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The Pennsylvania State College
The Graduate School

Department of Agricultural and Biological Chemistry

A Study of the Calcium Content of Pennsylvania
Cigar Leaf Tobacco

A Thesis

by

Ammon M. Brubaker

Submitted in partial fulfillment

for the degree of

Master of Science

August 1939

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INTRODUCTION AND HISTORICAL

Tobacco constitutes an important agricultural crop in Pennsylvania which annually amounts to several million dollars. Because of its economic value and because of its adaptability to mineral absorption studies, it is appropriate that its culture be studied in order to improve the yield and quality of this crop.

During the past years there have been a series of constant investigations of various phases of the tobacco industry in Pennsylvania. In 1893, Doctor William Frear started the investigations on tobacco in Pennsylvania. This work was done throughout the various tobacco growing sections of the state. Fertilizer practices, ^{cu}wring, variety and strain tests, some shelter tent experiments with Sumatra tobacco, and economic studies on the cost of tobacco production were included in this work. Recently, the processes involved in the fermentation of tobacco have been under investigation. Also, the cultural and fertilization practices of tobacco and their relation to "Wildfire" disease have been studied.

Experiment Stations for the study of tobacco were established at Lock Haven and Ephrata in 1916 where the original work was continued and additional investigations were made on steam sterilization of seed beds, the use of fertilizers on seed beds, seed cleaning, rate of seeding, fumigation, fertilizer treatments, various cultural practices,

variety and strain tests and high and low nicotine breeding.

In 1930 the tobacco experimental station was moved to Roseville, one mile from the City of Lancaster. The field is nearly level with a slight southern exposure, and the soil is of the Hagerstown silt loam type. There was no fertilizer or lime used on this field for more than twenty years although tobacco was grown there in 1929. A detailed description of the soil is given in a thesis by Thomas (24).

OBJECT OF THIS INVESTIGATION

The object of this investigation was first, to determine the calcium content of the tobacco samples from the experimental plots at Roseville, Lancaster County, and since the yield and quality of tobacco is correlated with potassium fertilization and potassium content of the tobacco leaves, it was thought advisable to compare the calcium content with the potassium and nitrogen content to show the interrelationship in the absorption of these elements, especially in regard to the yield and quality of the tobacco produced.

REVIEW OF THE LITERATURE

Calcium is recognized as one of the elements essential to the growth and development of all green plants. The functions of calcium in the plant are found in textbooks on Plant Physiology, Miller (15). Investigators have shown that definite deficiency symptoms occur in plants that are grown on soils containing an insufficient supply of calcium

McMurtrey (14). Nightingale (17) found that calcium deficient plants were practically unable to absorb or assimilate nitrates although they could absorb calcium immediately. A few hours after the absorption of calcium, there was absorption and assimilation of nitrates. Calcium deficient plants accumulated carbohydrates in large quantities and nearly all the calcium was insoluble in water. McMurtrey (14) defines the quantity of calcium necessary for normal growth of the leaves must be in excess of one per cent of their dry weight. It is highly improbable that any deficiency symptoms would be noted at present in tobacco grown on the soil of the experimental tobacco plots at Roseville, Lancaster County, Pennsylvania as these soils are known to be high in calcium and quite low in available potassium.

Haley et. al (6) found that the quality of smoke produced during combustion of a cigar is largely dependent on the chemical composition of the tobacco. The potassium content was correlated with the burning quality of the tobacco.

Recent work by Reid and Haley indicates a relationship of the mineral nutrition of plants and resistance to "Wildfire" disease of tobacco which is a serious problem in the production of good quality tobacco in Pennsylvania.

There are numerous and complex factors that affect the absorption of plant nutrients. The first of the many laws that have been advanced for defining the relationship between the amount of nutrients absorbed by the plant and the

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There are numerous and complex factors that affect the absorption of plant nutrients. The first of the many laws that have been advanced for defining the relationship between the amount of nutrients absorbed by the plant and the

dry matter produced was by "Liebig" who announced as a corollary to what afterwards became known as the "law of the minimum" that nutrient elements must be absorbed in certain definite proportions and in such a manner that when the rate of supply of one of the principal nutrient elements is reduced below the critical concentration for that element the rate of absorption of the other principal nutrient elements is retarded or depressed, because an inadequate supply will render the other element unavailable, and the plant will be unable to grow to any extent.

Wolff (22) in 1871 was the first to give definite proof that the composition of the ash of any plant could be changed by varying the proportion of salts in the nutrient culture medium. Newton (22) found that different species growing in media of identical composition possess selective powers with respect to any specific ion or ions. These differences may be due to the character of the species or the result of environmental or other unknown causes.

Hoaglund and Martin (9) state that the composition of the crop consistently reflects the supplying power of a soil for potassium under suitably controlled conditions. A striking interrelationship exists between calcium, magnesium, and potassium, but it is emphasized that crop growth is not limited by specific ratios of bases.

In studying the interrelationships of various salts that make up the nutrient medium of the plant, the term

"antagonism" is used to designate the hindrance of a given salt upon the toxic action of another salt. Calcium reduces the toxic effects of single salt solutions of sodium, potassium, and magnesium. Loew (15) proposed the hypothesis that one of the principal functions of calcium was to neutralize the effect of magnesium and that a certain calcium-magnesium ratio is necessary for the proper growth and development of plants. It has been shown by other workers Lipman (15), Wyatt (15) that the calcium-magnesium ratio can vary within rather wide limits without affecting the crop yield.

Liedjens and Schermerhorn (25) working with vegetable crops point out that the type of fertilizer and the manner in which the soil is handled depend on the potential calcium supply. Fertilizer residues have a marked effect on exchangeable and available calcium as well as on the reaction of light cultivated soils.

In discussing the agronomic importance of calcium, Kelly (10) concludes that in neutral soils, calcium is the dominant exchangeable cation. Under leaching conditions, calcium becomes replaced by hydrogen ions from the surface of the colloidal particles. In consequence these particles become acid. Important micro-biological soil processes are affected by inadequate supply of calcium and by soil activity. Within certain limits, an inverse relationship has been found between the absorption of calcium and potassium by plants. Ammonium salts are especially applicable where the soil con-

tains significant amounts of CaCO_3 .

In fertilizing with ammonium salts (26) effects such as plasmolysis of the root tissues were noticed when an insufficient supply of calcium was present. Calcium salts were antagonistic to ammonium ion toxicity. Calcium sulfate and chloride were more effective in this regard than calcium carbonate acid phosphate.

METHODS

The tobacco samples were obtained from the Experiment Station, Roseville, Lancaster County from the three- and four-year rotation plots, placement plots, and the out-laying plots on various farms in that section.

An outline of the general methods and cultural practices is found in a thesis by Thomas (24).

The calcium was determined volumetrically according to the following method:

Two grams of the sample were ignited in a porcelain crucible in a muffle furnace at 500°C . for at least two hours or until the sample was thoroughly ashed. The ash was carefully moistened with five ccs. of HCl , evaporated to dryness and heated on the steam bath for three hours to render the silicon dioxide insoluble. The residue was moistened with five ccs. of concentrated HCl and fifty ccs. of water were added and warmed on a water bath to take up the calcium. The resulting solution was filtered through a hardened filter and washed to a volume of approximately 50 ccs. After heating to boiling ten ccs. of saturated ammonium oxalate were

added and a drop of Methyl Red. After cooling, the solution was almost neutralized with ammonium hydroxide and heated until the precipitate was coarsely granular.

After again cooling, ammonium hydroxide (1 to 4) was added until the color became pale pink. It was then allowed to stand overnight. The precipitate was then filtered off and washed with water at room temperature to free it from oxalates. After the filter paper was pierced with a platinum wire, the precipitate was washed into the original beaker which held the precipitate with hot water and finally with hot H_2SO_4 (1 to 4).

Ten ccs. of H_2SO_4 (1 to 4) and 50 cc. of water were added and heated to 90°C . and titrated to a pale pink end point with standard potassium permanganate. Finally, the filter paper was added and the titration completed. From: Standard Methods of Analysis, Research Department, American Tobacco Company.

The moisture, nitrogen, and potassium contents were obtained from Clyde Underwood, who was working on these samples at the same time.

PRESENTATION OF DATA

The data on the four year rotation experiments is given in tables I to VI. The fertilizer treatments, total yield (pounds per acre), production of wrappers, burn, quality, nitrogenic content, potassium content, calcium content, nitrogen-calcium ratios, calcium-potassium ratios are given. The

percentage of wrappers, burn, and quality are indications of the value and condition of the crop produced.

Table III contains a list of the fertilizers used and percentage composition. The formulas of the fertilizers are based on these figures.

The arrangement of the plots in the four-year rotation experiment is shown in table VIII. Each plot is one-fortieth of an acre.

Similar data for the three-year rotations are found in tables IX and X.

Tables XI to XIII contain the condition of the fertilizer, formula, method of application, total yield, production of wrappers, burn, quality, remarks on the condition of the crop and the calcium content for the Placement Plots.

The mineral constituents and observations of wild-fire infection are given in tables XIV and XV.

Table XVI gives average values of calcium content, nitrogen-calcium ratios, calcium-potassium ratios among the three- and four-year rotations.

In figures 1 to 7 the yields and the nitrogen-calcium, calcium-potassium ratios are charted.

TABLE I

Four-Year Rotation Experiments at Roseville, Pennsylvania 1938

1.--Nitrogen Series. A.--Individual Plot Treatments Using Nitrogen in Different Forms in a 3-8-12 Mixture
Applied at the Rate of 1000 Pounds with 10 Tons of Manure Per Acre

Plot number	Carrier of Nitrogen	Total yield pounds per acre	Production of wrappers (per cent)	Burn	Quality	Per cent mineral constituents moisture free basis			N/Ca ratio	Ca/K ratio
						Nitrogen	Potassium	Calcium		
1	Mixed	1807	88	Good	Good	3.43	4.06	3.89	.88	.96
48	Mixed	1051	66	Poor	Very poor	2.55	2.74	3.40	.75	1.24
2	Check	1633	83	Fair	Fair	3.04	4.83	3.58	.85	.74
43	Check	1486	71	Poor	Poor	2.59	3.43	3.81	.68	1.111
3	Cottonseed meal	1774	84	Good	Fair sharp	3.15	5.27	3.45	.91	.66
44	Cottonseed meal	1540	79	Fair	Fair	2.63	3.36	4.08	.65	1.21
4	Urea	1804	88	Fair	Fair	3.30	4.88	3.82	.86	.78
45	Urea	1380	80	Poor	Poor	2.17	3.16	3.87	.56	1.23
5	Soybean meal	1880	89	Good	Good	2.96	4.81	3.36	.88	.70
46	Soybean meal	1508	81	Poor	Poor	1.99	3.52	3.41	.58	.97
6	Nitrate of soda	1785	85	Good	Good	2.97	4.72	3.29	.90	.70
47	Nitrate of soda	1351	81	Fair	Poor	2.19	3.30	3.83	.57	1.16
7	Nitrate of potash	1588	91	Fair	Fair	3.17	5.86	3.43	.92	.59
49	Nitrate of potash	1532	83	Good	Good	3.23	5.06	3.91	.83	.77
8	Sulfate of ammonia	1688	90	Good	Good	3.00	4.20	3.63	.83	.86
50	Sulfate of ammonia	1689	90	Fair	Fair	3.42	4.57	3.84	.89	.84
9	Check	1397	81	Fair	Fair	3.39	3.92	3.53	.96	.90
51	Check	1402	78	Fair	Poor	2.63	3.64	3.69	.71	1.01

TABLE II

Four-Year Rotation Experiments at Roseville, Pennsylvania 1938

1.---Nitrogen Series. B.---Individual Plot Treatments Using Nitrogen in Different Forms in a 6-8-12 Mixture
Applied at the Rate of 1000 Pounds Per Acre with No Mamure

Plot Number	Carrier of Nitrogen	Total yield pounds of per acre	Produc- tion of wrappers per cent	Burn	Quality	Per cent mineral constituents moisture free basis			N/Ca ratio	Ca/K ratio
						Nitrogen	Potassium	Calcium		
10	Cottonseed meal	1552	82	Poor	Poor	2.61	3.36	4.01	.65	1.19
52	Cottonseed meal	1640	81	Fair	Fair	3.00	3.79	3.59	.84	.95
11	Urea	1649	85	Slow	Poor	2.91	3.47	4.02	.72	1.16
53	Urea	1584	84	Fair	Fair	3.14	3.11	3.74	.84	1.20
12	Soybean meal	1350	73	Poor	Poor	2.32	2.80	4.37	.53	1.56
54	Soybean meal	1530	78	Good	Fair-mild	2.93	3.84	4.41	.66	1.15
13	Nitrate of soda	1590	86	Good	Good	3.30	3.44	4.04	.82	1.17
55	Nitrate of soda	1662	78	Fair	Fair	2.86	3.19	4.66	.61	1.46
14	Nitrate of potash	1300	82	Good	Fair	3.11	4.00	3.80	.82	.95
56	Nitrate of potash	1623	74	Fair	Fair	3.23	3.75	4.69	.80	1.25
15	Sulfate of ammonia	1622	77	Fair	Fair	3.04	3.60	4.27	.71	1.19
57	Sulfate of ammonia	1360	79	Poor	Very poor	2.23	2.92	4.49	.65	1.54
16	Mixed	1642	86	Very poor	Poor	3.22	3.78	3.72	.87	.98
58	Mixed	1456	82	Fair	Poor	2.49	2.67	4.24	.63	1.59

TABLE III

Four-Year Rotation Experiments at Roseville, Pennsylvania 1938

1.--Potash Experiments. Individual Plot Treatments Using Potash in Different Forms and Quantities in a 3-8-12 Mixture Applied at the Rate of 1000 Pounds with 10 Tons of Manure Per Acre

Plot Number	Formula	Total yield	Production of wrappers	Burn	Quality	Mineral constituents of leaf moisture free basis			N/Ca ratio	Ca/K ratio
						Nitrogen	Potassium	Calcium		
17	Check	1694	83	Fair	Fair	3.08	4.19	3.72	.83	.89
59	Check	1320	77	Poor	Poor	2.44	2.02	4.35	.46	2.15
18	3-8-4	1625	86	Fair	Fair	3.17	4.77	3.66	.87	.77
60	3-8-4	1059	62	Poor	Poor	2.16	3.04	3.91	.78	1.29
19	3-8-8	1539	88	Good	Good	2.88	4.70	3.55	.81	.76
72	3-8-8	1270	73	Fair	Poor	2.12	3.30	3.35	.99	1.02
20	3-8-16	1702	89	Good	Fair	2.87	5.11	3.95	.73	.77
71	3-8-16	1564	83	Fair	Fair	2.21	3.69	3.63	.61	.98
21	3-8-20	1756	92	Good	Good	---	---	---	---	---
70	3-8-20	1532	84	Fair	Poor	2.43	4.54	3.49	.70	.77
22	3-8-12	1585	80	Good	Good	2.44	4.73	3.85	.63	.81
69	3-8-12	1320	84	Slow	Fair	2.39	4.46	3.32	.72	.74
23	3-8-12	1617	89	Fair	Good	2.77	4.21	3.80	.73	.90
68	3-8-12	1576	83	Slow	Fair	2.24	3.75	3.45	.65	.92
24	3-8-12	1423	80	Fair	Fair	2.52	3.97	3.71	.68	.94
67	3-8-12	1564	82	Fair	Fair	2.87	4.14	3.69	.78	.89

TABLE IV

Four-Year Rotation Experiments at Roseville, Pennsylvania 1938

3.--Phosphorus Series A Plot Treatments Using Phosphoric Acid in Different Forms and Quantities in Mixtures of 1000 Pounds with 10 Tons of Manure Per Acre

Plot Number	Formula	Total yield pounds per acre	Production of wrappers per cent	Burn	Quality	Mineral constituents of leaf on a moisture free basis			N/Ca ratio	Ca/K ratio
						Nitrogen	Potassium	Calcium		
25	3-0-12	1609	86	Good	Good	3.65	5.02	3.81	.96	.76
66	3-0-12	1399	75	Fair	Fair	3.26	4.33	4.30	.76	.99
26	3-4-12	1712	85	Fair	Fair	3.56	4.61	4.12	.86	.89
65	3-4-12	1660	87	Fair	Fair	3.21	4.53	4.22	.76	.93
27	3-12-12	1788	84	Fair	Fair	2.99	4.72	4.34	.69	.92
64	3-12-12	1742	85	Quick	Good	3.08	4.56	4.00	.77	.88
28	3-8-12	1758	81	Fair	Fair	3.32	3.62	4.06	.82	.88
63	3-8-12	1694	89	Slow	Fair	3.12	4.62	4.34	.72	.94
29	3-8-12	1503	75	Fair	Fair	2.93	3.16	3.34	.88	1.06
62	3-8-12	1536	92	Fair	Fair	3.65	4.61	4.25	.86	.92
30	3-8-12	1587	75	Fair	Fair	3.04	4.23	3.88	.78	.92
61	3-8-12	1441	83	Good	Good	2.93	4.93	4.19	.70	.85

TABLE V

Four-Year Rotation Experiments at Roseville, Pennsylvania 1938

3.—Phosphorus Series. B.—Plot Treatments Using Phosphoric Acid in Different Forms and Quantities in Mixtures of 1000 Pounds Per Acre of Manure

Plot Numbers	Formula	Production of wrappers per cent	Burn	Quality	Mineral constituents of leaf on a moisture free basis			N/Ca ratio	Ca/K ratio	Total yield pounds per acre
					Nitrogen	Potassium	Calcium			
31	6-0-12	68	Poor	Poor	3.31	2.59	4.46	.74	1.72	1310
78	6-0-12	84	Poor	Fair	2.99	3.06	3.88	.77	1.27	1354
32	6-4-12	80	Very poor	Poor	2.99	3.06	4.02	.74	1.31	1552
77	6-4-12	84	Fair	Good	2.82	2.74	3.61	.78	1.32	1456
33	6-12-12	78	Very poor	Very poor	1.99	3.60	3.73	.53	1.06	1421
76	6-12-12	80	Poor	Poor	2.83	3.73	3.62	.78	.97	1416
34	6-8-12	78	Poor	Poor	2.12	2.49	3.81	.56	1.53	1476
75	6-8-12	83	Poor	Poor	3.23	3.62	3.52	.92	.97	1448
35	6-8-12	81	Slow	Poor	2.71	2.71	4.02	.67	1.48	1559
74	6-8-12	88	Good	Good	3.67	4.16	3.55	1.03	.85	1540
36	6-8-12	76	Fair	Fair	2.30	3.12	3.90	.59	1.25	1370
73	6-8-12	80	Good	Fair-sharp	3.18	4.26	3.79	.84	.89	1339

TABLE VI

Four-Year Rotation Experiments at Roseville, Pennsylvania 1938

4.--Miscellaneous Experiments--Individual Plot Treatments Featuring the Use of Sulfur and Manganese, with Fertilizer Mixtures Applies at the Rate of 1000 Pounds Per Acre, and Different Manure Treatment

Plot Numbers	Formula	Production of wrappers per cent	Burn	Quality	Total yield pounds per acre	Mineral constituents of leaf			N/Ca ratio	Ca/K ratio
						Nitrogen	Potassium	Calcium		
37	6-8-12	80	Very poor	Very poor	1544	3.26	4.26	4.44	.73	1.04
84	6-8-12	81	Poor	Poor	1642	2.64	4.84	4.11	.64	.85
38	3-8-12	86	Very poor	Very poor	1736	3.56	3.82	4.53	.79	1.19
83	3-8-12	76	Very poor	Very poor	1410	2.57	3.33	4.08	.63	1.23
39	3-8-12	81	Slow	Fair	1667	3.31	4.13	3.81	.87	.92
82	3-8-12	86	Fair	Fair	1665	2.75	4.32	3.52	.78	.82
40	No treatment	77	Fair	Fair	1431	3.31	2.13	4.16	.80	1.95
79	No treatment	67	Fair	Fair-sweet	1290	2.69	2.19	4.07	.66	1.86
41	Manure only	78	Poor	Poor	1428	3.36	2.16	3.70	.91	1.10
81	Manure only	76	Poor	Poor	1454	2.39	3.81	2.99	.80	.79
42	Manure only	71	Fair	Poor	1399	2.89	2.34	4.23	.68	1.81
80	Manure only	81	Good	Very poor	1560	3.08	4.12	3.80	.81	.92

TABLE VII

Composition of Materials Used

Material	Nitrogen	Phosphoric Acid	Potash	Manganese
	%	%	%	%
Cottonseed Meal	6			
Nitrate of Soda	15			
Soybean Meal	6			
Sulfate of Ammonia	20			
Tankage	8			
Urea	42			
Ammonium Phosphate	11	48		
Precipitated Bone		40		
Steamed Bone Meal	2	20		
Superphosphate		18		
Carbonate of Potash			61	
Nitrate of Potash	13		44	
Sulfate of Potash			48	
Manganese Sulfate				40

TABLE VIII

The Arrangement of the Plots for the Four-Year Rotation Experiment at
Roseville, Pennsylvania. Each plot 1/40 of an acre in area

West	North											East
	73	74	75	76	77	78	79	80	81	82	83	84
	61	62	63	64	65	66	67	68	69	70	71	72
	49	50	51	52	53	54	55	56	57	58	59	60
	37	38	39	40	41	42	43	44	45	46	47	48
	25	26	27	28	29	30	31	32	33	34	35	36
	13	14	15	16	17	18	19	20	21	22	23	24
	1	2	3	4	5	6	7	8	9	10	11	12
South												East

TABLE IX

Observations on the Total Yield, Production of Wrappers, Burn, and Quality of Tobacco Grown on the Plots of the Three-Year Rotation Experiment at Roseville, Pennsylvania in 1938, where Tobacco Follows Legumes

Plot number	Manure tons	Fertilizer		Total yield pounds	Production of wrappers per cent	Burn	Quality	Leaf constituents on moisture free basis			N/Ca	Ca/K
		Quantity	Formula					Nitrogen	Potassium	Calcium		
1		1000	6-8-4	1660	74	Fair	Fair	3.29	2.31	3.78	.87	1.64
2		1000	6-8-8	1368	79	Fair	Fair	2.78	2.53	3.82	.73	1.51
3		1000	6-8-12	1505	78	Fair	Fair	2.64	2.71	4.09	.65	1.51
4		1000	6-8-16	1584	80	Poor	Poor	2.76	2.80	3.85	.72	1.38
5		1000	0-8-12	1136	34	Fair	Poor	2.62	2.20	4.16	.63	1.89
6		1000	3-8-12	1279	76	Poor	Poor	2.42	2.20	3.88	.62	1.76
7		1000	9-8-12	1430	72	Fair	Fair	2.83	2.79	3.79	.75	1.36
8		1000	6-0-12	1224	68	Good	Fair	2.93	2.42	3.79	.77	1.57
9		1000	6-4-12	1342	70	Poor	Poor	3.00	2.47	3.89	.77	1.58
10		1000	0-8-12	1232	66	Good	Fair	2.49	2.36	3.75	.66	1.59
11		500	6-8-12	1594	66	Fair	Fair	3.04	1.80	4.03	.75	2.24
12		1500	6-8-12	1729	73	Fair	Fair	3.05	2.58	4.28	.71	1.66
13		1000	6-8-12	1373	63	Fair	Poor	2.61	2.62	3.69	.71	1.41
14		1000	6-8-12	1464	73	Fair	Fair	2.66	1.96	4.23	.63	2.16
15		1000	0-8-12	1240	61	Good	Fair	2.54	1.83	4.18	.61	2.28
16		500	6-8-12	1236	63	Poor	Poor	2.72	2.21	3.91	.70	1.77
17		1000	6-8-12	1523	74	Poor	Poor	3.20	3.10	4.42	.72	1.43
18		1500	6-8-12	1691	84	Poor	Poor	3.46	3.69	4.06	.85	1.10
19		-----	-----	953	47	Poor	Poor	2.97	.94	3.79	.78	4.03
20		1000	0-8-12	1263	69	Poor	Poor	2.34	2.22	3.98	.59	1.79
21	10	1000	0-8-12	1440	73	Good	Fair	2.71	3.47	3.54	.77	1.02
22	10	1000	3-8-12	1600	80	Good	Fair	2.77	3.57	3.79	.73	1.06
23	10	1000	3-8-8	1379	79	Fair	Fair	2.89	3.49	3.55	.82	1.02

TABLE X

Observations on the Total Yield, Production of Wrappers, Burn and Quality of Tobacco Grown on the Plots of the Three-Year Rotation Experiment at Roseville, Pennsylvania in 1938, where Tobacco Follows Legumes

Plot number	Manure tons	Fertilizer		Total yield pounds	Production of wrappers per cent	Burn	Quality	Leaf constituents on moisture free basis			N/Ca	Ca/K
		Quantity	Formula					Nitrogen	Potassium	Calcium		
24	10	500	3-8-12	1382	73	Good	Fair	2.79	3.56	3.17	.88	.89
25	—	1000	0-8-12	1262	68	Good	Poor	2.53	3.32	3.51	.72	1.51
26	10	1000	3-8-16	1648	82	Good	Good	2.81	4.19	3.39	.83	.81
27	10	—	—	1458	80	Fair	Fair	2.71	3.96	3.23	.84	.82
28	20	—	—	1676	83	Good	Good	2.80	4.50	3.13	.90	.70
29	—	—	—	1476	77	Poor	Poor	3.19	1.84	4.15	.77	2.26
30	—	1000	0-8-12	1374	75	Fair	Fair	2.74	2.64	3.72	.74	1.41
31	—	1000	6-8-12	1312	77	Fair	Fair	2.81	3.50	3.69	.76	1.05

- Notes: 1. Two-thirds of any nitrogen applied was in the form of cottonseed meal, the remainder as nitrate of soda, with the exception of Plot 14, where the quantities were reversed.
 2. Plot 13 received 1000 pounds of hydrated lime.
 3. Plots 29, 30, and 31 followed alfalfa. The others followed clover.
 4. Plots 16, 17, and 18 were supplied fertilizer in the row. Elsewhere the fertilizer was broadcast.

TABLE XI

Placement Tests on Tobacco Following Corn at Roseville, Pennsylvania 1938
 These Tests Involved Varying the Quantity of Potash and its Method of Application

Plot number	Condition of fertilizer	Formula	Method of application	Production of wrappers per cent	Burn	Quality	Total yield	Remarks
1A	Pulverized	4-8-35	Bands	63	Good	Fair	1260	Overripe
1B	Granulated	4-8-35	Bands	65	Fair	Fair	1352	Overripe
1C	Ordinary	4-8-35	Bands	64	Good	Fair	1205	Overripe
2A	Pulberized	4-8-35	Broken Bands	75	Good	Fair	1584	Overripe
2B	Granulated	4-8-35	Broken Bands	73	Good	Fair	1311	
2C	Ordinary	4-8-35	Broken Bands	66	Fair	Fair	1232	
3A	Pulverized	4-8-12	Bands	72	Fair	Fair	1523	
3B	Granulated	4-8-12	Bands	73	Fair	Fair	1368	
3C	Ordinary	4-8-12	Bands	71	Good	Fair	1489	
4A	Pulverized	4-8-12	Broken Bands	70	Good	Good	1498	
4B	Granulated	4-8-12	Broken Bands	75	Good	Fair	1394	
4C	Ordinary	4-8-12	Broken Bands	71	Good	Fair	1397	
5A	Pulverized	4-8-12	Broadcast	71	Good	Good	1337	
5B	Granulated	4-8-12	Broadcast	67	Very good	Good	1209	
5C	Ordinary	4-8-12	Broadcast	70	Very good	Fair	1363	
6A	Pulverized	4-8-12	Drilled in Row	77	Very good	Good	1663	
6B	Granulated	4-8-12	Drilled in Row	81	Very good	Fair	1580	
6C	Ordinary	4-8-12	Drilled in Row	76	Very good	Good	1368	
7A	Pulverized	4-8-12	Drilled in Row	72	Very good	Good	1436	
7B	Granulated	4-8-12	Drilled in Row	75	Fair	Fair	1613	
7C	Ordinary	4-8-12	Drilled in Row	78	Fair	Fair	1506	
8A	Pulverized	4-8-35	Bands	78	Fair	Fair	1397	Sharp
8B	Granulated	4-8-35	Bands	82	Fair	Fair	1403	Sharp
8C	Ordinary	4-8-35	Bands	74	Good	Fair	1403	

TABLE XII

Placement Tests on Tobacco Following Corn at Roseville, Pennsylvania 1938
 These Tests Involved Varying the Quantity of Potash and its Method of Application

Plot number	Condition of fertilizer	Formula	Method of application	Total yield	Production of wrappers per cent	Burn	Quality	Remarks
9A	Pulverized	4-8-35	Broken Bands	1644	75	Good	Good	Overripe
9B	Granulated	4-8-35	Broken Bands	1521	85	Good	Good	
9C	Ordinary	4-8-35	Broken Bands	1414	72	Good	Good	
10A	Pulverized	4-8-12	Bands	1494	76	Good	Good	Overripe
10B	Granulated	4-8-12	Bands	1374	75	Good	Good	
10C	Ordinary	4-8-12	Bands	1386	64	Good	Fair	
11A	Pulverized	4-8-12	Broken Bands	1320	68	Fair	Fair	
11B	Granulated	4-8-12	Broken Bands	1440	75	Fair	Poor	
11C	Ordinary	4-8-12	Broken Bands	1410	64	Good	Fair	
12A	Pulverized	4-8-12	Broadcast	1480	74	Good	Fair	
12B	Granulated	4-8-12	Broadcast	1231	67	Good	Fair	
12C	Ordinary	4-8-12	Broadcast	1293	52	Good	Good	
13A	Pulverized	4-8-12	Drilled in Row	1383	71	Good	Fair	
13B	Granulated	4-8-12	Drilled in Row	1465	80	Good	Fair	
13C	Ordinary	4-8-12	Drilled in Row	1320	67	Good	Fair	
14A	Pulverized	4-8-12	Drilled in Row	1350	69	Good	Fair	
14B	Granulated	4-8-12	Drilled in Row	1447	77	Good	Fair	
14C	Ordinary	4-8-12	Drilled in Row	1102	66	Good	Fair	

Notes: "Bands" = continuous bands 3 inches from row
 "Broken bands" = 18 inches along each plant on both sides of row, three inches away
 "Broadcast" = Broadcast and harrowed in
 "Drilled in Row" = Placed in rows and plants placed on top
 When 35 units of potash were applied 12 units were first applied, followed by 12 and 11 units at two other periods during the growing season.

TABLE XIII

The Calcium Content of the Placement Plots at Roseville,
Pennsylvania

Plot Number	% Calcium	Plot Number	% Calcium
1A	3.25	8A	3.37
1B	3.80	8B	3.92
1C	3.85	8C	3.37
2A	3.38	9A	3.30
2B	3.51	9B	3.87
2C	3.28	9C	3.81
3A	3.47	10A	3.67
3B	3.52	10B	3.63
3C	4.08	10C	3.40
4A	3.44	11A	3.70
4B	3.62	11B	3.56
4C	3.37	11C	3.73
5A	3.20	12A	3.69
5B	3.37	12B	4.10
5C	3.30	12C	4.30
6A	3.87	13A	4.07
6B	3.81	13B	4.12
6C	3.67	13C	3.29
7A	3.63	14A	3.43
7B	3.40	14B	3.70
7C	3.62	14C	3.74

TABLE XIV

Observations on the Outlying Plots given Fertilizer Treatment A*, on Farms in Lancaster County

Farmer	Wildfire infection	Mineral constituents of the leaf air dry basis		
		Nitrogen	Potassium	Calcium
King, E.	Low	3.47	5.20	2.52
Stoltzfus	Medium	3.18	5.14	2.89
Bowl, S.	Medium	3.08	3.25	2.77
King, J.	Medium	4.91	4.25	2.85
Bare	Medium	3.46	3.92	2.70
Reifsnyder	Medium	3.03	4.77	2.80
Hoover, J.	Low	4.02	2.34	2.95
Witman, E.	Low	3.71	3.99	3.15
Ranck, C.	Low	4.51	3.16	3.78
Mellinger	Medium	4.52	4.78	3.07
Stoltzfus, J.	Medium	3.35	3.85	3.35
Summers, S.	Low	3.56	2.47	2.96
Skiles, D.	Low	3.08	3.07	3.01
Barley, V.	High	3.72	1.89	3.34
Good, E.	Medium	3.47	2.80	3.26
Pomroning	Medium	2.57	3.50	3.16
Umble	High	3.70	2.44	3.12
Stoltzfus, I.	Medium	3.14	2.51	3.27

*Fertilizer treatment A =
 825 pounds Cottonseed meal
 2600 pounds Bone meal
 1800 pounds Potassium sulfate
 275 pounds KNO_3
 Total 5500 pounds
 700 pounds applied per acre

TABLE XV

Observations on the Outlaying Plots given Treatment B*,
on Farms in Lancaster County

Farmer	Wildfire infection	Mineral constituents on the leaf air dry basis		
		Nitrogen	Potassium	Calcium
King, E.	Low	3.59	4.61	2.50
Stoltzfus, L.	Medium	3.21	4.81	2.46
Bowl, S.	Low	2.53	4.18	2.39
Bare	Low	3.46	3.12	2.53
Reifsnnyder	Medium	4.15	3.35	2.80
Hoover, J.	Low	4.18	2.52	2.95
Witman, E.	Low	3.55	3.00	3.32
Mellinger	Low	3.86	3.50	3.07
Stoltzfus, J.	High	4.05	3.46	3.24
Summers	Medium	3.70	2.86	2.94
Skiles	Medium	2.99	3.10	2.87
Barley	High	3.48	2.66	3.20
Pomroning	Medium	3.50	3.25	3.20
Umble	High	3.62	2.35	3.70
Stoltzfus	Medium	4.17	1.99	3.69

*Fertilizer treatment B

825 pounds Cottonseed meal
 2600 pounds Bone meal
 2600 pounds Potassium carbonate
 275 pounds Potassium nitrate
 Total 6300 pounds
 700 pounds applied per acre

TABLE XVI

Average Values of the Calcium Content, Nitrogen-Calcium Ratios, Calcium-Nitrogen Ratios on the Three-and Four-Year Rotation Experiments

Plots	Average Calcium per cent	Average N/Ca Ratio	Average Ca/K Ratio
4-year Rotation Nitrogen Series A	3.66	.80	.91
4-year Rotation Nitrogen Series B	3.23	.73	.96
4-year Rotation Potash Experiment	3.73	.73	.97
4-year Rotation Phosphorus Series A	4.07	.80	.91
4-year Rotation Phosphorus Series B	3.83	.75	1.22
4-year Rotation Miscellaneous	3.95	.76	1.21
4-year Rotation General Average	3.86	.76	1.06
3-year Rotation	3.81	.74	1.56
3-and 4-year Rotations	3.84	.75	1.31

Figure 1. Nitrogen Series A
4 year rotationFigure 2. Nitrogen Series B
4 year rotation

Figure 3 Potash Experiments
4 year rotation

Figure 4 Phosphorus
4 year rotation

Figure 7. 3 year rotation plots

DISCUSSION OF RESULTS

In work of this type there are many factors that will influence the results and therefore must be taken into consideration in interpreting the data. Factors such as rainfall, amount of sunlight, erosion, disease, and condition of the plant affect the mineral metabolism of the plant. Plants from plots receiving identical fertilizer treatments may vary considerably in their mineral constituents. A large contributing factor to these variations may be the differences in inherent fertility among the various plots.

The yield and quality of the crop produced are criteria which are used in evaluating the various kinds and methods of fertilization. The mineral composition of the plant is also an indication of the value of the fertilizer treatment. It is of interest then, to compare these observations on yield and quality, and the mineral constituents in order to find the interrelationships that exist.

Throughout the three- and four-year rotation plots the calcium content can be considered as a constant in that the wide difference in the N/Ca and Ca/K ratios are due to the differences in nitrogen and potassium content. The average per cent calcium for the three-year rotations was found to be 3.81 per cent and 3.86 per cent for the four-year rotations.

The greatest variations are shown in the calcium content of the outlying plots on various farms in Lancaster County. (E. King 2.52 per cent calcium, and Rauck, C. 3.78

per cent calcium.) Much of this variation is probably due to the past usage and treatment of these plots.

Figures 1 to 7 show that the lines drawn for the nitrogen-calcium ratio more or less follow the yield curve while the calcium-potassium ratio lines show the opposite tendency. In general then, a high N/Ca ratio and a low Ca/K ratio was associated with high yields.

In the nitrogen series A on the four-year rotation plots this general tendency for the N/Ca ratio was followed except in plot 9 which was a check plot. The high ratio value is due to a high nitrogen value and slightly below average value for calcium. The Ca/K ratio value follow the same trend as stated above. Plots 48, 43, 45, 46 show poor burning and poor quality. In all these plots, the Ca/K ratios are higher than average, while in all but plot 43 the nitrogen-calcium ratio is lower than the average. In plot 48 and 46 the per cent calcium is low and in plot 43, 45, the per cent calcium is high.

In the nitrogen series B of the four-year rotation, the N/Ca ratio values again follow the yield values. The Ca/K ratio values show an opposite direction to the yield values. Plots 10, 12, 57, 16 show poor burning and poor quality. In all these plots the Ca/K ratio is high and in all but plot 16, the N/Ca ratio values are low. All the plots have a higher-than-average calcium value.

For the potash experiments of the four-year rotations,

the N/Ca ratio of plot 72 is high due to low nitrogen content. Plot 59, and 60 shows poor burning and poor quality. The Ca/K of both these plots are high and the N/Ca of plot 59 is low. The calcium contents from both of these plots is high.

The N/Ca ratio values follow the yield values in the phosphorus series A of the four-year rotations while the Ca/K ratio values have a fairly constant value due to a fairly even balance of potassium and calcium with an average ratio value of 91. There were no poor burning or poor quality samples from these plots. The calcium content was higher in these plots than the general average of all the four-year rotation plots.

No relation was observed with yield and the mineral ratios in the phosphorus series B of the four-year rotation plots but the N/Ca and Ca/K ratios are diametrically opposite. Good or fair burn and quality are listed for plots 77, 74, 36, 73. The Ca/K ratio values for these plots are average and the N/Ca ratio values are average with the exception of plot 36 which is low due to low nitrogen content. With the exception of plot 59, the per cent calcium was below the average value for these plots.

In the miscellaneous experiments of the four-year rotations, the N/Ca ratio values and the Ca/K ratio values follow the general tendency described in the previous plots. Poor burning and poor quality are listed for plots 37, 84,

38, 83, 41, 81. The Ca/K ratios are high with the exception of plot 84 and 81 where the potassium content is high. The N/Ca ratio is low in plots 84, and 83. The calcium content is high in all the plots except in plot 81 where it is abnormally low (2.99 per cent).

In the three-year rotation experiments the calcium-potassium ratios are extremely high due to low potassium content. The calcium values however are just average as well as the N/Ca ratios. The plots yielding good burn, and good quality samples have low Ca/K ratios.

Although the use of average values in a study of this kind may lead to erroneous conclusions, it is interesting to note that the average calcium content in the nitrogen series A where a 3-8-12 fertilizer was used is considerably higher than in nitrogen series B where a 6-8-12 fertilizer was used. Again in the phosphorus series A the highest average calcium value occurs where three units of nitrogen are used, while in the phosphorus series B the average calcium content is considerably lower where six units of nitrogen are used.

The results obtained in this study are based on one year's observations. In order to draw definite conclusions on the effects of the various fertilizers of the availability of calcium in the soil, the experiments would have to be repeated over a number of years and the changes noted.

SUMMARY

1. An average value of 3.84 per cent calcium was found in the tobacco-leaf samples from the experimental plots at Roseville, Lancaster County, Pennsylvania.
2. No instances of marked deficiency in calcium content were noted in the analysis of these samples.
3. High yields were associated with a high N/Ca ratio and a low Ca/K ratio.
4. The mineral constituents of the leaf samples are a good indication of availability of these constituents in the soil.
5. High nitrogen fertilizers suppressed the intake of calcium to some extent.
6. For good burn and good quality tobacco the N/Ca ratio was comparatively high and the Ca/K ratio comparatively low.

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