**	8.96	6.88	5.86	4.26	4.16	3.12
N-K_2SO_4 single	9.41	9.61	7.34	6.76	5.24	4.45	3.72
N-$Mg(KSO_4)_2$ single	9.27	9.60	8.74	6.79	5.31	4.12	3.84
N-Kainit single	9.40	8.99	7.00	6.35	4.72	3.87	3.17
N-KCl double	9.47	9.25	8.35	5.88	4.91	4.10	3.50
N-Kainit double	9.24	8.75	7.20	5.76	4.77	3.64	2.55
N-P-KCl	9.46**	9.43	7.95	6.41	4.88	4.07	3.19
N-P-Kainit	9.69	9.45	7.79	6.55	4.43	4.08	3.64

* Nitrate of soda - two pounds per tree.
Superphosphate - six pounds per tree.
Potash single - three pounds muriate of potash or equivalent.

** One bushel.

of potash, if any, has been harmful rather than beneficial, though in no instance were the differences significant.

Summary for 1929. In the second year of the experiment on Elberta peaches at Hancock, potash has shown no beneficial effects on firmness or keeping quality of the fruit.

Investigations Conducted in 1930

The summer of 1930 was the driest this section has experienced in many years. Terminal growth was reduced to less than three inches and the average yield per tree was less than a half-bushel. All plots received the same fertilizer treatments applied the previous years, including nitrate of soda, but no influence of treatment on vigor of tree or yield was evident (table 20).

Sampling and Testing. On August 27 three bushels of uniform fruit were taken from seven of the plots -- the four potassium salts in single amounts, muriate of potash double, muriate salt in a complete fertilizer, and nitrate of soda only. The fruit was pressure-tested immediately with a Blake peach tester, thirty peaches from each bushel. It was then hauled one-hundred miles by truck to College Park where it was held at prevailing temperatures for several days. Daily pressure tests, using thirty peaches from each bushel were made with the Blake peach tester.

Results. The daily pressure test averages are shown in table 32. Because of the lack of moisture, the fruit was small, and lacked firmness and color. To all

TABLE 32

Pressure Tests of Elberta Peaches From Fertilizer Plots at Hancock

(Picked 8/27/30, Hauled to College Park, and Held at 60 - 70°F)
(Blake Peach Tester Used)

Fertilizer Treatment.*	Pressure Tests in Pounds.		
	Aug. 27	Aug. 28	Aug. 29
Na NO_3	5.86	4.67	2.94
N-KCl single	6.03	4.56	2.78
N-K_2SO_4 single	6.02	5.06	2.90
N-Mg $(KSO_4)_2$ single	6.33	4.75	3.16
N-Kainit	5.74	4.59	2.72
N-KCl double	6.19	4.60	2.98
N-P-KCl	6.31	5.84	3.87

* Nitrate of soda -- 2 pounds per tree.
Superphosphate -- 6 pounds per tree.
Potash single -- 3 pounds muriate of potash or equivalent.

appearances the samples in this year were no riper than the samples selected in 1929, and the difference in size of fruit was negligible. However, at time of picking, the samples of the previous season tested three pounds higher in firmness. Fruit from all plots in 1930 though were of practically equal firmness at that time (table 32). The maximum difference in firmness between potash and no potash treatments was less than a half pound in favor of sulfate of potash magnesia.

In two days the fruit had ripened to the stage where it was too soft to be handled. The rate of ripening,

was not influenced to a significant degree by any of the fertilizer treatments (table 28) compared with nitrate of soda only, though in the brief interval of two days the average decrease in firmness was about three pounds.

Summary of 1930. Again as in 1928 and 1929 the use of potash fertilizers on Elberta peaches at Hancock, Maryland have not affected the firmness or keeping quality of the fruit.

Summary of Hancock Experiment

In three years studies on the effect of potassium fertilizers of different types, used in varying amounts, on the firmness and keeping quality of Elberta peaches grown near Hancock, only negative results were obtained, indicating that the effect of potash, if any, on these factors is negligible.

BELLE OF GEORGIA ORCHARD AT SALISBURY

Description of Plots. The orchard used in this experiment consisted of Belle of Georgia peach trees twelve years old in 1928, owned by W. F. Allen and Company. The trees were planted twenty-three feet by twenty-five feet on a Sassafras loamy sand (30). They were pruned regularly, and received an annual application of five pounds of sodium nitrate per tree. Soil management consisted of frequent cultivation plus cover crops in late summer.

Eighteen adjoining rows of sixteen trees each were included in the experiment, each receiving a different treatment as shown in table 33. Materials were applied in the

TABLE 33.

Outline of Fertilizer Treatments in Belle of Georgia Orchard at Salisbury. Single Application = Three Pounds of Muriate of Potash or Its Equivalent.

Row.	Treatment.	Amount.
1	Muriate of potash	half
2	Sulfate of potash	half
3	Sulfate of potash magnesia	half
4	Kainit	half
5	Muriate of potash	single
6	Muriate of potash plus lime	single
7	Sulfate of potash	single
8	Sulfate of potash magnesia	single
9	Kainit	single
10	Muriate of potash	double
11	Sulfate of potash	double
12	Sulfate of potash magnesia	double
13	Kainit	double
14	Complete with muriate	single
15	Complate with sulfate	single
16	Complete with sulfate magnesia	single
17	Complete with Kainit	single
18	Nitrate of soda only	

All trees received five pounds of nitrate of soda as a basic treatment.

Superphosphate was applied at the rate of six pounds per tree.

amounts given in table 21, standard for all peach experiments reported. Applications of fertilizer were made in the latter part of March in 1928, when the experiments were begun and likewise in 1929 and 1930. Because of an almost complete crop failure due to frost, no studies on keeping quality could be made in 1928.

Investigations Conducted in 1929

The average crop in 1929 was approximately six bushels per tree. The season was very nearly normal as regards rainfall. The fertilizer applications had no effect on the vigor of the trees or the stage of maturity of the crop.

Sampling and Testing. Samples of two or three bushels of uniform, shipping-ripe fruit were selected on August 3 and August 5 respectively from each of eight plots. This group included the same treatments which were studied in the other orchards -- the four potassium salts in single amounts, one double application of potash, one complete fertilizer, and the nitrate only treatment. The samples were held in a well ventilated cellar until the fruit was in a soft-ripe condition. Pressure tests, thirty peaches per bushel, were made with a Blake peach tester at time of picking and at daily intervals thereafter.

Results. The daily pressure test averages of the two tests are presented in tables 34 and 35. Belle of Georgia peaches ripen more rapidly after picking than the

TABLE 34

Pressure Tests of Belle Peaches From Fertilizer Plots at Salisbury

(Picked 8/3/29 and Held in Cellar. Blake Peach Tester)

Fertilizer Treatment.*	Pressure Test in Pounds			
	Aug. 3	Aug. 4	Aug. 5	Aug. 6**
Na NO_3 only	9.91	7.71	3.96	4.98
N-KCl single	8.95	8.39	4.81	5.75
N-KCl + Lime	9.38	8.25	4.03	6.50
N-K_2SO_4 single	8.80	6.70	3.98	4.68
N-Mg $(KSO_4)_2$ single	9.41	7.01	4.40	5.83
N-Kainit single	8.92	7.75	3.13	5.14
N-KCl double	9.66	8.11	4.18	5.63
N-P-KCl	8.16	7.37	4.70	4.64

*Nitrate of soda -- 5 pounds.per tree.
Superphosphate -- 6 pounds per tree.
Potash single -- 3 pounds muriate of potash or its equivalent.

** 5/16 plunger.

Elberta fruit in the other experiments and on the third day in storage it was necessary to use a 5/16 inch plunger on the Blake tester instead of a 3/16 inch plunger. In addition about thirty per cent of the fruit in the samples, infested with Oriental fruit moth, had to be discarded while pressure testing. Thus the variability of the samples was appreciably larger than that of the other experiments. Consequently, though fairly larger differences existed in the firmness

TABLE 35

Pressure Tests of Belle Peaches From Fertilizer Plots at Salisbury

(Picked 8/5/29 and Held in Cellar. Blake Peach Tester)

Fertilizer Treatment.*	Pressure Tests in Pounds			
	Aug. 5	Aug. 6	Aug. 7	Aug. 8 **
Na NO_3 only	8.98	7.14	4.73	4.59
N-KCl single	8.82	8.11	4.96	4.79
N-KCl + Lime	8.70	8.63	5.30	5.63
N-K_2 SO_4 single	8.91	7.76	4.88	4.94
N-Mg $(KSO_4)_2$ single	8.47	7.47	5.09	5.89
N-Kainit single	9.37	8.99	4.60	5.51
N-KCl double	8.39	7.45	5.04	5.41
N-P-KCl	8.58	8.50	4.68	5.19

* Nitrate of soda -- 5 pounds per tree.
Superphosphate -- 6 pounds per tree.
Potash single -- 3 pounds muriate or equivalent.

** 5/16 inch plunger

of the fruit from different treatments at time of picking in the August 3 test (table 34), it is questionable whether these differences can be considered significant. Incidently the firmest fruit was from the plot receiving nitrate of soda only.

In the August 5 test none of the differences between treatments at time of picking was large enough to be considered significant. A great deal of the variability in the

results was undoubtedly due to sampling error. After removal of the effect of differences in initial firmness on the final pressure test averages, the effect of the fertilizer treatments on rate of ripening can be seen in table 26, for both tests. No treatment influenced the firmness of the fruit to the extent of one pound in the August 3 picking, while in the August 5 test the greatest differences was less than four-tenths of a pound compared with nitrogen. The complete fertilizer treatment and single application of muriate of potash furnished fruit which was significantly firmer than the kainit treatment in the first storage test, but in the second test the differences were negligible.

Summary for 1929. One may conclude, therefore, from the 1929 season's work, that potash fertilizers have had no appreciable effect on Belle of Georgia peaches.

Investigations Conducted in 1930

While there was a deficiency in rainfall in the Salisbury section during 1930, the trees did not suffer nearly as much as those in western Maryland. The terminal growth averages six to ten inches (table 20) and the fruit was only slightly smaller than the previous year. The trees bore an average crop of four bushels. The infestation of Oriental fruit moth, which had caused great difficulty in the storage tests of 1929 was no longer an important factor.

Pressure Tests and Storage Studies.

Sampling and Testing. Samples of three bushels of carefully selected, shipping-ripe fruit were taken from the usual seven treatments on August 11, and again on August 13 (table 36 and 37). Pressure tests were made at time of picking, and at daily intervals during storage in an open shed, with a Blake pressure tester, using twenty and thirty peaches from each bushel.

TABLE 36

Pressure Tests of Belle Peaches from Fertilizer Plots at Salisbury.

(Picked 8/11/30 and Held in an Open Shed. Blake Peach Tester)

Fertilizer Treatment.*	Pressure Tests in Pounds.				
	Aug. 11	Aug. 12	Aug. 14	Aug. 15	Aug. 16
$NaNO_3$ only	7.82	7.36	5.82	3.52	2.35
N-KCl single	8.30	8.47	6.43	4.91	3.59
N-K_2SO_4 single	8.43	8.77	6.88	4.80	3.51
N-Mg $(KSO_4)_2$ single	8.51	8.70	7.00	5.41	4.08
N-Kainit single	7.93	8.69	6.99	5.09	3.94
N-KCl double	8.19	8.34	6.78	4.73	4.06
N-P-KCl	7.83	8.16	5.52	4.12	2.87

* Nitrate of soda -- 5 pounds per tree.
Superphosphate -- 6 pounds per tree.
Potash single -- 3 pounds muriate of potash or equivalent.

TABLE 37

Pressure Tests of Belle Peaches From Fertilizer Plots at Salisbury

(Picked 8/13/30 and Held in an Open Shed. Blake Tester Used)

Fertilizer Treatment.*	Pressure Tests in Pounds				
	Aug. 13	Aug. 14	Aug.15	Aug.16	Aug.17
$NaNO_3$ only	8.17	8.11	6.80	3.81	2.65
N-KCl single	8.71	9.09	7.69	5.27	3.45
N-K_2SO_4 single	8.55	9.08	7.56	5.39	3.33
N-Mg $(KSO_4)_2$single	9.24	9.54	8.19	5.33	4.08
N-Kainit single	9.16	9.30	8.15	6.57	4.15
N-KCl double	9.02	9.21	8.27	5.61	3.61
N-P-KCl	8.04	8.66	7.13	4.90	2.77

* Nitrate of soda -- 5 pounds per tree.
Superphosphate -- 6 pounds per tree.
Potash single -- 3 pounds muriate of potash or equivalent.

Results. The data are presented in tables 36 and 37. In both tests the fruit from the complete fertilizer and nitrate of soda treatments were softer than the fruit from any of the other treatments at time of picking. This difference in ripeness was evident before the samples were pressure tested and was purely the result of sampling error. Five persons assisted in picking the samples on each occasion. No single potash salt in either of the tests produced fruit which was firmer or softer than the fruit from any other treatment at time of picking, with the ex-

ceptions noted.

In table 28 are presented the results of the pressure tests on Belle peaches at the end of the storage period, compared with the check (nitrogen only). In the first picking the fruit from the kainit single and muriate double treatments showed distinctly less softening than the nitrate only, the values being + 1.44 and + 1.19 pounds respectively compared with nitrogen only, 0. All the potash treatments, however, are preceded by a positive sign, indicating a beneficial influence. In the second storage test the initial greater ripeness of the fruit from the nitrogen plot was compensated for in the method of interpretation (table 28) and the greatest difference due to treatment was only 0.35 pounds.

Chemical Studies

Sampling. During the second storage tests of 1930 with Belle peaches, chemical samples were obtained at time of picking and four days later, in order to study the effect of potash treatment on keeping quality as measured by changes in pectic constituents and acid content. A sample was also obtained for studies in carbohydrate and potassium content of the fruit four days after picking.

Three treatments were included -- nitrate of soda only, muriate of potash single, and complete with muriate of potash. Detailed methods of sampling and analyses are described on page 6.

Results. Pectin studies of Belle of Georgia fruit sampled during the second storage test of 1930 showed a large change in the pectic constituents during storage (table 38). A loss of protopectin during storage was accompanied by a corresponding increase in soluble pectin. The increase noted in total pectic materials on the second date of sampling was probably due to loss of moisture. Fruit from the nitrate plot had less protopectin at picking time than the potash treatments, but several days later the difference had disappeared. At the end of the test the muriate of potash fruit, the firmest according to the pressure test, had the least protopectin. Soluble pectin content was practically identical among treatments.

Appleman and Conrad (1) and Conrad (7) likewise found a decrease in protopectin in peaches during storage to be accompanied by an increase in soluble pectin, with little change in total pectic material. This transformation they considered the chief process responsible for the softening of the fruit.

Nightingale et al (26) studying pectin changes in Elberta peaches ripening on the trees, also found a considerable decrease in protopectin during the last stages of ripening, but without a corresponding increase in soluble pectin. However, in all cases their values for soluble pectin were one-hundred per cent larger than those of the Maryland Elbertas at time of picking. This difference in results was probably due to a difference in the methods of extraction,

TABLE 38.

Analyses of Belle of Georgia Peaches from Fertilizer Plots at Salisbury During Storage. Picked Aug.13, 1930. Expressed as Percentage Green Weight.

te of mpling	Treatment	Pressure Test	Soluble Pectin	Proto-Pectin	Total Pectin	Titratable Acidity *	Ph
g. 13	$NaNo_3$	8.17	.177	.779	.956	55.0	3.62
	N-KCl	8.71	.154	.810	.964	58.8	3.73
	N-P-KCl	8.04	.154	.814	.968	58.0	3.71
g. 17	$NaNo_3$	2.65	.453	.555	1.008	59.8	3.68
	N-KCl	3.45	.457	.527	.984	61.2	3.76
	N-P-KCl	2.77	.444	.564	1.008	60.8	3.62

c.c. of 1/50 N Na OH required to neutralize 10 c.c. of juice.

rather than composition of the fruit.

Titratable acidity determination showed that there was a slight increase in acid content of Belle peaches during ripening. The differences among treatments, however, were too small to be considered significant, in view of the variability involved. The Ph of the juice was 3.7 at time of picking and did not change appreciably in the ripening process.

Other chemical analyses of Belle of Georgia show (table 39) that the potassium content of the flesh was not affected by applications of muriate of potash. The fruit from the complete plot had the highest reducing sugar content, the muriate fruit the highest sucrose content, and the nitrate fruit the most acid hysrolyzable material. The data are too meager to fully appreciate the significance of this condition.

TABLE 39

Analyses of Belle Peaches From Fertilizer Plots at Salisbury

(Picked 8/13/30 -- Sampled 8/17/30)
(Analyses Expressed as Percentage Dry Weight)

Treatment.	Dry Weight	Reducing Sugars	Sucrose	Total Sugars	Hydro-lyzable Material	Potas-sium
Na NO_3	14.47	19.09	34.91	54.00	9.29	.509
N-KCl	14.25	21.50	40.13	61.63	7.76	.538
N-P-KCl	14.48	24.55	31.26	55.81	7.48	.461

Summary for 1930.

1. Thus the results of the 1930 pressure tests pre-

sent no conclusive evidence to show that potash fertilizers have improved the keeping quality of Belle peaches.

3. No differences in potash content, sugar content, acidity, or pectic constituents among the samples of Belle of Georgia peaches from fertilizer plots could be attributed to muriate of potash treatments.

Summary of Salisbury Experiment

Three years results of storage studies on Belle of Georgia peaches from trees receiving different amounts of various potash fertilizers show no benefits for the treatments in increased firmness of the fruit or superior shipping quality, compared with fruit from trees fertilized with nitrogen only.

Chemical studies with fruit from muriate of potash treatments compared with fruit from nitrogen only treatments show no effects of potash on pectic constituents or potash, sugar and acid content.

ELBERTA ORCHARD AT BERLIN

Description of Plots. In the spring of 1928 a fertilizer experiment was laid out in a nine-year old Elberta orchard owned by Harrisons' Nurseries at Berlin. The land was cultivated and cover cropped each year. The soil was classified as a Sassafras fine sandy loam (27). The trees, planted twenty-two by eighteen feet, were in only a moderately vigorous condition (table 20). They received a light pruning each year and two pounds of nitrate of soda per tree

annually during the experiment.

Twenty-seven adjoining rows of fifteen trees each received treatment as shown in a plan of the experiment in table 40. Every fifth row received nitrate of soda only. The standard amounts of the various fertilizers for peach trees as given in table 31 were used. Applications were made annually in the latter part of March.

Investigations Conducted in 1928

The season of 1928 was normal as regards rainfall and the trees bore an average crop of three bushels of fruit. No effect of fertilizers on the vigor of the trees, or the maturity of the crop was evident in this first year of the experiment.

Sampling and Testing. On August 22 one or two bushels from certain of the treatments as mentioned in table 41 were taken just as they were harvested by the pickers. Fruit of all sizes and stages of maturity were thus included. Since some samples had more green or ripe fruit than others, each sample was divided into a ripe and green lot. The fruit was placed in an open shed, and inspected and pressure tested with a corn tester three days after picking.

Results. The percentages of sound fruit found on inspection together with the pressure tests are presented in table 41. There appeared to be no correlation among treatments in the number of decayed fruits developing during

TABLE 40.

Outline of Fertilizer Treatments in Elberta Orchard at Berlin.

Single Application = Three Pounds of Muriate or Potash, or Its Equivalent.

Row.	Treatment.	Amount.
1, 2, 3	Sulfate of potash magnesia	double
4	Muriate of potash	half
5	Sulfate of potash	half
6	Sulfate of potash magnesia	half
7	Kainit	half
8	Nitrate of soda only	.
9	Muriate of potash	single
10	Sulfate of potash	single
11	Sulfate of potash magnesia	single
12	Kainit	single
13	Nitrate of soda only	
14	Muriate of potash	double
15	Sulfate of potash	double
16	Sulfate of potash	double
17	Kainit	double
18	Nitrate of soda only	
19	Complete with muriate	single
20	Complete with sulfate	single
21	Complete wi th sulfate magnesia	single
22	Complete with kainit	single
23	Muriate of potash plus lime	single
24	Muriate of potash only	single
25	Sulfate of potash only	single
26	Sulfate of potash magnesia only	single
27	Kainit only	single

Rows 1 to 23 inclusive received two pounds of nitrate of soda as a basic treatment.

Superphosphate was applied at the rate of five pounds per tree.

TABLE 41

Pressure Tests and Storage Counts of Elberta Peaches From Berlin.*

Fertilizer Treatment.	Ripe Samples.		Green Samples	
	Per Cent Sound	Pressure Test. gms.	Per Cent Sound	Pressure Test. gms.
Na NO_3	100	325.1	92.5	379.1
Na NO_3	100	294.2	98.2	369.3
N-KCl single	93.4	325.2	100	406.4
N-K_2SO_4 single	93.4	321.5	100	391.3
NOMg $(KSO_4)_2$ single	93.3	280.9	87.2	371.7
N-Kainit single	98.0	341.3	91.4	412.5
N-KCl double	97.0	374.8	98.6	383.7
N-K_2SO_4 double	90.4	292.1	86.9	383.6
N-Kainit	94.4	253.1	96.1	374.9

* Picked August 22nd. Held in common storage. Inspected and tested August 25th.

the storage test. In fact, the greener samples which should have remained sound for the longer period had just as many decayed peaches as the riper samples. It would seem, therefore, that other factors besides maturity were important in determining the susceptibility of fruit to decay organisms. For that reason, in the storage tests in later years, inspection counts on the samples were omitted in all peach experiments

and attention was concentrated on pressure test studies.

Pressure tests made on three samples of Elberta peaches three days afterpricking with a needle plunder on a corn tester, showed that none of the treatments studied had affected the firmness, compared with nitrate of soda only. The differences were practically all less than ten per cent, with not as great a difference between the firmness of the ripe and green samples as one might reasonably expect.

Summary for 1928. Potash fertilizer treatments had no effect on the development of decay in storage of Elberta peaches, or on the firmness of the flesh as measured with a #16 needle plunger.

Investigations Conducted in 1929.

In this experiment an influence of the fertilizer treatments on the vigor of the tree and maturity of the crop was first noticed in the summer of 1929. Here as in the Elberta orchard at Mount Airy, the plot receiving a double application of sulfate of potash magnesia had the darkest and apparently the densest foliage of any plot. The fruit also seemed a little slower in maturing. The double application of kainit appeared to have injured the trees to a slight degree. The foliage on this treatment was sickly and resembled to some extent adjacent plots which had not received nitrate of soda. The ripest fruit in the experiment was to be found in the plots lacking nitrogen. The average yield per tree amounted to over four bushels.

Sampling and Testing. Three bushel samples of uniform fruit were carefully selected from each of fourteen plots on August 7, and a duplicate sample of three bushels from the same plots on August 9. The fruit was pressure tested with a Blake tester immediately after picking and then placed in an open shed. Daily pressure tests, thirty peaches per bushel, were made during the storage of four days.

Results. The results of the pressure tests on the stored fruit are presented in tables 42 and 43. Analysis of the figures representing the firmness of the fruit at time of picking shows that no consistent differences existed between samples from plots receiving nitrate only and any of the four potassium salts, when the latter were used in single amounts, double amounts, and in a complete fertilizer. The usual variability of a pound or less which was principally due to sampling error, was present. The plot receiving the double application of sulfate of potash magnesia was the firmest sample in both tests. The cause of this was probably the difference in maturity of fruit on the trees of this treatment, since the single amounts were only of average firmness.

During storage all samples showed the same general trend of ripening (tables 42 and 43) which occurred in the other storage tests. During the first two days some samples showed an increase in firmness over the day of picking, followed by a rapid softening.

TABLE 42.

Pressure Tests of Elberta Peaches from Fertilizer Plots at Berlin.

(Picked Aug. 7, 1929 and Held in Open Shed. Blake Peach Tester.)

Fertilizer Treatment. *	Pressure Tests in Pounds.			
	August 7	August 8	August 9	August 11
$NaNo_3$ only	8.85	9.58	8.19	6.73
$NaNo_3$ only	8.41	9.18	8.64	6.26
$NaNo_3$ only	8.36	9.17	9.00	6.95
N-KCl single	8.83	9.28	7.66	4.52
N-K_2SO_4 single	9.17	9.76	8.88	7.13
N-$Mg(KSO_4)_2$ single	8.68	9.12	7.35	4.77
N-Kainit single	8.76	9.58	8.69	6.70
N-KCl double	8.49	9.46	9.43	7.23
N-K_2SO_4 double	8.76	9.61	9.71	7.10
N-$Mg(KSO_4)_2$ double	9.34	10.05	9.78	7.74
N-P-KCl	8.05	9.14	8.10	5.90
N-P-K_2SO_4	8.13	9.44	8.91	6.85
N-P-$Mg(KSO_4)_2$	7.95	9.10	7.75	5.52
N-P-Kainit	8.09	9.07	9.07	6.96

* Nitrate of soda - two pounds per tree.
Superphosphate - five pounds per tree.
Potash single - three pounds muriate of potash or equivalent.

TABLE 43.

Pressure Tests of Elberta Peaches from Fertilizer Plots at Berlin.

(Picked Aug.9, 1929 and Held in Open Shed. Blake Peach Tester.)

Fertilizer Treatment.*	Pressure Tests in Pounds.					
	Aug. 9	Aug. 9 ***	Aug.11	Aug.12	Aug. 12 ***	Aug.13
$NaNo_3$ only	8.46		7.85	6.23		5.08
$NaNo_3$ only	8.28		7.96	6.23		5.58
$NaNo_3$ only	8.62	5.45	8.98	7.53	7.75**	
N-KCl single	8.30		8.08	5.52		5.28
N-K_2SO_4 single	8.45		8.97	7.67		5.96
N-$Mg(KSO_4)_2$ single	8.32		7.69			4.23
N-Kainit single	8.19		9.03	7.52		6.55
N-KCl double	8.05		8.92	7.48		7.08
N-K_2SO_4 double	8.48		8.71	7.03		5.73
N-$Mg(KSO_4)_2$ double	8.75		9.59	7.92		7.53
N-Kainit double	8.05	4.83	7.24	6.09	4.89	
N-P-KCl	8.33	5.12	8.10	6.08	5.91	
N-P-K_2SO_4	8.40	5.26	9.13	8.69	10.07	
N-P-$Mg(KSO_4)_2$	8.42	5.14	7.64	6.57	6.31	
N-P-Kainit	8.15		8.71	7.90		7.75

* Nitrate of sodaa- two pounds per tree.
Superphosphate - five pounds per tree.
Potash single - three pounds of muriate of potash or equivalent.

** 5/16" plunger.

*** Skin off.

In table 26 are presented figures representing the actual influence of the fertilizer on the rate of ripening, in comparison with nitrate of soda only. Muriate and sulfate of potash magnesia treatments in single amounts have apparently had a detrimental effect on the keeping quality in both tests, but the double amounts of these salts show an equally large beneficial effect. Hence, it is doubtful whether these differences can be attributed to the fertilizer treatments. The sulfate of potash and kainit salts have not been influential to an appreciable degree.

Summary for 1929. The results of this season's work are fully in accord with those of the other experiments. The use of potash has not proven beneficial to the firmness or keeping quality of Elberta peaches.

Investigations Conducted in 1930

No effects of the fertilizer treatments on the vigor of the trees and maturity of the crop, noted in 1929, were noticeable in 1930. Part of this may be due to the fact that the average yield was less than one-fourth bushel per tree. While the rainfall for the season was below normal, the size of the fruit was not affected and the trees made a fair terminal growth of six to eight inches (table 20).

Pressure Tests and Storage Studies.

Sampling and Testing. Because of the small yield a

two-bushel sample of selected fruit from five plots in the Berlin Elberta orchard constituted the extent of the storage studies. This sample was picked on August 16th and held in an open shed. Pressure tests were made on August 16th and held in an open shed. Pressure tests were made on August 16, 18, 19, and 20, using twenty or thirty peaches per bushel.

Results. Table 44 shows the results of the pressure tests. No differences in firmness at time of picking between any two of the five plots sampled which do not fall within the sampling error were evident. The largest difference was slightly more than a half pound.

The values in table 28 show that at the end of the test only one treatment, muriate of potash double, had affected the keeping quality appreciably, (+ 0.63 pounds) but this effect was too small to be considered significant. Muriate of potash, sulfate of potash magnesium, and kainit had no effect.

Chemical Tests

Sampling. Samples for pectin analyses were taken from the storage samples of nitrate of soda only and muriate of potash treatments in the Berlin Elberta orchard on August 16, and again on August 21, 1930.

Results. The results of these studies are presented in table 45. The sodium nitrate fruit, having more total pectic material, had more protopectin than the muriate

TABLE 44.

Pressure Tests of Elberta Peaches From Fertilizer Plots at Berlin

(Picked 8/16/30 and Held in an Open Shed. Blake Tester Used)

Fertilizer Treatment.*	Pressure Test in Pounds			
	Aug. 16	Aug. 18	Aug. 19	Aug. 20
Na NO_3	9.14	7.81	6.87	5.49
N-KCl single	9.08	7.83	7.41	5.50
N-Mg $(KSO_4)_2$ single	8.78	7.47	6.45	5.49
N-Kainit single	8.60	7.60	7.41	5.57
N-KCl	8.74	8.13	6.79	6.25

* Nitrate of soda -- 2 pounds per tree.
Superphosphate -- 5 pounds per tree.
Potash single -- 3 pounds muriate of potash or equivalent.

of potash samples, (.824 and .775 per cent respectively) but considering the loss of protopectin as part of the ripening process we find very little difference between the two treatments. Pressure tests of the same fruit were almost identical in value, corroborating the above results.

Other chemical analyses of the same samples, for which fruit was selected, however, for uniformity in maturity, show only slight differences between treatments, (table 46). Moisture content, total acidity, Ph, and potassium content were practically identical for the two treatments, and carbohydrate results show but little variation. Acidity determinations (table 45) showed a

TABLE 45.

Analyses of Elberta Peaches from Fertilizer Plots at Berlin

During Storage. (Picked Aug. 16, 1930 Expressed as Percentage Green Weight.)

Date of Sampling	Treatment	Pressure Test	Soluble Pectin	Proto-Pectin	Total Pectin	Titratable Acidity*	Ph
Aug. 16	$NaNo_3$	9.14	.160	.824	.984	73.5	3.40
	N-KCl single	9.08	.185	.775	.960	70.4	3.57
Aug. 20	$NaNo_3$	5.49	.322	.662	.984	80.3	3.51
	N-KCl single	5.50	.312	.620	.932	79.2	3.45

* c.c. of 1/50 N NaOH required to neutralize 10 c.c. of juice.

TABLE 46

Analyses of Elberta Peaches From Fertilized Plots at Berlin

(Picked 8/16/30 -- Sampled 8/20/30)
(Analyses Expressed as Percentage Dry Weight)

Treatment	Dry Weight	Reducing Sugars	Sucrose	Total Sugars	Hydro-lyzable Material	Potas-sium.
Na NO_3	14.60	19.80	32.91	52.71	7.65	.498
N-KCl	14.65	18.25	33.25	51.50	8.03	.514

marked increase in acid during storage of ten per cent, but no effect of treatment.

Summary for 1930.

1. In this final storage study nothing new has developed, the data fully corroborating previously discussed results for 1928 and 1929.

2. Muriate of potash has not influenced the pectin constituents of sugar, acid, and potassium content of Elberta peaches to an appreciable degree.

Summary of Berlin Experiment

The use of potassium fertilizer has not affected appreciably the firmness or the keeping quality of the Elberta peaches in this orchard.

One treatment, magnesia sulfate of potash double, increased the vigor of the trees during the second year, but

the firmness of fruit of similar appearance was not influenced.

Applications of muriate of potash have not affected the pectic constituents, or sugar, acid and potassium content of the fruit to a marked degree.

General Discussion

The results with peaches are practically all negative, that is, no consistent effects of fertilizer treatment on firmness or keeping quality are discernible. During the course of the experiment over three-hundred bushels of peaches were tested. Probable errors, based on the single bushel average as the individual, were determined on certain of the plot averages of the last pressure tests in storage during 1929 and 1930. These errors are not presented in the tables because they are not strictly applicable to the method of interpretation of the data employed. However they do give an idea of the variability between bushel averages of a single treatment. With few exceptions, all differences between treatments greater than a pound are significant, practically all of the probable errors based on bushel averages falling between the values two-tenths and three-tenths. Considering the number of duplications made in orchards, in plots, in individual samples smaller difference should be detectable; but from a commercial standpoint, differences of less than a pound in firmness are not important. At least a pound difference between two lots of fruit must be

present in most cases before it is recognizable without the use of a mechanical tester.

Conclusions

Under the conditions of these experiments, applications of potash fertilizers to peach trees do not increase the firmness or improve the keeping quality of the fruit.

Under certain conditions, heavy applications of sulfate of potash magnesia causes peach trees to have a more vigorous appearance, and will delay the maturity of the fruit slightly.

Muriate of potash fertilizer does not influence the rate of change of pectic constituents or acidity. Carbohydrate and potassium content of peaches, though variable, appear to be unaffected.

Summary of Peach Studies

1. Elberta peach trees in three orchards and Belle of Georgia peach trees in one orchard were fertilized with four different potash fertilizers in various amounts and combinations, beginning in 1928.

2. During the three years the experiments were conducted, more than three hundred bushels of carefully selected fruit from the various treatments were tested at prevailing temperatures until in a soft ripe condition.

3. Over two hundred and fifty thousand pressure tests, made with a Blake peach tester on this fruit at time

of picking and during storage failed to show that potash has influenced appreciably the firmness or the keeping quality of the fruit.

4. Pectic changes during storage (though not correlated with potash treatments) are quite marked; but the actual amounts of the pectic constituents are not fine criteria of the firmness of the fruit.

5. Applications of muriate of potash in combination with nitrogen, and nitrogen and phosphate, have not affected the potassium or sugar content of Belle and Elberta peaches noticeably.

6. Superphosphate used in a complete fertilizer has not influenced the firmness or the keeping quality of the fruit.

7. The trees on the sulfate of potash magnesia double plots in the Berlin Elberta and Mount Airy Elberta orchards had a greener appearance of foliage in 1929. Double application of kainit appeared injurious in the same orchards. The effect was not evident in the Salisbury Belle and Hancock Elberta orchards.

III. STRAWBERRY STUDIES

In cooperation with certain strawberry growers on the Eastern Shore of Maryland, various fertilizer plots were laid out on Missionary and Gandy varieties in 1928, and Chesapeake and Premier (Howard 17) in 1929 and 1930. Two of the experiments begun in 1929 were continued a second year,

the second fruiting year of the plants.

MISSIONARY AND GANDY VARIETIES AT MARION.*

Description of Plots. Two very uniform one-year old plantings of strawberries of the Missionary and Gandy varieties were selected in the spring of 1928 for experimentation. They were located on the farm of Mr. P. G. Gunby at Marion Station, Somerset County, the center of one of the largest strawberry-producing sections in the state. The soil of the region was classified as Elkton loam (29). The soil was very fertile and fertilizer treatments showed no increases in yield, although nitrogen fertilizers increased the growth of the plants. The plants were grown under the matted row system of training, the method used almost exclusively by Eastern Shore strawberry growers.

The fertilizer treatments consisted of a topdressing in March of the first fruiting year with various combinations of nitrate of soda, muriate of potash, sulfate of potash, sulfate of potash magnesia, kainit (20 per cent) and super phosphate, as shown in table 47. Each plot, twenty-nine feet long, sixteen rows wide, covered approximately 1/30 of an acre. Applications of each element were made in amounts equivalent to six-hundred pounds per acre of a 5-8-8 fertilizer. Where one of the fertilizer constituents was omitted on a particular plot, the rate of application of the remaining constituents was not increased.

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*Work at Marion was performed by A. L. Schrader, W. E. Whitehouse, et. al.

TABLE 47.

Plans of 1928 Strawberry Fertilizer Experiments at P.G. Gunby, Marion Station.

Plot No.	Missionary Treatment.	Gandy Treatment.
1	KCl	KCl
2	N-KCl	N - KCl
3	K_2SO_4	K_2SO_4
4	N-K_2SO_4	N - K_2SO_4
5	$Mg(KSO_4)_2$	$Mg(KSO_4)_2$
6	N - $Mg(KSO_4)_2$	N - $Mg(KSO_4)_2$
7	Kainit	Kainit
8	N - Kainit	N - Kainit
9	Acid Phosphate	Acid Phosphate
10	N - Acid Phosphate	N - Acid Phosphate
11	Check	Check
12	N-P-KCl	N-P-KCl
13	N-P-K_2SO_4	N-P-K_2SO_4
14	N-P-$Mg(KSO_4)_2$	N-P-$Mg(KSO_4)_2$
15	N-P-Kainit	N-P-Kainit
16	P-KCl	P-KCl
17	$NaNo_3$	$NaNo_3$
18	$(NH_4)_2$ SO_4	$(NH_4)_2$ SO_4
19	N-P-K	
20	N-P	
21	P	
22	Check	
23	$(NH_4)_2$ SO_4	
24	P-K	
25	$NaNo_3$ (double)	
26	$NaNo_3$	

Sampling. In 1928 as the berries were harvested for commercial purposes a certain number of boxes were taken from each treatment for various holding and shipping tests. Each worker, after picking a plot, brought the berries to a central point, where a record was made of the yield and a part of the fruit was set aside for testing purposes. This method of sampling was not entirely satisfactory since all pickers did not have the same conception of proper size and maturity; and also the amount of bruising from handling varied with each plot. Size, maturity, and injury were very important factors in determining the keeping quality of the fruit, and in this particular year may have been responsible for a great deal of the variability in the results. Without question, the sampling error is the greatest difficulty to be overcome in work of this nature.

Testing. To measure the keeping quality, counts were made of the number of soft and decayed berries which developed during storage and shipping tests. A "soft" berry was easily recognizable by its darkened appearance. Samples of sixteen boxes of berries from each plot at two pickings were used in these studies. These were divided into four lots: (1) those shipped to College Park by pony express refrigerator, (2) those hauled one-hundred miles by automobile, and held for a number of days, (3) those placed in cold storage at 35°F. and those held at prevailing temperatures on the farm.

A great many tests of the firmness of the berries were made with a small nailhead plunger, one-fourth inch in diameter, on a Magoon and Culpepper corn pressure tester. Numerous types of plungers were experimented with, but the nailhead appeared to be the most satisfactory. A pressure tester similar in design to the Magness and Taylor pressure tester for apples was tried also. Some differences in firmness were found, although not consistent for various pickings; but these differences were not correlated with the results of shipping and storage tests. Tests on fruit the day after picking frequently showed increased firmness over the tests on the day of picking. Hence the pressure tester was not considered a true measure of shipping or keeping quality and its use was discontinued in 1929.

Shoemaker and Greve in 1930 (28) found differences in pressure tests of fruit from fertilizer plots, yet the shipping quality was unaffected by treatment.

Results -- Missionary Variety. A summary of the results of 1928 are presented in table 48. The per cent of sound soft, and decayed fruit in the four shipping and holding tests were averaged, since the results in the individual tests were practically identical as far as treatments were concerned. Each average represents counts on sixteen quarts of berries.

As shown by the data in table 48, none of the different potash carriers appreciably affected the number of decayed or soft berries developing during storage.

TABLE 48

Summary of Storage Counts of Missionary Strawberries From Fertilizer Plots at Marion.

Fertilizer Treatment.*	First Picking			Second Picking		
	Per Cent Sound	Per Cent Decay	Per Cent Soft	Per Cent Sound	Per Cent Decay	Per Cent Soft
Na NO_3	46.8	14.9	38.4	86.0	5.1	8.9
N-KCl	44.2	14.4	41.3	85.4	7.5	7.1
N-K_2SO_4	30.8	19.8	49.4	81.5	9.2	9.3
N-Mg $(KSO_4)_2$	41.0	17.9	41.0	82.9	7.4	9.8
N-Kainit	45.3	12.1	42.5	84.5	7.0	8.5
N-P	42.7	17.0	40.3	86.9	6.4	6.7
N-P-KCl	44.9	14.9	40.2	86.9	6.0	7.0
N-P-K_2SO_4	48.5	19.3	32.3	88.1	6.0	5.9
N-P-Mg $(KSO_4)_2$	52.5	12.9	34.6	87.9	6.1	6.0
N-P Kainit	53.5	13.1	33.3	87.3	4.3	8.3
Check	47.2	14.2	38.6	87.0	4.8	8.2
KCl	47.3	15.3	37.4	91.5	2.9	5.7
K_2SO_4	52.4	10.1	37.5	93.9	2.3	3.8
Mg $(KSO_4)_2$	47.6	9.5	43.5	88.1	4.1	7.8
Kainit	45.2	12.4	42.4	90.3	3.6	6.1
P	42.4	12.0	45.5	90.9	2.7	6.4
P-KCl	53.2	10.7	36.1	90.6	2.9	6.5

*Each fertilizer element was applied in amounts equivalent to 600 lbs. of a 5-8-8 fertilizer, per acre.

While small differences in the per cent of sound berries were evident between treatments, they were not significant, considering the method of sampling and the resulting variability. The average per cent of sound berries from all plots receiving potash regardless of date of picking, was 67.1 per cent, while the similar averages for all no potash plots was 66.2 per cent.

Summary. There is no indication in these tests that potash fertilizers have affected the shipping quality of Missionary strawberries.

Results -- Gandy Variety. The results of the 1928 tests with Gandy are summarized in table 49. Each average represents the average of the four shipping and holding tests on a total of sixteen quarts of berries. In the second picking, however, the truck shipment test was omitted, so only twelve quarts are included in the averages of the later test.

The larger size of the Gandy berries and the consequent fewer number per box were reflected in averages of decayed and soft berries in that considerably more variability was evident than in the Missionary variety. The nitrate only and check plots had the greatest number of decayed berries in both pickings. However the other two plots which did not receive potash, namely, phosphate only and phosphate with nitrate of soda, did not show the same results. It is doubtful then whether any of the differences between potash and no potash treatments can be considered significant. The percent-

TABLE 49

Summary of Storage Counts of Gandy Strawberries From Fertilizer Plots at Marion

Fertilizer Treatment.*	First Picking			Second Picking		
	Per Cent Sound	Per Cent Decay	Per Cent Soft	PerCent Sound	Per Cent Decay	Per Cent Soft
$NaNO_3$	58.3	21.4	20.3	58.8	29.0	12.2
N-KCl	71.4	12.8	15.8	70.4	16.9	12.7
N-K_2SO_4	69.5	12.6	17.9	68.9	17.7	13.4
N-Mg $(KSO_4)_2$	61.1	10.4	28.5	68.8	17.2	13.9
N-Kainit	46.2	11.9	41.9	62.2	16.8	21.1
N-P	62.7	14.1	23.2	66.6	21.4	12.0
N-P-KCl	51.0	13.7	35.3	70.0	15.9	14.0
N-P-K_2SO_4	58.2	11.0	30.8	73.7	11.0	15.3
N-P-Mg $(KSO_4)_2$	52.3	13.5	34.2	63.4	21.5	15.0
N-P-Kainit	50.3	14.2	35.5	66.1	13.6	20.3
Check	59.8	15.7	24.5	68.6	18.6	12.6
KCl	68.7	9.9	21.3	83.2	7.0	9.8
K_2SO_4	65.7	11.1	23.2	77.3	7.9	14.8
Mg $(KSO_4)_2$	66.7	9.8	23.4	75.1	12.2	12.7
Kainit	66.0	8.7	35.3	68.5	12.1	19.4
P	62.0	7.5	30.6	77.4	9.1	13.4
P-KCl	55.2	10.5	34.3	64.7	17.5	17.9

* Each fertilizer element was applied in amounts equivalent to 600 pounds per acre of a 5-8-8 fertilizer.

ages of soft berries developing during the tests varied a great deal among treatments, and were too inconsistent from which to draw postive conclusions. The average per cent of sound berries from all plots receiving potash was 65.2 per cent while the no potash plots had 64.3 per cent. The differences of 0.9 per cent is relatively unimportant.

Summary. The results of the tests with Gandy do not show any beneficial effect of potash fertilizers on keeping quality.

CHESAPEAKE VARIETY AT PARKER'S, PARSONSBURG

Description of Plots. In 1929 investigations were begun on the farm of W. F. Parker near Pittsville, also a large strawberry growing section in Maryland. The characteristic soil of the region was classified as Sassafras sandy loam (30),a type which is very well adapted to strawberry production. The matted row system of training was used. The beds were comparatively free from weeds, and had a good stand of plants.

Twenty-one rows of plants were divided into seven plots of three rows each. Each plot covered approximately 1/20 of an acre. Fertilizer applications were made as a top-dressing in March of the first fruiting year. Each fertilizer element was applied in amounts equivalent to those in a four hundred pound per acre application of a 5-8-5 fertilizer. One potash fertilizer, muriate of potash, was used in combination with nitrogen, and with nitrogen and phosphate. The

nitrogen, and nitrogen plus phosphorus treatments, respectively, served as checks for the treatments which included potash. In addition two plots receiving four hundred and six hundred pounds respectively of a commercial 5-8-5 fertilizer were included, as shown in table 50. Since the soil was very fertile, the fertilizer elements including nitrogen, had no appreciable influence on the growth of plants.

Investigations Conducted in 1929

Sampling. In order to avoid the errors in sampling introduced by having a large number of pickers take the samples, all sampling was done carefully by the same two or three persons each time, including the author. Each person picked a proportionate share of the sample from each treatment, thereby eliminating as far as possible the error of the individual. Only berries of the same size and maturity were taken for the samples, corresponding in every way with the fruit the grower picked for commercial purposes, except that the berries were of uniform size, and entirely free from defects. The size selected was slightly larger than the average run of the fruit, but the largest berries were avoided.

Testing. On May 25, the date of the first commercial picking on these experiments, eight quarts of fruit were selected from each plot, and placed in a shed where they would be exposed to the prevailing air temperature (60° - 70°F). Counts of the number of decayed and soft

berries developing were made on succeeding days. On May 27, another sample of four quarts per treatment was picked, and hauled to College Park, a distance of one-hundred miles, by car. The latter samples were stored at room temperature and inspected on succeeding days.

Results. The results of the final inspection are presented in table 50. One of the aims in taking a sample of eight boxes of berries, and studying each box separately, was to obtain an idea of the variability existing among boxes and thereby determine the reliability of the averages. The latter is shown in the probable errors of the averages of the sound fruits. In order for one treatment to have a significantly greater number of sound berries than another treatment, a difference of at least three times the probable error of the difference must be present.

As shown in table 50, the averages were quite uniform, and in only instance, namely, the complete fertilizer treatment in the May 27 picking, were the differences significant. This plot had a much greater percentage of soft berries in the shipping test, though the previous holding test showed no differences. It was noted at the time of inspection that the boxes which were in the bottom of the crate while they were being hauled to College Park suffered more bruising than those in the upper layers, and since all four boxes of the complete treatment happened to be in the lower tier, the greater number of

TABLE 50.

Summary of 1929 Storage Counts on Chesapeake Strawberries from Fertilizer Plots at Parker's, Parsonburg.

Fertilizer Treatment.*	Picked May 25, Final Inspected May 27.				Picked May 27, Inspected May 29.			
	No. Quarts	Percent of Fruit Sound	Decay	Soft	No. Quarts	Percent of Fruit Sound	Decay	Soft
$NaNo_3$	8	73.1 ± 1.79	6.7	20.2	4	45.8 ± 1.96	10.9	43.3
N-P	8	73.0 ± 1.44	7.5	19.5	4	45.5 ± 2.31	8.0	46.5
N-KCl	8	76.6 ± 2.35	3.8	19.6	4	45.3 ± 1.20	7.1	47.6
N-P-KCl	8	76.2 ± 1.80	6.0	17.8	4	31.0 ± .67	8.0	61.0
5-8-5(600#)	8	79.4 ± 1.16	8.8	11.8				

* Fertilizer elements applied in amounts equivalent to those in 400 pounds per acre application of a 5-8-5 fertilizer.

soft berries may have been due to mishandling rather than fertilizer treatment.

Summary. Potash has not shown a beneficial effect on keeping or shipping quality in these tests on the Chesapeake variety.

Investigations Conducted in 1930

The beds were carried over a second fruiting year by the grower and the experiments were continued by repeating the fertilizer treatments of the previous year. The amounts of application were increased from four hundred to six hundred pounds per acre. In this year nitrogen fertilizers increased the growth of plants but potash had no effect.

Sampling. The same method of sampling employed the previous year was used again. Two persons selected all the samples, for uniformity in size and maturity and freedom from defects.

Testing. Two tests were made in these experiments, beginning May 26 and May 28 respectively. Six quarts of berries were selected from each treatment on each occasion and held in an open shed for later inspection. Three days after picking, when the fruit was ripened somewhat, samples from the May 26 lot were preserved for chemical studies, to determine what effect the fertilizer treatments might have on the carbohydrate and potassium content of the fruit.

TABLE 51.

Summary of 1930 Storage Counts on Chesapeake Strawberries

from Fertilizer Plots at Parker's, Parsonburg.

Fertilizer treatment. *	Picked May 26, Final Inspection May 31.				Picked May 28, Final Inspection June 2.			
	No. Quarts	Percent of Fruit			No. Quarts	Percent of Fruit		
		Sound	Decay	Soft		Sound	Decay	Soft
No_3	6	56.00 ± 1.33	7.84	36.16	6	70.36 ± 4.55	4.23	32.46
No_3 + KCl	6	55.65 ± 2.29	6.525	37.90	6	64.94 ± 1.85	3.38	31.68
No_3 + P_2O_5	6	60.15 ± 1.70	7.37	32.48	6	63.31 ± 5.06	4.23	32.46
No_3 + P_2O_5 + KCl	6	63.15 ± 2.45	9.46	27.4	6	66.52 ± 2.71	3.11	30.37

Fertilizer elements applied in amounts equivalent to those in a 600 pound per acre application of a 5-8-5 fertilizer.

Results. The per cent of decayed and soft berries found in the final inspections for each test on May 31 and June 2 respectively are shown in table 51, together with the probable errors on the per cent of sound fruit. The chemical analyses are presented in table 52.

The picking season of 1930 was much colder than that of 1929. As a consequence the fruit softened more slowly and five days were required to reach the same stage of maturity after picking as was attained the previous season in two days. However the different treatments were remarkable uniform in the number of decayed and soft fruits developing during storage (table 51) and none of the differences between treatments was significant.

The sugar content (table 52) was quite variable among treatments. The two potash treatments were not

TABLE 52

Chemical Analyses of Chesapeake Strawberries From Fertility Plot at Parker's, Parsonsburg.

(Picked 5/26/30. Sampled 3/29/30. Analyses Expressed in Percentage Dry Weight).

Fertilizer Treatment	Dry Weight	Reducing Sugars	Sucrose	Total Sugars	Hydrolyzable Material	Potassium.
N	10.52	41.05	3.26	44.31	7.32	.479
N-KCl	10.54	37.93	2.09	40.02	6.35	.494
N-P	9.64	34.39	2.87	37.26	7.22	
N-P-KCl	10.54	40.27	2.47	42.74	6.98	.464

consistent in their influence on these constituents and consequently one cannot conclude that the differences were due

to treatment. The potassium content of the fruit also has not been affected by the potash applications.

Summary. Potash applications made in the second successive year had no influence on the keeping and shipping quality of strawberries, just as applications made in the first year of fruiting were ineffective.

CHESAPEAKE VARIETY AT ESHAM'S, PARSONSBURG

Description of Plots. Plots were laid out on a Chesapeake planting on the farm of R. S. Esham, which practically adjoined that of W. F. Parker. The soil type was Sassafras sandy loam (30). The experiment was begun in 1929, the first fruiting year, with applications of nitrogen, phosphorus and potassium fertilizers in amounts equivalent to those in a four hundred pound per acre application of a 5-8-5 fertilizer. Each plot consisted of three adjoining rows and included approximately 1/19 of an acre. The same treatments used on Chesapeakes at Parker's were repeated in this experiment (table 53). The soil was of medium fertility and though nitrogen fertilizer increased growth remarkably, potash had no effect on the vigor of the plants.

Sampling. The same method of sampling employed in 1929 on Parker's Chesapeake planting was used. However, the maximum amount of uniform fruit obtainable on a single date from each treatment was only three quarts.

Testing. A single holding test at prevailing temperature was begun on May 26. The number of decayed

and soft berries found during the two days was recorded.

Results. The results of the inspections in terms of per cent are given in table 53. Since only three boxes of

TABLE 53

Survey of Storage Counts on Chesapeake Strawberries From Fertilizer Plots at Esham's, Pittsville.

Fertilizer Treatment.*	Picked May 26. Inspected May 28.			
	Percent of Fruit.			
	No. of Quarts.	Sound	Decay	Soft
$NaNO_3$	3	67.9	1.7	30.4
N-P	3	69.1	5.3	25.6
N-KCl	3	73.0	6.6	20.4
N-P-KCl	3	63.3	7.5	29.2
5-8-5 (400#)	5	67.1	4.1	28.8
5-8-5 (600#)	4	67.9	8.4	23.7

*Fertilizer elements applied in amounts equivalent to those in 400 pounds per acre application for 5-8-5 fertilizer.

fruit were available, probable errors of the averages were not determined. However, the maximum differences in per cent of sound berries between a potash treatment and its check was six per cent. Even with a larger sample this difference would not be significant.

Summary. Potash fertilizers again proved ineffective in influencing the keeping quality of Chesapeake strawberries.

PREMIER VARIETY AT ESHAM'S, PARSONSBURG

Description of Plots. This experiment was on a planting of Premier strawberries in the same field as the Chesapeake plots. The soil, plan of plots, amounts of applications, and size of plots were identical in every respect.

Investigations Conducted in 1929

Sampling and Testing. Eight quarts of berries of uniform size and maturity were selected from each of the treatments on May 15. These were placed in an open shed and inspected on two succeeding days.

Results. The data taken at the final inspection of the fruit on May 17, are presented in table 54 in terms of

TABLE 54.

Summary of 1929 Storage Counts on Premier Strawberries at Esham's, Pittsville.

(Picked May 15. Inspected May 17)

Fertilizer Treatment.*	No. of Quarts.	Per Cent of Fruit: Sound	Decay	Soft
$NaNO_3$	8	68.3 ± 1.59	3.0	28.7
N-P	8	68.3 ± 2.04	4.1	27.6
N-KCl	8	68.4 ± .73	4.3	26.3
N-P-KCl	8	66.4 ± 3.13	2.3	31.3
5-8-5 (400#)	8	54.5 ± 1.94	5.2	40.3
5-8-5 (600#)	8	53.2 ± 1.32	2.0	44.8

per cent. The differences between the two potash treatments and their checks, N and N-P respectively, in the per cent of decayed and soft fruits were well within the limits of the probable error. The two commercial fertilizer treatments had significantly more soft berries than any of the other treatments. To what this detrimental effect may be due is difficult to determine, for the other complete fertilizer composed of nitrate of soda, superphosphate, and muriate of potash in the same amounts did not have a similar effect.

Summary. There is no evidence in these tests that potash has influenced the keeping quality of Premier strawberries.

Investigations Conducted in 1930

The same plots of Premiers at Esham's which were used in 1929 were continued a second year, the amounts of applications being increased from four-hundred pounds to six hundred pounds per acre. The yield was low and the berries were extremely small. Consequently it was impossible to obtain a suitable sample for a holding test. However, a sample for chemical analyses was picked on May 25 and preserved on May 27, after the berries had ripened appreciably.

The results of the analyses are tabulated in table 55. Since two nitrate only samples are included, an idea of the variability within a treatment may be obtained. The data show that there was a greater difference in this

TABLE 55.

Chemical Analyses of Premier Strawberries from Fertilizer Plots at Esham, Pittsville. (Picked May 25, 1930 - Sampled May 27, 1930).

(Analyses expressed in percentage dry weight.)

Fertilizer Treatment.	Dry Weight	Reducing Sugars	Sucrose	Total Sugars	Hydrolyzable Material	Potassium
N	12.10	41.50	11.39	52.89	6.35	.363
N	13.98	38.77	5.89	44.66	5.44	.---
N-KCl	12.55	38.09	8.17	46.26	5.71	.467
N-P	11.98	34.89	7.45	42.34	6.22	.---
N-P-KCl	11.92	40.95	5.95	46.90	6.29	.370

case within a treatment than between treatments as far as carbohydrates were concerned. The per cent of dry weight also varied among plots. Undoubtedly a great deal of the variability may be attributed to the small number of berries which were used for each sample. The potassium analyses (table 55) indicate that the muriate of potash treatment had increased the potassium content of the fruit, though when used with phosphate, the same fertilizer was ineffective in this respect. This lack of corroboration, together with the lack of substantiation in other varieties indicates that the difference might be due to error in sampling and analysis.

PREMIER VARIETY AT HAMLIN, PITTSVILLE

Description of Plots. An experiment was begun in the spring of 1929 on a Premier planting on the farm of Mr. A. J. Hamlin near Pittsville in Wicomico County. The soil was classified as Sassafras sandy loam type (30) but lacked fertility. The growth of the plants was comparatively weak, considering the usual vigor of the beds used in these experiments, and the stand of plants was only fair. There was a marked response in growth from nitrogen fertilizers, though potash had no effect.

The planting was divided into plots, each plot consisting of three adjoining rows. A plot included approximately 1/20 of an acre. The treatments were the same as those given the plots of Premier of Esham's,

Parsonsburg (table 55). Each fertilizer element was applied in amounts equivalent to those in a four-hundred pound per acre application of a 5-8-5 fertilizer. The soil was comparatively poor and nitrogen fertilizer increased growth of plants markedly. Potash fertilizers had practically no affect on either growth or yield of plants.

Sampling. The same method of sampling used in the other Premier studies was employed in this experiment.

Testing. A sample of four quarts per plot was selected from five plots on May 18 and hauled to College Park by auto. The fruit was inspected the following day and the number of decayed and soft berries recorded.

Results. The data in per cent are given in table 56, together with the probable errors. Practically no decay had developed, though there was a fair number of soft berries. The difference between treatments, however, were not significant as far as potash was concerned. The greatest percentage of sound berries was found in the four hundred pound application of a 5-8-5 fertilizer, in contrast to the Premier results at Esham's where this treatment had the least number of sound berries.

Summary. Potash fertilizer again showed no influence on the keeping quality of Premier strawberries.

CHESAPEAKE VARIETY AT SHOCKLEY'S, PITTSVILLE

Description of Plots. In the spring of 1930 a fertilizer experiment was begun on a one year old planting

TABLE 56

Summary of 1929 Storage Counts on Premier Strawberries From Hamlin's, Pittsville

(Carried 100 miles by Auto. Picked May 18. Inspected May 19).

Fertilizer Treatment.*	No. of Quarts	Per Cent of Fruit. Sound	Decay	Soft
$NaNO_3$	4	70.8 ± 1.50	.8	28.4
N-P	4	70.2 ± 1.47	.8	29.0
N-KCl	4	69.0 ± 1.99	.8	30.2
N-P-KCl	3	62.1 ± 1.37		37.9
5-8-5 (400#)	2	72.6		27.4

* Fertilizer elements applied in amounts equivalent to those in 400 pounds per acre applications of a 5-8-5 fertilizer.

of Chesapeake strawberries on the farm of Wm. Shockley near Pittsville in Wicomico County. The soil type was Sassafras sandy loam (30). The matted row beds had an exceptionally good stand of plants, and were fairly free from weeds. Though the land was very fertile, nitrogen fertilizers increased the growth of the plants markedly. Potash fertilizers on the other hand had no observable effect on growth or yield.

In order to reduce soil variability to a minimum, adjoining rows, approximately 180 feet long, were given

different treatments. A series of five treatments, which included a no fertilizer treatment, nitrate of soda only, nitrate of soda plus muriate of potash, nitrate of soda plus superphosphate, and nitrate plus phosphate plus muriate, was repeated five times in the experiment. Rows 1, 6, 11, 16, etc. received the same treatment. Each fertilizer element was applied in amounts equivalent to those in a 400 pound per acre application of a 5-8-5 fertilizer.

Sampling. The same method of sampling was used in this experiment as in the other 1930 experiments. Only uniform berries of the same size and maturity, and entirely free from defects were selected.

Testing. Ten boxes of berries were selected from each treatment on May 28, 1930 and held on an open porch. Inspections were made at intervals to June 2 and records were taken on the number of decayed and soft berries developing during the test. Three days after picking samples were taken from this lot for chemical analyses. On May 31 another sample of six boxes per treatment was selected and held on an open porch until June 3 when they were carried to College Park by auto. The final inspection was made June 5.

Results. The data of the final inspections are presented in table 57, together with the probable errors on the per cent of sound berries. The results of the

TABLE 57.

Summary of 1930 Storage Counts on Chesapeake Strawberries from Fertilizer Plots at Shockley's, Pittsville.

tilizer atment. *	Picked May 28, Final Inspection June 2.				Picked May 31, Final Inspection June 5.			
	No. Quarts	Percent of Fruit Sound	Decay	Soft	No. Quarts	Percent of Fruit Sound	Decay	Soft
KO_3	10	61.2 ± .73	2.9	35.9	6	30.22 ± 1.94	10.92	58.86
KO_3 + KCl	10	57.8 ± 1.26	1.8	40.4	6	31.34 ± 1.93	10.16	58.50
KO_3 + P_2O_5	10	59.5 ± 1.01	2.9	37.6	6	27.87 ± 1.33	10.61	61.52
KO_3 + P_2O_5 + KCl	10	61.1 ± 1.33	3.2	35.7	6	28.24 ± 3.47	9.68	62.08

Fertilizer elements applied in amounts equivalent to those in a 400 pound per acre application of a 5-8-5 fertilizer.

carbohydrate and potassium determinations are given in table 58.

TABLE 58.

Chemical Analyses of Chesapeake Strawberries From Fertilizer Plots at Shockley's, Pittsville.

(Picked 5/28/30. Samples 5/31/30)

Fertilizer Material.	Dry Weight	Reducing Sugars	Sucrose	Total Sugars	Hydrolyzable Material	Potassium
N	10.02	41.03	1.19	42.22	6.88	.471
N-KCl	9.93	40.60	8.30	48.90	7.16	.475
N-P	9.55	41.35	5.61	46.96	7.68	
N-P-KCl	11.31	38.59	5.62	44.21	6.81	.450

As previously stated, the picking season of 1930 was unusually cool, and at the end of the five day holding test, 60 per cent of the berries of the first test remained perfectly sound. The differences between the potash treatments and their checks (table 57) in the per cent of sound berries were not significant, and even if they were significant, were so small as to be practically negligible.

In the second test (table 57) five days after picking, only 30 per cent of the berries remained sound. In spite of this great change, the greatest difference between the potash and the complete treatments and their checks in the per cent of soft berries, or in the per cent of decayed fruit was less than one per cent. This uniiformity among

treatments indicates that the methods of sampling and testing employed were reliable.

The data on chemical composition (table 58) resemble the chemical studies in the previous experiments in that the difference between treatments lack consistency. As far as potassium is concerned one cannot say that the sugar content of the fruit on the dry weight basis has been affected. The fruit from these plots contained more sucrose than the Chesapeake berries at Parker's though the reducing sugar content was practically the same.

The potassium content of the fruit has not been affected by the treatments.

Summary. There was not the slightest indication in this test thatpotash fertilizers have influenced the keeping or shipping quality of the fruit.

General Discussion

Growth and yield records taken each year on all plots showed that the vigor of the plants had not been affected by potash fertilizers. The soils on which the experiments were located were of low, medium and high fertility, representative of the soils used for strawberry growing in Maryland. Had the fertilizer increased or decreased the size of the berry, an indirect effect of potash on keeping quality might have resulted, since, in general, small berries keep and ship better than large ones. However, no differences due to treatment in

size of berries, or maturity, could be observed. Consequently, the selected fruit used in the 1929 and 1930 experiments was more or less representative of the fruit on the particular plots and no other factors than fertilizer treatments need be considered in drawing conclusions.

Since the results of this work are all negative from a practical standpoint, that is, the potassium treatments have not influenced the keeping or shipping quality significantly, the question arises as to whether any differences which could be proven significant in these data are small enough to be considered unimportant commercially. Unless that is the case, the results are practically valueless, for variability in the data might conceal important effects of treatment. The question can best be answered by consulting the values for the probable errors. The average error in the per cent of sound fruits for the 1929 and 1930 work is approximately two per cent. Thus an eight or nine per cent difference in a single test could be considered significant. However, because of the number of duplications made in tests, in plots, and in varieties, any difference due to treatment greater than three per cent would be made significant in the data by the frequency with which it would appear. From a commercial standpoint a difference of three per cent in the number of sound berries, the equivalent of one or two soft berries per box, is unimportant. Therefore the

results of these experiments are a fair indication of what one should expect in actual practice on a commercial scale.

CONCLUSIONS

It is apparently safe to conclude from these extensive studies, that at least under Maryland conditions, the use of potassium fertilizers, alone or in combination with nitrogen and phosphorus, does not influence the keeping or shipping quality of strawberries. Thus it cannot be considered as a corrective for any possible effects nitrogen fertilizers might have on the shipping quality of the fruit.

SUMMARY

1. Random samples of Missionary and Gandy strawberries from field plots receiving muriate of potash, sulfate of potash, sulfate of potash magnesia, or kainit, alone or in combination with nitrogen and phosphorus, showed practically identical shipping and keeping qualities regardless of treatment in 1928.

2. Selected samples of uniform fruit from Premier and Chesapeake fertilizer plots in 1929 and 1930 had, within the limits of error, the same number of decayed and soft berries at the end of a holding test at prevailing temperatures, indicating that muriate of potash, in combination with nitrogen or nitrogen and phosphorus, does not influence the keeping quality.

3. Observations on growth and vigor of plants showed no effect of potash treatments in these experiments.

4. Sugar and potassium content of the Premier and Chesapeake berries, though variable, was not correlated with potash treatments.

5. Superphosphate, used with potash, also had not affected the keeping quality of strawberries.

GENERAL CONCLUSIONS

As a result of three years study, potash fertilizers cannot be considered as improving the shipping or keeping quality of peaches and strawberries in Maryland, since fruit from plots receiving potash in addition to nitrogen was no firmer at time of picking and withstood storage in no better condition than fruit from plots receiving nitrogen only. Thus potash also cannot be considered as a counteractant in overcoming any supposedly deleterious effects of nitrogen fertilizer on the shipping or keeping quality of peaches and strawberries.

The same conclusion is applicable to apples with the exception of one potash fertilizer, sulfate of potash magnesia. A definite increase in firmness and improvement in keeping quality may be attributed to this treatment, though under normal moisture conditions the effect was of no practical significance. Muriate of potash, sulfate of potash and kainit, on the other hand, were almost totally ineffective.

Fruit growers who fertilize with the muriate, sulfate or kainit potash carriers need expect no improvement in firmness and keeping quality of the fruit, or increases in yield

and growth, under conditions similar to those in Maryland.

LITERATURE CITED

1. Appleman, C. O. and C. M. Conrad. Pectic constituents of peaches and their relation to softening of the fruit. Md. Agric. Exp. Sta. Bul. 283. 1926.

2. Auchter, E. C. and A. L. Schrader. A preliminary report on peach fertilizer experiments in Maryland. Proc. Amer. Soc. Hort. Sci. 25: 263. 1928.

3. Blake, M. A. Some results of flesh texture tests with peaches. Proc. Amer. Soc. Hort. Sci. 25: 300-305. 1928.

4. Brown, W. G. Fertilizer tests for strawberries. Ore. Agric. Exp. Sta. Bul. 159. 1919.

5. Burke, R. T. and H. F. McCall. Soil survey of Washington County Maryland. Bureau of Soils, U.S.D.A. 1917.

6. Carre[1], M. H. and D. Haynes. The estimation of pectin as calcium pectate and the application of this method to the determination of soluble pectin of apples. Biochem. Jour. 16: 60-69. 1922.

7. Conrad, C. M. A furfural-yielding substance as a splitting product of protepectin during the ripening of fruits. Plant Phys. 5:93-103. 1930.

8. Cooper, J. R. A study of the effect of commercial fertilizers on the performance of apple trees. Ark. Agric. Exp. Sta. Bul. 227. 1928.

9. Cooper, J. R. and C. B. Wiggans. A study of the effect of commercial fertilizers on the performance of peach trees. Ark. Agric. Exp. Sta. Bul. 239. 1929.

10. Fletcher, L. A. A study of the factors influencing the red color of apples. Unpublished thesis, University of Maryland. 1930.

11. Gore, H. C. Studies on fruit respiration. U.S.D.A. Bur. Chem. Bul. 142. 1911.

12. Grubb, N. H. An analysis of the effects of potash fertilizers on apple trees at East Malling. Jour. Pom. and Hort. Sci. 7.33-58. 1928.

13. Haller, M. H. Changes in pectic constituents of apples in relation to softening. Jour. Agr. Res. 39, No. 10: 739-746. 1929.

14. Harding, P. L., J. T. Maney, and H. H. Plagge. Apparatus for the determination of carbon dioxide in the respiration of apples. Science LXX. No. 1805: 125-126. Feb. 1929.

15. Haynes, D. and H. K. Archbold. A relation between the sugar and nitrogen content of the apple at the time of gathering and the length of its subsequent life in storage. Dept. Sci. and Ind. Res. Rept. Food Invest. Bd. 1925 and 1926:42-45.

16. Kidd, F. and Cyril West. A relation between the respiratory activity and the keeping quality of apples. Dept. Sci. and Indust. Res. Rept. Food Invest. Bd. 1925 and 1926: 37-39.

17. Kidd, F. and Cyril West. Physiology of fruit. 1. Changes in the respiratory activity of apples during their senescence at different temperatures. Proc. Royal Hort. Soc. Series. B. Vol.106:93. 1930.

18. Kimbrough, W. D. The quality of strawberries as influenced by rainfall, soil moisture, and fertilizer treatments. Proc. Amer. Soc. Hort. Sci. 27:184-186. 1930.

19. Latimer, W. J., R.T. Burke, and O. C. Bruce. Soil survey of Frederick County, Maryland. Bureau of Soils, U.S.D.A. 1922.

20. Magness, J. R. and A. M. Burroughs. Studies in apple storage. Storage Investigations, 1921-1922. The Marble Laboratory, Inc., Canton, Pa. 17-98. 1923.

21. Magness, J. R. and H. C. Diehl. Physiological studies on apples in storage. Jour. Agr. Res. 27:1-38. 1924.

22. Magness, J. R., H. C. Diehl, M. H. Haller, and W. S. Graham. The ripening, storage, and handling of apples. U.S.D.A. Bul. 1406. 1926.

23. Magness, J. R. and F. L. Overly. Effect of fertilizers on storage qualities of apples. Proc. Amer. Soc. Hort. Sci. 26: 18-181. 1929.

24. Magness, J. R. and G. F. Taylor. An improved type of pressure tester for the determination of fruit maturity. U.S.D.A. Circ. 350. 1925.

25. McCue, C. A. A fertilizer experiment with peaches. Proc. Amer. Soc. Hort. Sci. 11:86-92 1914.

26. Nightingale, G. T., R. M. Addoms, and M. A. Blake. Development and ripening of peaches as correlated with physical characteristics, chemical composition, and histological structure of the fruit flesh; III. Macrochemistry, New Jersey Agric. Exp. Sta. Bul. 494. 1930.

27. Perkins, S. O. and R. S. Bacon. Soil survey of Worcester County, Bureau of Soils, U.S.D.A. 1928.

28. Shoemaker, J. S. and E. W. Greve. Relation of nitrogen fertilizers to the firmness and composition of strawberries. Ohio Agric. Exp. Sta. Bul. 466. 1930.

29. Snyder, J. M. and J. H. Barton. Soil survey of Somerset County, Maryland. Bureau of Soils, U.S.D.A. 1924.

30. Snyder, J. M. and R. L. Gillet. Soil survey of Wicomico County, Maryland. Bureau of Soils, U.S.D.A. 1925.

31. Stuckey, H. P. Fertilizing peaches. Better Crops With Plant Foods. Feb. 1928. 20-22.

32. Wallace, T. Factors influencing the storage qualities of fruits. Unpublished paper presented at Botanical Conference in London, 1930. Long Ashton Research Station, University of Bristol.

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