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T H E S I S

FERTILIZER TREATMENTS AND THEIR EFFECTS ON THE BURNING
QUALITIES OF THE PENNSYLVANIA CIGAR-LEAF TOBACCOS

Submitted to the Committee
on Graduate Study and Advanced Degrees
of The Pennsylvania State College

by

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in partial fulfillment of the requirements

for the degree of
Master of Science

1 9 2 8

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FERTILIZER TREATMENTS AND THEIR EFFECTS ON THE BURNING QUALITIES OF THE PENNSYLVANIA CIGAR-LEAF TOBACCOS

Introduction

The value of a good cigar-leaf tobacco depends primarily on its burning qualities.

The term "burning quality" as suggested by Garner⁽¹⁷⁾ is a very comprehensive one, including several different factors, chief of which are the fire-holding capacity, the evenness and completeness of combustion, and the character of the ash. The fire-holding capacity refers simply to the length of time the tobacco will continue to burn. As to the quality of the ash, the important characters are the color and cohesiveness. Garner⁽¹⁷⁾ states that there is an essential difference between combustion of most substances and the burning of tobacco. In the first case, the substance when ignited burns with a flame and as soon as the flame is extinguished the combustion ceases. On the other hand, tobacco of good quality will not burn with a flame but will continue to glow almost indefinitely.

In general it may be said that tobacco which shows a tendency to burn with a flame has the least capacity for glowing and vice versa. Tobacco that has a tendency to burn with a flame usually has had a very rank growth, produces coarse and very thick leaves

lacking in certain desirable organic and inorganic constituents.

There are two different methods of attacking the problem of the relation of the composition of the tobacco to the burn, namely: (1) analytical, and (2) synthetical methods. Practically all of the investigation along this subject falls under the head of analytical methods, which consists of making a comparative analysis of samples of tobacco having good and poor burning qualities.

An examination of the composition of a typical ash will show how extremely difficult it is to draw any positive conclusions from any set of analyses which will not be subsequently contradicted by the results of other analyses.

In the first place, there are present in the tobacco, three inorganic acids and three bases, all of which occur in sufficient quantities to exert an important influence on the burn and all of which are subject to wide variation in quantity in different tobaccos. With such complex variations, it is almost impossible to single out those differences which really exert detrimental influences on the burn. Also, with the many acids and bases present in the leaf, there is the possibility of very considerable differences in

the distribution of the latter among the former and in some cases this difference might exert a very important influence on the burning qualities.

As opposed to the method of directly analyzing the samples of tobacco with good and bad burning qualities, the synthetical method may be used. This method consists in determining the effect on the burn of adding to the tobacco those compounds normally occurring in the leaf. By this method it is very difficult to get quantitative results but positive results may be obtained, which in the case of any one constituent added, are largely independent on the effect of the others.

From what has been said, it is not surprising that the relation of the chemical composition to the burning qualities of tobacco has attracted the attention of chemists for several years and has led to many chemical investigations.

Garner⁽¹⁷⁾ believes the chemical composition of tobacco as reflected in its burning qualities, is greatly influenced by the character of the soil, the climate, wet and dry seasons and the kind of fertilizer applied to the soil.

Moreover there are reasons for believing that certain strains or varieties of tobacco possess

the power of obtaining from the soil those constituents which are conducive to a good burn more efficiently than others.

It was thought, therefore, that a study of the soil, fertilizer treatment, variety of tobacco and analysis of tobacco and their effect on burning quality would be of value to this question as a whole, hence this investigation was undertaken.

Historical

Potassium and its Effect on the Burning quality. - Schlösing⁽⁴⁰⁾ was one of the first investigators to attempt a determination of the chemical factors which influence the burning qualities of tobacco. He showed that the fire-holding capacity is not proportional to the amount of potassium nitrate present and concluded that potassium, in combination with organic acids, is decidedly beneficial. He attributes this beneficial action to the tendency of these salts to swell on heating and thus expose a greater surface of material for combustion.

After impregnating filter paper with solutions of various salts, Nessler⁽³⁵⁾ found that potassium, especially in the form of sulphate and carbonate, increased the fire-holding capacity. He

also found that potassium nitrate gives a quicker but incomplete burn. He found that potassium sulphate entirely lacked the power of swelling when heated, which led him to combat the theory of Schlösing. He believes the favorable action of potassium salts is due to the formation of a small amount of free potassium during combustion and this acts as a catalyst during the process.

Jenkins⁽²⁴⁾ determined the amount of potassium in the form of carbonate in the ash of a number of different types of tobacco and he found that no constant reaction existed between the amount of carbonate and the fire-holding capacity, and he concluded that the burning qualities are largely influenced by the organic constituents in the tobacco.

Barth⁽⁴⁾ agrees with the work of Nessler⁽³⁵⁾ and also of Mayer⁽³⁰⁾, that the beneficial action of potassium is due to the reduction of a small amount of potassium to carbonate the oxide form during combustion and this acts as an oxidation catalyst.

Carpenter⁽¹⁰⁾ found that potassium existing in proper combinations is conducive to complete combustion, while Nessler⁽³⁵⁾ found that an abundance of potassium overcame the effect of chlorine to a certain extent and also stated that potassium and

calcium are the elements of most importance for proper combustion.

Frear⁽¹⁵⁾ points out that the use of commercial fertilizers containing potassium in the form of sulphate or carbonate, give tobacco better burning qualities than stable manure. Frear⁽¹⁵⁾ states that any fertilizer which enriches the tobacco with considerable quantities of chlorine is very undesirable.

Carpenter⁽¹⁰⁾ realizes the importance of potassium, for he states that relatively larger quantities of potassium seem to be required for growth and production of a good quality smoking tobacco than any other element.

Halley⁽²¹⁾ reports that a relatively high potassium content is highly desirable in the case of cigar-leaf tobacco but the form of potassium used as a fertilizer must be taken into consideration and that the predominance of potassium over the acid elements is most desirable.

The experiment carried out by Nelson and Anderson⁽³⁴⁾ seemed to show no advantage in using sulphate of potassium and magnesium. This work is in accordance with Goessman⁽¹⁸⁾ who sums up his work by stating, "Our results with potassium and magnesium sulphate as a main source of tobacco fertilizers are

not encouraging." Goessman found that cottonseed hull ashes and high grade sulphate of potassium proved to be the most valuable sources of potassium and that potassium nitrate produced excellent results when used in connection with alkaline phosphates.

According to Carpenter⁽¹⁰⁾, potassium seems to be the element most necessary for good burning qualities, but in order that its application may insure the best results, it must be applied in a particular form, either as carbonate or sulphate. He believes that muriate of potassium is to a great extent injurious because of its chlorine content.

It has been generally observed by investigators that large amounts of potassium carbonate and potassium in certain other combinations are conducive to the most perfect combustion. Considering the amount present in the leaf and the beneficial effect on the burning qualities, it is believed that its application is required in larger proportions than is generally applied in normal fertilizers.

Jenkins⁽²⁵⁾ found that tobacco fertilized with one-half the quantity of potassium carbonate, contained as much potassium as did a full amount of potassium sulphate. When potassium sulphate is used

for fertilizer, the percentage of sulphuric acid is very much higher in the leaf and he has shown that sulphuric acid impairs the burning qualities of tobacco leaves.

Potassium in Organic Combinations. - Ames⁽¹⁾ believes the principal object to be obtained in efforts to improve the burning qualities of tobacco by breeding and improved method of production are the relatively high content of potassium combined with citric and malic acids with a minimum of inorganic salts especially chlorides and sulphates and with a moderate quantity of lime and a comparatively small amount of magnesium.

Garner⁽¹⁷⁾ says the oxalate, citrate, malate, and acetate of potassium all showed very beneficial effects in every case, though much larger quantities were required for some samples of tobacco than for others. Excessive amounts of these salts injure the burning qualities especially in regards to the ash. He also found that a number of organic acids such as citric, malic, oxalic, and acetic in combination with potassium, exert a favorable influence on the burning qualities. This work agrees well with that reported by Nasset⁽³³⁾. Citric and malic acids are undoubtedly of fundamental importance in producing good burning

qualities. Kissling⁽²⁶⁾ found that organic salts of potassium, potassium carbonate, tri-potassium phosphate, di-potassium phosphate and potassium sulphate improved the burning qualities, while potassium chloride, potassium acid sulphate and mono-potassium phosphate were injurious to the burn.

Relation and Composition of the Ash Content to the Burn. - A tobacco with satisfactory burning qualities, besides having the necessary capacity for holding fire, must also yield a good ash. Although the potassium salts greatly favor the fire-holding capacity, they tend to the production of a dark colored ash.

According to Nessler⁽³⁵⁾, of the several ash constituents which seem to be more or less interchangeable in the composition of the plant according to conditions attending growth, potassium and calcium are the most important in promoting proper combustion. Carpenter⁽¹⁰⁾ found that the best burning tobaccos were accompanied by a high percentage of ash constituents. Jenkins⁽²⁴⁾ found that the ash of tobacco fertilized with stable manure generally contained much chlorine. The ash of tobacco fertilized with potassium sulphate contained a smaller per cent of potassium and a higher per cent of lime than tobacco

treated with double sulphate of potassium and magnesium.

In the ash of good burning tobacco, van Hemmelen⁽⁷⁾ found that the glowing capacity is largely due to the relative quantities of alkali and hydrochloric and sulphuric acid present. He assumed that the favorable influence of potassium on the burn may also be replaced by calcium and magnesium but this is probably false, as pointed out by Garner⁽¹⁷⁾.

Frear⁽¹⁵⁾ in his studies of the ash content of Pennsylvania tobacco found the total quantity of ash in the finished leaf to range from 15 to 25 per cent of the entire dry weight and one-third of this to be potassium oxide, one-third calcium oxide and the remainder to be other basic compounds.

Kissling⁽²⁶⁾ considers the ash content to have little influence upon the burning qualities while Patterson⁽³⁷⁾ and Garner⁽¹⁶⁾ conclude that a high ash was conducive to good burn.

Moodie⁽³²⁾ expresses the opinion that the best burning qualities of tobacco are always accompanied by a high percentage of ash and that the percentage of calcium is always high.

Calcium and Magnesium and Their Effect on the Burning Quality. - It was found by Ames⁽¹⁾ that the

addition of lime to the soil decreased the calcium and increased the magnesium content of tobacco. Tobacco from limed plots as a rule contained less phosphorus and potassium than from unlimed plots.

According to Anderson⁽²⁾ the presence of calcium is very beneficial in the burning quality of dark tobacco but is of no benefit in the burning of a light tobacco.

Jenkins⁽²⁴⁾ shows that tobacco highly fertilized with the double sulphate of potassium and magnesium also contained a relatively high per cent of calcium. Nessler⁽³⁵⁾ is of the opinion that calcium and magnesium exert no influence on the burn except to whiten the ash.

Garner⁽¹⁷⁾ found that tobacco containing excessive amounts of lime give an ash which although it is very light in color, it lacks cohesion and is flakey.

Nessler⁽³⁵⁾ found that calcium and magnesium had little effect except to whiten the ash. Kissling⁽²⁶⁾ reports samples of good burning tobacco to be high in calcium and fairly high in magnesium. Garner⁽¹⁷⁾ is of the opinion that magnesium in excess injures the burn and calcium, while it does not generally effect the fire-holding capacity, is essential to the

production of a good ash.

Extracts of the Leaf and their Relation to the Fire-Holding Capacity. - Some research has been done to show a relation between the water-, ether-, and alcohol-soluble extracts of the tobacco leaf to its burning qualities. Garner⁽¹⁷⁾ made water extracts of a tobacco leaf having a good glowing capacity and found it lost this property. He then added the extract and the glowing power was restored. On examining the extract he found that it contained the chlorides, sulphates, nitrates, citrates, and malates of potassium, ammonia and nicotine and a very small quantity of calcium. He made extracts of both good and poor burning tobaccos and found the potassium content to be nearly the same, but the inferior leaf contained much higher amounts of mineral acids, and less potassium in combination with organic acids. From this he indicates that the principal factor governing the burn is potassium in excess of the amount required for combining with mineral acids.

According to Frear and Olson⁽¹⁶⁾, water extracts practically all substances that give the leaf a fire-holding capacity. The chlorides, sulphates, nitrates, citrates, and malates of potassium and ammonia and in part calcium and magnesium as well.

The phosphorus is largely in the insoluble residue.

Graham and Carr⁽¹⁹⁾ made ether, petroleum ether, alcohol and hot water extractions and showed a relation between poor burning qualities and high content of material extracted. Their data shows that tobacco fertilized with muriate of potassium and sodium nitrate yield the largest quantities of extracted materials.

The Effect of Chlorine on the Burn. - That chlorine is very injurious to the burn of a cigar-leaf has been definitely established. Nessler⁽³⁵⁾, Kissling⁽²⁶⁾, Behrens^(5, 6), van Bemmelen⁽⁷⁾, Barth⁽⁴⁾, Patterson⁽³⁷⁾, Carpenter⁽¹⁰⁾, Olson⁽³⁶⁾, and Garner⁽¹⁷⁾ have shown this to be the case. Because of this fact any fertilizer which contains a large amount of this element should be avoided.

Fesca⁽¹⁴⁾ working on Japanese tobacco found that chlorine and sulphur had a very detrimental effect on the burn.

Garner⁽¹⁷⁾ shows that calcium chloride is more injurious to the burn than potassium chloride.

According to Frear⁽¹⁵⁾ an excess of chlorine remaining from an application of high chlorine fertilizer to an open sandy loam soil, is largely removed if a leafy crop be taken from the land after the application and the soil is then exposed to

winter rains and snow before tobacco planting. He also expresses the opinion that some chlorine is probably necessary for the growth of the tobacco plant.

Jenkins⁽²⁴⁾ is of the opinion that a small quantity of chlorine is absolutely necessary to normal development of the plant but a large excess is very injurious to the burn.

According to Carpenter and Allen⁽¹¹⁾ there is no evidence to support the popular notion that small amounts of chlorine in fertilizers injure the quality of tobacco grown and existing prejudice against fractional percentages of this element is not justified. Excessive amounts of this element are not desirable but relatively large percentages do not injure the burn. In normally grown tobacco, chlorine is seldom found in large enough quantities to be injurious.

The Effect of Grain and Other Factors on the Fire-Holding Capacity. - Ridgway^(38, 39) asserts that there is a close correlation between the grain of tobacco leaf and the burning qualities. He found that leaves which had poor burning qualities were very close grained, had a very hard texture, contained little or no elastic properties and seldom exhibited grain bodies on the surface, while leaves of good burning qualities

were very open grained, comparatively soft in texture, possessed a large elastic power and usually possessed grain bodies sufficiently large to be visible to the unaided eye. He believed that the substance contained in the grain bodies are injurious to the burn and that the quality of the latter is dependent upon the degree to which the former are aggregated into definite bodies, sufficiently separated one from the other to permit a considerable fire carrying zone of cells emptied of grain materials around each. Chemical analysis showed the grain to be composed chiefly of calcium with a small amount of potassium and magnesium in combination with citric and malic acid. Grain is thought to be developed during the curing process when water is slowly removed from the leaf and the salts in solution crystallize out.

According to Kissling⁽²⁶⁾ the tobacco tars exert an important influence on the burn and fire-holding capacity. The amount of amino compounds has been shown to produce a favorable influence on the burn while the albuminoids produce the opposite effect.

Kraybill⁽²⁷⁾ demonstrated that there was a marked difference in the action of alkali salts upon the fire-holding capacity of tobacco even when the

salts have similarities. For instance, the carbonates of potassium and calcium promotes the combustion of tobacco to a very much greater extent than the carbonates of sodium or lithium. The chlorides of sodium, lithium and potassium retard combustion but the action of potassium chloride is not nearly as detrimental as that of lithium or sodium chloride.

Chesley⁽¹²⁾ is of the opinion that the ratio of ammonia, phosphoric acid and potassium in fertilizers are of great importance but must be controlled to suit the type of tobacco. Lack of ammonia decreases the growth and causes the tobacco to be dark, strong, and increases the nicotine content. A fertilizer deficient in potassium or containing chlorides will yield tobacco of inferior burning qualities while an excess of sulphate is harmful but is not as injurious as the chlorine.

Object of the Investigation

The object of this investigation was to make a partial study of:

1. - The chemical composition of cigar-leaf tobacco as modified by climatic and soil conditions.
2. - The response of different strains of tobacco to the same environmental factors.

Methods of Analysis

Moisture.

The method used in the determination of moisture is the one employed by Ames and Boltz⁽¹⁾.

A 2 gram sample was weighed into a weighing bottle and dried to a constant weight in a vacuum desiccator. The desiccating agent used being commercial sulphuric acid. The samples were dried until a constant weight was obtained.

Ash.

A 2 gram sample was ignited in a weighed flat bottom platinum dish at a comparatively low temperature. A full red heat was not employed because of the damage of volatilizing the chlorides, etc. The charred mass was treated with hot water to remove the soluble salts and filtered through Whatman No. 42 11 cm. ashless filter paper. The filter was then dried and burned, the filtrate added to the burned residue and evaporated to dryness on a steam bath, ignited at a low heat to a constant weight and weighed as crude ash. The results are expressed as the percentage crude ash in a moisture-free sample.

Organic Matter.

The organic content was considered as the loss on ignition or the percentage of ash minus 100 per cent.

Water-Soluble Alkalinity.

The method employed in the determination of the water-soluble alkalinity is one devised by Haley⁽²⁰⁾ which is a slight modification of the official method⁽³⁾.

Add 150 to 200 cc. of hot water to the total ash. Filter and wash with hot water several times to remove all soluble material. Titrate the filtrate with N/10 sulphuric acid solution using methyl red as an indicator. The alkalinity is expressed as the number of cc. of normal acid necessary to neutralize the alkalinity in a 100 gram sample.

Water-Insoluble Alkalinity.

Add an excess of standard N/10 sulphuric acid to the residue from the soluble ash and heat to boiling over a low flame. Filter and wash well with hot water to remove all traces of any acid and titrate the excess acid with standard N/10 NaOH using methyl red as an indicator.

The results are expressed as the number of cc. of normal acid necessary to neutralize the alkalinity in a 100 gram sample.

Chlorine.

To the combined filtrates from the determination of the soluble and insoluble alkalinity, an excess of N/10 silver nitrate is added. The

mixture is stirred and three cc. of ethyl ether are added to coagulate the silver chloride. Two cc. of ferric alum indicator and five cc. of concentrated nitric acid are added. Titrate the excess silver nitrate with N/10 ammonium thiocyanate until a permanent light brown color appears.

The chlorine is expressed as per cent. in a moisture-free sample.

Calcium.

The calcium was determined according to the method described by Ames and Boltz⁽¹⁾.

Char five grams of material in a platinum dish at a low heat. Cool the dish and cover with a watch glass. Moisten with water and add 3 cc. of concentrated hydrochloric acid. Add sufficient water to make about 25 cc. of solution. Filter the clear solution into a 150 cc. beaker, wash the residue several times with hot water, return filter paper with residue to platinum dish, dry and ignite to a white ash, transfer residue to a beaker containing filtrate with hot water and 5 cc. of hydrochloric acid.

Evaporate to dryness, take up with a small amount of hydrochloric acid and hot water and filter into a 500 cc. volumetric flask. Wash with hot water

and make the volume up to about 250 cc. To the solution in the flask add one-third more standard N/10 ferric chloride than necessary to precipitate the phosphorus present. Neutralize with ammonium hydroxide and make slightly acidic with hydrochloric acid, using litmus as an indicator.

Add 10 cc. of a 20% solution of ammonium acetate, boil for two minutes, cool and make up to volume. Mix, filter into a dry beaker and measure 200 cc. into a dry beaker. Make alkaline with concentrated ammonium hydroxide, using one cc. excess and precipitate the calcium with 10 cc. of a saturated solution of ammonium oxalate.

Allow the precipitate to settle over night, filter on asbestos mat and wash with a 2% ammonium hydroxide and dry.

Transfer to a beaker, add 100 cc. of hot water and 25 cc. of concentrated sulphuric acid and heat to 80° and titrate with standard potassium permanganate until a permanent pink color appears for 30 seconds or longer. Calculate the results as CaO.

Magnesium.

To the filtrate from the precipitation of calcium oxalate add 30 cc. of concentrated nitric acid, evaporate to dryness, take up with 5 cc. of hydro-

chloric acid and hot water, filter and wash several times with hot water. To the filtrate add 10 cc. of a 10 per cent. solution of ammonium phosphate, make slightly alkaline with ammonium hydroxide, let stand for 30 minutes and add 15 cc. of concentrated ammonium hydroxide and allow to stand over night. Filter and wash the precipitate thoroughly with a 2 per cent. ammonium hydroxide solution, dry, ignite and weigh the precipitate as magnesium pyrophosphate. Calculate the result as MgO.

Potassium.

Five grams of tobacco were transferred into a 500 cc. Kjeldahl digestion flask. 7 cc. of concentrated sulphuric acid and 5 cc. of concentrated nitric acid were added. The contents were thoroughly mixed and heated slowly over a low flame until frothing ceases, then add 1 cc. of nitric acid, repeat the treatment with 1 cc. portions of nitric acid until all the organic matter is destroyed. Cool, add about 50 cc. of water, filter into a 250 cc. volumetric flask, wash the filter paper and residue thoroughly with hot water, and make the filtrate up to the 250 cc. mark.

Transfer 50 cc. of the solution obtained from the sulphuric and nitric acid digestion to a

4 inch porcelain evaporating dish. Evaporate excess water and acid over a steam bath and finally over a burner adapted especially for removal of sulphuric acid without direct heating of the bottom of the dish and consequent spattering. This burner consists of a Meeker Burner and above the flame placing a piece of asbestos board about 3 inches square and $1/4$ to $1/2$ inch thick. This is supported by a ring stand and on this is placed the dish.

After acid is removed, heat at a low red heat over a Bunsen burner to volatilize remaining ammonium salts and organic matter. Allow dish to cool, add 1 cc. of concentrated hydrochloric acid and about 25 cc. of hot water. Rub with a glass rod and heat if necessary to bring salts into solution. Transfer to a 150 cc. Pyrex beaker. Add necessary excess of platinum chloride solution and evaporate to syrupy constituent on steam bath, care being taken not to go to complete dryness. Cool, add 15 cc. of acidulated alcohol, allow to stand for five minutes and filter through a weighed Gooch crucible, transferring all the precipitate from the beaker with 80 per cent. alcohol. Wash the precipitate and filter free from excess platinum chloride solution with 80 per cent. alcohol, then

wash several times with Lindo-Gladding solution and finally wash free from ammonium chloride with 80 per cent. alcohol. Dry to a constant weight in a 100° oven and weigh as potassium platinum chloride.

The potassium is expressed as per cent. potassium oxide in the sample.

To prepare acidulated alcohol, use 1500 cc. of 95 per cent. alcohol, add 1139.9 cc. of concentrated hydrochloric acid 1.2 specific gravity and pass enough hydrochloric gas into the solution to make it 2.25 normal hydrochloric acid.

Lindo-Gladding wash is prepared by dissolving 100 grams of ammonium chloride in 50 cc. of water. Add 5-10 grams of pulverized potassium platinum chloride and shake at intervals for 6 - 8 hours. Allow the mixture to settle over night and filter.

Soil Analysis

Colloidal Content.

The procedure employed in the determination of the colloidal content is the one described by Bouyoucos⁽⁸⁾.

The general procedure consists of weighing accurately 50 grams of air dry soil, placing it in the cup and adding 1050 cc. of distilled water and 5 cc. of N KOH. The cup is then connected to the stirrer of the

motor and stirred exactly 9 minutes. The mixture is then washed into a cylinder having a capacity of about 1250 cc., a diameter of 2 1/2 inches and a height of 18 inches. The hydrometer is then placed in the mixture and at the end of an exact fifteen minute period the reading of the liquid was taken. Just a minute before the end of the 15 minute period the hydrometer was gently pushed down into the liquid to avoid any error in the reading caused by lag or sticking of the hydrometer. The temperature of the mixture is recorded and a temperature correction made. The reading on the hydrometer multiplied by two gives the percentage of colloids in that soil.

A temperature change of 1°F. makes a difference of 0.350 per cent. of soil colloids. The hydrometer was calibrated at 67°F. In order to have accurate results for readings above 67°F., 0.350 per cent. must be added for every degree and 0.350 per cent. subtracted for each degree less.

Water-Soluble and Insoluble Alkalinity

Preparation of Sample.

The procedure used in the preparation of the sample is the one described by Schollenberger⁽⁴¹⁾.

One hundred grams of air dry soil were leached

with 750 cc. of neutral ammonium acetate. A very small amount of suction being used. The leachings were made up to a volume of one liter.

Water-Soluble Alkalinity.

100 cc. aliquots were evaporated to dryness on a steam bath in a 4 inch porcelain evaporating dish and heated over a low flame. Add 100 to 200 cc. of hot water and filter on a quantitative filter paper and wash several times with hot water to remove all soluble materials. Cool the filtrate and titrate with N/50 sulphuric acid using methyl red as an indicator.

The results are expressed as the number of cc. of normal acid necessary to neutralize the alkalinity in 100 grams sample of soil.

Water-Insoluble Alkalinity.

Add an excess of standard N/10 sulphuric acid to the residue from the soluble alkalinity and heat to boiling.

Filter through qualitative filter paper and wash well with hot water. Titrate the excess acid with N/10 sodium hydroxide, using methyl red as indicator.

The results are expressed as the number of cc. of normal acid necessary to neutralize the insoluble alkalinity in a 100 gram sample.

TABLE I
Fertilizer Treatment*
Crop 1927
Treatment - Experimental

Plot	Cotton- seed meal	Nitrate of Soda	Carbon- ate of Potash	Pre- cipitated Bone	Preceding Crop and Treatment	
					Crop	Manure
	lbs.	lbs.	lbs.	lbs.		Tons
A-1	610	130	155	140	Corn	2
A-2	610	130	155	140	Corn	----
A-3	610	130	155	140	Corn	10
A-4	610	130	155	140	Corn	----
A-5	610	130	155	140	Sod	10
A-6	610	130	155	140	Sod	----
A-7	610	130	155	140	Corn	----
A-8	610	130	155	140	Corn	----

*

All are based on acre applications.

TABLE II.
Fertilizer Treatment*
Crop 1927
Treatment - General

Plot	Manure	Bone Meal	Sulphate of Potash	Cotton-seed Meal	NaNO ₃	16% Super-phosphate
	Tons	lbs.	lbs.	lbs.	lbs.	lbs.
B-1	15					
B-2	10		26		152	45
B-3	10	350	350	300		
B-4	-		200		100	160
B-5	10	120	120	310		
B-6	10		100	300		100
B-7	20					
B-8	20					

* All are based on acre applications.

K as K₂SO₄ - 26.

N as NaNO₃ - 152.

P as 16% Superphosphate - 45.

TABLE III.

The Chemical Composition of Tobacco Leaves
as Modified by Locality*

Crop 1927

Treatment = Experimental

Plot	Moisture	Crude Ash	Organic Matter	Chlorine	Alkalinity**			CaO	MgO	K ₂ O
					Sol.	Insol.	Total			
	%	%	%	%	cc.	cc.	cc.	%	%	%
A-1	4.93	20.83	79.17	None	32.80	321.17	354.57	6.55	1.12	5.04
A-2	3.35	20.52	79.48	Trace	30.89	318.85	349.74	5.54	1.70	4.27
A-3	4.39	20.07	79.93	Trace	49.80	216.87	266.67	5.52	1.41	5.13
A-4	4.40	24.77	75.23	None	72.91	215.39	288.30	5.68	0.96	4.91
A-5	3.35	20.53	79.47	None	62.95	235.69	298.64	5.71	0.78	4.72
A-6	3.79	22.16	77.98	None	35.71	286.25	321.96	5.91	0.98	4.32
A-7	4.67	20.27	79.73	None	29.34	242.45	271.79	6.67	0.92	3.39
A-8	4.01	20.98	79.02	Trace	30.89	325.24	356.13	6.63	1.59	4.27

*

All percentages are based on moisture-free materials.

**

Alkalinity is expressed as cc. normal per 100 grams.

TABLE IV.

The Chemical Composition of Tobacco Leaves
as Modified by Locality*

Crop 1927

Treatment = General

Plot	Moist- ure	Crude Ash	Organic Matter	Chlor- ine	Alkalinity**			CaO	MgO	K ₂ O
					Sol.	Insol.	Total			
	%	%	%	%	cc.	cc.	cc.	%	%	%
B-1	3.20	20.71	79.29	0.74	37.77	309.77	347.54	5.64	1.09	4.63
B-2	3.97	19.74	80.26	0.65	36.85	290.03	326.88	5.43	1.37	4.49
B-3	1.22	20.05	79.95	Trace	29.37	290.49	319.86	5.19	1.54	5.03
B-4	3.51	20.77	79.23	1.24	48.26	263.92	312.18	5.49	0.60	4.79
B-5	2.84	21.45	78.55	Trace	64.96	275.07	340.03	5.62	0.83	5.24
B-6	1.35	20.88	79.12	Trace	48.00	286.64	334.64	5.45	1.10	5.40
B-7	3.69	20.67	79.23	None	37.72	263.39	301.11	4.89	0.89	4.42
B-8	4.20	19.76	80.21	0.50	22.77	301.99	324.76	5.55	1.61	4.64

* All percentages are based on moisture-free material.

** Alkalinity is expressed as cc. normal per 100 grams.

TABLE V.

Analysis of Soil Plots in
Lancaster County - 1927.*

Plot No.	Average Colloidal Content %	Alkalinity		
		Sol.	Insol.	Total
		cc.	cc.	cc.
1	32.9	1.29	5.44	6.73
2	31.9	1.00	4.61	5.61
3	40.3	1.14	8.25	9.39
4	36.3	0.96	6.06	7.02
5	39.1	1.51	8.14	9.65
6	45.0	1.30	7.36	8.66
7	30.0	1.36	7.15	8.51
8	37.0	1.02	5.49	6.51

*

Alkalinity is expressed as cc. normal per
100 grams.

TABLE VI

Fertilizer Treatments for Experimental Plots
for 1925 - 1926 - 1927 Crops

Plots	Manure	Sul- phate of Pot- ash	Muri- ate of Pot- ash	Nit- rate of Pot- ash	Manure Salt	Bone Flour	Pre- cipi- tated Bone Phos- phate	Acid Phos- phate	Urea	Cotton- seed Meal	(NH ₄) ₂ - NO ₃
A-1	10		200			250				400	
A-2	10	200						300		500	
A-5	10										
A-6	10	200						300		500	
A-9	10				400	250				400	
A-10	10		200					300		500	
B-1	10		200					300	65		
B-2	10			214			120				
B-3	10	200						300	65		
B-6	10	200						300			85

The potash, phosphoric acid and nitrogen carrying materials with the exception of manure and cottonseed meal constituted acre applications of approximately 100 lbs. of potash, 48 lbs. of phosphoric acid, and 38 lbs. of nitrogen.

TABLE VII.

Per cent. of K_2O and CaO of Cured Tobacco as Influenced by Fertilizer Treatment.*

Plot	Year					
	1925		1926		1927	
	K_2O	CaO	K_2O	CaO	K_2O	CaO
	%	%	%	%	%	%
A-1	1.89	7.88	2.13	6.39	3.83	-----
A-2	1.94	7.06	2.29	6.43	-----	-----
A-5	1.93	7.30	2.55	6.44	4.63	-----
A-6	1.65	7.58	2.38	6.29	5.34	-----
A-9	1.95	7.93	2.69	6.56	4.89	-----
A-10	1.97	7.64	2.33	6.79	4.22	-----
B-1	1.84	7.08	2.04	6.83	-----	-----
B-2	1.97	7.83	2.13	6.79	-----	-----
B-3	1.93	7.30	3.37	6.75	-----	-----
B-6	2.03	7.17	2.19	6.78	-----	-----

*

All results are based on moisture-free material.

TABLE VIII.

Percentage of K_2O in Two Different Strains
having the same Fertilizer Treatment. -
1927 Crop.*

Plot	Potassium	
	Hibshman	Swarr
	%	%
A-1	3.83	5.22
A-5	4.63	5.05
A-6	5.34	5.02
A-9	4.89	5.42
A-10	4.22	5.59

*
All results are based on moisture-
free materials.

Discussion

1. - The Influence of Climatic and Soil Conditions.

Comparison of Tables III and IV show that the chemical composition of the 1927 crop from an elemental standpoint was rather constant regardless of fertilizer treatment. Slightly more chlorine was found in the general crop which was supplied with chlorine-bearing materials.

The water-soluble and water-insoluble alkalinity also show a variation between the two treatments. In general it is much higher in the experimental than in the general. The form of potassium used for fertilizer seemed to play an important rôle here. There is a marked individual difference between the different plots but the difference is nearly the same in both treatments.

With the "Experimental treatment" the highest potassium content was found in plot A-3 and the lowest in A-7, followed by A-2. Comparing these results with the average colloidal content of the soil (Table V), we find the lowest in plot number 7 followed by plot number 2. The same is shown with the "General treatment." The lowest potassium being found in plot B-7 followed by B-2. This would lead one to believe that the estimation

of the soil colloidal content is a measure of soil fertility and is also a means of classifying the soil as to its value for tobacco growing.

The highest colloidal content is found in soil number 6 and the highest potassium content of the "General treatment" in plot B-6. In the "Experimental treatment" the highest potassium content is found in A-3.

There seems to be a greater tendency for the calcium and potassium content of both the "Experimental" and "General" treatments to form a ratio of 1 to 1. This is very desirable in the production of a good tobacco, for according to Garner⁽¹⁷⁾ calcium, while it does not generally effect the fire-holding capacity, is essential to the production of a good ash. The analyses of Tables III and IV show the calcium and magnesium content to be higher in the "General" than in the "Experimental."

The principal results obtained from these investigations show that on the whole there is a variation in the chemical composition of the tobacco according to the locality and the colloidal content of the soil.

The differences in the potassium content between 1925, 1926 and 1927 crop is quite apparent,

(Table VII). It is noticed that there is a general increase in the potassium content from 1925 to 1927 with the same fertilizer treatment.

It has been commonly believed that lime makes soil potassium more available by Lyon and Bizzell⁽²⁸⁾ ⁽²⁹⁾. Briggs and Breazeale⁽⁹⁾ and Haley⁽²²⁾, however, present data which seem to disprove this theory. McHargue and Peters⁽³¹⁾ analyzed a great variety of drainage waters and found in every case that calcium and magnesium were present in larger quantities than potassium. It is believed that the heavy rains of 1926 and 1927 leached out large amounts of calcium and magnesium, leaving relatively larger quantities of potassium for plant utilization. The data in Table VII lends support to this hypothesis.

According to Haley, Nasset and Olson⁽²³⁾, it is a well known fact that the principal replaceable bases of the soil colloids in a calcareous district as Lancaster County, Pennsylvania, is calcium, and that the addition of potassium salts to such a soil should lead to the replacement of calcium from such combinations and the formation of calcium salts. At the same time it is possible to reverse the process. In other words, there is a competition existing between calcium and potassium whereby either one or the other

goes into colloidal combination.

Under laboratory conditions a sample of soil may be treated with muriate of potassium and the replaced calcium may be completely removed by leaching, leaving potassium behind in basic form. On the other hand it is quite possible to remove all adsorbed potassium by the use of a solution of calcium chloride, leaving calcium behind in colloidal combination and in basic form.

Under soil conditions neither condition is ever attained but a relatively dry year such as 1925 would have a different effect on the availability of potassium than a comparatively wet year as 1926 and 1927. Continual leaching would have the effect of rendering potassium available for absorption in basic form by tobacco plants, while such a condition would not hold true under relatively dry conditions where soluble calcium salts tends to accumulate in the upper soil layers. Under the former conditions, the tendency would be for potassium to assume the carbonate form. Under the latter conditions potassium would tend to assume the form of muriate or sulphate.

These reasons would tend to explain the beneficial effects of a wet season on the burning qualities of Pennsylvania cigar-leaf tobacco, but would not hold true to any appreciable extent on soil lacking

in colloidal material.

Table VII shows a large variation in the potassium content among different individuals. Plot A-2 and A-6 which were treated with sulphate of potash are higher in potassium content than A-1, A-10 and B-1, which were treated with muriate of potassium. It appears evident that the form of potassium and too a greater extent the seasonal conditions, has a greater effect on the potassium content of tobacco.

Table V indicates that there is a marked difference in the colloidal content between the soil from different localities in Lancaster and this difference in colloidal content is apparent in Tables III and IV.

2. - The Influence of Environmental Factors on the Potassium Content of Different Strains.

Analysis of the 1927 crop having the same fertilizer treatment but of two different varieties, as given in Table VIII, shows that with the exception of A-6 there is a slightly higher potassium content in the Swarr variety than is found in the Hibshman, but this difference is not sufficient enough to consider it one of variety.

Plan of the Experiment

Materials Used

The soil samples were obtained from eight plots of one acre each in different localities of Lancaster County, Pennsylvania, and uniformly sampled to a depth of six inches.

The samples were air dried, under laboratory conditions, sieved through a 100 mesh sieve and transferred to air tight cans.

The plots from which the soil samples were taken were divided into two portions. One portion received a fertilizer treatment with no manure and the other a treatment of manure and fertilizer. Tobacco of the Hibshman strain was grown on these plots and when fully matured and ripened was carefully selected and harvested. The samples were air cured in the ordinary manner. After curing the samples were dried under laboratory conditions.

The leaves were separated from the stems and stalks, finely ground and transferred to air tight glass jars. The samples from these plots are designated as A -Experimental and B -General.

The samples for the 1925, 1926, and 1927 crops were obtained from ten plots from a similar station at Ephrata, Pennsylvania. The same procedure was followed

in harvesting and curing of these samples as in the 1927 crop.

Fertilizer Treatment

All the 1925, 1926 and 1927 plots at Ephrata received application of manure at the rate of 10 tons to the acre. The chemical treatments, expressed in pounds are also based on acre applications.

Experimental

It was originally planned to make the same determinations on the soil as was made on the tobacco, also to determine the sodium and potassium content of the tobacco together according to the method described by Crooks⁽¹³⁾. However this method was found to give unreliable results and was abandoned for the method herein described for potassium.

The determination of the water-soluble and water-insoluble alkalinity was substituted for the separate determination of potassium, sodium, calcium and magnesium that can be replaced in the soil.

The filter paper from the water-soluble and water-insoluble alkalinity determinations was boiled with distilled water, filtered and washed several times and the filtrate titrated with N/50 acid in order to be sure that no alkali was adsorbed by the filter paper which was used for filtering the ash residue.

The alkalinity of tobacco and soil was determined because of their value in the estimation of sodium, potassium, calcium and magnesium that is present in the soil and tobacco.

The colloidal content of the soil was determined because of its value in the estimation of the soil fertility and as a means of classifying the soil.

Summary and Conclusions

1. - The purpose of this investigation was to study the chemical composition of cigar-leaf tobacco as modified by climatic and soil conditions. To study the response of different strains of tobacco to the same environmental factors.
2. - Data are presented to show that more chlorine is found in tobacco treated with chlorine-bearing materials than where it is not added.
3. - In general the water-soluble and water-insoluble alkalinity is higher in the "Experimental."
4. - The lowest potassium content was found in the plots having the lowest colloidal content.
5. - The quantity of soil colloids bears some relation to the potassium content of the plants grown there-upon.
6. - There seems to be a tendency for the potassium and calcium content to be about the same in the "General" and "Experimental" plots.
7. - The season and form of potassium applied as fertilizer affects the potassium content of tobacco.
8. - The phenomenon of base exchange in the soil and the removal of certain active substances through leaching have considerable to do with the composition and burn of tobacco.

9. - There is a marked difference in the colloidal content of the soil depending on the locality.
10. - There was very little difference in the potassium content of the two different varieties having the same fertilizer treatment.

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