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The Pennsylvania State College

The Graduate School

Department of Agricultural and Biological Chemistry

The Effect of Potassium on the Yield and Composition
of Pennsylvania Cigar-leaf Tobacco

A Thesis

by

Jose Ramon de la Torre

Submitted in partial fulfillment
of the requirements for the degree of

Master of Science

October, 1945

Approved:

Sept. 18, 1945 C. Jensen

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I. Introduction

Among the essential elements found by many workers to be present in the plant tissues we have: carbon, hydrogen, and oxygen, obtained by plants from water or from atmospheric gases, and therefore abundant for all practical purposes. Also, considered as essentials we have nitrogen, phosphorous, potassium, calcium, sulphur, magnesium and iron, all of which enter the plant from the soil. Of these elements nitrogen, phosphorous and potassium are in general not only essential for plant growth, but the more used from the soil, and therefore they have to be supplied in the form of artificial fertilizers for further use and assimilation by the plant in order to increase the yield and improve the qualities of such plants.

Numerous workers have reported that the element potassium plays an important role in the physiological economy of the tobacco plant. It is absolutely essential for plants and cannot be entirely replaced by any other element. Even if the exact role of potassium is obscure its role is undoubtedly to be interpreted as chiefly a catalytic one, and appears to be necessary for some physiological processes. Among them we have: (a) the metabolism and translocation of carbohydrates; (b) the synthesis of proteins and related nitrogen-containing compounds (c) normal cell division, (d) exerts a great and favorable effect on the good burning qualities of tobacco, and (e) increases disease resistance.

On the other hand, there is no doubt of the importance of nitrogen in the nutrition of cigar-leaf tobacco provided that it is supplied in a readily available form and not in excess. The presence of nitrogen in the tobacco plant is closely related to the color of the leaves; the ripening of the tissues, the strength of the smoke, and finally the presence of nitrogen - containing compounds as protein, nicotine, etc.

II. Object of these Investigations

These investigations were pursued to find out how the amount of potassium fertilizer applied to the soil affected: (1) The amount of available potash in the soil. (2) The amount of potash and total nitrogen in the tobacco grown on these soils. (3) The amount of potash removed from the soil by the tobacco plants. (4) The ratio between the nitrogen and potassium found in the plant. (5) The yield and quality of the tobacco produced.

III. Historical

The Pennsylvania Tobacco Experiment Station has devoted a great amount of time to fertilizer studies basing these works on a number of theses. Manure alone, manure supplemented with fertilizers, and fertilizers alone have been compared. Fertilizers alone had showed not to be as good producer of tobacco in weight and quality as fertilizers supplemented with manure. The original project for this study considered the use of manure primarily supplemented with different amounts of fertilizers.

Potassium is taken from the soil by the plant ordinarily in the earlier stages of its life, forming generally very soluble inorganic compounds. Growing portions of the plant system are always rich in potassium, as buds, root tips, young leaves, etc. Older tissues contain relatively little potash.

That the amount of potassium in the plant is increased by the amount of available potassium in the soil has been accepted by many investigators. Ward (26) stated that increasing the quantity of potash fertilizer applied caused a corresponding increase in the percentage of potash in the leaf. Schmitt (24) found that increasing potassium or nitrogen in the fertilizer increased the amount of these nutrients in the plant. Nightingale, Schermerhorn and Robbins (22) found that when potassium was present in tomato plants in limited quantities it was translated from regions of less intensive to regions of more intense metabolism. Anderson (3) found that the potash increases from the lower

to the tenth or twelfth leaves declining then regularly to the top. Gribbins (8) found that if the quantity of available potash is low, the greater concentration occurs at the upper leaves, but if the quantity is satisfactory there is about a uniform concentration throughout the leaves. Thomas (25) concluded that the potassium absorbed by the plant was proportional to the amount applied in the fertilizer.

Since the tobacco plant is a heavy feeder it has been used as an indicator for the availability of fertilizer elements in the soil (15, 16, 20). The importance of the presence of potash in the tobacco leaf has been established in relation to its burning quality, by the work of Garner (6), Haley (9, 10), Gribbins (8), and many others.

The utilization of nitrogen and its use by the tobacco plant has been studied extensively especially because of its importance in metabolism, and its influence upon other elements in the plant. Garner (7) has performed interesting work in the nitrogen nutrition of tobacco. He concluded that nitrogen deficiency appears in some manner to produce a plant which shows a lower water content than where nitrogen is supplied in liberal amounts. Beaumont (4) also worked in the assimilation of nitrogen by the tobacco plant, and found that the higher the total nitrogen in the plant, the higher the nicotine content in the leaf. Haley (9,10,11,12) stated that nitrogen has to be supplied in an available form at the earlier stages of growth, but that it is more harmful than beneficial at the latter stages. Mc. Murtrey (15, 16,17) studied nitrogen assimilation by the tobacco plant especially

in connection with disease characteristics. Moss (21) and Thomas (25) have also shown the importance of nitrogen and other elements in the nutrition of tobacco and its quality. Emerson (5) studied the influence of the supply of potash upon the nitrogen-potash ratio in red clover and stated that the solubility of soil potassium is increased by applications of manure, but varies with the kind of compound supplied in the fertilizers. He showed also that the K/N ratio is widened slightly by the application of lime but narrowed by the application of manure.

Gribbins (8) stated that the ratio of nitrogen to potash should approximate 1:1 in the leaves being wider when the amount of potash supplied was minimum and narrower when the potash was excessive.

IV. Materials Used

Soil samples were taken from the plots of the four-year rotation experiment (tobacco following corn) at Roseville, Pa., featuring the use of fertilizer as a supplement to manure. Tobacco was grown in a four-year rotation of wheat, hay (clover and timothy), corn, and tobacco. Manure at rate of 15 tons per acre, without fertilizer supplements, constituted the control treatment. All treatments were in triplicate. Plot size was designed as $1/60$ of an acre, to furnish a final sample from one hundred plants, based on a distance of 40 inches between rows, 26 inches between plants in the row, approximately 6,000 plants per acre.

The treatments were distributed over a block of 30 plots, consisting of 3 tiers of ten plots, each treatment occurring once in a tier. The treatments and their arrangement follows:

TABLE I

Plot Treatments - Manure plus fertilizer

Potash Series

Plot	Numbers	Manure Tons/A	Fertilizer		Nutrients	
			N		P ₂ O ₅	Lbs./A K ₂ O
A	1, 16, 29	10				
B	6, 20, 22	10	30		90	0
C	3, 19, 27	10	30		90	60
D	9, 13, 25	10	30		90	120
E	2, 15, 30	10	30		90	180
F	8, 11, 24	10	30		90	240

Phosphorus Series *

G	5, 17, 23	10	30	0	120
H	10, 12, 28	10	30	60	120
I	4, 18, 26	10	30	120	120

Nitrogen Series *

K	7, 14, 21	10	0	90	120
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Plot Diagram

K	B	G	F	D	I	C	H	A	E
21	22	23	24	25	26	27	28	29	30
F	H	D	K	E	A	G	I	C	B
11	12	13	14	15	16	17	18	19	20
A	E	C	I	G	B	K	F	D	H
1	2	3	4	5	6	7	8	9	10

The fertilizer materials used were as follows:-

Nitrogen - derived from cottonseed meal and nitrate of soda;
Phosphoric acid, triple superphosphate, 48% P₂O₅; Potash,
sulfate of potash, 51.9% K₂O. A formula for Plot F is given on
next page:

Fertilizer Formula F

Pounds	Ingredient	Analysis Basis	Pounds Nutrients per Acre				
			N	P ₂ O ₅	K ₂ O	CaO	MgO
150	Cottonseed meal	6.6% N 3.0% P ₂ O ₅ 2.0% K ₂ O 0.3% CaO 0.7% MgO	10.0	4.5	3.0	0.5	1.1
125	Nitrate of soda	16% N	20.0				
178	Triple superphosphate	48% P ₂ O ₅		85.5		35.6	
457	Sulfate of potash	20% CaO 51.9% K ₂ O			237		
910			30	90	240	36.1	1.1

* The phosphorus and nitrogen series were not used in these studies, only the potash series. The tobacco samples used were two out of every triplicate as shown in the results.

The four crops in the rotation were tobacco, wheat, hay (red clover and timothy mixture), and corn. Corn was grown in 1941 on the tier which grew tobacco in 1942. These plots received the fertilizers as a broadcast treatment on the surface immediately before planting. After the fertilizers were applied, a spring-tooth harrow was used to incorporate it in the surface soil, followed by planting.

The amount and distribution of rainfall recorded for the growing season of 1942 represented a typical wet season.

Season of 1942

Month	Inches rainfall
June	3.84
July	7.15
August	<u>7.67</u>
Grand total for growing season:	18.66

This season was marked by excessive rainfall, but well distributed.

TABLE II
THE INFLUENCE OF MANURE ALONE OR
SUPPLEMENTED WITH DIFFERENT FERTILIZER
MIXTURES ON THE YIELD AND QUALITY OF PENNSYLVANIA
CIGAR-LEAF TOBACCO FOR THE SEASON OF 1942

Plot No.	Fertilizer formula	Yield Lbs/A	Wrappers per-cent	Burn	Quality
1	Manure only	1288	53	good	fair
16	" "	1260	46	good	fair
29	" "	1408	42	good	fair
Ave		1319	47	good	fair
6	3-9-0	1389	46	good	fair
20	"	1350	35	good	fair to good
22	"	1305	29	good	fair to good
Ave		1348	37	good	fair to good
3	3-9-6	1357	49	good	good
19	"	1475	34	good	fair to good
27	"	1487	52	good	fair to good
Ave		1440	45	good	fair to good
9	3-9-12	1521	59	good	fair
13	"	1470	51	good	fair to good
25	"	1434	40	good	fair
Ave		1475	50	good	fair

TABLE II(contd.)

Plot No.	Fertilizer formula	Yield Lbs/A	Wrappers per-cent	Burn	Quality
2	3-9-18	1508	53	good	good
15	"	1572	52	good	fair
30	"	1394	34	good	fair
Ave		1491	46	good	fair to good
8	3-9-24	1429	53	good	poor
11	"	1304	47	good	fair
24	"	1390	47	good	good
Ave		1374	49	good	fair

Manure was applied at the rate of 10 tons per acre in 1941 and 15 tons per acre in 1942. Fertilizers, when used, were applied at the rate of 1000 lbs. per acre.

Table I and II, were taken from the data available by the Department of Biochemistry in their tobacco investigations, and I wish to thank Dr. O. E. Street for providing them.

V. Methods of Analysis

A. Tobacco Analysis.

Samples of cured tobacco were secured when the leaves were stripped from the stalk. The leaves selected were chosen from the middle portion of representative plants. One leaf was selected from each of 15 such plants out of the total of about 100 plants grown on each plot. The samples were dried and the midribs removed, the remaining portions were then finely ground and kept in air-tight bottles until used.

The methods used in the chemical analysis of tobacco were essentially those used by Haskins (13).

Moisture was determined on a two gram sample by drying at 80°C for three hours in a vacuum drying oven, maintained at a pressure of less than 50 mm. of mercury.

For the determination of ash, two grams of powdered tobacco were weighed in a tared porcelain crucible and placed in an electric muffle, allowed to remain there for two hours at 500°C , cooled and weighed.

Potassium was determined on a neutral solution of the ash, using trisodium cobaltinitrite as the precipitating agent. The two gram sample used for the determination of the ash was ignited in a muffle furnace at $480\text{--}500^{\circ}\text{C}$ for 24 hours. The resultant ash was transferred to a 400 ml. beaker using distilled water and one ml. of concentrated nitric acid. This solution was heated to boiling and cooled before filtering into a 200 ml. volumetric flask, washed and made up to volume with distilled water.

A 10 ml. aliquot was then measured into a 100 ml. beaker and neutralized by the dropwise addition of normal sodium hydroxide, using a drop of methyl red as an indicator. The solution was then acidified with one ml. of normal nitric acid and the potassium precipitated by the addition of five ml. trisodium cobaltinitrite solution, containing one gram of reagent per five ml. The beaker was placed in a water bath maintained at 20°C. for two hours and then filtered through a tared porous bottomed porcelain filtering crucible. The transfer was made with 0.01 N nitric acid from a wash bottle. The precipitate was washed ten times with two ml. portions of the dilute nitric acid and five times with two ml. portions of 95% alcohol. Suction was applied until the precipitate was quite dry, the crucible was then wiped with a clean cloth and placed in an electric drying oven for one hour at 110°C. After cooling in a desiccator, it was weighed. The weight of precipitate multiplied by the factor 0.17216 gave the corresponding weight of potassium.

Total nitrogen was determined by the Kjeldahl method modified to include the nitrogen of nitrates. A one gram sample of the ground tobacco was placed in an 800 ml. Kjeldahl digestion flask. To this 40 ml. of concentrated sulfuric acid, containing one gram of selenic acid were added and the flask rotated to insure a thorough mixing of reagent and sample. The mixture was allowed to stand at least thirty minutes, with frequent shaking. Five grams of sodium thiosulfate were then added and the resultant mixture heated slowly until white fumes appeared. After cooling, ten grams of potassium sulfate, a few crystals

of copper sulfate and a Hengar selenium pellet were added and the mixture heated in a moderate flame for one hour after clearing. The flask was allowed to cool and then diluted with 250 ml. of distilled water. A pre-determined volume of Greenbank alkali was added (to make the solution strongly alkaline), followed by a few pieces of mossy zinc, then connected to the condenser and the contents mixed. The released ammonia was collected in about 50 ml. of saturated boric acid solution (5%) a total volume of about 200 ml. being distilled over. The distillate was then titrated with 1/14 normal sulfuric acid using a mixed indicator of methyl red and methylene blue. A blank determination was run on the reagents employed.

B. Soil Analysis

Soil samples secured from the fertilizer plots were dried and pulverized. One portion of each soil sample was ground to pass a 40 mesh screen and another portion to pass a 100 mesh screen. The 40 mesh sample was used for the determination of potassium, and the 100 mesh soil was used for the determination of nitrogen. Moisture was determined in both samples as it is described in the Official Methods of Analysis, for Soils (23).

The method used for the determination of available potash in the soil was the method in general use at the Pennsylvania Agricultural Experiment Station, which is described below:

Fifty grams of prepared soil were weighed and placed in a 300 ml. Erlenmeyer flask, 125 ml. of ammonium acetate added, shaken and the soil allowed to settle. The supernatant liquid was decanted through

a filter on a ribbed funnel into a 500 ml. Erlenmeyer flask. The operation was repeated with another 125 ml. portion of ^mamonium acetate and then a 100 ml. portion added. Fifty ml. of extracting solution were added and soil and extractant were poured on the filter paper. Finally the soil was leached on the paper with another 50 ml. portion of ^mamonium acetate. A few drops of the filtrate from the last addition were tested for calcium and when found free of calcium (the leachings) were made up to a volume of 500 ml.

A 250 ml. aliquot of the amonium acetate leachate was evaporated to dryness on a hot plate at about 60° to 65°C. After complete evaporation, the sides of the beaker were washed down and evaporated again.

To the fluffy residue, 5 ml. of 10% hydrogen peroxide were added to destroy organic matter and the beaker was shaken with a rotary motion so as to wet the sides. Evaporated to dryness again. The treatment was repeated if necessary in order to oxidize all organic matter. The sides of the beaker were washed thoroughly and sufficient 10% sodium hydroxide solution was added to turn phenolphthalein distinctly red. An excess of over 1 ml. of the alkaline solution was avoided. The contents of the beaker were evaporated again to dryness in order to drive off the last traces of ammonia, and, after cooling 25 ml. of approximately 0.15 N acetic acid were exactly added. After polishing thoroughly the sides and bottom of the beaker, one drop of the solution was tested for ammonia with Nessler reagent. The solution filtered through a dry

filter into a dry vessel and a 20 ml. aliquot, representing 20 gms. of soil, placed in a beaker and set in a water bath at 10°C or below. To the cooled solution, 5 ml. of the cooled (10°C or below) solution of $\text{Na}_3\text{Co}(\text{NO}_2)_6$ were added with vigorous stirring.

The solution was allowed to stand in a refrigerator overnight and the precipitate collected on a compact asbestos pad in a Gooch crucible. The beaker was rinsed five times and the rinsings poured into the Gooch so as to also wash the precipitate, and the precipitate washed five additional times. Cooled water to 10°C was always used to do the washings. The outside of the crucible was rinsed, the pad removed, and both pad and crucible were placed into the original beaker and covered with water. First a few ml. of 0.05 N potassium permanganate from a burette were added, and then immediately 5 ml. of dilute sulfuric acid were added too. The mixture stirred vigorously to break up the asbestos, and permanganate was added until an excess was present. The beaker and contents were placed over a low flame and heated just to boiling. More permanganate was added if the color was about to disappear.

After removing from the flame, 0.05 N oxalic acid, was added, with stirring until an excess of about 1 ml. was present, and the mixture allowed to stand for several minutes, stirring frequently, until perfectly white. The excess of oxalic acid was titrated with 0.05 N permanganate. Each ml. of 0.05 N permanganate used was equivalent to 0.0003259 gm. of potassium or 0.0003926 gm. of potash.

Total nitrogen in soils was determined by the Kjeldahl method including the nitrogen of nitrates as used for the tobacco samples. But 10 gms sample were used and 60 ml. of sulfuric-salycilic acid added.

VI. Results

TABLE III.

Results of Analysis

Soils							Tobacco			
Sample	Moisture 40 mesh %	AVE. 100 mesh %	Available K ₂ O %	P.P.M.	Nitrogen %	P.P.M.	Moisture AVE. %	Ash %	K ₂ O %	Nitrogen %
A-1-1	1.13	0.76	0.0261	261	0.13	1300	6.18	20.40	3.98	3.09
A-1-2			0.0271	271	0.13	1300		20.28	3.88	3.04
A-16-1	1.21	0.81	0.0165	165	0.11	1100	6.28	21.80	3.99	3.27
A-16-2			0.0161	161	0.11	1100		21.72	3.97	3.28
A-29-1	1.32	0.85	0.0188	188	-	-	-	-	-	-
A-29-2			0.0180	180	-	-	-	-	-	-
B-6-1	1.05	0.93	0.0126	126	0.11	1100	5.63	20.20	4.25	3.47
B-6-2			0.0155	155	0.11	1100		20.29	4.34	3.53
B-20-1	1.36	0.96	0.0136	136	0.12	1200	5.75	21.35	4.57	3.70
B-20-2			0.0138	138	0.12	1200		21.58	4.62	3.56
B-22-1	0.97	0.88	0.0160	160	-	-	-	-	-	-
B-22-2			0.0160	160	-	-	-	-	-	-
C-3-1	1.01	0.76	0.0208	208	-	-	-	-	-	-
C-3-2			0.0206	206	-	-	-	-	-	-
C-19-1	1.06	0.92	0.0278	278	0.10	1000	6.07	22.69	4.63	3.48
C-19-2			0.0286	286	0.10	1000		22.63	4.62	3.40
C-27-1	1.14	0.83	0.0199	199	0.10	1000	5.94	19.92	4.32	3.27
C-27-2			0.0202	202	0.10	1000		20.11	4.43	3.24

TABLE III.(contd.)

Soils						Tobacco				
Sample	Moisture 40 mesh %	100 mesh %	Available K ₂ O %	P.P.M.	Nitrogen %	P.P.M.	Moisture %	Ash %	K ₂ O %	Nitrogen %
D-9-1	1.22	0.81	0.0238	238	0.11	1100	6.74	21.79	4.48	3.23
D-9-2			0.0250	250	0.10	1000		21.75	4.57	3.38
D-13-1	1.07	0.75	0.0262	262	0.095	950	6.74	21.87	4.83	3.55
D-13-2			0.0294	294	0.090	900		21.76	5.01	3.58
D-25-1	0.98	0.74	0.0228	228	-	-	-	-	-	-
D-25-2			0.0224	224	-	-	-	-	-	-
E-2-1	0.96	0.72	0.0392	392	0.10	1000	6.49	21.69	4.99	3.19
E-2-2			0.0396	396	0.10	1000		21.68	5.01	3.20
E-15-1	1.02	0.83	0.0367	367	0.11	1100	6.14	20.24	4.19	4.02
E-15-2			0.0371	371	0.12	1200		20.13	4.17	3.82
E-30-1	1.19	0.94	0.0372	372	-	-	-	-	-	-
E-30-2			0.0368	368	-	-	-	-	-	-
F-8-1	1.13	0.74	0.0378	378	0.11	1100	7.08	23.20	4.85	3.14
F-8-2			0.0436	436	0.11	1100		23.13	4.96	3.29
F-11-1	0.93	0.70	0.0443	443	-	-	-	-	-	-
F-11-2			0.0447	447	-	-	-	-	-	-
F-24-1			0.0437	437	0.11	1100	6.56	21.72	4.66	3.57
F-24-2	0.99	0.65	0.0400	400	0.11	1100		21.66	4.70	3.58

TABLE IV.

EFFECT OF VARIOUS FERTILIZER
TREATMENTS ON THE AMOUNT OF AVAIL-
ABLE POTASH IN THE SOIL, AND THE AMOUNT
OF POTASH ON CURED TOBACCO, ON MOISTURE FREE BASIS

Plot No.	Fertilizer	Available Potash in soil %	Potash in Tobacco %
A-1	None	0.027	3.93
A-16	None	<u>0.016</u>	<u>3.98</u>
Ave.		0.022	3.96
B-6	3-9-0	0.014	4.30
B-20	3-9-0	<u>0.014</u>	<u>4.60</u>
Ave		0.014	4.45
C-19	3-9-6	0.028	4.63
C-27	3-9-6	<u>0.020</u>	<u>4.38</u>
Ave.		0.024	4.51
D-9	3-9-12	0.024	4.53
D-13	3-9-12	<u>0.028</u>	<u>4.92</u>
Ave.		0.026	4.72
E-2	3-9-18	0.039	5.00
E-15	3-9-18	<u>0.037</u>	<u>4.18</u>
Ave.		0.038	4.59
F-8	3-9-24	0.041	4.90
F-24	3-9-24	<u>0.042</u>	<u>4.68</u>
Ave.		0.042	4.79

TABLE V.

EFFECT OF VARIOUS FERTILIZER
TREATMENTS ON THE TOTAL NITROGEN
IN THE SOIL AND THE TOTAL NITROGEN
IN THE CURED TOBACCO, ON MOISTURE FREE BASIS

Plot No.	Fertilizers	Nitrogen in Soil %	Nitrogen in Tobacco %
A-1	None	0.13	3.07
A-16	None	<u>0.11</u>	<u>3.28</u>
Ave.		0.12	3.18
B-6	3-9-0	0.11	3.50
B-20	3-9-0	<u>0.12</u>	<u>3.63</u>
Ave.		0.12	3.57
C-19	3-9-6	0.10	3.44
C-27	3-9-6	<u>0.10</u>	<u>3.26</u>
Ave.		0.10	3.35
D-9	3-9-12	0.11	3.30
D-13	3-9-12	<u>0.10</u>	<u>3.57</u>
Ave.		0.11	3.44
E-2	3-9-18	0.10	3.20
E-15	3-9-18	<u>0.12</u>	<u>3.92</u>
Ave.		0.11	3.56
F-8	3-9-24	0.11	3.21
F-24	3-9-24	<u>0.11</u>	<u>3.58</u>
Ave.		0.11	3.40

TABLE VI.

EFFECT OF VARIOUS FERTILIZER
TREATMENTS ON THE AMOUNT OF ASH
AND POTASH IN THE CURED TOBACCO ON
MOISTURE FREE BASIS

Plot No.	Fertilizer	Ash %	Potash in Tobacco %
A-1	None	20.34	3.93
A-16	None	<u>21.76</u>	<u>3.98</u>
Ave.		21.05	3.96
B-6	3-9-0	20.25	4.30
B-20	3-9-0	<u>21.47</u>	<u>4.60</u>
Ave.		20.86	4.45
C-19	3-9-6	22.66	4.63
C-27	3-9-6	<u>20.02</u>	<u>4.38</u>
Ave.		21.34	4.50
D-9	3-9-12	21.75	4.53
D-13	3-9-12	<u>21.82</u>	<u>4.92</u>
Ave.		21.79	4.73
E-2	3-9-18	21.69	5.00
E-15	3-9-18	<u>20.19</u>	<u>4.18</u>
Ave.		20.94	4.59
F-8	3-9-24	23.17	4.90
F-24	3-9-24	<u>21.69</u>	<u>4.68</u>
Ave.		22.43	4.79

TABLE VII.
THE RATIO BETWEEN
NITROGEN AND POTASSIUM
IN THE TOBACCO

Plot No.	Fertilizer	N in Tobacco %	K in Tobacco %	N/K Ratio
A-1	None	3.07	3.26	0.97
A-16	None	<u>3.24</u>	<u>3.30</u>	
Ave.		3.18	3.28	
B-6	3-9-0	3.50	3.57	0.97
B-20	3-9-0	<u>3.63</u>	<u>3.82</u>	
Ave.		3.57	3.70	
C-19	3-9-6	3.44	3.84	0.90
C-27	3-9-6	<u>3.26</u>	<u>3.64</u>	
Ave.		3.35	3.74	
D-9	3-9-12	3.30	3.76	0.88
D-13	3-9-12	<u>3.57</u>	<u>4.08</u>	
Ave.		3.44	3.92	
E-2	3-9-18	3.20	4.15	0.93
E-15	3-9-18	<u>3.92</u>	<u>3.47</u>	
Ave.		3.56	3.81	
F-8	3-9-24	3.21	4.07	0.85
F-24	3-9-24	<u>3.58</u>	<u>3.88</u>	
Ave.		3.40	3.98	

TABLE VIII.

APPROXIMATE AMOUNT OF
POTASH REMOVED PER ACRE

Plot No.	Yields Wet Basis	Approximate Yields on Dry Basis	Approximate Pounds of K ₂ O removed per acre
A	1274	1019	40.4
B	1370	1096	48.8
C	1481	1185	53.4
D	1496	1197	56.5
E	1540	1232	56.6
F	1410	1128	54.0

For the purpose of these calculations the cured tobacco was assumed to contain 20% moisture.

VIII. Discussion

Investigations on soil and plant interrelationships often yield results which are difficult to evaluate, especially when conducted under field conditions, because there are many factors involved which are not under the direct control of the investigator.

These experiments are no exception to the general rule, but by repeating such experiments at frequent intervals we can arrive at certain definite conclusions. However from the data obtained some conclusions can be drawn.

When the experimental plots received increasing quantities of potash while nitrogen and phosphorus were held constant a corresponding increase was found in available potash in the soil and potash in the plant, as shown in Tables III and IV. Also, an increase in the potash fertilizer showed an increase in the yield and the approximate weight of K_2O removed per acre from the soil, as shown in Tables II and VIII, up to application of 180 Lbs. per acre.

These general results are in close agreement with the results found by Gribbins (8), Thomas (25), Anderson (3), and Ward (26) who stated "each increase in the quantity of potash fertilizer applied causes a corresponding increase in the percentage of potash in the leaves." Although the general results of this study agree with the above statements that increasing the amount of potash applied to the soil increases the amount found in the plant, plot E failed to give this result. For some unknown reason the tobacco grown on plot E-15

had a very low potassium content. In order to be sure that this was not an analytical error the analysis of this sample was repeated in duplicate and it was found that results checked closely with the original analysis.

It is interesting that although the potash was lower in the plants from plot E than was to be expected, the yield was very good and the amount of potash removed per acre was equal to that removed from plot D.

In the plots studied, the amount of nitrogen in the fertilizer was held constant but the amount of potash increased. One third of the nitrogen was supplied in a readily available form for out of the 30 pounds applied, 20 pounds were in the form of cottonseed meal and 10 pounds in the form of nitrate of soda. This form of nitrogen application has proven to be especially good and the plants in all the plots were grown without any sign of nitrogen deficiency. We can conclude as is shown in the Table V, that the amount of potash in the fertilizer or available potash in the soil apparently did not affect the amount of nitrogen in the plant, which is in accordance with the work of Haley (9,10,11,12) showing the importance of supplying the nitrogen in the earlier stages of growth rather than in the latter ones. An important thing to take into consideration at this point is that the 1942 crop season was a wet season and that the manure applied to the soil before planting helped to keep the available nitrogen on a high level, even in the check plot, and supplied nitrogen to the plant at approximately a constant rate. The importance of the rainfall and weather conditions on the yield of tobacco, and the

potash and nitrogen metabolism has been showed previously by the work of Garner (7), Mc. Murtrey (16), and Thomas (25).

The increase in the potash fertilizer did not show an increase in the amount of ash in the plant, as was expected, because by the work of Anderson (1, 3) and by Ward (26) it was shown that by increasing the potash in the soil there is no increase particularly in the amount of ash. For the amounts of Magnesium and calcium were found to be inversely proportional to the amount of potash. In this connection Ward (26) found that the Calcium Magnesium ratio is an important factor in the tobacco leaf. In all cases studied, both calcium and magnesium showed a decidedly antagonistic effect towards potassium; also, the sum of $\text{CaO} + \text{MgO}$ increased regularly with each decrease in potash content of the leaf. Anderson (3) and Gribbins (8) found the same results. "Any increase in the potash content of the leaf resulted in a decrease in the calcium and magnesium content of the same leaf, the total ash being constant."

Gribbins et al (8) stated "From the results obtained, the writers are inclined to believe that the ratio of nitrogen to potassium should approximate 1:1 in the leaves. It is apparent that the plots receiving minimum quantities of potassium had a wider ratio, while those receiving excessive quantities had a narrower ratio than this value." He also stated "It would appear that there is some correlation between the nitrogen potassium ratio of the leaves and the fertilizer treatments of the plants." This statement is in agreement with the results obtained and showed in the Table VII. A and B plots did not have any

potash fertilizer and the N/K ratio was a little wider than the plots that received potash in the fertilizer. The E plots in this discussion were out of the line too, for some reason which we cannot explain. Further investigation will be necessary.

VII. Summary

Samples were taken from soils in which fertilizers were applied as a supplement for manure; nitrogen and phosphorus were held constant, but potash was increased from none to 240 pounds per acre. Cured tobacco samples grown on those soils were also taken ^{or} from analysis. Results of these studies lead to the following conclusions:

- I. Each increase in the amount of the potash applied to the soil resulted in a corresponding increase in the available potash, and as a consequence a corresponding increase in the potash content of the tobacco plant.
- II. The approximate amount of potash removed by the tobacco increases with increased potash applications to the soil up to 180 pounds per acre. In all cases the amount removed per acre was less than 60 pounds.
- III. The nitrogen contents of the soils of the different plots showed no significant differences.
- IV. The amount of potash in the fertilizer apparently did not affect the amount of nitrogen in the plant.
- V. The amount of ash in the tobacco was found to be practically constant independent of the increase in the potash of the fertilizer.
- VI. The N/K ratio of the tobacco is wider when grown on plots that do not have any potash fertilizer and narrower from plots that have potash in the fertilizer.

- VII. No significant differences resulting from potash applications were found in the quality of the tobacco grown in 1942.
- VIII. Increased potassium applications showed a favorable effect in increasing the yield of tobacco up to additions of 180 pounds per acre of potash. The plots receiving 240 pounds per acre showed a significant decrease in yields.

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