THE INFLUENCE OF CERTAIN PROPERTIES OF ORGANIC NITROGEN COMPOUNDS ON THE MOVEMENT OF PLANT NUTRIENTS IN GRANVILLE SANDY LOAM AND ON THE YIELD AND QUALITY OF FLUE-CURED TOBACCO

by

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INTRODUCTION

The fertilization of flue-cured tobacco is one of the most important agronomic problems of the tobacco farmer. The cost of fertilizers, averaging from $10.00 to $15.00 per acre, is his largest single item of expense in producing the crop. Since 1907 the Virginia Agricultural Experiment Station has conducted field experiments (18, 19, and 22)* to determine the most economical and efficient fertilizer mixtures for the production of high quality tobacco. On the basis of these experiments and of experiments conducted in other states, the Agronomy Tobacco Research Committee issues annually specific recommendations (1) for the formulation of fertilizer mixtures to be used on flue-cured tobacco.

The recent developments in the production of synthetic organic fertilizers, such as urea and urea mixtures, have made it possible to substitute a part of the recommended natural organics with the newer synthetic organic materials. Thus the question arises as to the extent to which this substitution can be practiced without lowering the yield and quality of the tobacco.

* Figures in parenthesis refer to "Literature Cited" p. 55.

Although there are numerous experiments conducted each year in an attempt to find the comparative value of the organic and inorganic sources of nitrogen for the production of flue-cured tobacco, the farmers still insist that a certain proportion of natural organic nitrogen carriers be included in the fertilizer mixture. This experiment is the first in a series to be conducted to determine the effects of organic nitrogen compounds upon the soil, and upon the yield and quality of flue-cured tobacco.

The purpose of this study was:

1. To determine which of the organic compounds of plant and animal origin, such as cottonseed meal, soybean meal, castor pomace, fish meal, process tankage, and sewage sludge, is the most economical and efficient source of nitrogen for the production of high quality flue-cured tobacco.
2. To determine the most economical ratio between organic nitrogen compounds of plant and animal origin and inorganic nitrogen compounds in the fertilizer mixture for flue-cured tobacco.
3. To determine whether nitrogen compounds of plant or animal origin influence the movements of other plant nutrients (potassium, calcium, and magnesium) in the soil and their availability to the tobacco plant.

4. To determine whether nitrogen compounds of plant or animal origin contain a sufficient amount of minor elements (boron, manganese, magnesium, zinc, and iron) to have a measurable effect on plant growth.

REVIEW OF LITERATURE

The use of fertilizers for the growing of flue-cured tobacco (class 1) (34) has been a general practice among tobacco growers for many years. The proper rate of application and use of the various fertilizing materials have been the objects of many experiments. Flue-cured tobacco is grown on well drained, light colored sands and sandy loams. Liberal quantities of nitrogen, phosphorus, potassium, and magnesium must be applied, but an excess of nitrogen should be avoided in order to prevent the production of tobacco of an undesirable grade and quality.

According to Garner et al (14) the most important effect of the nitrogen supply on the development of the tobacco plant pertains to the character of the leaf. The effect of the nitrogen supply on the color and luster of the leaf is of great practical importance since shade, evenness and the brilliancy of color largely determine the commercial value of the crop. The amount of nitrogen is important in determining not only the grade and quality but also the class of the leaf produced. Tobacco leaves used for cigar wrappers and binders (classes 5 and 6) require a heavy application of nitrogen. In the Connecticut Valley, tobacco types U. S. 51, 52, and 61 are fertilized with 160-200 pounds of nitrogen per acre, the nitrogen being derived from a mixture of cottonseed meal, castor pomace, and fish meal, although one-third, or even more (5), of the total nitrogen may be derived from a combination of urea and nitrate of potash or similar inorganic sources (3 and 13). Cigar filler leaf tobacco grown in Pennsylvania (U. S. type 41) and Ohio (U. S. types 42, 43, and 44) require 30-40 pounds of nitrogen per acre. Haley (17), recommends for Pennsylvania that two-thirds of the nitrogen be derived from nitrate of soda and the remainder from cottonseed meal. Air-cured and fire-cured tobacco (classes 2 and 3) require 20-30 pounds of nitrogen per acre and the recommended sources are one-third of the nitrogen from organics of plant or animal origin, one-third in the nitrate form, and one-third from urea or any standard inorganic source (13 and 8).

Flue-cured tobacco (class 1) is a striking example of a tobacco which has to mature under conditions of nitrogen starvarion. Optimum growth of bright tobacco is obtained when the added nitrogen provides a rapid and uninterrupted growth during the season and becomes practically exhausted at ripening time (27). Ames and Blotz (2) state that organic compounds become slowly available to the tobacco plant and continue the supply of nitrogen throughout the season. Organic sources of nitrogen, such as dried blood (9) and cottonseed meal (26), do not lose nitrogen by excess leaching, even in wet years, and thus they furnish a more even and uninterrupted supply of nitrogen than inorganic sources, such as nitrate of soda or ammonium sulphate. Benson and Barnette (6), showed that fish meal, castor pomace, and tankage lost less nitrogen through leaching than did nitrate of soda, câlcium nitrate, ammonium nitrate and urea.

Since quality of the leaf is the final measure of the success of growing a tobacco crop, it is essential to use those sources of nitrogen which produce the best quality. From experiments in Maryland with cigarette tobacco (class 3) Garner et al (15) have concluded that organic sources produce better quality than inorganic sources, but the inorganics produce higher yields. By combining the properties of these two sources of nitrogen, high yields of good quality tobacco can be obtained, After ten years of experimenting at Chatham, Virginia, Hutcheson and Copley (19) concluded that satisfactory sources of nitrogen are one-fourth nitrogen from high grade organics and three-fourths nitrogen from high grade inorganics. Results from later experiments at Chatham (22) indicate that from one-fourth to one-third of the nitrogen should be derived from organic materials.

Since this study deals primarily with the nitrogen fertilization of flue-cured tobacco, a review of literature will not be made of experiments with reference to phosphorus and potassium. It should be borne in mind, however, that, as pointed out by McMurtrey et al (28), a proper balance of nitrogen and potassium must be maintained for optimum growth of tobacco.

Garner (11, 12 and 16) stresses that not only nitrogen, phosphorus, and potassium but also the amount of calcium, magnesium, sulphur, and chlorine have to be considered in the growing of tobacco. According to Garner et al (16) a 1000 pound leaf crop of tobacco contains six pounds of magnesia (MgO) and four to five times as much calcium. McMurtrey (27) states that tobacco plants manifest distinctive symptoms when the soil is deficient in one of the essential elements for its development, namely, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, boron, manganese, and iron.

Garner (12), states in his latest paper (1939) that it has become apparent that results obtained from the old conventional methods of conducting field experiments and recording the fertilizer effects merely in terms of crop yields and values can not be a basis of determining the mode of action of the fertilizer. He recommends the development of a physiological approach whereby excellent results can be obtained on absorption of plant nutrients by the plant using only a single essential element as a variant and keeping the others constant from a soil selected with a known chemical composition.

It can be seen that the formation of a correct fertilizer mixture for flue-cured tobacco is a complex problem. Each year a committee of tobacco research workers from Virginia, North Carolina, South Carolina, Georgia, and Florida formulate fertilizer recommendations for the optimum growth of flue-cured tobacco in this region (1). The present recommendations are:

A. <u>Analyses of Mixtures and Rates of Application:</u>

1. Heavy or more productive soils - 800-1000 pounds per acre 3-10-6.
2. Light or less productive soils - 800-1200 pounds per acre 3-8-6.
3. Method of application - in bands 3-4 inches to the sides of row at the approximate level or slightly below the root crowns: plants to be set between these bands.

B. Sources of Plant Food:

1. Nitrogen - 1/3 nitrogen from high grade organics of plant or animal origin.
   1/3 nitrogen from materials supplying nitrogen in the nitrate form.
   1/3 nitrogen from standard inorganic sources. Urea is considered an inorganic source.
2. Phosphoric acid - from any source of available phosphoric acid provided the available calcium in the mixture conforms to section 7.
3. Potash - from any source of available potash, provided the chlorine content of the fertilizer mixture does not exceed 2 percent except when pH of the soil is above 5.6, the maximum may be 3 percent.
4. Magnesia - 2 percent MgO in mixture - 1/2 shall be derived from water soluble materials.
5. Chlorine - not over 2 percent in fertilizer mixture except where soil pH is above 5.6 and maximum may be 3 percent. Small amount increases the acre value.
6. Sulphur - Fertilizers be formulated in such a manner as to reduce the more soluble sulphur compounds.
7. Calcium - fertilizer mixture carry in an available form a minimum of 6 percent calcium oxide (CaO) equivalent.

C. Neutral Fertilizer

1. If non-acid fertilizers are to be produced, it is suggested that the neutralizing agent be dolomitic limestone, as this material not only neutralizes but carries magnesia (MgO) and calcium (CaO), which are important plant nutrients.

INVESTIGATION

Field Experiment with Flue-Cured Tobacco at Chatham Virginia, 1940

The Pittsylvania County Experiment Station located near Chatham, Virginia, has conducted fertilizer experiments with flue-cured tobacco since 1907. The scheme of these experiments has been changed several times (18, 19 and 22), since their establishment, the last time for the season of 1939. At that time "The Sources of Nitrogen Experiment" was set up to test whether it was justifiable to include the higher priced and relatively slow acting plant and animal carriers of nitrogen in the fertilizer mixture. The experiment which is reported herein (the O. N. I. experiment) is a supplement to the above experiment.

Method of Procedure. This experiment was conducted on Granville sandy loam in connection with the Pittsylvania County Experiment Station, Chatham, Virginia.

The size of each plat was one-fortieth of an acre (4 rows, 4 feet apart, and 68 feet long), each plat containing 136 tobacco plants.

Each treatment was conducted in triplicate; however, two of the parallels of treatments 4, 7, 9, 10, and 11 were included in "The Sources of Nitrogen Experiment".

Fertilizer was applied at the rate of 900 pounds 3-10-6 and 2 percent MgO per acre.

The ratios and sources of nitrogen are given in Table 3. Phosphorus was applied in the form of 20 percent superphosphate, two-thirds of the potassium was applied in the form of sulphate of potash, and one-third of the potassium in the form of muriate of potash. In order that all treatments receive the required amount of phosphorus and potassium, the amount carried by the organic fertilizer materials listed in Table 1. was subtracted from the total amount and the remainder was added through the above inorganic sources. All of the fertilizer mixtures were neutralized according to the method employed by W. H. Pierre (30).

The harvesting, grading, and evaluating of the tobacco was performed by the experiment station and the procedure followed for determining the yields and values as reported by E. M. Matthews in his 1940 Annual Report (21)was as follows:

"Ripe leaf from each plat is harvested weekly and each stick of tobacco, after being strung, is properly tagged to show the project and the plat number. After curing and early bulking (probably several months after harvesting time), the leaf from each plat is carefully graded into three to five grades for each weekly harvest, making a total of 20 to 50 grades for the entire crop from each plat. Each grade is weighed for the plat and the weight carefully recorded. The leaf is then sold on the market with like grades from other plats. Values obtained are based upon the actual sale price of the tobacco with some adjustments

Table 1. Analyses of fertilizer materials used for flue-cured tobacco on the O. N. I. plats at Chatham, Virginia, 1940.

Fertilizer Material	N	P_2O_5	K_2O	MgO
	Percent	Percent	Percent	Percent
1. Nitrate of Soda	16.0	---	---	---
2. Ammonium Sulphate	20.5	---	---	---
3. Uramon	42.0	---	---	---
4. Cottonseed Meal	7.0	2.0	1.5	---
5. Soybean Meal	7.0	2.0	1.5	---
6. Fish Meal	8.5	7.0	---	---
7. Sewage Sludge	6.0	2.0	---	---
8. Process Tankage	9.3	---	---	---
9. Castor Pomace	5.5	2.0	1.0	---
10. Superphosphate	----	20.0	---	---
11. Muriate of Potash	----	---	60.0	(47% Cl)
12. Sulphate of Potash	----	---	50.0	---
13. Magnesium Sulphate	----	---	---	30.0
14. Dolomite	----	----	---	20.0

up or down if the price obtained is not in line with the average price for that grade for the entire marketing season as determined by the government grade."

Results. The intensity of rainfall at Chatham, Virginia, during the tobacco season of 1940 is reported in Table 2.

Table 2. Weekly and monthly precipitation during 1940, and 17 year average precipitation at Chatham, Virginia, during the tobacco season.

	Precipitation during 1940					
Month	1st. week	2nd. week	3rd. week	4th. week	Month Total	17 yr. average
	Inches	Inches	Inches	Inches	Inches	Inches
May	0.38	0.58	0.50	2.61	4.07	3.80
June	0.00	1.30	1.39	0.88	3.57	3.77
July	1.00	0.07	0.95	1.40	3.42	4.23
August	0.52	3.33	7.51	0.84	12.22	4.15

The yield and value of tobacco in the various treatments is presented in Table 3 and the increase in yield and value over P-K of the various treatments is presented in Table 4.

The fluctuation in yield and value of the tobaccoo between replicated was in some cases so great that no conclusions could be drawn from the average of these replicates - particularly for treatments 4, 7, and 12. In these treatments the deviations from the average were so large that the average had no significant value.

Generally the deviation from the average of the value was greater than the deviation from the average of the yield.

From the first year of the experiment the following deductions can be made:

Organic nitrogen carriers of animal origin, such as, fish meal, tankage and sewage sludge, produced a higher quality of flue-cured tobacco than organic carriers of plant origin, such as, cottonseed meal, soybean meal and castor pomace.

Castor pomace produced a larger yield and a higher quality of flue-cured tobacco than cottonseed meal or soybean meal during a wet season.

A mixture which contained urea and sulphate of ammonia together with nitrate and organic nitrogen was superior to a mixture which combined only urea, nitrate, and organic nitrogen.

In attempt to explain the reasons for deriving nitrogen from different sources, absorption experiments were conducted at Chatham in 1939 and 1940 (10 and 20). The results of these experiments showed that the variation in the absorption of plant nutrients by the tobacco plant can not always be explained with the distribution of rainfall or with the use of different nitrogen carriers.

Table 5. Yield and value of flue-cured tobacco on Granville sandy loam following various nitrogen treatments

Treatment	Yield per Acre				Value per Acre			
	Replication			Average	Replication			Average
	1	2	3		1	2	3	
	Pounds	Pounds	Pounds	Pounds	Dollars	Dollars	Dollars	Dollars
1. 1/6 N from standard*, 1/3 N from $NaNO_3$, 1/2 N from $(NH_4)_2SO_4$	956	848	1136	980	167.60	157.60	183.20	169.47
2. 1/3 N from standard*, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	996	1052	948	999	176.80	199.60	150.00	175.47
3. 1/2 N from standard*, 1/3 N from $NaNO_3$, 1/6 N from $(NH_4)_2SO_4$	972	932	1056	987	172.00	166.80	185.60	174.80
4. All N from standard*	1144	876	832	951	201.20	126.80	143.60	157.20
5. 1/3 N from standard*, 1/3 N from $NaNO_3$, 1/3 N from Uramon.	952	972	980	968	128.40	166.00	175.60	156.67
6. 1/4 N from standard*, 1/4 N from $NaNO_3$, 1/4 N from $(NH_4)_2SO_4$, 1/4 N from Uramon	1096	1036	1048	1072	168.40	172.80	185.20	175.47
7. 1/3 N from cottonseed meal, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	880	1076	928	961	139.60	163.60	167.20	156.80
8. 1/3 N from soybean meal, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	1056	900	956	971	176.80	122.00	156.80	151.87
9. 1/3 N from fish meal, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	1092	1040	960	1031	185.60	194.40	164.00	181.33
10. 1/3 N from sewage sludge, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	1060	1020	988	1023	190.80	181.20	161.20	177.73
11. 1/3 N from process tankage, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	1000	1052	968	1007	194.80	171.60	158.80	175.07
12. 1/3 N from castor pomace, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	1068	908	1048	1008	216.40	137.60	171.20	175.07
13. No Nitrogen	744	820	796	787	112.80	126.80	131.20	123.60

* Standard = 1/3 N from cottonseed meal, 1/3 N from fish meal, and 1/3 N from process tankage.

Table 4. Increase over no nitrogen treatment and relative increase in yield and value of flue-cured tobacco on Granville sandy loam following various nitrogen treatments.

Treatment	Yield per Acre		Value per Acre	
	Increase over No Nitrogen	Relative Increase**	Increase over No Nitrogen	Relative Increase**
	Pounds	Percent	Dollars	Percent
1. 1/6 N from standard*, 1/3 N from $NaNO_3$, 1/2 N from $(NH_4)_2SO_4$	193	91	45.87	88
2. 1/3 N from standard*, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	212	100	51.87	100
3. 1/2 N from standard*, 1/3 N from $NaNO_3$, 1/6 N from $(NH_4)_2SO_4$	200	94	51.20	99
4. All N from standard*	164	77	33.60	65
5. 1/3 N from standard*, 1/3 N from $NaNO_3$, 1/3 N from Uramon.	181	85	33.07	64
6. 1/4 N from Standard,* 1/4 N from $NaNO_3$, 1/4 N from $(NH_4)_2SO_4$, 1/4 N from Uramon	285	134	51.87	100
7. 1/3 N from cottonseed meal, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	174	82	33.20	64
8. 1/3 N from soybean meal, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	184	87	28.27	55
9. 1/3 N from fish meal, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	244	115	57.73	111
10. 1/3 N from sewage sludge, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	236	111	54.13	105
11. 1/3 N from process tankage, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	220	104	51.47	99
12. 1/3 N from castor pomace, 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$	221	104	51.47	99
13. No Nitrogen	0	0	00.00	0

* Standard = 1/3 N from cottonseed meal, 1/3 N from fish meal, and 1/3 N from process tankage.

** Comparative increase in yield of tobacco with increase of treatment 2 (standard treatment as recommended by Tobacco Research Committee) rated as 100 percent.

A Field Study of the Vertical Movement of Plant Nutrients in Granville Sandy Loam During the Growing Period of Flue-Cured Tobacco 1940.

The object of this experiment was to get a clear conception of the amount of available plant nutrients in the soil during the tobacco season and to determine whether the different nitrogen carriers (in particular, uramon and nitrogen fertilizers of plant and animal origin) have any influence on the vertical movement of available calcium, magnesium, and potassium during the tobacco growing season.

Method of Procedure. To prevent the lateral movement of soil moisture and to insure the sampling of the same soil area at the various time intervals, wooden frames (6 feet long, 12 inches wide, and 9 1/2 inches deep) were inserted in the ground (Figure 1).

Figure 1. Field leaching frames at Chatham.

Fertilizer was applied at the rate of 900 pounds of 3-10-6 and 2 percent MgO per acre. This application amounted to 6.74 grams N, 22.5 grams P_2O_5, 13.5 grams K_2O and 4.83 grams MgO per frame. The fertilizer was mixed with the 100 pounds of soil which filled the 5-8 inch layer of the wooden frame. The nitrogen, the only variant, was derived from the following:

1. 1/3 N from $NaNO_3$, 1/3 N from $(NH_4)_2SO_4$, 1/3 from Uramon
2. 1/2 N from $(NH_4)_2SO_4$, 1/2 from Uramon
3. 1/3 N from standard*, 1/3 N from $NaNO_3$, 1/3 from $(NH_4)_2SO_4$
4. All N from standard
5. 1/3 N from standard, 1/3 N from $NaNO_3$, 1/3 N from Uramon
6. No nitrogen.
7. No fertilizer

* Standard = 1/3 N from cottonseed meal, 1/3 from fish meal, 1/3 N from process tankage.

Treatments 1 and 2 deal with the effect of uramon, while treatments 3, 4, and 5 deal with the effect of natural organics on the movement of plant nutrients. This report deals only with treatments 4, 5, 6, and 7.

Each fertilizer treatment was subjected to both cropped and uncropped conditions, and conducted in duplicate. Three tobacco plants were planted in each of the cropped frames on May 20, 1940. Soil samples were taken from each frame with a soil auger at depths of 0-2, 2-5, 5-8, 8-11, and 11-16 inches;

four borings were composited in order to obtain at least 100 grams of soil. The samples were taken on May 14 (before fertilization), June 4, June 10, June 25, July 10, July 24, and August 9, and August 23. These soil samples were analyzed for base exchange capacity, exchangeable hydrogen, available calcium, available potassium, and available magnesium.

Chemical Methods. The triethanolamine acetate-barium hydroxide method for determining base exchange properties in soil (23), has been developed and modified (24) for rapid determinations of base exchange capacity and exchangeable hydrogen. This modified method was used in the determination of base exchange capacity and exchangeable hydrogen in this study.

To determine the amount of calcium, potassium, and magnesium which may have been available to the tobacco plant at the various dates of sampling, the following methods were used:

A sodium acetate extracting solution was used which was prepared by dissolving 12.5 grams sodium hydroxide in about 700 cc water, adding 30 cc glacial acetic acid, cooling, and making up to one liter volume. Ten grams of soil and 25 cc extracting solution were shaken in a mechanical shaker for fifteen minutes and then filtered through Whatman number 1 filter paper inserted in funnelled test tubes. The soil extract obtained, approximately 15 cc, was used in the determination of calcium, potassium, and magnesium.

Potassium was determined turbidimetrically by the following procedure:

1. 3 cc soil extract made up to 10 cc with distilled water in a 25 cc volumetric flask was cooled below 10° C in an ice bath.
2. 1 cc cold 6 percent solution sodium cobalti-nitrite, made up fresh daily, was added to the cold soil extract.
3. 10 cc cold 95 percent ethyl alcohol was added gently down the side of flask.
4. Flask was rotated gently after five minutes and made up to 25 cc with cold distilled water.
5. The concentration of turbid potassium solution was measured in the Evelyn colorimeter using a 620 mu wave length filter. The amount of potassium was read from a calibrated curve previously established from known standards under identical conditions.

Magnesium was determined colorimetrically by the following method:

1. 1 cc soil extract was pipetted into a 25 cc volumetric flask and made up to 20 cc volume with distilled water.
2. 1 cc of .02 percent solution titan yellow, made up fresh daily from a 0.1 percent stock solution (not more than 4 weeks old) was added.
3. 1 cc 4N sodium hydroxide (low in CO_2) was added.
4. Solutions were mixed and made up to 25 cc with distilled water.

5. The intensity of color produced was read in Evelyn colorimeter using a 540 mu wave length filter. The amount of magnesium was read from a calibrated curve previously established from known standards under identical conditions.

Calcium was determined turbidimetrically by the following procedure:

1. To 10 cc solution of 0.5 percent ammonium oxalate and 1 percent triethanolamine, adjusted to pH 8.5 with acetic acid, was added 10 cc soil extract.
2. Solution was made up to 25 cc with distilled water.
3. The turbidity of the calcium solution was read in Evelyn colorimeter using a 540 mu wave length filter. The amount of calcium was read from a calibrated curve previously established from known standards under identical conditions.

<u>Results.</u> Not all of the soil samples were analyzed for base exchange capacity and exchangeable hydrogen, because the results obtained from soil samples taken May 14, June 25, and August 23 (table 6 and 7) did not appear to justify spending additional time on this particular branch of study. The average base exchange capacity and exchangeable hydrogen per 110 grams of soil of all treatments in the various layers taken May 14 and June 25, and August 23, are given in table 5.

The average base exchange capacity of the 5-8 inch layer was slightly higher than the base exchange capacity of the 0-2 and 2-5 inch layer, but the difference was not enough to be of any

Table 5. Base exchange capacity and exchangeable hydrogen (per 100 grams soil) at different depths of soil from field frames. (average of 15 samples).

Layer Sampled	Base Exchange Capacity	Exchangeable Hydrogen
Inches	Milli-equivalents	Percent
0-2	4.13	70.0
2-5	4.08	72.2
5-8	4.19	69.6
8-11	4.10	73.1
11-16	4.28	71.3

significance. It can be noted from Table 6 and 7 that the variation in the base exchange capacity and exchangeable hydrogen within treatments was greater in some cases than between treatments; therefore, no conclusions could be drawn concerning the effect of the different nitrogen sources. The variations within treatments were probably due to the difficulty of accurate sampling and the heterogeneity of the soil.

The soils subjected to the following treatments were analyzed for available calcium, magnesium, and potassium:

1. All N from standard, soil with crop.
2. 1/3 N from standard, 1/3 N from $NaNO_3$, 1/3 N from Uramon, soil left bare.
3. No nitrogen, soil with crop.
4. No fertilizer, soil left bare.

Table 6. Base exchangeable capacity (milliequivalents per 100 grams soil) at different depths of cropped and bare Granville sandy loam following different fertilizer treatments. (Average of two series).

Treatment	Inches Sampled	Soil left bare Sampling Date 5/14	 6/25	 8/23	Soil with crop Sampling Date 5/14	 6/25	 8/23
		m.e.	m.e.	m.e.	m.e.	m.e.	m.e.
All N from Standard**	0-2	4.9*	3.97	3.99	4.74	4.55	4.00
	2-5	4.6*	3.60	4.00	5.28	4.08	3.71
	5-8	4.53	4.29	4.10	3.60	3.94	3.85
	8-11	3.8*	3.90	4.44	3.95	3.94	4.65
	11-16	3.8*	3.53	4.18	4.43	4.50	5.55
1/3 N from Standard** 1/3 N from $NaNO_3$ 1/3 N from Uramon	0-2	4.18	3.71	4.09	4.45	3.88	4.10
	2-5	4.19	3.95	3.60	4.17	3.92	4.47
	5-8	3.76*	4.83	4.09	4.43	3.85	4.62
	8-11	4.06	4.08	3.94	4.80	3.65	4.30
	11-16	4.76	4.00	4.27	3.98	3.61	5.40
No Nitrogen	0-2	4.39	3.85	4.65	3.9*	3.60	4.00
	2-5	4.00	3.84	4.29	3.9*	3.60	4.16
	5-8	3.76	4.09	4.23	4.1*	3.75	4.07
	8-11	4.41	3.53	3.86	4.6*	3.59	4.52
	11-16	3.91	3.90	4.02	4.4*	4.38	4.20

* Determined by Dr. A Mehlich, N. C. Agri. Exp. Sta., Raleigh, N. C.

** Standard = 1/3 N from cottonseed meal, 1/3 N from fish meal, 1/3 N from process tankage.

The amount of available potassium at intervals during the tobacco growing season is presented in Table 8. From this table it can be noted that the no fertilizer treatment had very small amounts of available potassium as compared to the various fertilized treatments. During the growing season

Table 7. Percent exchangeable hydrogen of the base exchange capacity at different depths of cropped and bare Granville sandy loam following different fertilizer treatments (average of two series).

Treatment	Inches Sampled	Soil left bare			Soil with crop		
		Sampling date			Sampling date		
		5/14	6/25	8/23	5/14	6/25	8/23
		Percent	Percent	Percent	Percent	Percent	Percent
All N from Standard**	0-2	62.4*	79.9	66.1	65.4	67.8	70.4
	2-5	66.5*	76.8	66.5	69.3	72.7	69.5
	5-8	67.5	75.0	68.3	72.6	77.0	66.5
	8-11	72.1*	78.5	68.0	77.5	76.8	69.5
	11-16	73.7*	84.4	68.2	70.0	76.2	68.4
	0-2	72.2	76.7	67.9	68.2	72.5	66.5
1/3 N from Standard** 1/3 N from $NaNO_3$ 1/3 N from Uramon	2-5	78.9	77.5	69.0	64.4	69.5	64.8
	5-8	68.1*	70.0	64.6	68.4	77.3	68.0
	8-11	73.6	80.0	75.5	66.5	77.9	64.4
	11-16	71.2	74.0	67.8	60.7	69.9	62.7
	0-2	69.6	70.7	78.6	76.4*	68.9	69.3
	2-5	73.4	71.4	69.5	78.5*	86.5	69.7
No Nitrogen	5-8	66.7	69.9	67.3	69.8*	70.4	63.4
	8-11	71.5	77.4	71.8	73.5*	75.9	63.9
	11-16	74.9	75.3	69.6	67.8*	74.7	69.4

* Determined by Dr. A Mehlich, N. C. Agri. Exp. Sta., Raleigh, N. C.

** Standard = 1/3 N from cottonseed meal, 1/3 N from fish meal, 1/3 N from process tankage.

the amountt of potassium in all treatments increased in the 0-2 inch
1
layer, decreased in the 2-5 and 5-8 inch layers, and remained more or less constant in the 8-11 and 11-16 inch layers. The potassium content was higher in the 5-8 inch layer due to the fact that added fertilizer was mostly applied to this layer. A possible explanation of the increase of potassium in the 0-2 inch

Table 8. Available K_2O(milligrams per 100 grams soil) in cropped and bare Granville sandy loam following various fertilizer treatments when sampled at different depths and time intervals during the tobacco season.

Treatment	Layer Sampled	Before Fertilization	After Fertilization Sampling dates						
		5/14	6/4	6/10	6/25	7/10	7/24	8/9	8/23
	Inches	mgms	mgms	mgms	mgms	mgms	mgms	mgms	mgms
	0-2			5.8				3.2	4.6
No Crop	2-5			3.5				1.4	2.5
	5-8			2.1				1.4	1.7
No Fertilizer	8-11			4.6				1.1	1.7
	11-16			6.8				0.6	1.1
No Crop	0-2	1.7	4.5	5.0	5.8	8.5	6.0	8.0	7.8
	2-5	0.6	5.0	8.0	5.8	4.5	3.2	4.5	4.2
1/3 N from Standard*	5-8		22.5	25.75	8.2	10.0	3.2	9.5	5.8
1/3 N from $NaNO_3$	8-11	2.1	10.0	7.5	5.0	6.3	4.2	5.6	4.2
1/3 N from Uramon	11-16	0.6	4.5	6.3	2.5	3.5	3.8	5.6	2.8
	0-2	2.5	4.2	4.2	1.7	4.6	5.3	7.8	6.8
Crop	2-5	4.2	7.5	3.2	6.8	3.5	5.0	2.5	3.5
	5-8	1.7	12.2	10.8	9.8	8.2	5.8	3.5	4.6
All N from Standard*	8-11	1.1	8.9	6.8	3.5	3.5	4.2	3.2	4.6
	11-16	2.8	4.6	4.6	2.5	3.5	2.8	2.1	2.1
	0-2	6.0	3.8	2.8	3.5	11.8	7.5	8.9	7.2
Crop	2-5	9.8	7.8	4.6	6.8	6.8	5.3	8.2	2.8
	5-8	10.0	8.9	11.8	9.3	11.5	12.2	11.8	4.6
No Nitrogen	8-11	5.0	7.5	6.0	4.2	11.8	2.8	6.0	5.3
	11-16	3.8	5.8	4.2	2.8	3.8	4.2	3.2	4.6

* Standard = 1/3 N from cottonseed meal, 1/3 N from fish meal, 1/3 N from process tankage.

Table 9. Available MgO (milligrams per 100 grams soil) in cropped and bare Granville sandy loam following various fertilizer treatments when sampled at different depths and time intervals during the tobacco growing season.

Treatment	Layer Sampled	Before Fertilization	After Fertilization Sampling Dates						
		5/14	6/4	6/10	6/25	7/10	7/24	8/9	8/23
	Inches	mgms	mgms	mgms	mgms	mgms	mgms	mgms	mgms
	0-2			4.5				4.5	4.5
No Crop	2-5			10.0				10.0	8.0
	5-8			4.0				5.0	4.0
No Fertilizer	8-11			6.3				6.9	5.6
	11-16			15.0				10.0	8.5
No Crop	0-2	5.0	4.0	4.0	5.7	4.5	4.0	3.5	5.7
	2-5	7.5	4.0	5.0	6.9	6.3	4.0	4.5	3.5
1/3 N from Standard*	5-8		7.5	7.5	5.0	6.9	4.5	4.0	3.5
1/3 N from $NaNO_3$	8-11	8.0	12.0	9.5	8.0	6.3	4.0	11.0	4.0
1/3 N from Uramon	11-16	15.0	17.5	17.5	17.5	11.0	9.5	11.0	13.0
	0-2	1.0	2.3	3.0	3.0	3.0	3.0	3.0	4.0
Crop	2-5	3.0	2.3	3.0	3.5	3.5	1.0	3.0	4.0
	5-8	1.0	6.9	4.0	2.3	.57	1.8	3.5	3.0
All N from Standard*	8-11	4.5	12.0	9.0	9.0	9.5	20.8	13.0	9.0
	11-16	9.5	11.0	9.5	17.5	9.0	9.0	13.0	15.0
	0-2	5.6	5.0	6.9	5.7	8.5	6.9	12.0	4.0
Crop	2-5	10.0	7.5	7.5	5.0	9.0	8.0	9.0	7.5
	5-8	9.0	12.0	9.5	5.7	9.0	9.0	11.0	7.5
No Nitrogen	8-11	6.3	9.5	8.0	7.5	8.5	12.0	10.0	9.5
	11-16	14.0	16.3	16.3	11.0	19.3	22.5	22.5	28.0

* Standard = 1/3 N from cottonseed meal, 1/3 N from fish meal, 1/3 N from process tankage.

layer is that the thermal movement of water during the summer caused potassium
potassium to accumulate near the surface.

The amount of available magnesium at different depths in Granville sandy loam for the various sampling periods is given in Table 9. As can be seen by this table the movement of magnesium was irregular within treatments and no significant results could be drawn concerning the effect of the different nitrogen treatments on the movement of magnesium. However, the average of all the treatments before fertilization and after fertilization was made and the resulting data (Table 10) seem to indicate that there was a downward movement of magnesium in all layers except the 0-2 inch layer.

Table 10. Average available MgO (milligrams per 100grams soil) of all treatments before and after fertilization at different soil depths. (Average of 24 samples)

Layer Sampled	MgO per 100 grams soil	
	Before Fertilization	After Fertilization
Inches	Milligrams	Milligrams
0-2	3.9	4.8
2-5	6.2	5.7
5-8	5.0	5.7
8-11	6.3	9.2
11-16	12.8	14.6

The amount of available calcium at different depths in Granville sandy loam for the various sampling periods is given in Table 11. The calcium content of the soil varied greatly within treatments from sampling date to sampling date; consequently, no definite trends could be determined. The average

Table 11. Available CaO (milligrams per 100 grams soil) in cropped and bare Granville sandy loam following various fertilizer treatments when sampled at different depths and time intervals during the tobacco growing season.

Treatment	Layer Sampled	5/14 Before Fertilization	After Fertilization						
			Sampling Dates						
			6/4	6/10	6/25	7/10	7/24	8/9	8/23
	Inches	mgms	mgms	mgms	mgms	mgms	mgms	mgms	mgms
	0-2			10.0				15.0	1.2
No Crop	2-5			16.3				3.1	5.0
	5-8			1.2				5.0	6.7
No Fertilizer	8-11			5.0				8.3	5.0
	11-16			26.0				12.5	5.0
No Crop	0-2	16.7	3.3	3.3	6.2	6.2	6.2	3.3	10.0
	2-5	22.5	10.0	10.0	20.0	10.0	6.2	10.0	10.0
1/3 N from Standard*	5-8		20.0	20.0	10.0	25.0	20.0	25.0	13.3
1/3 N from $NaNO_3$	8-11	16.7	20.0	20.0	13.3	20.0	6.2	20.0	10.0
1/3 N from Uramon	11-16	20.0	25.0	27.5	13.3	27.5	6.2	22.5	22.5
	0-2	6.7	5.0	3.1	10.0	6.7	5.0	5.0	5.0
Crop	2-5	5.0	12.5	6.2	10.0	10.0	10.0	5.0	3.5
	5-8	6.7	12.5	6.7	12.5	12.8	11.3	13.8	8.3
All N from Standard*	8-11	13.8	18.8	11.3	10.0	6.7	10.0	6.7	6.7
	11-16	13.6	8.3	6.7	13.3	6.7	6.7	8.3	13.3
	0-2	12.5	8.3	6.7	6.7	6.7	8.3	11.3	12.5
Crop	2-5	6.7	10.0	3.1	6.7	10.0	6.7	8.3	8.3
	5-8	8.3	8.3	18.8	8.3	15.0	11.3	15.0	13.8
No Nitrogen	8-11	13.8	18.8	6.7	10.0	12.5	12.5	10.0	12.5
	11-16	17.5	16.3	11.3	8.3	12.5	11.3	15.0	8.3

* Standard = 1/3 N from cottonseed meal, 1/3 N from fish meal, 1/3 N from process tankage.

amount of calcium in the various layers from all treatments(Table 12.) showed that the calcium content of the soil increased with depth.

Table 12. Average available CaO (milligrams per 100 grams soil) of all treatments at the different soil depths. (average of 24 samples).

Layer Sampled	CaO per 100 grams soil.
Inches	Milligrams
0-2	7.5
2-5	9.1
5-8	12.7
8-11	12.0
11-16	14.3

The amount of rainfall between sampling dates is given in Table 13. An attempt was made to correlate the intensity of rainfall between sampling dates with the movement of plant nutrients, but no relationship could be obtained.

Table 13. Amount of rainfall between sampling dates.

Interval Between Sampling	Inches of Rainfall
May 14 - June 4	3.11
June 4 - June 10	.43
June 10 - June 25	2.89
June 25 - to July 10	1.25
July 10 - July 24	1.42
July 24 - August 9	1.55
August 9 - August 23	10.81

GREENHOUSE LEACHING STUDIES WITH DIFFERENT NITROGEN SOURCES.

A greenhouse pot experiment using Granville sandy loam was set up to determine the loss of nitrogen, phosphorus, and potassium during eleven weeks (length of tobacco season in Virginia) as affected by some nitrogen carriers, such as uramon, process tankage, sewage sludge, and castor pomace. These fertilizer materials were also used in the field and value experiment (Page 10).

The purpose of this leaching experiment was to determine (1) the amount of nitrogen in the form of ammonia and nitrate that was leached under excessive leaching conditions, (2) whether the leaching of potassium and calcium was influenced by various nitrogen carriers, and (3) the amount of nitrogen, phosphorus, and potassium that was lost by leaching at certain intervals during a tobacco season.

Method of Procedure. In order to maintain soil conditions similar to the field conditions under which the yield and value experiment was conducted, sufficient top soil of the same type (Granville sandy loam) was taken from an area in the immediate vicinity of the tobacco field and used in this experiment. This soil had been uncultivated and unfertilized for at least 20 years and was well set in broom sedge and old field pines.

Twenty-four earthenware pots (six treatments, four parallels) of two gallon capacity were used. The hole in the side and adjacent to the bottom of the pot was plugged with a cork (see Figures 2 and 3) through which was inserted a short piece of glass tubing to facilitate drainage. After the drainage apparatus had been thoroughly paraffined in the pot, sufficient glass wool was placed over the outlet tube to permit even and steady drainage without the loss of soil. The leachate from all pots was comparatively clear.

All of the soil used in the experiment was screened through a 2 mm sieve and was mixed thoroughly in order to obtain a homogeneous soil. The moisture content of the untreated soil was o.85 percent with a pH of 5.2. The mechanical analysis by the Bouyoucos method (7) was 69.6 percent sand, 14.5 percent silt and 15.9 percent clay.

Fertilizer was applied at the rate of 2000 pounds of 3-10-6 per acre. This high application was used because the usual rate of fertilizer application under greenhouse conditions is double that for field conditions. Ground limestone was applied at the rate of 1 ton per acre. This application was made in order to bring the pH of the soil to 7.0. Phosphorus was applied in the form of monopotassium phosphate and monocalcium phosphate, and potassium was applied in the form of monopotassium phosphate. In order that all pots should receive the required amount of phosphorus and potassium, the amount carried

Figure 2. View of equipment used in leaching experiment.

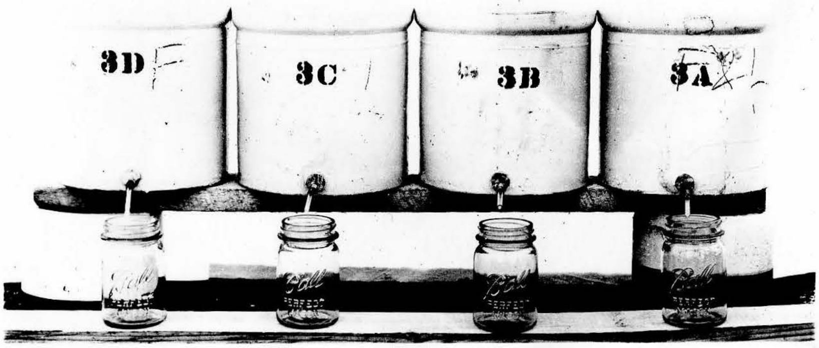


Figure 3. View of one treatment of leaching experiment showing method of leaching.

by the organic fertilizer materials listed in Table 1 was subtracted from the total amount and the remainder was added through the above inorganic sources.

The various treatments were as follows:

1. No fertilizer + limestone
2. No nitrogen + P-K + limestone
3. Uramon + P-K + limestone
4. Process tankage + P-K + limestone
5. Sewage sludge + P-K + limestone
6. Castor pomace + P-K + limestone

Sufficient soil, eighteen pounds per pot, for the four parallels of each treatment was thoroughly mixed with the limestone and twelve pounds of this mixture was placed in each pot. Over this limed soil was placed the five pounds of soil containing the fertilizer mixture, which was mixed for all four pots simultaneously. Approximately one pound of limed soil was added on top of the fertilized layer in order to bring all pots up to the same weight.

These uncropped pots were kept in the greenhouse from August 26 to November 14 at an average temperature of 20° C. The moisture capacity was maintained as near 50 percent of the maximum capillarity (34percent) as possible. After each leaching period, of about eight days were needed for the soil moisture to gradually decrease to the desired content, and after that time, rainwater was added to maintain the moisture content above 50 percent of the maximum capillarity.

All pots were leached with three liters of rainwater, which is equivalent to 3.6 inches rainfall (surface of pot - 50.25 square inches), at 21, 35, 49, 63, and 77 days after fertilization. The water was applied in one liter aliquots, allowing an interval of at least an hour between applications. The leachate collected (1500 to 2000 cc per pot) was analyzed for the amount of ammonia and nitrate nitrogen, potassium, and calcium.

__Chemical Methods.__ Nitrate nitrogen was determined by the following procedure:

1. 10 cc of leachate was evaporated to dryness without igniting.
2. 1-2 cc of phenoldisulphonic acid was added to dissolve residue.
3. 10-15 cc of distilled water was added.
4. Dilute ammonium hydroxide (1-1) was carefully added until distinctly alkaline or until a permanent yellow color was developed.
5. Solutions was diluted to 50 cc and read in Cenco photometer using a green filter. The amount of nitrate nitrogen was calculated from a known calibrated curve.

Calcium was determined by the following procedure:

1. To 1 cc of 10 percent triethanolamine and 5 cc of 1 percent ammonium oxalate was added sufficient water to bring volume to about 14 cc.
2. 10 cc of leachate and sufficient distilled water to make volume to 25 cc was added.

3. The turbidity of the solution was read on the Evelyn colorimeter using a 540 mu wave length filter. The amount of calcium was determined from a known calibrated curve established under identical conditions.

Potassium was determined by the following procedure:

1. All solutions were cooled below 10° C. in ice bath.
2. To 10 cc of leachate was added 1 cc of sodium cobaltinitrite.
3. 10 cc of 95 percent ethyl alcohol was added gently down side of flask.
4. The flask was rotated gently after about 5 minutes. Before rotating the alcohol should have a cloudy color characteristic of potassium.
5. Solution was made up to 25 cc volume with distilled water and read in the Evelyn colorimeter using a 540 mu wave length filter. The amount of potassium was determined from a known calibrated curve established under identical conditions.

Ammonia nitrogen was determined by the method used by the Association of Official Agricultural Chemists (4).

Results: The amount of ammonia nitrogen leached at two intervals during the entire leaching period is presented in Table 14. It can be noted from this table that very little ammonia nitrogen was lost through leaching; however the uramon pots leached more ammonia nitrogen (3.9 milligrams) during 5 weeks than either the no nitrogen pots (2.5 milligrams) or the organic

Table 14. Milligrams of ammonia nitrogen leached per pot at intervals from Granville sandy loam treated with various nitrogen fertilizer materials and limestone.(average of two parallels).

Fertilizer Treatments.	Ammonia nitrogen leached per pot		
	0-21 days	36-49 days	Total for 35 days
	Milli-grams	Milli-grams	Milli-grams
1. No fertilizer + limestone	1.5	1.0	2.5
2. No Nitrogen + limestone	1.0	1.5	2.5
3. Uramon + P-K + limestone	3.0	0.9	3.9
4. Process tankage + P-K + limestone	0.7	1.0	1.7
5. Sewage sludge + P-K + limestone	0.5	1.0	1.5
6. Castor pomace + P-K + limestone	1.5	1.0	1.5

nitrogen pots (1.5-1.7 milli-grams)

The amount of nitrate nitrogen leached from the various treatments at intervals is given in table 15. During the first 21 days the no nitrogen treatments lost more nitrate nitrogen than the no fertilizer treatments; but both treatments lost practically the same total amount of nitrates over the entire leaching period, which seems to indicate that under these high lime conditions there was an apparent stimulation of nitrifying organisms by phosphorus and potassium in the first 21 days.

Table 15. Milligrams of nitrate nitrogen leached per pot at intervals from Granville sandy loam treated with various nitrogen fertilizer materials and limestone. (Average of four parallels).

Fertilizer Treatments	Nitrate Nitrogen leached per pot at intervals					
	0-21 days	22-35 days	36-49 days	50-63 days	64-77 days	Total
	mgms	mgms	mgms	mgms	mgms	mgms
1. No fertilizer + limestone	84.6	72.2	63.5	24.0	19.6	264.1
2. No Nitrogen + limestone	122.6	65.3	27.5	18.8	20.2	254.4
3. Uramon + P-K + limestone	160.9	164.8	91.5	18.5	20.0	455.7
4. Process tankage + P-K + limestone	109.5	135.4	82.0	24.7	20.5	372.1
5. Sewage sludge + P-K + limestone	134.2	149.2	92.0	40.5	22.8	438.7
6. Castor pomace + P-K + limestone	117.0	153.0	136.5	33.0	32.8	472.3

The uramon treated pots leached more nitrates the first 35 days while the castor pomace pots lost more nitrates than any of the other treatments between 35 and 49 days. An equalizing tendency was observed between 50 and 63 days. All pots leached practically the same amount of nitrate nitrogen from 63 to 77 days.

From Table 15 it may be noted that during the first 35 days the uramon treated pots leached 71 percent of the total amount of nitrogen lost in this treatment and the pots treated with organic materials leached 57 percent to 63 percent of the total lost.

Table 16. Cumulative percentage of nitrate nitrogen leached per pot from Granville sandy loam treated with various nitrogen fertilizer materials and limestone with average total for each treatment equal to 100. (Average of four parallels).

Fertilizer Treatments	Nitrate Nitrogen leached per pot at intervals 0-21 days	0-35 days	0-49 days	0-63 days	0-77 days
	Percent	Percent	Percent	Percent	Percent
1. No fertilizer + limestone	32	59	83	93	100
2. No nitrogen + limestone	46	74	85	92	100
3. Uramon + P-K + limestone	35	71	92	96	100
4. Process tankage + P-K + limestone	29	66	88	95	100
5. Sewage sludge + P-K + limestone	31	65	86	95	100
6. Castor pomace + P-K + limestone	25	57	86	93	100

Of the 244.9 milligrams of nitrogen added to each pot, castor pomace lost the most nitrate nitrogen (89 percent) through leaching, while process tankage leached the least amount of nitrate nitrogen (48 percent) during the entire eleven week leaching period. Castor pomace treated pots followed by the uramon and sewage sludge treated pots, lost considerably more nitrate nitrogen than the process tankage treated pots (Table 17).

Assuming that the amount of nitrate nitrogen determined in the leachate is directly proportional to the amount of available

Table 17. Milligrams nitrate nitrogen leached per pot over No Nitrogen / limestone (254.4 milligrams) and percentage nitrate nitrogen leached over No Nitrogen / limestone of the total amount (244.9 milligrams) nitrogen added in form of organics.

Fertilizer Treatments	Nitrate Nitrogen added	Nitrate Nitrogen leached over No N	NO_3 N leached of NO_3 N added
	milligrams	milligrams	Percent
1. Uramon / P-K / limestone	244.9	201.3	82
2. Process tankage / P-K / limestone	244.9	117.7	48
3. Sewage sludge / P-K / limestone	244.9	174.3	71
4. Castor pomace / P-K / limestone	244.9	217.9	89

nitrate nitrogen in the soil, one could conclude from the experimental results that, under extreme wet conditions (18 inches rainfall in 11 weeks), castor pomace together with sewage sludge delivers the most even supply of nitrogen (Figure 4). Since, according to absorption data, the tobacco plant has the greatest demand for nitrogen from 5 to 7 or 8 weeks after fertilization, castor pomace would be an ideal source of nitrogen during wet seasons. Due to the fact that uramon leached readily at the beginning of the season, there is a decrease in the amount of nitrogen delivered after 5 weeks.

The amount of potassium leached at intervals during the entire leaching period is given in Table 18. It can be noted that the no nitrogen pots leached less potassium than the no fertilizer pots. No significant differences in the amount of potassium leached from the pots containing the different nitrogen carriers could be observed. Contrary to results secured with nitrate nitrogen, the heaviest leaching of potassium occurred between 49 and 77 days. The no fertilizer pots lost practically no potassium during the entire leaching period while the fertilized pots lost from 87.4 to 132.6 milligrams of the 489.9 milligrams of potassium added to each pot. The no nitrogen pots and the castor pomace treated pots leached considerably less potassium the first 35 days as compared to the other fertilized pots.

The various nitrogen materials showed no significant effects on the leachability of calcium. All treatments leached approximately 1 gram CaO of the 4.5 grams of CaO applied in the form of $CaCO_3$(Table 19).

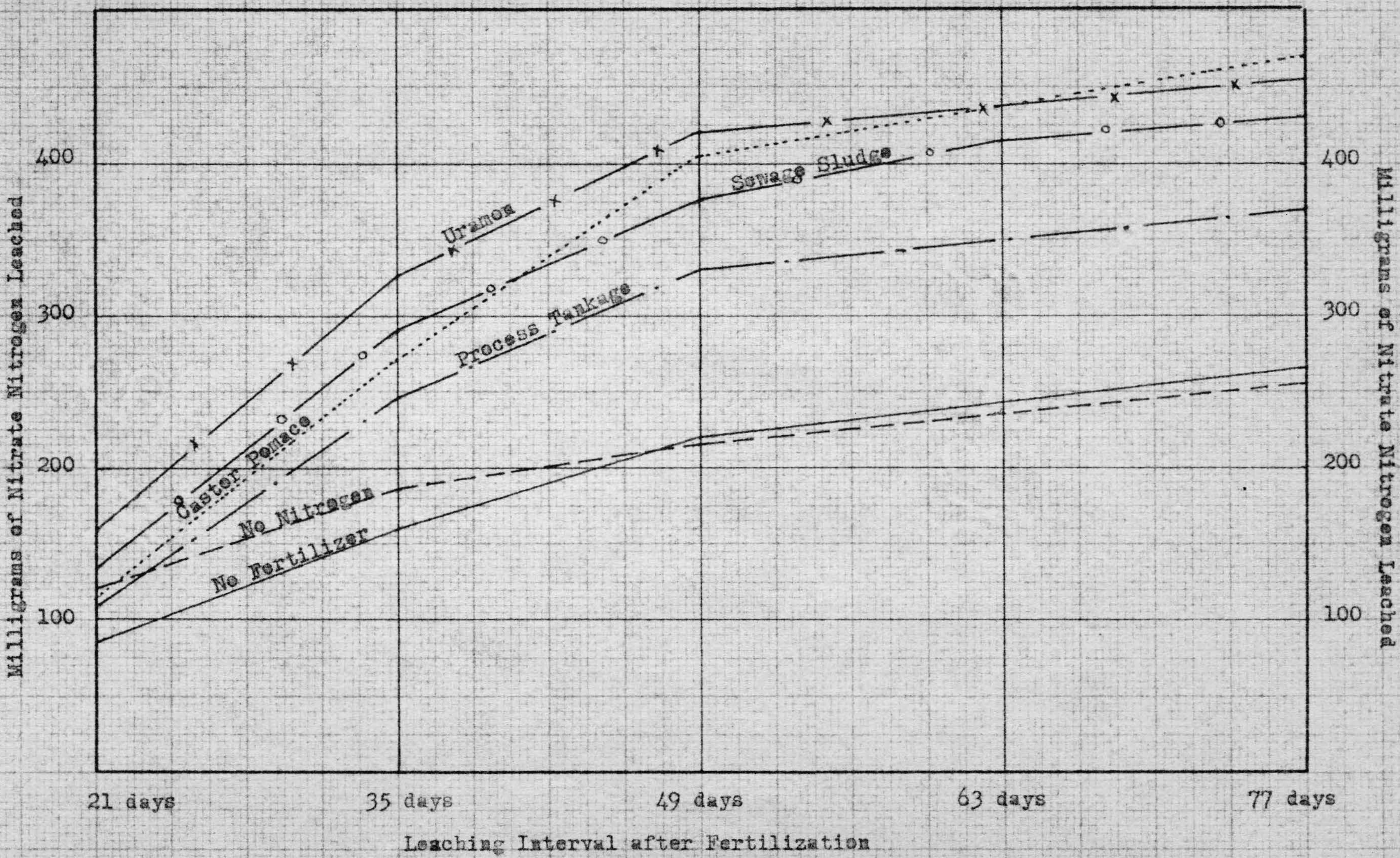
Table 18. Milligrams of potassium oxide leached per pot at intervals from Granville sandy loam treated with various nitrogen fertilizer materials and limestone (Average of four parallels).

Fertilizer Treatments	K_2O leached per pot at intervals					
	0-21 days	22-35 days	36-49 days	50-63 days	64-77 days	Total
	mgms	mgms	mgms	mgms	mgms	mgms
1. No fertilizer + limestone	0.0	0.0	0.5	0.0	5.1	5.6
2. No nitrogen + limestone	0.9	1.9	24.9	27.3	32.4	87.4
3. Uramon + P-K + limestone	6.5	14.0	31.6	30.6	30.8	113.5
4. Process tankage + P-K + limestone	0.0	22.0	20.1	28.9	33.9	104.9
5. Sewage sludge + P-K + limestone	3.6	23.5	29.2	38.9	37.5	132.6
6. Castor pomace + P-K + limestone	0.0	9.3	29.7	30.3	35.1	104.4

Table 19. Milligrams of calcium oxide leached per pot at intervals from Granville sandy loam treated with various nitrogen fertilizer materials and limestone. (Average of four parallels).

Fertilizer Treatments	CaO leached per pot at intervals					
	0-21 days	22-35 days	36-49 days	50-63 days	64-77 days	Total
	mgms	mgms	mgms	mgms	mgms	mgms
1. No fertilizer + limestone	221.2	201.9	247.5	170.0	195.3	1036.0
2. No nitrogen + limestone	243.7	201.9	195.0	137.0	187.0	964.6
3. Uramon + P-K + limestone	247.5	249.4	215.0	138.5	181.5	1031.9
4. Process tankage + P-K + limestone	235.5	244.6	207.5	220.0	192.5	1100.1
5. Sewage sludge + P-K + limestone	258.8	220.9	210.0	192.5	195.3	1077.5
6. Castor pomace + P-K + limestone	215.6	225.6	257.5	190.0	174.4	1063.1

Figure 4.- Cumulative milligrams of nitrate nitrogen leached per pot at intervals from Granville sandy loam treated with various nitrogen fertilizer materials and limestone.



AVAILABILITY OF MINOR ELEMENTS IN NATURAL ORGANICS

Considerable work has been done in the last ten years in determining the effect of so-called "minor elements" (magnesium, boron, copper, zinc, and iron) on plant growth. Most of the studies have been conducted with crops from the Chenopodeaceae Family (mangels, sugar beets, and spinach), the Cruciferae Family (turnips, mustard, radishes, and cabbage), the Leguminosae Family (soybeans and alfalfa), the Rutaceae Family (citrus), the Solanaceae Family (potatoes, tomatoes, and tobacco), and the Umbelliferae Family (carrots and celery).

Flue-cured tobacco, which is grown on well drained sandy loams with a low content of organic matter, requires only a small amount of these minor elements (28). It can be expected that under practical conditions the small amounts of minor elements present in natural organics may have some beneficial influence on the growth of the tobacco plant but as yet this has not been definitely proved.

The quantitative determination of boron, copper, zinc, and manganese in fertilizer materials is a very tedious procedure and beyond the scope of this study; furthermore, the content of minor elements in natural organics varies within a wide range. The following table by A. L. Mehring (25) of the Fertilizer Division, Bureau of Plant Industry, U. S. D. A. gives the analysis for minor elements in some of the natural organics:

Table 20. Percentage Minor Elements in various natural organics.

	B	Cu	Zn	Mn	Mg
Cottonseed Meal	.0031	.0032	.032	.0023	.33
Castor Pomace	trace	.0008	----	.023	.32
Process Tankage	.0059	.00008	----	.000016	trace
Sewage Sludge	.002	.10	.101	.073	.38
Sewage Sludge (32)	.0036	.0345	.024	.0194	----

This table shows that sewage sludge and cottonseed meal contain relatively large amounts of all of these minor elements. Process tankage contains a relatively large amount of boron but little or no copper, zinc, manganese, and magnesium, Castor pomace has a small amount of manganese and magnesium and little or no boron, copper, and zinc.

In order to determine whether the minor elements in some of these nitrogen materials of plant and animal origin have any beneficial effects on plant growth, a sand culture experiment was conducted in the greenhouse.

EXPERIMENTAL

As a medium for plant growth quartz sand, from which all cations has been removed by repeated treatments with 0.5 N Sulphuric acid and distilled water, was used. Two gallon earthenware pots with glazed surface, which held twenty pounds of dry sand, were used as containers. Each pot was washed with 0.5 N sulphuric acid and distilled water before being filled with sand. The hole in the bottom of the pot was provided with a stopper through which was inserted a piece of glass tubing to facilitate drainage.

Fertilizer was applied at the rate of 2 grams each of N, P_2O_5, and K_2Oper pot, except treatments 6 and 7 which received only 1.5 grams n, 2 grams of P_2O_5, and 2 grams of K_2O.

The fertilizer treatments per pot were:

1. 2 grams C. P.* N, 2 grams C. P. P_2O_5, and 2 grams C. P. K_2O.
2. 2 grams C. P. N, 2 grams C. P. P_2O_5, 2 grams C. P. K_2O, and 2 ppm. of Fe, Mn, B, Zn, and 40 ppm of MgO.
3. 1 gram, N from castor pomace, 1 gram C. P. N, 2 grams C. P. P_2O_5, and 2 grams C. P. K_2O.
4. 1 gram N from sewage sludge, 1 gram C. P. N, 2 grams C. P. P_2O_5, and 2 grams C. P. K_2O.
5. 1 gram N from process tankage,1/2 gram C. P. N, 2 grams P_2O_5, and 2 grams C. P. K_2O.
6. 1 gram N from castor pomace, 1/2 gram C. P. N, 2 grams P_2O_5 from T. V. A. orthophosphoric acid, and 2 grams C. P. K_2O.

7. 1 gram N from sewage sludge, 1/2 gram C. P. N, 2 grams P_2O_5 from T. V. A. orthophosphoric acid, and 2 grams C. P. K_2O.

* C. P. = chemically pure.

C. P. N derived from $Ca(NO_3)_2.4H_2O$ - (11.9 percent N)

C. P. P_2O_5 derived from KH_2PO_4 -(52.1 percent P_2O_5 and 34.6 percent K_2O.

C. P. K_2O derived from KH_2PO_4 and K_2SO4 - (K_2SO_4 - 54 percent K_2O)

Minor elements derived from $FeSO_4.7H_2O$, $MnSO_4.H_2O$, and H_3BO_4, $ZnSO_4,7H_2O$, and $MgSO_4.7H_2O$.

T. V. A. orthophosphoric acid - H_3PO_4 (36.7 percent by weight)

Treatments 6 and 7 were included in this experiment in order to find out the efficiency of phosphorus in orthophosphoric acid which is produced by Tennessee Valley Authority at Muscle Shoals, Alabama. This acid with a specific gravity of 1.34 and a P_2O_5 percent of 36.7 by weight may be used in the future as a fertilizer material. In order to provide 2 grams of P_2O_5, 4 cc of the acid was added to the castor pomace and the sewage sludge.

All fertilizer was mixed thoroughly with the six pounds of sand which made up the top layer of the twenty pounds of sand in each pot. Each treatment was conducted in four parallels. Turnip plants (Purple top white globe), which had been growing for five weeks in Muskingum fine sandy loam fertilized with only chemically pure Nitrogen, phosphorus and potassium were transplanted into the sand on February19. All pots were kept at optimum moisture conditions with distilled water, care being taken that all leachate was caught and returned to the pots.

Results. The crop was harvested on April 12, or two months after transplanting. The average yield of the four parallels of each treatment is given in Table 21, and the minor element deficiency symptoms are given in Table 22.

Table 21. Green weight of turnips as affected by various fertilizer treatments in minor element experiment. (Average of four parallels).

Treatment	Green weight (gms.) root	Green weight (gms.) top	Green weight (gms.) Total	Deviation from mean of total
1. C.P. N-P-K	6.5*	31.9*	38.3*	
2. C.P. N-P-K + minor elements	8.4	38.2	46.6	+ 12.3
3. Castor pomace + C.P. N-P-K	35.0*	70.2*	105.2*	
4. Sewage sludge + C.P. N-P-K	48.7	106.4	155.2	+ 13.0
5. Tankage + C. P. N-P-K	48.3	102.1	150.4	+ 17.2
6. Castor pomace + T.V.A. P + C.P.K	53.3	105.5	158.9	+ 5.0
7. Sewage sludge + T.V.A. P + C.P.K	79.0	108.1	187.1	+ 7.8

* Average of two parallels.

Discussion. The low yield of turnips obtained in treatments 1 and 2 (Table 21) can be explained by the fact that, since all of the nitrogen was applied in a quickly available form ($(CaNO_3)_2.4H_2O$), a toxicity was encountered which was due to the NO_3 radical. After leaching these two treatments with a small amount of distilled

Table 22. Deficiency symptoms of minor elements in turnips as affected by various treatments.

Treatment	Deficiency	
	Mg	B
1. C. P. N-P-K	x	x
2. C. P. N-P-K + minor elements	-	-
3. Castor pomace + C. P. N-P-K	-	x
4. Sewage sludge + C. P. N-P-K	-	-
5. Tankage + C. P. N-P-K	-	-
6. Castor pomace + T. V. A. P + C. P. K	-	x
7. Sewage sludge + T. V. A. P + C. P. K	-	-

water, all of the plants responded markedly, except two plants in the chemically pure treatment which had apparently been too severely affected to give any response.

Where only 1/2 gram of nitrate nitrogen and 1 gram nitrogen from castor pomace or sewage sludge and T. V. A. orthophosphoric acid (treatments 6 and 7) were used, the plants made a much quicker growth immediately following transplanting and produced the highest yields in the whole experiment. Two explanations can be given for the superior yields of treatments 6 and 7 (1.5 grams N and T. V. A. orthophosphoric acid) over treatments 3 and 4 (2 grams N and chemically pure phosphorus): (1) the nitrate nitrogen application in treatments 3 and 4 were too high or (2) the T. V. A. orthophosphoric acid caused a quick decomposition of the organics which promoted early start of the plants.

Symptoms of minor element deficiencies (boron and magnesium) were noted on the chemically pure pots (Table 22) during the growing of the crop. After harvesting, the roots of all 24 plants were halved and examined for deficiency symptoms. Boron deficiency as described by Purvis and Hanna (31), was prevalent in all four parallels of both castor pomace treatments and in the chemically pure treatment. No boron deficiency symptoms were noted in any of the other treatments. The fact that sewage sludge provides sufficient minor elements for plant growth is in agreement with the work of Rehling and Truog (33) on "Milorganite".

SUMMARY AND CONCLUSIONS.

This investigation, consisting of four experiments, was conducted in order to study the effects of organic nitrogen compounds on plant growth and the movement and availability of plant nutrients.

A fertilizer experiment was conducted on Granville sandy loam at Chatham, Virginia, to determine the effect of organic nitrogen fertilizer materials, such as sewage sludge, process tankage, fish meal, cottonseed meal, soybean meal, and castor pomace on the yield and quality of flue-cured tobacco. It was concluded that:

1. Nitrogen carriers of animal origin (fish meal and tankage, also sewage sludge) produce a larger yield and higher quality of flue-cured tobacco than organic nitrogen compounds of plant origin (cottonseed meal, soybean meal, and castor pomace).
2. A mixture of organic nitrogen with nitrate and ammonia nitrogen or a mixture of organic, nitrate, and ammonia nitrogen with urea is superior to a mixture which contains only organic and nitrate nitrogen with urea.

In connection with the fertilizer experiment a plant nutrient experiment was conducted in wooden frames in the field to study the effect of organic materials on the movement of plant nutrients. Soil samples were taken from bare and cropped frames at different depths at intervals during the tobacco season. These samples were analyzed for base exchange capacity, exchangeable hydrogen, available calcium, magnesium, and potassium, and data showed that:

1. No differences in base exchange capacity, exchangeable hydrogen and calcium could be observed between treatments.
2. The amount of available potassium in the top layer increased toward the end of the tobacco season.
3. Magnesium showed no regular movements in any of the treatments but an average of all treatments showed a downward movement in all layers except the 0-2" layer.

A pot experiment was conducted to determine the relative leaching of ammonia and nitrate nitrogen, phosphorus, and potassium from Granville sandy loam following treatment with various nitrogen materials (uramon, fish meal, process tankage, and castor pomace). The pots had a heavy lime application and were leached with 18 inches of rainfall over a period of eleven weeks. Results show that:

1. Very little ammonia nitrogen was lost from any treatment.
2. Uramon treatments leached more nitrate nitrogen the first 35 days after fertilization, but the castor pomace treatments, followed by the uramon treatments, leached more nitrate nitrogen over the entire leaching period.
3. Potassium leached more between 49 and 63 days and all pots lost about one-fourth of the total amount of potassium added.

4. All treatments lost approximately the same amount of calcium through leaching, each pot losing about 1 gram CaO of the 4.5 grams of CaO applied in the form of $CaCO_3$.

A sand culture experiment was conducted to determine whether the amount of minor elements contained in organic nitrogen compounds (castor pomace, sewage sludge, and process tankage) have any beneficial results on plant growth. Results from turnips growing in sterile sand, treated with the organics and watered with distilled water, show that castor pomace was deficient in boron while sewage sludge and process tankage supplied sufficient amounts of the minor elements for optimum plant growth.

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