THE EFFECT OF FERTILIZER RATE AND RATIO ON THE COMPOSITION OF THE LEAVES AND GRAIN OF CORN GROWN ON A KALAMAZOO SANDY LOAM SOIL

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ABSTRACT

Leaf and grain samples of corn grown in a field experiment located on a Kalamazoo sandy loam soil were analyzed for nitrogen, phosphorus, potassium, magnesium, sodium, and calcium. The corn had been fertilized with fifty seven different combinations and rates of nitrogen, phosphoric acid, and potash.

The nitrogen, phosphorus, and potassium contents of the leaf were significantly affected by the respective amounts of fertilizer nitrogen, phosphoric acid, and potash. The nitrogen, phosphorus, and potassium content of the grain was relatively constant regardless of the rate of fertilizer used.

Nitrogen and potash fertilizers tended to increase corn yields. The use of phosphorus fertilizers had little effect on corn yields.

The following reversible relationships were found to be significant at the indicated level of probability:

Leaves of low yielding corn were high in sodium and magnesium. (5%)

Leaves of high yielding corn were high in nitrogen. (1%)

An increase in the nitrogen content of the leaf was associated with a decrease in the leaf's potassium content. (5%)

Leaves with a high nitrogen content were low in sodium. (1%)

Leaves with a high calcium content contained the largest percentages of sodium (5%) and magnesium (1%).

Leaves high in magnesium were high in phosphorus. (5%)

Leaves with either a high calcium or magnesium content were low in potassium. (1%)

An increase in the grain's nitrogen content was accompanied by a decrease in magnesium. (5%)

Grain containing the most magnesium also contained the most potassium, phosphorus, (5%) and calcium (1%).

Leaves with high nitrogen contents were associated with grains of high nitrogen content. (5%)

A negative correlation existed between the magnesium content of leaves and grain. (5%)

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INTRODUCTION

The genetic composition of a plant species is related to its chemical composition. Variations in environment, e.g. nutrient supply, may modify the chemical composition in such a way that the quality or growth factors, as well as yield, are significantly affected.

Many investigations have been designed to show the effect of nitrogen, phosphorus, and potassium fertilizers on plant characteristics such as growth, color, maturity, and chemical composition. Such studies have given variable results. They indicate that variations in use of nitrogen, phosphorus, and potassium fertilizers may affect growth and chemical composition. The plant leaves and stems often vary greatly in chemical composition, depending on the fertilizer treatment. The chemical composition of the leaf is frequently more indicative of nutrient supply than the grain.

This study, a part of a nutrient level and balance project, was designed to determine the effects of various levels and ratios of fertilizer on the chemical composition of corn.

The objective of the study was to determine the effect of several widely varying combinations of nitrogen, phosphoric acid, and potash fertilizers on the yield of grain and the nitrogen, phosphorus, potassium, magnesium, calcium, and sodium contents of grain and leaves.

LITERATURE REVIEW

Man has always been puzzled and awed by those surroundings of nature which supplied him with food, fuel, and shelter. As time passed, he investigated in great detail, his surroundings and learned more concerning these natural phenomena. He learned to use this information for his own betterment.

As early as 1889, some wondered if it might be possible to alter the chemical composition of corn by using different treatments of nitrogen, phosphorus, or potassium. Several investigators (5, 12, 19, 20, 21, 26) found that nitrogen used alone increased the nitrogen content of either the corn leaf, grain, sap, or a combination of these plant parts.

Other investigators (11, 21, 26, 30, 32) demonstrated that potassium fertilizer used alone increased the potassium content of the corn leaf. They noted also that potassium fertilization resulted in a reduced calcium and magnesium content of the plant. From field experimental plots located on nonproductive soils, Stanford, et al (22) showed that the addition of potassium repressed the plants' uptake of calcium and magnesium. Boswell and Parks (6), in a field experiment, found that the phosphorus content of the grain was unaffected by different levels of potassium fertilization. According to their experimental data, the use of 75 pounds of K_2O per acre gave significant yield increases. Rates above this reduced the corn yield.

Nitrogen fertilizers, when supplemented with phosphates, affect neither the nitrogen nor the phosphorus content of corn grain, according to Jacob and Gottwick (9). Lowry, et al (13) found an increased calcium content in the plant sap when nitrogen fertilizers were supplemented with phosphates. They found that the combination of nitrogen and potash resulted in a decreased calcium content of the plant sap.

Vandecaveye (29), in a summarization of the literature prior to 1940, reported that only the late or very large applications of nitrogen affected the composition of the grain. Complete fertilizers gave irregular results, although in a substantial number of cases, the fertilizer treatments produced grain with an increased content of nitrogen or phosphorus or both. Kling (10) reported that complete fertilizers had no significant effect on the nitrogen, phosphorus, or potassium content of the grain, but increasing amounts of nitrogen produced green corn with a high nitrogen content. Weeks, et al (30), from a field experiment, reported that fertilizer treatments affected the amount of calcium, potassium, phosphorus, and magnesium and to a lesser extent the nitrogen content of the grain. Other investigators (11, 20, 21, 31) did not find any consistent differences in the grain composition resulting from phosphorus or potassium fertilizer applications. Munsell and Brown (14) reported that the phosphorus and calcium contents of the leaf and grain were not increased with increasing rates of fertilization. From their field studies they noted a decrease in the calcium to potassium ratio and the magnesium to potassium ratio with each increase in applied potassium fertilizer.

Stubblefield and Deturk (23) observed that seeds had a more constant chemical composition than leaves. They indicated that the composition of the leaf can be expected to be variable since it represents the minerals left over in the plant after the seeds have formed. They also noted that weather conditions exert a profound influence upon the yield and chemical composition of corn grown on a given plot from year to year.

Lawton and Browning (12), from their field study of how different methods of tillage affect the mineral composition of corn, observed a higher percentage of potassium in plants grown on plots that were plowed than in plants grown on plots which were tilled by other means. They reported that applications of fertilizers usually decreased the nitrogen content of the plant.

Beeson (3) analyzed corn grain grown on different New York soils for the mineral composition of the grain and found some widely variable data. The sodium content ranged from .125% to .001% with an average of .043%. The potassium content ranged from .92% to .22% with an average of .40%. The calcium content varied from .045% to .006% with an average of .010%. The magnesium content varied from .27% to .09% with an average of .16%. The phosphorus content ranged from .80% to .23% with an average of .43%. The averages presented were for the total number of samples analyzed for each of the specified elements.

MATERIALS AND METHODS

The samples analyzed in this study were obtained from the nutrient level and balance plots on the John Campbell farm. (17) The soil on this farm was mapped as Kalamazoo sandy loam. (1) This is one of the more droughty agricultural soils of Southern Michigan.

Field Plot Design

One hundred forty plots, measuring 14 by 50 feet, were planted to corn in 1956. These plots were arranged in a randomized block design. Sixty-two of the 140 plots were selected to be sampled for chemical analysis. This selection included six "no fertilizer" plots. A minimum of nine plots, which represented one level of a given nutrient, were sampled. The field key to the levels and the pounds of fertilizer nutrients applied per acre for each plot sampled is shown in Table 1.

Fertilizer

The fertilizer carriers of the three major plant nutrients were ammonium nitrate (33.5% N.), superphosphate (45% P_2O_5), and potassium chloride (60% K_2O). The soil had recently been limed to pH of 5.9 to 6.3.

The nitrogen and potassium fertilizer was broadcast on the plots prior to plowing. If the plot was to receive more than forty pounds of P_2O_5 per acre, the amount of P_2O_5 over forty pounds was broadcast prior to plowing. Therefore, all of the nitrogen and potassium and the amount of P_2O_5 over forty pounds

TABLE I

KEY TO APPLIED FERTILIZER NUTRIENTS

Treatment key			Pounds per acre		
N.	P.	K.	N.	P_2O_5	K_2O
0	0	0	0	0	0
0	1	1	0	40	20
0	3	3	0	160	80
0	5	5	0	480	240
1	0	1	20	0	20
1	1	0	20	40	0
1	1	1	20	40	20
1	1	5	20	40	240
1	2	4	20	80	160
1	3	3	20	160	80
1	3	5	20	160	240
1	4	2	20	320	40
1	5	1	20	480	20
1	5	3	20	480	80
1	5	5	20	480	240
2	1	2	40	40	40
2	1	4	40	40	160
2	2	1	40	80	20
2	2	2	40	80	40
2	2	3	40	80	80
2	2	5	40	80	240
2	4	1	40	320	20
2	4	3	40	320	80
2	4	5	40	320	240
3	0	3	80	0	80
3	1	1	80	40	20
3	1	3	80	40	80
3	1	5	80	40	240
3	2	2	80	80	40
3	2	4	80	80	160
3	3	0	80	160	0
3	3	1	80	160	20
3	3	3	80	160	80
3	3	5	80	160	240
3	4	2	80	320	40
3	4	4	80	320	160
3	5	1	80	480	20
4	1	2	160	40	40
4	1	4	160	40	160
4	2	2	160	80	40
4	3	2	160	160	40

TABLE I "continued"

Treatment key			Pounds per acre		
N.	P.	K.	N	P_2O_5	K_2O
4	4	1	160	320	20
4	4	4	160	320	160
4	4	5	160	320	240
4	5	2	160	480	40
4	5	4	160	480	160
5	0	5	240	0	240
5	1	3	240	40	80
5	2	4	240	80	160
5	3	1	240	160	20
5	3	3	240	160	80
5	3	5	240	160	240
5	5	0	240	480	0
5	5	1	240	480	20
5	5	3	240	480	80
5	5	4	240	480	160
5	5	5	240	480	240

per acre was plowed down. Forty pounds of P_2O_5 per acre was used as a starter fertilizer on all plots except the "no fertilizer" plots. One half was placed in a band two inches below and two inches to the side of the seed, and the other half in a band two inches to the side and six inches below the seed.

The seed bed was prepared by plowing with a rotating spade tiller trailed behind the plow. Certified Michigan 250 corn seed was planted immediately after plowing.

Weather

The growing season for corn (April through September) was not normal in 1956 as is shown in Figures 1 and 2. These data were obtained from the Battle Creek, Michigan airport weather bureau. (27, 29) April and July were wetter than average in 1956 but the other months were drier than average. September, 1956 was very dry in comparison with the twenty year average. The total rainfall for these six months in 1956 was 2.8 inches lower than for the twenty year average. June, 1956 was 2.4° F. warmer than the twenty year average. July, 1956 was 1.8° F. cooler than the twenty year average. The temperature differences for the other months were small.

Samples

Leaf samples consisting of ten basal ear leaves per plot were taken on August 13, 1956. The leaf, at the base of the ear, was sampled because it is considered to be representative of the chemical status in the plant at sampling time. (23) Pollination was complete and seeds had started to form at the time of sampling. The samples were ground and stored in cardboard containers until the analyses were made.

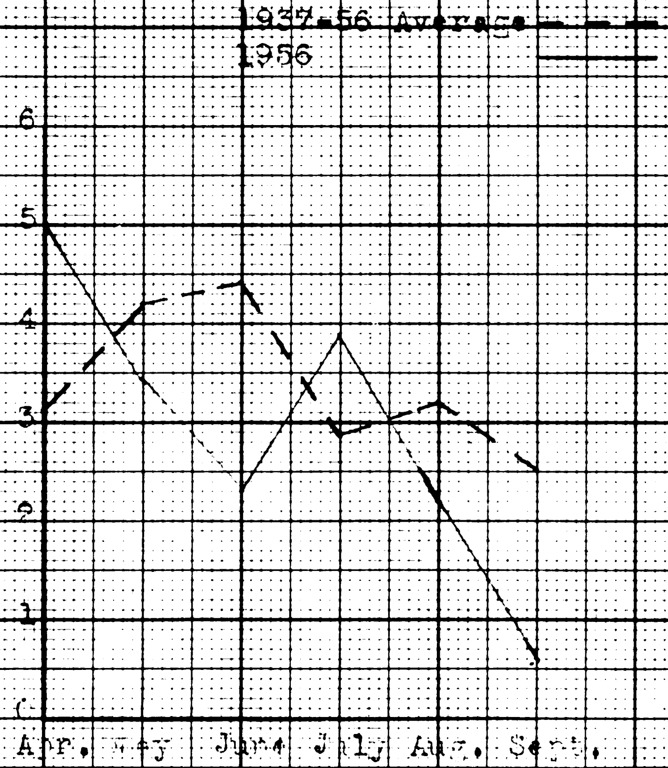

Fig. 1. A comparison of April-Sept., 1956 rainfall and the twenty year (1937-56) average.

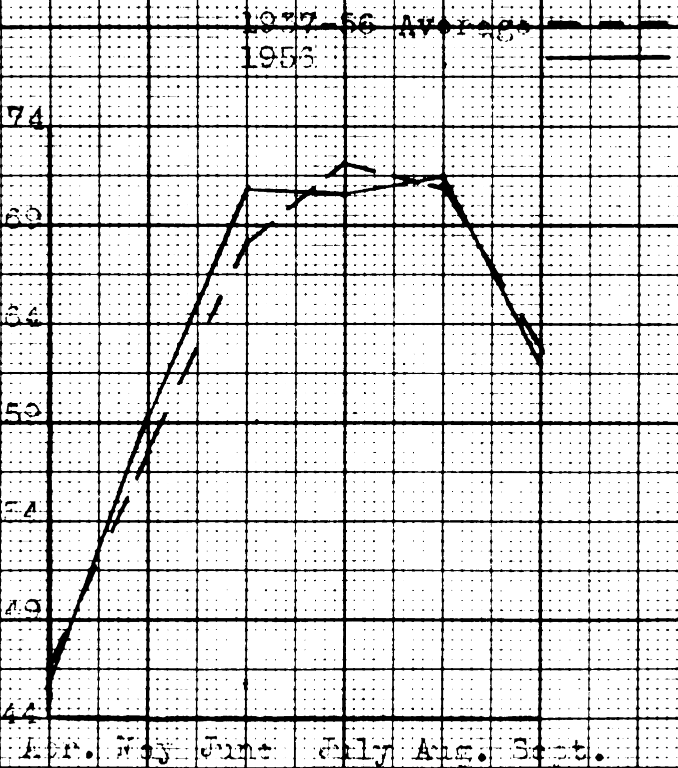

Fig. 2. A comparison of April-Sept., 1956 temperatures and the twenty year (1937-56) average.

The grain samples were obtained at harvest time. Twenty ears were taken from each plot. These were dried and then shelled. Subsamples were taken from the shelled corn. They were ground and stored in glass bottles until the analyses were made.

Chemical Analysis of Samples:

Wet Ashing

The plant tissue samples were wet ashed with certain modifications of the nitric acid - perchloric acid method described by Piper. (16) A two gram sample of material was ashed. The residue was taken up to volume (fifty milliliter) in 0.1 N. hydrochloric acid. This solution was filtered through Whatman # 42 filter paper into a clean glass bottle and stored as a stock solution.

Nitrogen Determination

The nitrogen content was determined by the Kjeldahl procedure with certain modifications of the method described by Pierce and Haenisch. (15) The nitrogen determinations were made prior to the author's study.

Phosphorus Determination

The phosphorus content was determined by the ammonium molybdate method. One milliliter of the stock solution was placed in a fifty milliliter volumetric flask and diluted to volume 0.5N. hydrochloric acid. Ten milliliters of this solution was then placed in a Coleman colorimeter tube. Six drops of ammonium molybdate reagent and six drops of Fiske-Subarrow (8) reagent were added [illegible] the contents of the colorimeter tube was shaken thoroughly. After standing twenty minutes, the transmittancy of the solutions was measured using a red filter (650 mu) on the Coleman Universal Spectrophotometer Model 14. These readings were compared to those on a previously developed standard curve.

Potassium Determination

Potassium was determined on the Perkin-Elmer flame photometer Model 52A using modifications of the method described by Toth, et al. (25) The stock solution was poured directly into the flame photometer and the readings compared to those on standards of known potassium content.

Calcium and Sodium Determination

Calcium and sodium contents were determined on the Beckman spectrophotometer Model DU with a flame attachment. The readings obtained were compared to those on standards of known calcium and sodium contents. The elements were not determined simultaneously. In each case the stock solution was poured directly into the cup and then placed in the flame. The spectrophotometer was adjusted as shown in Table II.

Magnesium Determination

Magnesium was determined by the method described by Drosdoff and Nearpass. (7)

TABLE II

ADJUSTMENTS OF THE BECKMAN SPECTROPHOTOMETER FOR THE DETERMINATION OF CALCIUM AND SODIUM

	Ca.	Na.
Wave length (mu)	422.7	589.3
Phototube filter	Blue	Blue
Phototube resistor	2.	2.
Phototube selector	0.1	0.1
Slit width	.01	.01
Photomultiplier sensitivity	Full	Full
Photomultiplier zero depression	1.	1.

RESULTS and DISCUSSION

Grain Composition as Affected by Various Rates and Ratios of Fertilizers

The corn grain had a relatively constant chemical composition as shown by Table III. It did not reflect large differences caused by various fertilizer treatments.

Nitrogen fertilizers frequently increase the nitrogen content of corn grain. This was not the case in this study. The plants apparently were able to obtain sufficient nitrogen from the soil to produce grain with a relatively constant nitrogen content. In this experiment, the corn followed clover - alfalfa hay. The nitrogen content of the grain varied between 1.15 and 1.87 percent, and averaged 1.55 percent. The high percentage in grain was produced on a plot which received forty pounds of nitrogen per acre. The low percentage in grain was produced on a plot which did not receive nitrogen fertilizer. One plot which received 240 pounds of nitrogen per acre produced grain containing 1.28 percent nitrogen.

The phosphorus content of the grain was not significantly affected by the various rates of phosphorus fertilizers. The phosphorus content of the grain averaged .21 percent and ranged between .13 and .23 percent. Beeson reported corn of a higher percent phosphorus content (3). Two plots, one of which received 480 pounds of phosphoric acid per acre and another which received 80 pounds, produced grain with the same phosphorus content.

TABLE III

THE EFFECT OF FERTILIZERS ON THE CHEMICAL COMPOSITION OF CORN GRAIN

Pounds Fertilizer per Acre			Percent (oven dry weight)					
N	P_2O_5	K_2O	N	P	K	Mg	Ca	Na
0	0	0	1.52	.23	.35	.19	.008	.007
0	40	20	1.15	.18	.30	.19	.009	.009
0	160	80	1.30	.17	.31	.19	.005	.008
0	480	240	1.57	.19	.33	.18	.011	.009
20	0	20	1.43	.17	.37	.15	.009	.010
20	40	0	1.53	.23	.37	.19	.010	.009
20	40	20	1.81	.18	.30	.20	.006	.010
20	40	240	1.51	.23	.35	.17	.010	.011
20	80	160	1.73	.22	.35	.19	.008	.007
20	160	80	1.56	.19	.30	.17	.002	.007
20	160	240	1.71	.17	.25	.19	.004	.009
20	320	40	1.63	.17	.33	.16	.002	.007
20	480	20	1.67	.23	.25	.18	.005	.007
20	480	80	1.28	.28	.33	.19	.008	.008
20	480	240	1.62	.26	.36	.20	.009	.011
40	40	40	1.77	.19	.21	.15	.006	.008
40	40	160	1.65	.25	.30	.15	.006	.006
40	80	20	1.87	.24	.30	.13	.007	.007
40	80	40	1.71	.21	.30	.15	.007	.008
40	80	80	1.46	.27	.36	.25	.005	.010
40	80	240	1.27	.26	.29	.10	.006	.009
40	320	20	1.46	.23	.30	.15	.006	.010
40	320	80	1.59	.26	.30	.20	.006	.011
40	320	240	1.73	.23	.36	.28	.009	.011
80	0	80	1.62	.25	.35	.18	.010	.010
80	40	20	1.44	.16	.35	.28	.009	.006
80	40	80	1.33	.17	.40	.23	.009	.011
80	40	240	1.44	.18	.30	.20	.006	.010
80	80	40	1.45	.18	.33	.20	.013	.008
80	80	160	1.60	.13	.2[illegible]	.23	.002	.007
80	160	0	1.50	.18	.39	.15	.00[illegible]	.008
80	160	20	1.21	.16	.38	.33	.007	.009
80	160	80	1.38	.20	.41	.23	.006	.007
80	160	240	1.74	.19	.36	.23	.010	.007
80	320	40	1.41	.22	.39	.20	.007	.008
80	320	160	1.72	.20	.38	.10	.005	.008
80	480	20	1.64	.17	.30	.13	.006	.010
160	40	40	1.75	.18	.34	.08	.008	.010
160	40	160	1.78	.23	.41	.25	.008	.006
160	80	40	1.59	.20	.37	.15	.007	.008
160	160	40	1.49	.19	.29	.13	.006	.009
160	320	20	1.55	.17	.27	.05	.00[illegible]	.010

TABLE III "continued"

N	P_2O_5	K_2O	N	P	K	Mg	Ca	Na
160	320	160	1.39	.22	.30	.28	.002	.006
160	320	240	1.62	.20	.27	.13	.007	.011
160	480	40	1.72	.23	.29	.20	.006	.009
160	480	160	1.18	.22	.30	.13	.007	.007
240	0	240	1.56	.24	.27	.13	.011	.009
240	40	80	1.73	.19	.22	.10	.006	.002
240	80	160	1.42	.28	.41	.33	.009	.008
240	160	20	1.34	.19	.27	.20	.009	.007
240	160	80	1.72	.19	.27	.02	.007	.011
240	160	240	1.05	.21	.29	.10	.009	.009
240	480	0	1.64	.19	.22	.18	.009	.007
240	480	20	1.56	.19	.29	.13	.009	[illegible]
240	480	80	1.28	.17	.30	.23	.011	.010
240	480	160	1.65	.16	.25	.22	.009	.002
240	480	240	1.50	.20	.37	.05	.009	.008

No apparent correlation was noted in regard to the amount of potash fertilizer used and the grain's potassium content. The grain's potassium content varied between .21 and .42 percent with an average of .32 percent. The grain containing .21 percent potassium was grown on a plot which received forty pounds of potash per acre, whereas, the highest testing grain had not received potash fertilizer.

Relationships Between Chemical Composition of Grain and Corn Yield

A statistical analysis of the data in Table III suggests several correlations. These are summarized in Table IV. The coefficient of multiple correlation, +.472, is significant at the 1% level of probability. This correlation coefficient relates yield as the dependent variable to the nitrogen, phosphorus, potassium, magnesium, calcium, and sodium content of the grain.

Figures 3 and 4 show the significant relationships between the grain's nitrogen and magnesium content to yield. The straight line in each figure represents a line of best fit for the data or a line which minimizes the sum of squared deviations from regression.

High yields were associated with grain that had a high nitrogen content. The highest yielding plot produced grain containing 1.85 percent nitrogen. The lowest yielding plot produced grain containing 1.51 percent nitrogen. The positive correlation between yield and the grain's nitrogen content, r = +.519, is significant at the 1% level of probability (Fig. 3).

TABLE IV

CORRELATION COEFFICIENTS BETWEEN YIELD, NITROGEN, PHOSPHORUS, POTASSIUM, MAGNESIUM, CALCIUM, AND SODIUM CONTENTS OF CORN GRAIN

	N	P	K	Mg	Ca	Na	Yield
N	1.	.036	-.160	-.254*	-.100	.010	.510**
P	.036	1.	.292*	.058	.133	-.038	-.032
K	-.160	.292*	1.	.282*	.309**	.004	-.205
Mg	-.254*	.058	.282*	1.	.071	-.118	-.259*
Ca	-.100	.133	.309**	.071	1.	.100	-.045
Na	.010	-.038	.004	-.118	.100	1.	.119

** Significant at the 1% level of probability
* Significant at the 5% level of probability

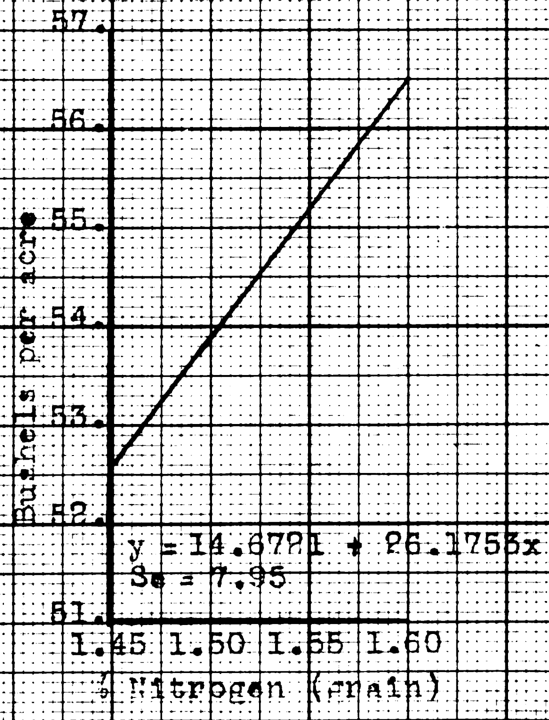

Fig. 3 The relationship between nitrogen contents of grain and corn yield.

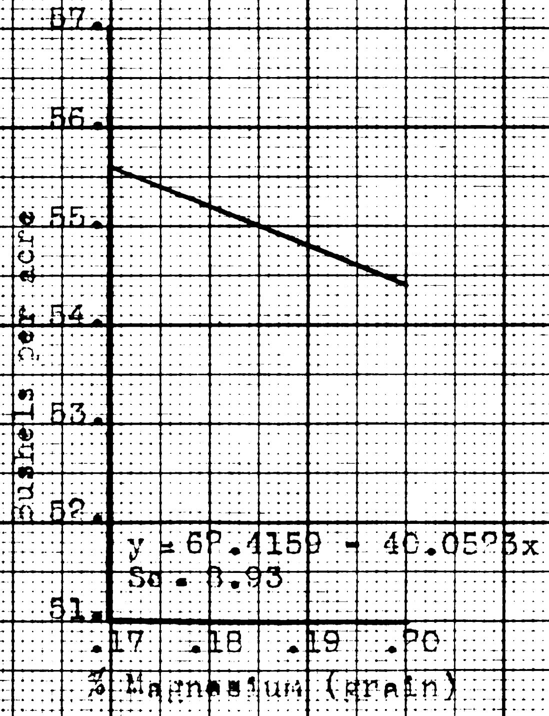

Fig. 4 The relationship between magnesium contents of grain and corn yield.

High yields were associated with grain of a low magnesium content. The highest yielding plot produced grain containing .10 percent magnesium. The grain from the lowest yielding plot contained .13 percent magnesium. The negative correlation between yield and the grain's magnesium content, r = -.259, is significant at the 5% level of probability (Fig. 4).

There were no significant correlation between grain yields and percentages of phosphorus, potassium, calcium, and sodium.

Interactions of Nutrient Elements in Corn Grain

There were a few significant relationships within the corn grain percentages of nitrogen, phosphorus, potassium, magnesium, calcium, and sodium. They are shown in Figures 5 through 8.

Grain with a relatively high nitrogen content had a low magnesium content (Fig. 5). The grain with the highest nitrogen content (1.27 percent) had a low magnesium content (.13 percent). The negative correlation between the grain's nitrogen and magnesium, r = -.254, is significant at the 5% level of probability.

Fig. 6 shows the relationship between the grain's percentages of phosphorus and potassium. The grain with the lowest phosphorus content (.13 percent) was very low in potassium (1.22 percent). The positive correlation between phosphorus and potassium, r = +.282, is significant at the 5% level of probability.

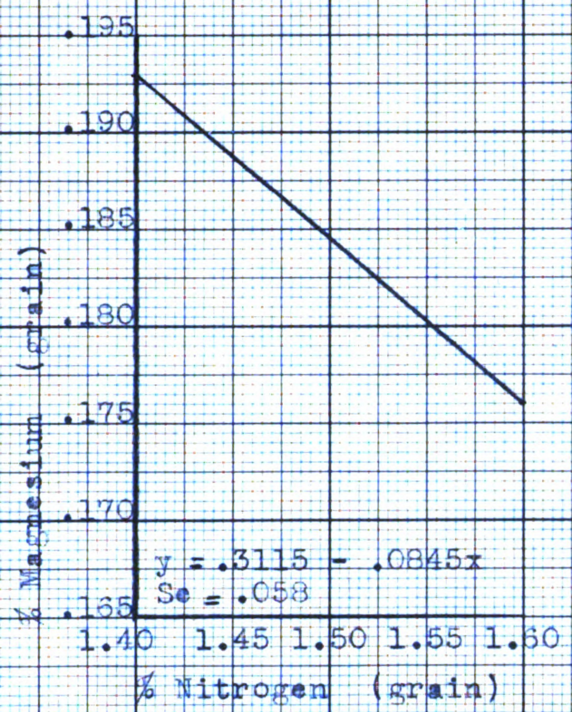

Fig. 5 The relationship between magnesium and nitrogen contents of the grain.

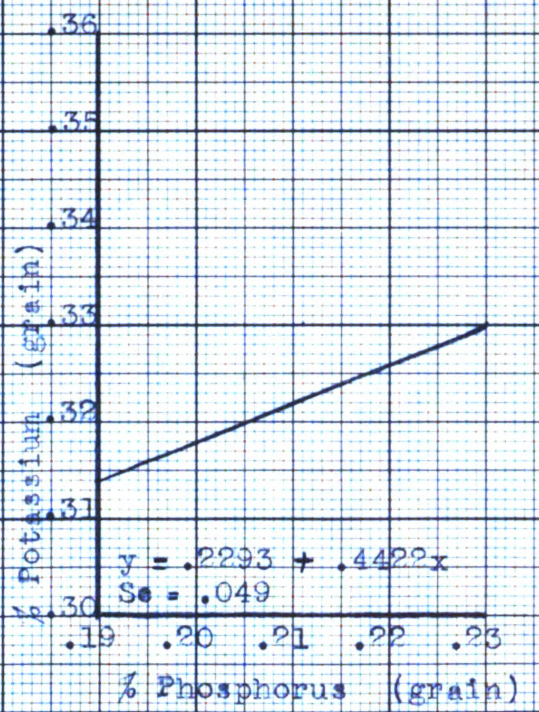

Fig. 6 The relationship between potassium and phosphorus contents of the grain.

A positive relationship was noted between potassium and magnesium (Fig. 7). The grain with the highest potassium content (.41 percent) was high in magnesium (.33 percent). The correlation between the grain's potassium and magnesium content, r = +.282, is significant at the 5% level of probability.

Fig. 8 shows the relationship between the grain's calcium and potassium content. The grain with the lowest calcium (.002 percent) was very low in potassium (.22 percent). The positive correlation between the grain's calcium and potassium percentages, r = +.300, is significant at the 1% level of probability.

The statistical analyses showed there was no relationship between nitrogen and phosphorus, potassium, calcium, or sodium content. Likewise the grain's phosphorus content was not significantly correlated with magnesium, calcium, or sodium, and potassium and sodium percentages were not significantly related. Further there were no significant correlations between magnesium, calcium, and sodium.

Leaf Composition as Affected by Various Rates and Ratios of Fertilizers

The data in Table V show that leaf tissue varied more in chemical composition, as affected by fertilizer, than did grain.

The effect that the different levels of nitrogen fertilizer had on percentages of nitrogen is shown in Fig. 9. The correlation coefficient between the amount of nitrogen fertilizer applied and the percent nitrogen in the leaf, r = +.564, is significant at the 1% level of probability. The nitrogen content varied from 1.83 to 3.15 percent with an average of 2.53

TABLE V

THE EFFECT OF FERTILIZERS ON THE CHEMICAL COMPOSITION OF CORN LEAF

Pounds Fertilizer per Acre			Percent (oven dry weight)					
N	P_2O_5	K_2O	N	P	K	Mg	Ca	Na
0	0	0	2.35	.15	1.51	.45	.[illegible]7	.010
0	40	20	2.13	.13	1.69	.45	1.01	.010
0	160	80	1.83	.11	2.25	.33	.81	.014
0	480	240	2.12	.14	2.30	.28	.66	.009
20	0	20	2.55	.13	1.65	.41	.75	.010
20	40	0	2.78	.13	1.20	.49	.86	.010
20	40	20	2.20	.18	1.73	.40	.66	.007
20	40	240	2.30	.14	2.43	.[illegible]	.69	.010
20	80	160	2.41	.12	2.30	.29	.73	.010
20	160	80	2.34	.17	2.13	.34	.62	.010
20	160	240	2.14	.13	2.43	.23	.75	.007
20	320	40	2.30	.13	1.46	.56	.84	.010
20	480	20	2.66	.22	1.02	.60	.91	.009
20	480	80	2.41	.25	2.00	.26	.71	.011
20	480	240	2.14	.24	2.26	.35	.68	.010
40	40	40	2.53	.12	1.73	.34	.84	.010
40	40	160	2.52	.13	2.38	.29	.63	.008
40	80	20	2.38	.17	1.27	.31	.93	.011
40	80	40	2.56	.19	1.69	.43	.93	.008
40	80	80	2.52	.18	1.62	.30	.72	.009
40	80	240	2.31	.20	1.24	.28	.80	.011
40	320	20	2.21	.23	2.43	.35	.80	.008
40	320	80	2.25	.23	1.65	.43	.73	.007
40	320	240	2.11	.20	1.80	.28	.67	.008
80	0	80	2.96	.23	1.78	.43	.80	.010
80	40	20	2.64	.23	1.41	.53	.[illegible]9	.009
80	40	80	2.67	.24	1.75	.30	.93	.009
80	40	240	2.30	.23	1.83	.34	.73	.009
80	80	40	2.65	.20	1.75	.30	.73	.007
80	80	160	2.83	.22	2.14	.25	.62	.007
80	160	0	2.85	.21	1.08	.83	1.28	.009
80	160	20	2.59	.24	1.65	.41	.84	.010
80	160	80	2.34	.25	1.[illegible]	.39	.71	.010
80	160	240	2.62	.20	2.13	.23	.57	.008
80	320	40	2.45	.26	1.49	.43	.80	.00[illegible]
80	320	160	2.33	.24	1.95	.33	.69	.009
80	480	20	2.52	.30	.99	.73	1.06	.011
160	40	40	2.60	.19	1.58	.38	.89	.006
160	40	160	2.94	.19	1.84	.25	.71	.006
160	80	40	3.00	.13	1.65	.43	.88	.014
160	160	40	2.44	.11	1.19	.56	1.25	.011
160	320	20	2.73	.19	1.20	.61	1.09	.006

TABLE [illegible] "continued"

[illegible]	P_2O_5	K_2O	[illegible]	[illegible]	[illegible]	[illegible]	Ca	[illegible]
160	320	160	[illegible].31	.13	2.10	.31	.77	.011
160	320	240	2.76	.15	2.[illegible]	[illegible]	.3[illegible]	[illegible]
[illegible]	[illegible]	40	2.91	.24	1.10	.30	.30	.007
160	4[illegible]0	160	2.20	.19	2.16	.28	.2[illegible]	.007
240	0	240	3.01	.17	2.41	.25	.47	.007
240	40	80	2.17	.14	2.16	.3[illegible]	[illegible]	.00[illegible]
240	80	160	2.[illegible]1	.16	2.13	.23	.2[illegible]	.003
240	120	[illegible]0	2.5[illegible]	.14	1.69	.40	[illegible]	[illegible]
240	160	[illegible]0	2.[illegible]	.17	1.45	.51	.94	.005
240	160	240	3.15	.1[illegible]	1.73	.25	.57	.004
240	4[illegible]	0	2.71	.22	1.6[illegible]	.53	.39	.005
240	4[illegible]0	[illegible]0	2.54	.22	1.23	.58	1.02	[illegible]
240	4[illegible]0	[illegible]0	2.05	.17	2.4[illegible]	.25	.30	.004
240	480	1[illegible]0	2.27	.2[illegible]	1.[illegible]	.40	.35	.007
240	480	240	2.[illegible]0	.23	1.7[illegible]	.36	.2[illegible]	.007

percent. The leaf sample containing 3.15 percent nitrogen was taken from a plot which received 240 pounds of nitrogen per acre. A plot which received no nitrogen produced the leaf containing 1.83 percent nitrogen.

The data in Fig. 10 show that the phosphorus content of the leaf was directly proportional to the amount of phosphoric acid applied. The correlation between applied phosphoric acid and the phosphorus content of the leaf, r= +.447, is significant at the 1% level of probability. Phosphorus content varied from .11 to .36 percent with an average of .19 percent. The leaf sample which contained .36 percent phosphorus was taken from a plot which had received 480 pounds of phosphoric acid per acre. Two plots which received 160 pounds per acre produced leaf samples containing .11 percent phosphorus.

Increasing increments of potash fertilizer increased the potassium content of corn leaf (Fig. 11). The correlation coefficient between applied potash and the percent potassium in the leaf, r= +.600, is significant at the 1% level of probability. Potassium varied from .99 to 2.43 percent with an average of 1.76 percent. The leaf sample which contained 2.43 percent potassium was produced on a plot which received 240 pounds of potash per acre. A plot which received 20 pounds of potash per acre produced the leaf sample containing .99 percent potassium.

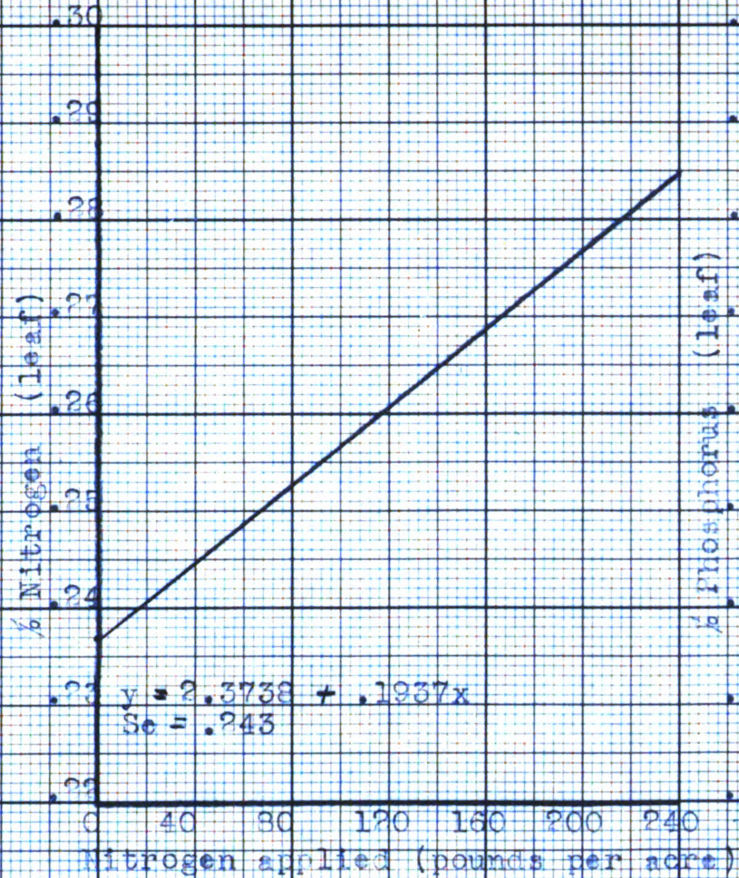

Fig. 9 The relationship between nitrogen content of the leaf and applied nitrogen

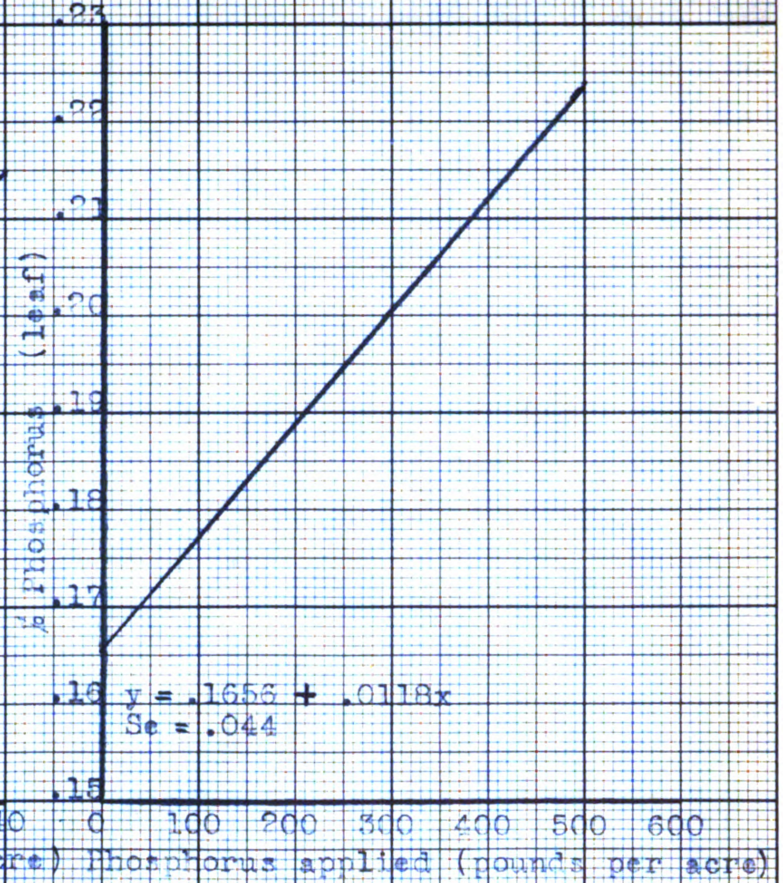

Fig. 10 The relationship between phosphorus content of the leaf and applied phosphorus.

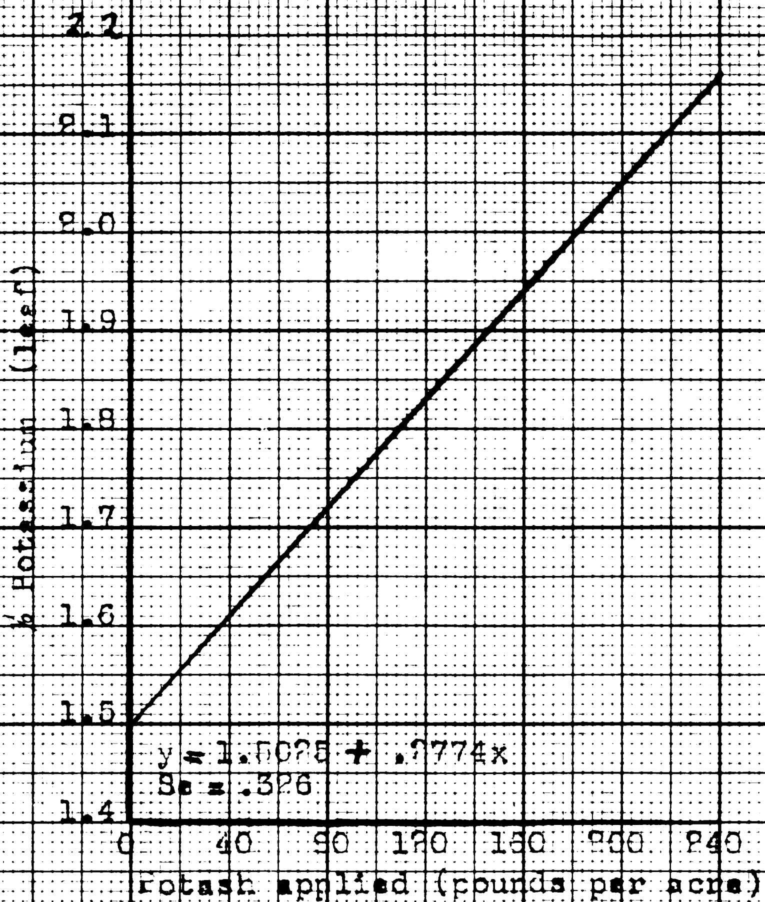

Fig. 11 The relationship between potassium content of the leaf and applied potash.

Relationships Between Chemical Composition of Leaf and Corn Yield

The data in Table VI summarizes the relationships found in a statistical analysis of the data shown in Table V. The coefficient of multiple correlation, +.412, is significant at the 1% level of probability. This correlation coefficient relates yield as the dependent variable to the percentages of nitrogen, phosphorus, potassium, magnesium, calcium, and sodium.

Corn which had leaves with a high nitrogen content yielded more than corn with leaves of a low nitrogen content. The highest yielding plot produced leaves containing 3.15 percent nitrogen while the lowest yielding plot produced leaves containing 2.54 percent nitrogen. The positive correlation between yield and the leaf's nitrogen content, r = +.415, is significant at the 1% level of probability. This relationship is shown in Fig. 12.

Corn which had leaves with a high sodium content yielded less than corn with leaves of a low sodium content. The highest yielding plot produced leaves containing .004 percent sodium while the lowest yielding plot produced leaves containing .006 percent sodium. The negative correlation between yield and the leaf's sodium content, r = -.234, is significant at the 5% level of probability. Fig. 13 shows this relationship.

There were no significant relationships between yield and percentages of phosphorus, potassium, magnesium, or calcium.

TABLE VI

CORRELATION COEFFICIENTS BETWEEN YIELD, NITROGEN, PHOSPHORUS, POTASSIUM, MAGNESIUM, CALCIUM, AND SODIUM CONTENTS OF CORN LEAF

	N	P	K	Mg	Ca	Na	Yield
N	1.	.108	-.219*	.082	-.017	-.337**	.415**
P	.108	1.	-.203	.231*	.034	-.133	-.040
K	-.219*	-.203	1.	-.806**	-.667**	-.172	-.018
Mg	.082	.231*	-.806**	1.	.817**	.190	-.031
Ca	-.017	.034	-.667**	.817**	1.	.220*	-.184
Na	-.337**	-.133	-.172	.190	.220*	1.	-.234*

** Significant at the 1% level of probability
* Significant at the 5% level of probability

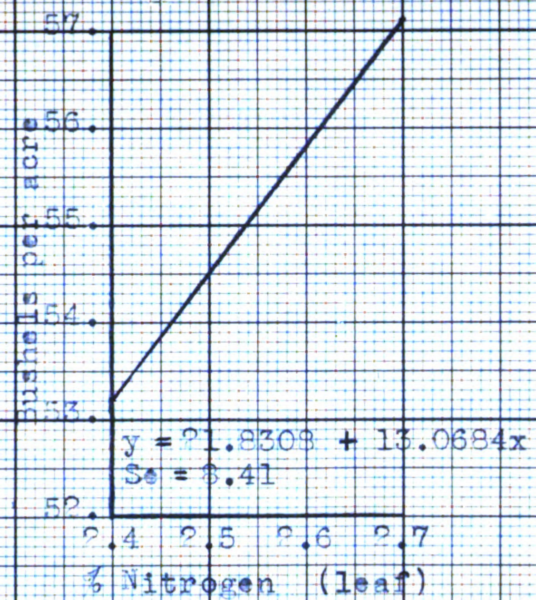

Fig. 12 The relationship between yield and nitrogen content of the leaf.

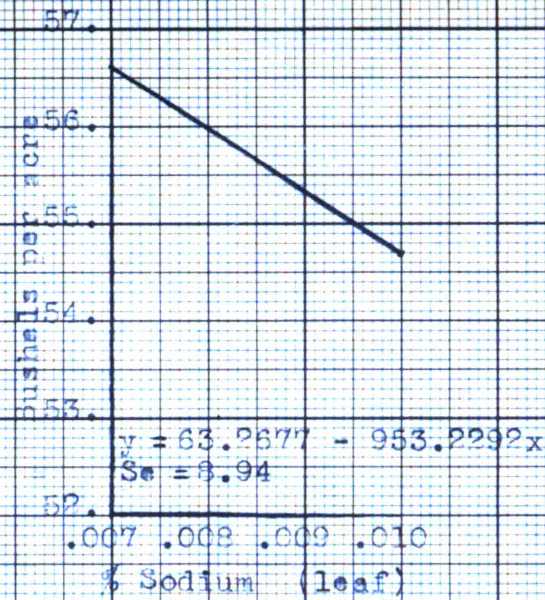

Fig. 13 The relationship between yield and sodium content of the leaf.

Interactions of Nutrient Elements in Corn Leaf

An inverse relationship was found between the nitrogen and potassium percentages in the leaves (Fig. 14). The leaf sample which had the highest nitrogen content (3.15 percent) had a below average potassium content of 1.73 percent. The leaf sample which had the highest potassium content (2.43 percent) also had a low nitrogen content (2.03 percent). The negative correlation between percentages of nitrogen and potassium, r= -.913, is significant at the 5% level of probability.

Fig. 15 shows the inverse relationship, r = -.337 (1%), noted between nitrogen and sodium. The sample with the lowest nitrogen content (1.83 percent) had the highest sodium content (.014 percent).

A direct relationship was noted between phosphorus and magnesium. The sample which had the highest phosphorus content (.36 percent) was high in magnesium (.73 percent). The correlation, r= +.931, is significant at the 5% level of probability (Fig. 16).

A statistically significant inverse relationship was noted between potassium and magnesium (Fig. 17). The samples with the highest potassium content (2.43 percent) were low in magnesium (.29 percent). The negative correlation, r = -.806, is significant at the 1% level of probability.

Corn leaves with a high potassium content had a low calcium content (Fig. 18). The leaves with the most potassium (2.43 percent) were below average in calcium (.75 percent). The negative correlation, r = -.667, is significant at the 1% level of probability.

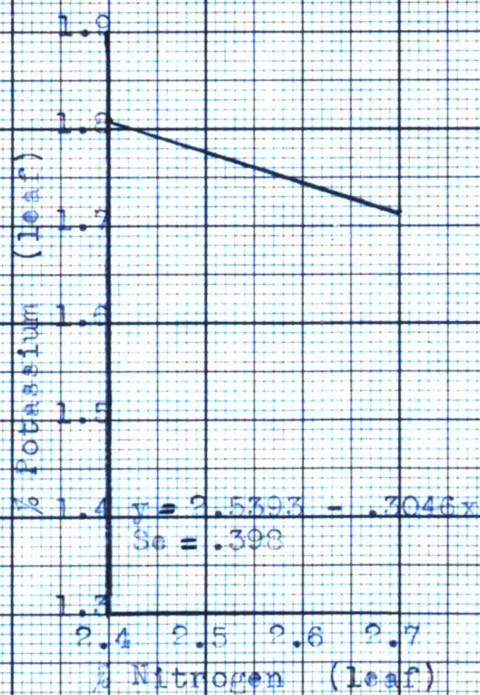

Fig. 14 The relationship between potassium and nitrogen contents of the leaf.

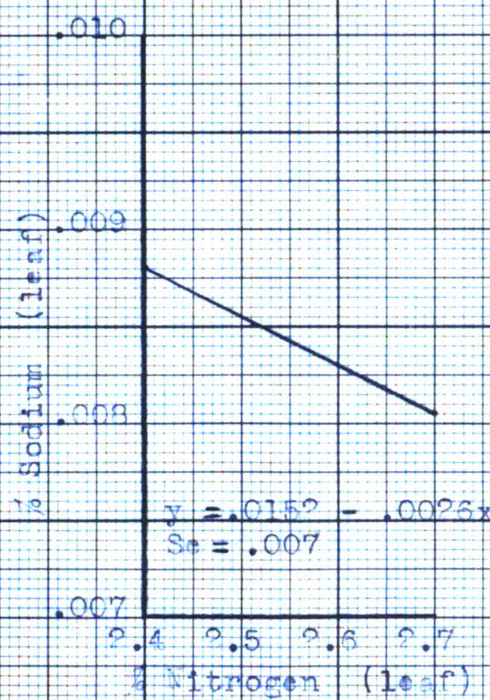

Fig. 15 The relationship between sodium and nitrogen contents of the leaf.

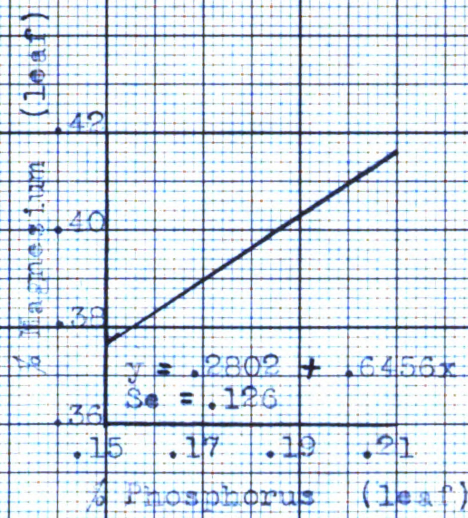

Fig. 16 The relationship between magnesium and phosphorus contents of the leaf.

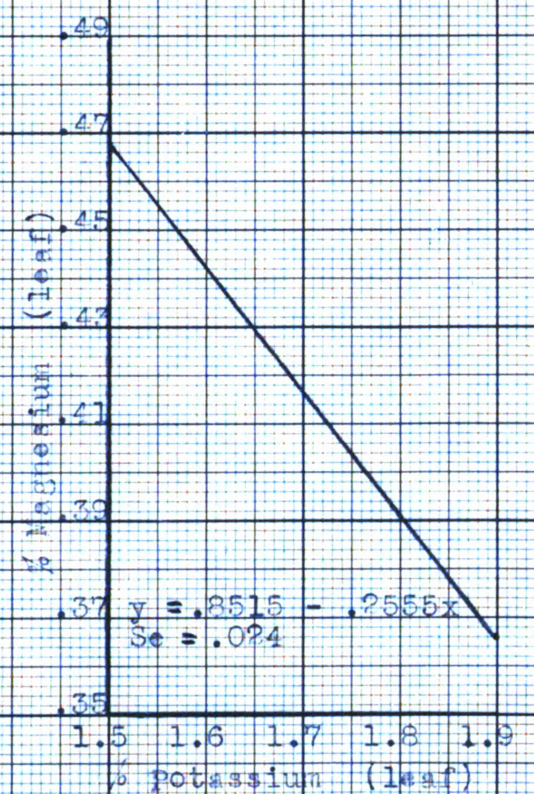

Fig. 17 The relationship between magnesium and potassium contents of the leaf.

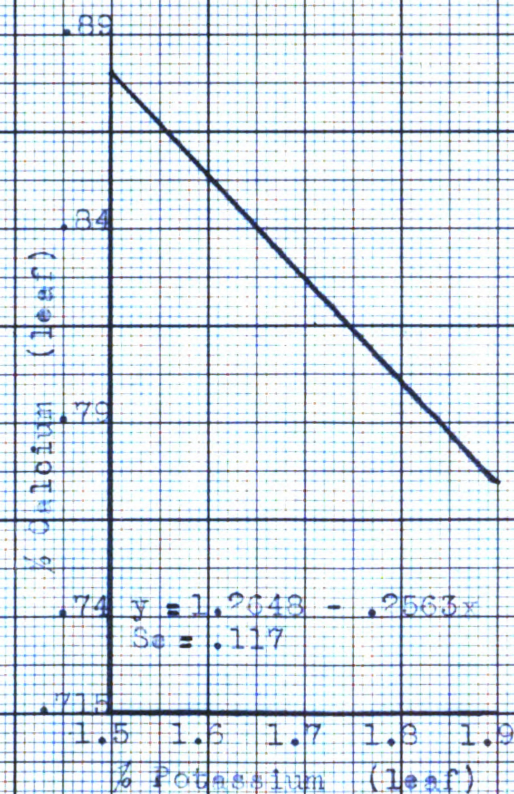

Fig. 18 The relationship between calcium and potassium contents of the leaf.

Calcium and magnesium percentages were found to be closely correlated (Fig. 19). The leaves with the highest calcium (1.28 percent) had the highest magnesium content (.83 percent). The positive correlation between calcium and magnesium, r= +.817, is significant at the 1% level of probability.

The leaves with a high calcium content were high in sodium (Fig. 20). The sample with the most calcium (1.28 percent) was average in content of sodium (.009 percent). The positive correlation, r= +.220, is significant at the 5% level of probability.

There was no significant relationship between the nitrogen content of corn leaves and percentages of phosphorus, potassium, calcium, or sodium. Also phosphorus content was not related to percentages of potassium, calcium, or sodium. Potassium and sodium percentages and the leaf's magnesium and sodium contents were not related.

Interchangeable Chemical Elements of Leaf and Grain of Corn

Percentages of nitrogen in grain and leaves were directly related as shown in Fig. 21. The plot which produced the leaves with the highest nitrogen content (3.15 percent) also produced grain with a high nitrogen content (1.25 percent). The positive correlation, r= +.219, is significant at the 5% level of probability.

The data in Fig. 22 show that the grain with a high magnesium content was associated with leaves of low magnesium content. The plot which produced the grain with the highest magnesium content (.33 percent) produced leaves average in magnesium content. The negative correlation, r= -.238, is significant at the 5% level of probability.

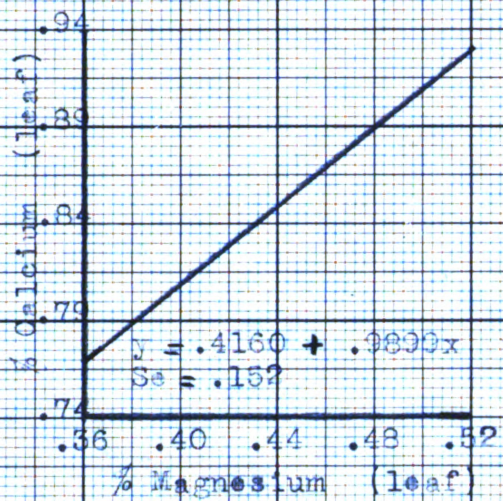

Fig. 19 The relationship between calcium and magnesium contents of the leaf.

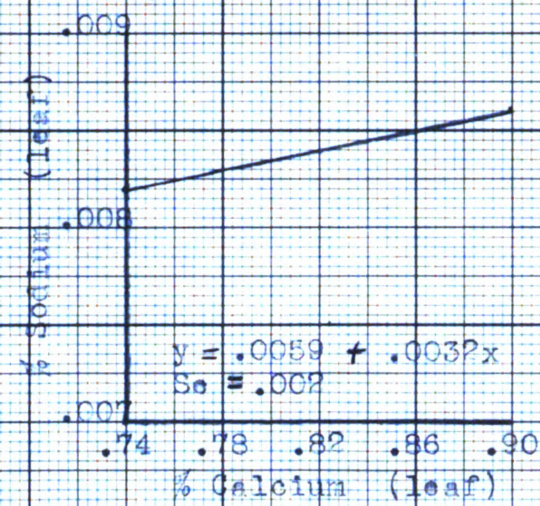

Fig. 20 The relationship between sodium and calcium contents of the leaf.

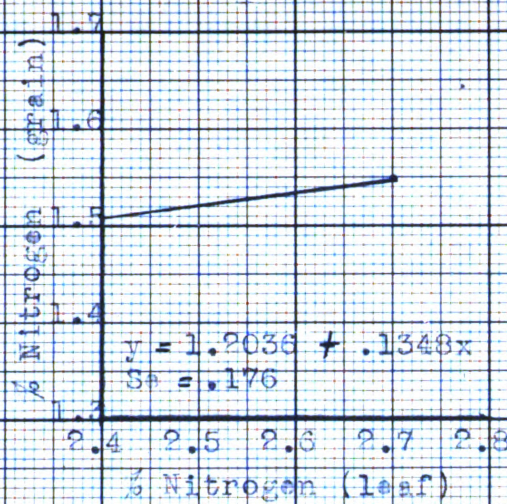

Fig. 21 The relationship between the nitrogen content of the grain and leaf of corn.

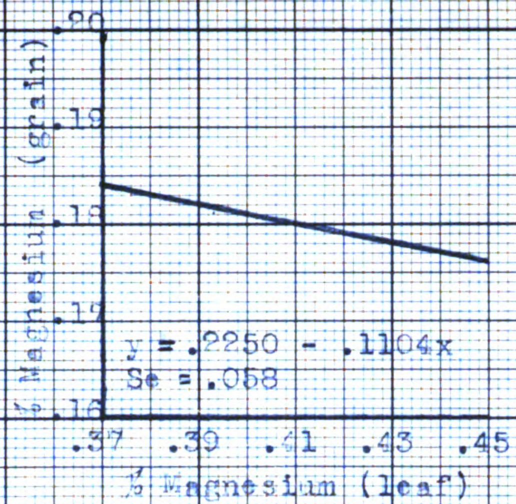

Fig. 22 The relationship between the magnesium content of the grain and leaf of corn.

There were no consistent relationships between percentages of phosphorus, potassium, calcium, and sodium in the grain with the percentages of the same elements in the leaves.

Yield as Affected by Various Fertilizer Rates and Ratios

The effect of nitrogen, phosphoric acid, and potash on corn yield is shown in Table VII. The yields ranged from 39.8 to 76.2 bushels shelled corn per acre with an average of 55.2 bushels per acre. The yields were probably affected by the lower than average precipitation which fell in 1956.

The lowest yielding plot (39.8 bushels per acre) and the highest yielding plot (76.2 bushels) each received 240 pounds of nitrogen per acre. The highest yielding plot received 160 pounds of phosphoric acid and 240 pounds of potash per acre. The lowest yielding plot received 480 pounds of phosphoric acid and 80 pounds of potash per acre. The low potash application was probably a yield limiting factor. The high phosphoric acid application also may have been a yield limiting factor.

Nitrogen fertilizers were found to increase the leaf's nitrogen content. As the leaf's nitrogen content increased, yields increased. Leaves of a high nitrogen content were associated with leaves of a low sodium content. High yields were associated with leaves of a low sodium content. Corn grain from high yielding plots contained a high percentage of nitrogen. Grain from low yielding plots contained a low percentage of magnesium. A high magnesium content in the grain was associated with a low yield of corn. In this study, nitrogen fertilizers increased the corn yield.

TABLE VIII

THE EFFECT OF FERTILIZERS ON CORN YIELD

Pounds Fertilizer per Acre N	P_2O_5	K_2O	Bushels shelled corn per acre
0	0	0	51.1
0	40	20	55.4
0	160	80	41.5
0	480	240	53.6
20	0	20	50.2
20	40	0	53.8
20	40	20	70.1
20	40	240	50.4
20	80	160	53.6
20	160	80	50.4
20	160	240	42.4
20	320	40	57.1
20	480	20	51.2
20	480	80	51.9
20	480	240	52.8
40	40	40	69.2
40	40	160	67.5
40	80	20	57.1
40	80	40	62.3
40	80	80	51.2
40	80	240	53.8
40	320	20	46.3
40	320	80	55.4
40	320	240	55.4
80	0	80	55.4
80	40	20	45.0
80	40	80	50.6
80	40	240	46.7
80	80	40	50.2
80	80	160	51.9
80	160	0	57.1
80	160	20	46.7
80	160	80	57.1
80	160	240	55.4
80	320	40	45.0
80	320	160	53.8
80	480	20	57.1
160	40	40	57.1
160	40	160	69.2
160	80	40	72.7
160	160	40	43.3
160	320	20	62.3

TABLE VII "continued"

	Fe_2O_3	K_2O	
160	320	160	43.4
160	320	240	30.6
160	480	40	43.3
160	480	160	48.4
240	0	240	60.6
240	40	80	57.1
240	80	160	41.5
240	160	[illegible]	43.4
240	160	80	74.4
240	160	240	76.2
240	420	0	74.4
240	480	80	39.3
240	480	[illegible]	43.4
240	480	160	69.2
240	480	240	48.4

Phosphoric acid fertilizers did not increase the yield but increased the amount of phosphorus, magnesium, sodium, and calcium in the leaf. Low yields were associated with leaves of a high sodium content.

Potash fertilizers increased the leaf's potassium content. Leaves with a high potassium content contained less calcium, sodium, and magnesium than did leaves of a low potassium content. Leaves with a high calcium content generally had a high sodium content. Potash fertilizers increased corn yields in this study.

SUMMARY

The grain and the "ear leaf" of corn which had been fertilized with various wide combinations and rates of nitrogen, phosphoric acid, and potash were analyzed for nitrogen, phosphorus, potassium, magnesium, calcium, and sodium.

The coefficients of multiple correlation which related corn yield to the nitrogen, phosphorus, potassium, magnesium, calcium, and sodium contents of the grain and leaf were significant at the 1% level of probability.

Several other relationships were noted in a statistical analysis of the data. The following reversible relationships were found to be significant at the indicated level of probability:

Low yielding corn had leaves which were high in sodium and magnesium. (5%)

High yielding corn had leaves and grain which were high in nitrogen. (1%)

An increase in the nitrogen content of the leaf was associated with a decrease in the leaf's potassium content. (5%)

Leaves with a high nitrogen content had a low sodium content. (1%)

Leaves with a high calcium content also had a high sodium content. (5%)

Leaves with a high calcium content had a high magnesium content. (1%)

Leaves with a high magnesium content had a high phosphorus content. (5%)

Leaves with either a high calcium or magnesium content had a low potassium content. (1%)

An increase in the grain's nitrogen content was accompanied with a decreased magnesium content. (5%)

Grain with a high magnesium content had a high potassium content. (5%)

Grain with a high potassium content had a high phosphorus content. (5%)

Grain with a high potassium content had a high calcium content. (1%)

Leaves with high nitrogen contents were associated with grains of high nitrogen content. (5%)

Leaves with high magnesium contents were associated with grains of low magnesium content. (5%)

The nitrogen, phosphorus, and potassium content of the leaf was significantly affected by the amount of nitrogen, phosphoric acid, and potash applied. The nitrogen, phosphorus, and potassium content of the grain was relatively constant regardless of the rate of fertilizer application.

Nitrogen and potash fertilizers tended to increase the corn yield. Phosphoric acid fertilizers did not alter the corn yield.

The growing season of 1950 was not normal ([illegible] inches less precipitation than the twenty year average).

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