CHEMICAL STUDIES OF NUTRIENT REQUIREMENTS OF CORN AND MILO

by

CARL JACOB KNAUSS

B. S., Kansas State College
of Agriculture and Applied Science, 1952

A THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1953

TABLE OF CONTENTS

INTRODUCTION

The farm economy of Kansas is dependent upon the corn and milo crops to a greater extent than most people realize. The corn crop ranks second among cultivated crops in the state. Since this is true, more information is needed with respect to the nutrient needs of both crops.

The purpose of this investigation was to acquire facts concerning the nutrient requirements of these crops, both with respect to the three primary fertilizer elements, nitrogen, phosphorus and potassium and in some cases the secondary nutrient, magnesium. These nutrient elements were applied alone and in combination with one another under various Kansas conditions. In order to acquire facts relative to plant nutrient needs, chemical studies were made with the leaves of the plants because the leaves play a vital part in the plants nutritional processes. Other areas of the country have acquired data of this nature but because of the difference in environment, such as variations in temperature, rainfall and soil, the findings of such research may not apply to Kansas.

Leaf analysis with its proper interpretation reveal shortages of essential plant foods, and gives a most direct guide to better fertilizer practices and better crops.

REVIEW OF LITERATURE

Investigations have shown that there are potassium deficiencies in the soils in Southeast Kansas. For this reason, more work is necessary in arriving at the fertilizer needs of most of these soils.

In early studies done at Rothamsted by Hall (8) plant diagnosis was used to determine the nutrient content of the barley plant. He concluded that though the straw of the barley showed very considerable fluctuation in its potash content it was not always possible to interpret the results. Salter and Ames (13) in 1928 also did work on the problem of nutrient uptake of plants and concluded that so many factors influence the nutrient composition of the plant that the use of plant analysis as a guide to evaluate the fertilizer requirements of crops was not likely.

Up to the present time many surveys have been made throughout the country to determine the nutrient requirement of crops. Most of these surveys were made to plot the areas of nutrient deficiencies of the soil on which horticultural crops were grown. Leaf samples of apple trees from areas over New York and Washington were analyzed to locate such deficiencies. In states like California, leaf samples have been taken from vineyards and citrus groves to determine areas of nutrient deficiencies. These surveys were invaluable in estimating the fertilizer requirements of such crops.

It has not been until more recent years that leaf analysis has been applied to field crops for purpose of evaluating the fertilizer needs. Following this kind of work Tyner (15) established the critical lower limits for content of nitrogen, phosphorus and potassium in the sixth leaf of the corn plant at about 2.90 per cent N, .295 per cent P and 1.30 per cent K. It was noted that an increase above these levels of nitrogen, phosphorus and potassium content resulted in a doubtful or rapidly decreasing response to greater applications of these nutrient elements.

Bennett and Stanford (5) found that there was a significant increase in the phosphorus uptake when nitrogen increased the uptake of nitrogen. There was a definite relationship between yield and the nitrogen and phosphorus content of the leaf. When the nitrogen percentage in the leaf reached the level of 2.8 per cent there was no increase in yield above this level.

For the proper use of potassium fertilizers an understanding must be had as to the needs of the particular crop that is to be fertilized. The supplying power of the soil is of great importance in respect to the use of potassium for crop production. Most root crops and legumes require large quantities of potassium for best growth according to Baver (3). The quality of the crop depends greatly on the quantity of potassium available for growth. Hoffer (9) found that if the potassium was deficient the crop was often found to be poor in quality. The amount of potassium used by the corn crop is great. If corn is produced on soil low in potassium like some of those found in Southeast Kansas there may occur reductions in both yield and quality.

Investigations at the Columbus Experiment Field on soil fertility reported on by Smith (14) showed an average increase in yield by the addition of potassium to corn, wheat, alfalfa and soybeans. The greatest yield response was with corn. Soybeans seem to have responded to potassium in recent years. The response to potash to alfalfa has been very small but almost always present. Oats and wheat have not given response every year to fertilizer potassium.

Pierre and Bower (10) concluded that potassium absorption by plants usually was decreased by the presence of high concentrations of other cations in solution, but in some cases it may be increased.

Potassium, having a higher competitive ability than other cations, may affect the absorption of calcium and magnesium to a greater extent than potassium absorption is affected by the calcium or magnesium concentration. They stated that the influence of plant species and ratios of other cations influence the potassium absorption by plants.

MATERIALS AND METHODS

Cultural Methods

Representative farms were selected from corn and milo producing regions of Kansas and fertilizer experiments were located on these. The corn was planted at the following Southeast Kansas locations: (1) Fred Oplotnik, Girard; (2) Shaffer brothers, Columbus; (3) Chester Stapleton, Oswego; (4) Andy Aubert, Wier; (5) W. L. Murray, Mound City; (6) J. B. Warren, Garnett; (7) W. F. Zimmerman, Parker; (8) Thayer Experiment Field, Thayer, and (9) Ernest Harms, Thayer. The locations where corn was planted in Northeast Kansas were: (1) Fred Fouth, Reserve; (2) James Howard, Belleville, and (9) Glenn Topliff, Esbon. There were three milo locations that were used in this work: (1) James Howard, Belleville; (2) Glenn Topliff, Esbon, and (3) Edward Voight, Great Bend.

The treatments that were given to the soil on which the Southeast Kansas corn grew are listed in Table 1.

Table 1. Fertilizer treatments employed in nutrient studies made with corn grown in Southeastern Kansas.

Treatment No.	Fertilizer treatment (pounds per acre) N	P_2O_5	K_2O
1	No treatment		
2	0	80	80
3	0	0	80
4	0	80	0
5	80	80	0 + 80# N sidedressed[1]
6	80	0	80 + 80# N sidedressed
7	80	0	0 + 80# N sidedressed
8	80	80	80 + 80# N sidedressed
9	St	St	St[2]
10	St	St	St + Mg

1/Sidedressing made in late June or early July
2/St refers to applications of fertilizer elements made according to existing soil test recommendations. These amounts were 60-30-20 (N, P_2O_5 and K_2O respectively) for the Oplotnik, Thayer Experiment Field, Harms, Warren and Zimmerman locations; 30-30-20 at the Murray location; 60-20-30 at the Stapleton location; 60-20-20 at the Shaffer location and 60-30-30 at the Aubert location.

The treatments used in the Northeast Kansas corn fields and the milo fields were the same with one exception, 333 pounds of commercial 12-12-12 fertilizer were placed on the milo in place of the 40-40-40 split boot application that was placed on the corn. The treatments used are listed in Table 2.

Table 2. Fertilizer treatments employed in nutrient studies made with milo and with corn grown in Northeastern Kansas.

Treatment No.	Fertilizer treatment (pounds per acre)		
	N	P_2O_5	K_2O
1	No treatment		
2	40	0	0
3	0	40	0
4	0	0	40
5	40	40	0
6	40	0	40
7	0	40	40
8	40	40	40
9	80	0	0
10	80	40	0
11	80	0	40
12	80	40	40
13	20	40	20 + 20# N sidedressed
14	0	40	40 + 40# N sidedressed
15	40	40	40 + 40# N sidedressed
16	40	40	40 + Split boot application

The first two weeks of May were the planting dates for all the locations. The corn hybrid grown at most locations was K-1830 with the exception of the locations at Oswego and Wier where U. S. 523 W was grown, Reserve where Steckley's 100 A was grown, Esbon where Funks 94 was used, and at Belleville where K-1859 was planted. All the treatments were placed in randomized blocks with four replications.

The fertilizers used to carry the nutrients in all cases were the same. Ammonium nitrate, which contains 33 1/2 per cent N was used as the nitrogen carrier for the treatments. Muriate of potash, containing 60 per cent K_2O, was the potassium carrier. Phosphorus was applied to the soil by using triple superphosphate which contained approximately 43 per cent available P_2O_5. "Sul-Po-Mag" was used to supply the magnesium and potassium to the corn at the locations where magnesium was added. This material contains approximately 21 per cent K_2O and 18.5 per cent MgO.

Chemical Analysis of Soils

The soils on which the corn and milo was planted was first analyzed by the soil test methods used in the Kansas State soil testing laboratory. The laboratory determinations included pH, lime requirement, available phosphorus, exchangeable potassium, and organic matter.

The pH of the soil was determined with a Leeds-Northrup glass electrode. Ten milliliters of distilled water were added to a 10 gram sample of soil. This mixture was stirred and allowed to stand for 30 minutes and then stirred again. A lime requirement determination was made on each sample having a pH value below 6.10 by using Woodruff's buffer (16). Twenty milliliters of the buffer solution were added to each of these samples and after 30 minutes the pH was again taken. For every tenth of a pH unit under pH 7.0 one thousand pounds of lime per acre was recommended.

The phosphorus determination was made by Bray's fulfonic acid reduction colorimetric method (6) as modified by Arnold and

Kurtz (1). The Coleman Jr. Spectrophotometer was used to measure the intensity of the blue color produced.

Exchangeable potassium of the soil was determined by shaking 10 grams of the soil in 50 milliliters of one normal ammonium acetate for a period of 10 minutes. Twenty milliliters of this extract were taken after filtering and added to two milliliters of 1100 ppm of lithium as lithium nitrate. The potassium extract was passed through the Perkin-Elmer flame photometer and content of K was determined by use of a standard curve.

The organic matter determination (7) of the soil was made by taking one gram of soil and adding 10 milliliters of one normal potassium dichromate and 20 milliliters of concentrated sulfuric acid. This mixture was allowed to stand for 30 minutes and then 100 milliliters of distilled water were added. After filtering the solution, a reading was made by use of the Coleman Jr. Spectrophotometer.

The results of the soil tests from which the soil test fertilizer recommendation were made are listed in Table 3 and 4.

Table 3. Chemical properties of soils used in milo tests.

Location	pH	Organic matter %	Pounds per acre		
			Lime requirement	Available phosphorus	Exchangeable potassium
1. James Howard, Belleville	5.5	1.55	3500	55	550
2. Glenn Topliff, Esbon	6.2	1.10	none	110	550
3. Edward Voight, Great Bend	5.8	.35	2000	57	412

Table 4. Chemical properties of soils used in the corn tests.

Location	pH	Organic matter %	Pounds per acre: Lime requirement	Pounds per acre: Available phosphorus	Pounds per acre: Exchangeable potassium
1. Fred Oplotnik, Girard	6.0	1.60	2500	11.5	103
2. Shaffer Bros., Columbus	5.3	1.10	3750	25.5	100
3. Chester Stapleton, Oswego	6.3	.80	none	29.0	78
4. Andy Aubert, Wier	6.8	1.20	none	23.0	81
5. W. F. Murray, Mound City	5.8	2.10	3000	13.0	178
6. J. B. Warren, Garnett	6.4	1.90	none	20.0	260
7. W. B. Zimmerman, Parker	6.1	2.35	none	12.0	163
8. Thayer Expt. Field, Thayer	5.7	1.20	3000	14.0	129
9. Ernest Harms, Thayer	5.6	1.30	3000	12.0	108
10. Fred Fouth, Reserve	5.3	1.80	3000	40.0	485
11. James Howard, Belleville	5.5	1.55	3500	55.0	550
12. Glenn Topliff, Esbon	6.2	1.10	none	110.00	550

Collection and Preparation of Leaf Samples for Analyses

The third leaf from the base of the plants was the one selected for this study. Leaf samples were taken from the nine locations of corn at approximately the time of tasseling of the plant. This was the last week in July. These locations were again samples the third week of August when a number of leaves were taken from each of the four replications in the randomized blocks. The leaf samples were taken from the Northeast Kansas corn locations and the milo locations during the second week in August.

The leaf samples were then dried in an oven at 100 degrees Fahrenheit. After the samples were dried for two days, the samples were ground in a Wiley mill. After the grinding the samples were dried until they were weighed for digestion.

A slightly modified procedure originally described by Piper (12) was used for the wet digestion of the plant material. A one gram sample of the dried material was placed in a 150 milliliter beaker and treated with four milliliters of 60 per cent perchloric acid, 15 milliliters of concentrated nitric acid, and two milliliters of concentrated sulfuric acid. A glass hook was placed on the rim of the beaker and covered with a watchglass. After the initial vigorous reaction had subsided, the mixture was heated gently on a hot plate until the appearance of copious white fumes. The mixture never was allowed to go to boiling. If the sample charred before the digestion was complete, a few milliliters of concentrated nitric acid were added to the reaction to bring it to completion. After cooling, the digest was filtered and transferred to a 50 milliliter volumetric flask and made to volume with .4N HCl.

Each sample was digested in duplicate and single determinations were made on each duplicate. The digest prepared was used to determine the potassium, phosphorus, calcium, magnesium, and sodium content in the leaf.

Chemical Analyses of Plant Digests

All determinations that were made with the exception of nitrogen, were conducted by using the perchloric acid digests. The procedure for each element is given briefly in the following paragraphs.

Calcium in the plant digest was determined photometrically by means of the Beckman flame photometer, Model, DU. The method of analysis was based on suggestions given in the Beckman bulletin (4). After locating the calcium line, 554 m,u, on the wavelength scale the instrument was adjusted to 100 per cent transmittancy for a concentration range of 0-300 ppm of calcium. The unknown solution, after being filtered, was then passed through the flame and the per cent transmittancy was read and then compared to the standard curve which was previously made by using a solution of calcium carbonate dissolved in four-tenths normal hydrochloric acid.

Magnesium content of the digest was determined by placing the digest into the Beckman flame photometer after the wavelength had been set at 383 m,u and the instrument adjusted for a concentration range of 0 - 250 ppm of magnesium. The per cent transmittancy was read and the reading was compared to a standard curve that was made from solutions of magnesium ribbon that was dissolved in four-tenths normal hydrochloric acid.

Phosphorus concentration in the digest solution was determined by the molybdemum blue method as proposed by Bray (6). A two milliliter aliquot of the digest was diluted with distilled water to volume in a 25 milliliter volumetric flask. From this dilution, 20 milliliters of the solution was pipetted into an Evelyn colorimeter tube and one milliliter of ammonium molybdate solution in hydrochloric acid was added. One milliliter of the reducing agent, 1-amino-2-naphthol-4-sulfonic acid, in solution with sodium sulfite and sodium bisulfite was added. After 15 minutes the intensity of the color developed was measured in the Evelyn colorimeter with a 660 m,u filter in place.

The per cent of phosphorus was determined by reading the per cent transmittancy and comparing it to a curve made from known concentrations of potassium phosphate.

Potassium. The Beckman flame photometer was used to determine the potassium in the plant digest obtained by the perchloric acid procedure. Two milliliters of the digest were diluted to volume in a 50 milliliter volumetric flask with four-tenths normal hydrochloric acid. The solution was passed through the flame after the instrument had been adjusted to 771 m,u and standarized with a potassium chloride solution for a range of 0-25 ppm of potassium. The readings again were compared with a standard curve.

Sodium. The concentration of sodium was found by using the flame photometer set at 589 m,u and standarized for a concentration of 0-2 ppm of sodium as sodium chloride. The same procedure was followed as described in the calcium and magnesium methods.

Nitrogen. One gram of the ground plant material was used in the nitrogen determination. The Kjeldahl-Gunning method (2) was used, with slight modifications, for the determination.

Table 5. Mean[1] nutrient content of corn leaves at the time of the first sampling (Southeast Kansas).

Treatment	Nutrient content (per cent)					
N - P_2O_5 - K_2O	Ca	Mg	K	Na	P	N
No treatment	.32	.86	.90	.02	.18	2.18
0-80-80	.28	.63**	1.79**	.02	.18	1.98**
0-0-80	.28	.68**	1.84**	.02	.16	2.16
0-80-0	.36	.92	.92	.02	.24**	2.20
80-80-0 + 80#N	.35	.94	.89	.02	.22*	2.45**
80-0-80 + 80#N	.28	.71**	1.74**	.02	.18	2.55**
80-0-0 + 80#N	.35	.90	.93	.02	.19	2.44**
80-80-80 + 80#N	.27*	.64**	1.75**	.02	.19	2.38**
L. S. D. (.05)	.05	.12	.27		.04	.11
L. S. D. (.01)	.06	.17	.34		.06	.14

* Differs from no treatment at .05 level.
** Differs from no treatment at .01 level.
1/ Mean of 9 locations.

Table 6. Calcium concentration of corn leaves at the time of first sampling (Southeast Kansas)

Treatment $N - P_2O_5 - K_2O$	Calcium concentration (per cent)								
	Aubert Wier	Warren Garnett	Shaffer Columbus	Zimmerman Parker	Thayer Exp.Fld Thayer	Harms Thayer	Murray Mound City	Stapleton Oswego	Oplotnik Girard
No treatment	.36	.22	.30	.45	.25	.23	.40	.31	.38
0-80-80	.30	.31	.24	.35	.25	.16	.33	.25	.32
0-0-80	.36	.29	.22	.34	.30	.16	.30	.25	.30
0-80-0	.52	.27	.30	.51	.36	.21	.37	.33	.40
80-80-0 + 80#N	.38	.37	.30	.34	.42	.24	.35	.32	.40
80-0-80 + 80#N	.24	.33	.20	.50	.25	.18	.31	.24	.30
80-0-0 + 80#N	.37	.26	.34	.47	.32	.24	.42	.34	.38
80-80-80- + 80#N	.25	.32	.22	.31	.22	.23	.27	.30	.28
L. S. D. (.05)	.05								
L. S. D. (.01)	.06								

Table 7. Magnesium concentration of corn leaves at the time of first sampling (Southeast Kansas).

Treatment $N - P_2O_5 - K_2O$	Magnesium concentration (per cent)								
	Aubert Wier	Warren Garnett	Shaffer Columbus	Zimmerman Parker	Thayer Exp.Fld Thayer	Harms Thayer	Murray Mound City	Stapleton Oswego	Oplotnik Girard
No treatment	1.10	.54	.77	1.24	1.00	.70	.63	.85	.90
0-80-80	.66	.64	.54	.77	.62	.55	.52	.59	.75
0-0-80	.72	.58	.76	.69	.80	.66	.61	.63	.68
0-80-0	1.15	.58	.88	1.14	1.24	.60	.64	.94	1.08
80-80-0 + 80#N	1.16	.74	1.07	.88	1.32	.65	.64	.92	1.08
80-0-80 + 80#N	.67	.66	.61	1.05	.80	.58	.56	.76	.70
80-0-0 + 80#N	1.22	.54	1.08	1.13	.88	.68	.62	.96	1.06
80-80-80 + 80#N	.64	.63	.65	.70	.60	.63	.52	.72	.63
L. S. D. (.05)	.13								
L. S. D. (.01)	.17								

Table 8. Potassium concentration of corn leaves at the time of first sampling (Southeast Kansas).

Treatment $N - P_2O_5 - K_2O$	Potassium concentration (per cent)								
	Aubert Wier	Warren Garnett	Shaffer Columbus	Zimmerman Parker	Thayer Exp.Fld Thayer	Harms Thayer	Murray Mound City	Stapleton Oswego	Oplotnik Girard
No treatment	.56	2.35	.77	.61	.68	1.27	.87	.39	.63
0-80-80	1.46	2.83	1.64	1.27	1.81	1.92	1.74	1.99	1.46
0-0-80	1.57	2.93	1.99	1.40	1.99	1.87	1.40	1.52	1.66
0-80-0	.54	2.53	.84	.57	.47	1.15	1.10	.51	.53
80-80-0 + 80#N	.49	1.78	.68	.92	.43	.97	1.12	.51	1.09
80-0-80 + 80#N	1.31	2.56	1.75	1.35	1.68	1.86	1.60	2.24	1.32
80-0-0 + 80#N	.44	2.56	.61	.63	1.04	1.21	.94	.48	.48
80-80-80 + 80#N	1.88	2.34	1.62	1.28	1.90	1.70	1.72	1.64	1.64
L. S. D. (.05)	.27								
L. S. D. (.01)	.35								

Table 9. Phosphorus concentration of corn leaves at time of first sampling (Southeast Kansas).

Treatment $N - P_2O_5 - K_2O$	Phosphorus concentration (per cent)								
	Aubert Wier	Warren Garnett	Shaffer Columbus	Zimmerman Parker	Thayer Exp.Fld Thayer	Harms Thayer	Murray Mound City	Stapleton Oswego	Oplotnik Girard
No treatment	.15	.15	.15	.23	.11	.16	.19	.27	.21
0-80-80	.17	.17	.13	.21	.13	.17	.16	.29	.19
0-0-80	.16	.18	.14	.13	.11	.15	.17	.23	.16
0-80-0	.23	.21	.17	.24	.16	.19	.20	.49	.25
80-80-0 + 80#N	.29	.20	.18	.19	.22	.18	.20	.30	.24
80-0-80 + 80#N	.18	.18	.15	.24	.10	.16	.20	.21	.19
80-0-0 + 80#N	.18	.19	.18	.23	.10	.18	.18	.34	.16
80-80-80 + 80#N	.18	.21	.18	.22	.13	.17	.19	.27	.17
L. S. D. (.05)	.04								
L. S. D. (.01)	.06								

Table 10. Nitrogen concentration of corn leaves at time of first sampling (Southeast Kansas).

Treatment $N - P_2O_5 - K_2O$	Nitrogen concentration (per cent) Aubert Wier	Warren Garnett	Shaffer Columbus	Zimmerman Parker	Thayer Exp. Fld Thayer	Harms Thayer	Murray Mound City	Stapleton Oswego	Oplotnik Girard
No treatment	2.07	2.00	1.84	2.36	2.19	2.31	2.14	2.29	2.50
0-80-80	1.95	2.00	1.56	2.15	1.95	2.20	1.93	1.96	2.13
0-0-80	2.00	2.09	1.76	2.32	2.35	2.20	2.19	2.20	2.36
0-80-0	2.14	2.32	1.66	2.65	2.19	2.27	2.05	2.25	2.29
80-80-0 + 80#N	2.33	2.54	2.06	2.84	2.63	2.49	2.29	2.50	2.39
80-0-80 + 80#N	2.52	2.39	2.26	2.79	2.56	2.80	2.50	2.59	2.58
80-0-0 + 80#N	2.32	2.57	2.16	2.76	2.63	2.24	2.35	2.50	2.46
80-80-80 + 80#N	2.18	2.51	2.10	2.80	2.41	2.37	2.12	2.54	2.42
L. S. D. (.05)	.11								
L. S. D. (.01)	.14								

Table 11. Mean[1] calcium content of corn leaves at time of second sampling (Southeastern Kansas).

Treatment $N - P_2O_5 - K_2O$	Calcium concentration (per cent)								
	Oplotnik Girard	Shaffer Columbus	Stapleton Oswego	Aubert Wier	Murray Mound City	Warren Garnett	Zimmerman Parker	Thayer Exp.Fld Thayer	Harms Thayer
No treatment	.29	.27	.36	.36	.46	.26	.35	.38	.28
80-80-80 + 80#N	.24**	.23*	.37	.28**	.36	.28**	.34	.36	.35**
60-30-20	.29					.26	.45	.35	.27
60-30-20 + Mg	.29					.27**	.39	.44	.26
30-30-20					.42				
30-30-20 + Mg					.46				
60-20-30			.38						
60-20-30			.38						
60-30-30				.28**					
60-30-30 + Mg.				.26**					
60-20-20		.29							
60-20-20 + Mg.		.26							
L. S. D. (.05)	.03	.03		.05		.007			.03
L. S. D. (.01)	.04	.05		.07		.01			.05

1/ Mean of 4 replications.

Table 12. Mean[1] magnesium content of corn leaves at time of second sampling (Southeast Kansas).

Treatment $N - P_2O_5 - K_2O$	Magnesium concentration (per cent)								
	Oplotnik Girard	Shaffer Columbus	Stapleton Oswego	Aubert Wier	Murray Mound City	Warren Garnett	Zimmerman Parker	Thayer Exp.Fld Thayer	Harms Thayer
No treatment	.57	.87	.74	.93	.50	.41	.76	.74	.66
80-80-80 + 80#N	.40**	.73*	.75	.73**	.50	.39	.71	.66	.72
60-30-20	.49					.40	.81	.63	.65
60-30-20 + Mg.	.58					.48**	.87	.74	.67
30-30-20					.54*				
30-30-20 Mg.					.59**				
60-20-30			.79						
60-20-30 Mg.			.76						
60-30-30				.72**					
60-30-30 Mg.				.87					
60-20-20		.70**							
60-20-20 + Mg.		.84							
L. S. D. (.05)	.09	.10		.08	.03	.06			
L. S. D. (.01)	.13	.15		.11	.05	.08			

1/ Mean of 4 replications.

Table 13. Mean[1] potassium content of corn leaves at time of second sampling (Southeast Kansas).

Treatment $N - P_2O_5 - K_2O$	Potassium concentration (per cent)								
	Oplotnik Girard	Shaffer Columbus	Stapleton Oswego	Aubert Wier	Murray Mound City	Warren Garnett	Zimmerman Parker	Thayer Exp. Fld Thayer	Harms Thayer
No treatment	.62	.71	.41	.51	.92	1.41	.76	.83	1.19
80-80-80 + 80#N	1.24**	1.03**	1.20**	1.32**	1.33**	1.87**	1.22**	1.23**	1.35*
60-30-20	.79					1.71**	1.02*	1.11*	1.12
60-30-20 + Mg.	.75					1.71**	.99	.79	1.24
30-30-20					1.11				
30-30-20 Mg.					.97				
60-20-30			.69**						
60-20-30 + Mg.			.56**						
60-30-30				.80**					
60-30-30 + Mg.				.81**					
60-20-20		.93*							
60-20-20 + Mg.		.81							
L. S. D. (.05)	.20	.21	.15	.07	.19	.16	.25	.24	.12
L. S. D. (.01)	.28	.30	.21	.11	.28	.23	.36	.34	.17

1/ Mean of 4 replications.

Table 14. Mean[1] phosphorus content of corn leaves at time of second sampling (Southeast Kansas).

Treatment $N - P_2O_5 - K_2O$	Phosphorus concentration (per cent) Oplotnik Girard	Shaffer Columbus	Stapleton Oswego	Aubert Wier	Murray Mound City	Warren Garnett	Zimmerman Parker	Thayer Exp. Fld Thayer	Harms Thayer
No treatment	.138	.145	.299	.219	.143	.213	.141	.132	.165
80-80-80 + 80#N	.137	.169	.224	.242	.153	.182	.167	.175**	.171
60-30-20	.147					.179	.150	.152*	.174
60-30-20 Mg.	.140					.192	.182	.148*	.175
30-30-20					.166				
30-30-20 Mg.					.156				
60-20-30			.268						
60-20-30 Mg.			.233						
60-30-30				.252					
60-30-30 + Mg.				.257					
60-20-20		.138							
60-20-20 + Mg.		.155							
L. S. D. (.05)								.015	
L. S. D. (.01)								.022	

1/ Mean of 4 replications.

Table 15. Mean[1] nitrogen content of corn leaves at time of second sampling (Southeast Kansas).

Treatment $N - P_2O_5 - K_2O$	Nitrogen concentration (per cent)								
	Oplotnik Girard	Shaffer Columbus	Stapleton Oswego	Aubert Wier	Murray Mound City	Warren Garnett	Zimmerman Parker	Thayer Exp.Fld Thayer	Harms Thayer
No treatment	1.84	1.48	1.79	1.66	1.69	1.60	1.98	1.70	1.87
80-80-80 + 80#N	1.81	1.58	1.75	1.72	1.76	1.94**	1.92	2.09**	2.03
60-30-20	1.70					1.76	1.86	1.91*	2.04
60-30-20 + Mg.	1.62					1.83*	1.98	1.84	2.06
30-30-20					1.68				
30-30-20 + Mg.					1.70				
60-20-30			1.83						
60-20-30 + Mg.			1.74						
60-30-30				1.54					
60-30-30 + Mg.				1.62					
60-20-20		1.48							
60-20-20 + Mg.		1.56							
L. S. D. (.05)						.24		.17	
L. S. D. (.01)						.34		.25	

1/ Mean of 4 replications.

Table 16. Mean* elemental content of corn leaves (Northeast Kansas)

Treatment	Elemental composition (per cent)					
$N - P_2O_5 - K_2O$	K	Ca	Mg	Na	N	P
No treatment	2.05	.21	.37	.02	1.67	.22
0-0-40	2.13	.22	.39	.02	1.57	.17
40-0-0	2.31	.19	.34	.02	1.81	.19
0-40-0	2.15	.20	.38	.02	1.73	.22
0-40-40 + 40	2.27	.20	.39	.02	1.87	.20
0-40-40	2.18	.23	.38	.02	1.73	.22
40-40-0	2.27	.18	.38	.02	1.86	.19
40-40-40	2.49	.20	.39	.02	1.67	.19
40-40-40 + 40	2.29	.25	.37	.02	2.07	.22
20-40-40 + 20	2.33	.20	.42	.01	1.80	.21
40-40-40 SB	2.29	.20	.42	.02	1.74	.21
40-0-40	2.24	.19	.44	.01	1.77	.17
80-0-0	2.27	.21	.41	.02	2.25	.21
80-0-40	2.47	.20	.38	.01	2.24	.21
80-40-0	2.37	.18	.38	.02	1.98	.21
80-40-40	2.32	.21	.37	.02	2.02	.21

* Mean of 3 locations.

Table 17. Mean* elemental content of milo leaves (Northcentral Kansas).

Treatment	Elemental composition (per cent)					
N - P205 - K20	K	Ca	Mg	Na	N	P
No treatment	2.46	.19	.48	.02	2.20	.21
0-0-40	2.72	.21	.50	.02	2.08	.24
40-0-0	2.59	.17	.48	.02	2.46	.25
0-40-0	2.66	.19	.46	.02	2.18	.24
0-40-40 + 40#N	2.49	.17	.52	.02	2.47	.25
0-40-40	2.54	.21	.54	.02	2.18	.22
40-40-0	2.99	.28	.46	.02	2.46	.24
40-40-40	2.42	.16	.38	.01	3.02	.32
40-40-40 + 40#N	2.77	.23	.48	.01	2.62	.25
20-40-40 + 20#N	2.90	.22	.41	.02	2.30	.24
40-40-40 SB**	2.63	.18	.45	.02	2.73	.28
40-0-40	2.72	.16	.35	.01	2.79	.24
80-0-0	2.51	.14	.34	.02	2.92	.27
80-0-40	2.50	.15	.33	.02	3.02	.28
80-40-0	2.51	.16	.32	.02	2.92	.30
80-40-40	2.48	.21	.37	.02	3.01	.27

* Mean of the Esbon and Belleville locations.
**Split boot application.

Table 18. Mean* elemental content of milo leaves (Great Bend).

Treatment	Elemental composition (per cent)					
$N - P_2O_5 - K_2O$	K	Ca	Mg	Na	N	P
No treatment	2.24	.18	.42	.02	1.92	.23
0-0-40	2.13	.19	.37	.02	1.37**	.24
40-0-0	2.54	.24	.43	.02	1.19**	.10
0-40-0	2.36	.20	.42	.01	1.66	.26
0-40-40 + 40#N	2.41	.22	.42	.02	1.63	.20
0-40-40	2.32	.19	.36	.02	.89**	.11
40-40-0	2.57	.18	.42	.01	2.01	.24
40-40-40	2.59	.19	.41	.02	1.90	.22
40-40-40 + 40#N	2.51	.20	.40	.02	2.03	.20
20-40-40 + 20#N	2.53	.20	.41	.02	1.99	.24
333# 12-12-12	2.46	.20	.42	.03	2.34**	.20
40-0-40	2.63	.19	.40	.01	1.19**	.10
80-0-0	2.42	.20	.42	.02	2.22*	.20
80-0-40	2.76	.20	.42	.02	1.88	.13
80-40-0	2.52	.24	.40	.02	2.08	.17
80-40-40	2.38	.20	.41	.02	2.25*	.27
L. S. D. (.05)					.27	
L. S. D. (.01)					.37	

*Mean of 2 replications.

Table 19. Relationship of exchangeable K content of soil and corn yields.

Exchangeable K content of soil (lbs/A)	Approximate yield of corn (%)
40	49
80	72
120	85
160	92
200	95
240	98
280	99

Table 20. Relationship of exchangeable K content of soil to K content of corn leaves* at tasseling stage.

Exchangeable K content of soil (lbs/A)	Approximate K content of corn leaf (%)
80	.47
120	.64
160	.82
200	1.00
240	1.17
280	1.35
320	1.52
360	1.70
400	1.86
440	2.04
480	2.22
520	2.40

* Third green leaf from base of plant.

Table 21. Relationship of exchangeable K to increase in K content of corn leaves at tasseling stage.

Exchangeable K content of soil (lbs/A)	Increase in K content (%) of corn leaves from application of 80# K_2O/A
80	1.10
120	.86
160	.67
200	.52
240	.40
280	.31
320	.23
360	.16
400	.10
440	.05
480	.02
520	.01

DISCUSSION OF RESULTS

First Sampling of Corn from Southeastern Kansas Locations

The data discussed in this section are reported in Tables 5 to 10, inclusive.

A check of the average of the analyses for calcium revealed that there was a decrease in calcium content of the corn leaf tissue when the soil was treated with potassium. This effect was significant only in the case of the treatment furnishing 80-80-80 + 80, however, when comparison is made with the corn leaf tissue produced on the untreated soil. Certain of the treatments supplying 80 pounds per acre of available P_2O_5 resulted in a significantly greater concentration of calcium than was found in certain cases where nitrogen and/or potassium was employed without phosphatic fertilizer. This effect may be attributed to the considerable amount of calcium supplied in superphosphate. However, in general where potassium was furnished as part of the soil treatment, the calcium from superphosphate was not effective insofar as plant uptake was concerned. Addition of NH_4^+ in ammonium nitrate apparently did not influence calcium concentration in the corn leaves appreciably.

Each treatment that supplied potassium resulted in a highly significant repression in the uptake of magnesium. The treatments that supplied no potassium did not reflect much change where compared with no treatment, insofar as the uptake of potassium and magnesium was concerned. Other treatments apparently did not repress magnesium uptake. The magnesium-potassium relationship was the most outstanding one noted insofar as cationic relationships were concerned.

For each treatment, there was a highly significant increase in the potassium uptake where potassium was added. For all treatments that did not have potassium, there was no great difference in the uptake when considering it with the no treatment.

The nitrogen content was increased with a high degree of significance for all the treatments that contained nitrogen. Where phosphorus and potassium were added in combination there was a highly significant depression in the nitrogen content.

The only significance for the sodium content was the variation between the locations.

The phosphorus content of the corn leaves showed a highly significant increase over no treatment when phosphorus was applied alone. There was statistical significance between the treatment of phosphorus and nitrogen compared to no treatment. Treatments containing the high amount of potassium did not have any significant change in the uptake of phosphorus.

Second Sampling of Corn from Southeast Kansas Locations

Each of the results that is reported was calculated from an average of four replications. The data are presented in Tables 11 to 16 inclusive.

It might be noted that there was a decrease in the per cent of nitrogen taken up by the corn plants at the second time of sampling compared to the previous sampling. The total amount of plant material was greater; as a result the nitrogen was diluted throughout the plant. There was not nearly the significant difference between the no treatment and nitrogen treatments at this time as compared to the July sampling. The only locations that showed any significance in these comparisons were at Garnett and Thayer Experiment Field.

There was a highly significant increase in the calcium content over the no treatment when considering the 80-80-80 + 80 treatment at Garnett and Thayer. The rest of the treatments showed a depression in calcium uptake. This depression was highly significant at Girard and Wier, while it was only significant at Columbus. There was also a highly significant depression of the calcium at Wier for the soil test treatment which contained 30 pounds of K_2O and MgO per acre. The reduction in uptake of calcium resulted from potassium repression. Both locations that showed an increase in calcium were ones that had the highest per cent of potassium in the no treatment samples. There was not much depression due to the potassium added and the increase in calcium was a result of the addition of calcium with the superphosphate. The range of calcium for these locations was from .23 to .46 per cent.

The magnesium content was increased to a highly significant amount at Garnett and Mound City with the application of magnesium with the soil test treatment. The content of magnesium for the no treatment was the lowest of the nine locations at both of the fields. When potassium was added as a fertilizer element without magnesium there was a repression of the magnesium uptake. This repression was highly significant at Girard and Wier for the 80 pounds of K_2O and for 30 pounds of K_2O at Wier. There was a significant repression of magnesium at Columbus for 80 pounds of K_2O. Wier had .93 per cent magnesium and Columbus .87 per cent magnesium for the no treatment plots. These plots were the highest in magnesium of the nine locations. There seemed to be a tendency of the magnesium treatment to bring the magnesium content of the leaf back up to the magnesium content of the no treatment. The range in magnesium was .40 to .93 per cent.

Other investigators (10,11) have noted that potassium supresses the uptake of magnesium and other cations by the plant. This work gave good opportunity to check this relationship and interpretation of the data seems to verify these investigators work.

There was a highly significant increase in potassium for all locations when 80 pounds of K_2O were added. Generally, there was an increase in potassium when the soil test recommendation was followed, but at a number of locations this increase was not significant. This seemed to indicate that an increase in these recommendations should be made.

For all of the phosphorus treatments, there was only one location, Thayer Experiment Field, where a significant increase over the no treatment took place. There was a low amount of available phosphorus in the soil at this location. Phosphorus content of the leaves ranged from .132 per cent at Thayer Experiment Field to .299 per cent at Oswego.

The sodium uptake did not change to any degree; the uptake for all treatments and locations was about .02 per cent.

The treatments as recommended by soil tests did not increase the potassium, phosphorus or nitrogen content much above the no treatment. The soil test applications did bring about an increase in the potassium content when the chemical test of the soil showed a very low amount of exchangeable potassium in the soil.

Sampling of Northeast Kansas Corn

The summary of the analysis of the Belleville, Esbon and Reserve locations of corn, Table 16, does not show any statistically significant variation in the uptake of the nutrients. There was a high level of fertility of the soil before the fertilizers were placed on the fields. There was a statistical difference between the locations of these tests.

Potassium content ranged from 2.05 to 2.49 per cent. This range was much greater than the per cent potassium uptake for the Southeast Kansas locations. When nitrogen was added at the rate of 80 pounds per acre an increase in the uptake of nitrogen was noted. The per cent phosphorus for these locations was higher on the average than the per cent of phosphorus at the Southeast Kansas locations.

The calcium had a narrow range of .18 to .25 per cent. The treatments did not influence the uptake of calcium to any appreciable extent.

Milo Plots

Comparing the nutrient uptake of corn for Belleville and Esbon with that of milo for the same locations, it was noted that the uptake of potassium, nitrogen and phosphorus was greater for the milo. The milo grown at Great Bend showed a lower uptake of potassium, nitrogen and phosphorus than did the two locations in Northcentral Kansas.

There was not a significant variation between most treatments, but when nitrogen was added there was an increase in this nutrient in the leaf. At Great Bend the nitrogen content was increased significantly for some treatments.

The summary of the elemental content of the milo leaves is in Tables 17 and 18.

General Comparisons

When the potassium content of the leaves from the no treatment plots was ploted against the exchangeable potassium content of the soil before treatment, there was found to be a linear relationship between these two contents. As the soil potassium increased the potassium content in the leaves also increased. This information is in Table 20.

Ploting per cent yields against the per cent potassium in the leaves, it was noted that there was little increase in the yields when the leaf content went above 1.3 per cent. This content compared with what Tyner found (15). From tables 19 and 20 it was noted that 280 pounds of exchangeable potassium in the soil was calculated to give 99 per cent yield and that 280 pounds of potassium in the soil showed an elemental content of the leaf at about 1.35 per cent.

When the exchangeable potassium content was ploted against yield it was noted that approximately 280 pounds of exchangeable potassium per acre was what was needed to give 99 per cent yield for the locations (Table 19).

When the total cations were expressed in milliequivalents the uptake of the total cations for each location was very constant. The total milliequivalents of cations changed from location to location due to the original characteristics of the soil.

SUMMARY

1. The potassium in the leaf increased considerably over no treatment when it was added to the soil in Southeast Kansas.

2. There was a definite potassium-magnesium relationship. When the potassium increased the magnesium decreased.

3. Nitrogen increased considerably for the first sampling of corn but the per cent of nitrogen decreased and the differences were not as great for the second sampling as the first.

4. There was a linear relationship between the exchangeable potassium in the soil and the per cent of potassium in the leaf.

5. Calcium, sodium and phosphorus did not change to any great degree. The phosphorus and potassium were higher for the corn leaves analyzed from Northeast Kansas compared to the corn leaves from Southeast Kansas.

6. The uptake of magnesium was greater for Southeast Kansas corn than for Northeast Kansas corn due to the repression by potassium originally in the soil.

7. The total cations expressed in milliequivalents are quite constant for each location.

8. Magnesium treatments brought the content of magnesium back to the no treatment level when only a small amount of potassium was added.

9. Milo showed a higher requirement for potassium and nitrogen than did corn.

ACKNOWLEDGMENT

The author wishes to express appreciation to Dr. Floyd W. Smith, major professor, for the helpful suggestions and assistance with problems encountered while working on this thesis. Appreciation is also expressed to Dr. John Grava, Mr. Robert Leyden and Mr. James Kirkwood for assistance with the laboratory work. Assistant Professor Roscoe Ellis, Jr. is extended appreciation for his helpful suggestions in the laboratory.

LITERATURE CITED

(1) Arnold, C. Y. and T. Kurtz.
Photometer method for determining available phosphorus in soils. Ill. Agr. Expt. Sta. Pamphlet A. G. 1306 1946.

(2) A. O. A. C. Methods of Analysis.
Protein analysis. Washington, D. C. : A.O.A.C. 5th ed. 1940.

(3) Baver, T. D.
Practical applications of potassium interrelationships in soils and plants. Soil Sci. 55:121-126. 1943.

(4) Beckman.
Bulletin 259. South Pasadena, Calif. Beckman Instruments, Inc., 1952.

(5) Bennett, W. F. and G. Stanford.
Nitrogen, phosphorus, and potassium content of the corn leaf and grain as related to nitrogen fertilization and yield. Abstracts of Amer. Soc. Agr. Meetings. 72 p. Nov. 17, 1952.

(6) Bray, R. H.
Rapid tests for measuring and differentiating between the adsorbed and acid-soluble forms of phosphate in soils. Mimeo. pamphlet, Univ. of Ill. Agr. Expt. Sta. AG1028. March, 1942.

(7) Graham, E. R.
Determination of soil organic matter by means of a photoelectric colorimeter. Soil Sci. 65:181-183. 1948.

(8) Hall, A. D.
The analysis of the soil by means of the plant. Jour. Agr. Sci. 1:65-88. 1905.

(9) Hoffer, G. N.
Potash in plant metabolism. Indus. and Engin. Chem. 30:685-688. 1938.

(10) Pierre, W. H., and C. A. Bower.
Potassium absorption by plants as affected by cationic relationships. Soil Sci. 55:23-33. 1943.

(11) Prince, Arthur T., M. Zimmerman, and Firman E. Bear.
The magnesium-supplying power of 20 New Jersey soils.
Soil Sci. 63:69-78. 1947.

(12) Piper, C. S.
Soil and plant analysis. New York, Interscience
Publishers, Inc., 272 and 293 p. 1950.

(13) Salter, R. M., and J. W. Ames.
Plant composition as a guide to the availability of
soil nutrients. Jour. Amer. Soc. Agron. 20:808-836. 1928.

(14) Smith, F. W.
Twenty-five year results of fertility investigations
on a claypan soil at Columbus, Kansas. Minutes of
Joint Agronomist-Industry Meeting Sponsored by the
Middle West Soil Improvement Committee.
p. 1-7. Feb. 24, 1950.

(15) Tyner, E. H.
The relation of corn yields to leaf nitrogen, phosphorus,
and potassium content. Soil Sci. Soc. Amer. Proc.
11:317-323. 1946.

(16) Woodruff, C. M.
Testing soils for lime requirement by means of a
buffered solution and the glass electrode. Soil Sci.
66:53-64. 1948.

CHEMICAL STUDIES OF NUTRIENT REQUIREMENTS OF CORN AND MILO

by

CARL JACOB KNAUSS

B. S., Kansas State College
of Agriculture and Applied Science, 1952

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1953

An experiment was established at twelve locations for corn and three locations for milo over the eastern half of Kansas for the purpose of establishing the fertilizer requirements of these crops for different soils. At these locations nitrogen, phosphorus, potassium, and in some cases, magnesium were added at different rates to determine the nutrient needs of these crops.

In order to furnish an answer to the nutrient requirements, the experiment was laid out at each location following a randomized block design. Chemical analyses of the soils were made for each location to help determine the amount of fertilizer to be added for some treatments. A sample of the third leaf from the base of the plant was collected from various treatments at these locations at the tasseling time for corn. Some areas were again sampled the third week of August to note what changes took place in the nutrient uptake as the plant matured. These leaf samples were digested and analyzed for the nitrogen, calcium, magnesium, sodium, potassium and phosphorus contents. A statistical analysis was made on the data obtained.

The results of the experiment showed:

(1) that the potassium content of the leaves of corn increased considerably when potassium was added to the soil in Southeast Kansas;

(2) that there was a definite potassium-magnesium relationship in the leaf;

(3) that nitrogen increased considerably for the first sampling of corn over the no treatment at tasseling time but

decreased for the second sampling made in August;

(4) that there was a linear relationship between the exchangeable potassium in the soil and the per cent of potassium in the leaf;

(5) that the calcium, sodium, and phosphorus content did not change greatly when compared with the no treatment;

(6) that the uptake of magnesium was greater for Southeast Kansas than for Northeast Kansas;

(7) that the total cations expressed in milli-equivalents are quite constant for each location;

(8) that magnesium treatments brought the content of magnesium back to the no treatment level when only a small amount of potassium was added;

(9) that 1.3 per cent of potassium was the critical percentage for potassium in the leaf for top yields; and

(10) that the content of milo leaves had a higher amount of potassium and nitrogen present than did the corn leaves.