Chemical characterization of some soils from four counties that produce Flue-cured tobacco

Caracterización química de algunos suelos de cuatro municipios productores de tabaco Virginia

Marcela Rodríguez[1], Verónica Hoyos[1], and Guido Plaza[1]

ABSTRACT

The municipalities or counties of Campoalegre and Garzón (State of Huila) and Capitanejo and Enciso (State of Santander) show different chemical soil characteristics when their origin is taken into account, based on their edaphogenetic environments. For the characterization of the soils from these counties, samples from 65 farms were arranged, based on the database of farmers associated with the Protabaco Company. With the soil samples taken, chemical and texture analyses were performed, codifying the results in order to analyze them, keeping in mind the ideal parameters for the tobacco crop. In the counties of Huila, the texture, pH and organic matter were found to have ideal levels, in contrast to the phosphorus, potassium, magnesium, sulfur and chloride levels which were unsuitable, but the calcium content showed levels between suitable and good. In Santander, the pH, organic matter, phosphorus, calcium, sulfur and chloride were at unsuitable levels, in contrast, the contrary occurred with the texture and potassium which were at normal levels. It is recommended, due to the difference among the chemical parameters, that a fertilization program be handled differently for the zones of Santander and Huila, bearing in mind that the chemical parameters were found to be more limited in Santander than in Huila.

Key words: fertility, *Nicotiana tabacum*, Santander, Huila.

RESUMEN

Los municipios de Campoalegre y Garzón (Huila), Capitanejo y Enciso (Santander), presentan características químicas del suelo diferentes, teniendo en cuenta los ambientes edafogenéticos de origen. Para la caracterización de los suelos de estos municipios, se dispuso de una muestra de 65 fincas, teniendo en cuenta la base de datos de agricultores de la empresa Protabaco. Con las muestras de suelo tomadas, se realizaron análisis químicos y de textura, teniendo en cuenta los parámetros ideales para el cultivo de tabaco. Para los municipios de Huila, la textura, pH y materia orgánica se encuentran en niveles ideales; el fósforo, potasio, magnesio, azufre y cloruro, no adecuados y los contenidos de calcio entre adecuados y buenos. En Santander, el pH, materia orgánica, fósforo, calcio, azufre y cloruro no se encuentran en niveles adecuados, lo contrario ocurre con la textura y el nivel de potasio se encuentra como regular. Se recomienda por las diferencias entre los parámetros químicos del suelo, que la fertilización de las zonas de Santander y Huila, se les de un manejo diferente, teniendo en cuenta que estos se encuentran más limitados en Santander que en Huila.

Palabras clave: fertilidad, *Nicotiana tabacum*, Santander, Huila.

Introduction

In Colombia, as in many counties in the world, the tobacco crop is important because it generates employment and income for the producers, is labor intensive, captures market interest and financing from the purchasing companies, and is also an important source for income taxes and foreign exchange generated by the raw and finished products for export (CCI, 2001; Agrocadenas, 2005, 2006).

The states which had a larger cultivated field area of Flue-cured tobacco during 2008 were: Santander 56%, Huila 24%, North Santander 7%, Boyacá 8% and Cesar, Tolima and Valle del Cauca 5% each, for a total of 7,931 sown field hectares (DNP, 2009). In 2008, the average yields of tobacco production in Colombia fluctuated between 1.18 t ha^{-1} and 2.6 t ha^{-1}, whereas Santander and Huila showed an average yield of 1.63 t ha^{-1} and 2.35 t ha^{-1} respectively (CCI *et al*., 2008; DNP, 2009), being low in Santander and high in Huila, with respect to the global average yield of 1.6 t ha^{-1} in 2005 (Agrocadenas, 2006).

At the present, agricultural production is dynamic and competitive, because of this, tobacco producers have to be more efficient with production, meaning they have to attain greater production and quality with the lowest possible cost. This efficiency depends on many factors, such as the adequate selection of the variety which is going to be sown,

Received for publication: 14 March, 2011. Accepted for publication: 30 October, 2012.

[1] Department of Agronomy, Faculty of Agronomy, Universidad Nacional de Colombia. Bogota (Colombia). lmrodriguezj@unal.edu.co

irrigation management, phytosanitary conditions, among others, without excluding adequate nutritional support management and supply as a fundamental variable (Rojo, 2006; Ballari, 2005).

Crop practices and nutritional requirements for the different types of tobacco vary according to the characteristics demand in the final product (the cured tobacco leaf), so, the handling of the fertilization has been evolving continuously in order to reach maximum yields, high quality and profitability. The tobacco crop is one where the effects of adequate fertilization are clearly demonstrated by the quality and quantity. Appropriate and correctly balanced fertilization allows for the obtainment of the required characteristics for commercialization (Ballari, 2005).

And so, in order to obtain optimum development of the plants, it is necessary to take into account the chemical, physical, mineralogical and biological conditions of the soil, and also the parental material and the environmental conditions, as well as the soil fertility (Thompson and Troeh, 2002). These characteristics determine the water and nutrient supply; maintaining and supporting the plant and the interactions with the solid, liquid and gaseous stages (Prasad and Power, 1997; Thompson and Troeh, 2002). Additional components which have been observed to be in constant change when they are subjected to climatic, atmospheric and anthropic variations, allowing a fertility characteristics for each zone (Thompson and Troeh, 2002; Urquiza, 2002; Moreno and Coronado, 2006).

The chemical characteristics of the soil were evaluated at the laboratory, with a preliminary assessment of the soil fertility which is fundamental in agricultural production (Prasad and Power, 1997; Thompson and Troeh, 2002). Additionally, the pH was determined for the solid and colloidal stages of the soil, as well as the ionic interchange and consequently, the availability of the elements for the plants (Prasad and Power, 1997; Thompson and Troeh, 2002; Ballari, 2005).

For Flue-cured tobacco crops, Ballari (2005) reported interpretation rankings of the chemical and physical analyses of soils which are ideal for production, based on 10 years of research with this crop in Argentina.

Colombian soils are very young for the most part and receive an appreciable and sharp tropical influence, such as: high temperatures, intense solar brightness, and abundant rainfall. Additionally, these soils area characterized by being too fragile and susceptible to losing productive capacity due to degradation and contamination caused by agricultural and farming exploitations, road construction, urban and industrial public works, among others (Mantilla *et al*., 2001).

The soils from Santander originated from igneous, intrusive rocks of the Paleozoic era, based on chemical composition; basic, acid and intermediate types are found (Carrizosa and Vega, 1969). On the other hand, in Huila, the soils are from metamorphic, igneous, intrusive rocks and volcano sedimentary made between the Precambric and Triasic-jurassic eras (Ruiz *et al*., 1969; IDEAM, 1999). These differences are reflected by the chemical, physical and biological properties, causing the need for specific handling for the nutrition of the plants.

Santander is considered a state with a high anthropic influence, showing hillside intensive agriculture which is known to be unstable. The soils on the prairies of Huila are affected by compression and compactness and contamination of the soils with agricultural toxicants, as a result of the intensive agriculture and human settlements (Mantilla *et al*., 2001).

Due to the importance of knowing the chemical characteristics of the soils assigned to agricultural production, the objective of this present study was to interpret the analysis of the soils from the studied zones and compare them with the ideal parameters for the production of Flue-cure tobacco.

Materials and methods

This present study was carried out in two tobacco producing counties or municipalities in the state of Santander in the García Rovira province: Enciso and Capitanejo, located at 1,100 m a.s.l., with an average annual temperature of 25ºC, and an average precipitation between 900-1.100 mm year^{-1}; the other two counties were Campoalegre and Garzón in Huila, located at an altitude between 500 and 1,000 m a.s.l., with an annual temperature of 27°C, and an average precipitation between 800-1,300 mm year^{-1}.

The basic information for interpreting this study was taken from the soil analysis carried out on 65 producing and supplying tobacco farms connected with Productora Tabacalera de Colombia (Protabaco). The number of samples was calculated through the methodology of Hernández *et al.* (2003), in which the standard error is taken into account with the purpose of obtaining the variance analysis and the arithmetic mean sample fluctuation $\bar{y}$ with respect to the mean population $\overline{Y}$ given by the following equation (Eq. 1):

$$n = \frac{\left(\frac{s^2}{V^2}\right)}{1+\left(\frac{\left(\frac{s^2}{V^2}\right)}{N}\right)} \quad (1)$$

Where,

N = size of the population (number of producers hired for each municipality).

V^2 = variance of population, $(SE)^2$ square of the standard error.

SE = standard error = 0.04, defined by the authors.

s^2 = variance of the sample expressed as the occurrence of $\bar{y}$, determined in terms of the probability (s^2 = p (1-p)), where *p* represents the probability (95%).

n = size of the sample.

Keeping this equation in mind, a total of 65 samples were obtained, evaluated and distributed in the following way: 11 in Capitanejo, 20 in Enciso, 17 in Campoalegre and 17 for Garzón.

For the samples taken for the analysis of soils, the area assigned for the sowing of tobacco (commercials plots) was traveled, identifying the variations and characteristics of the ground (topography, erosion, drainage and physical appearance of the soil) with the purpose of establishing the site of the subsamples (from 5 to 10 subsamples/ha), at a depth between 20 and 30 cm, treated as a compound sample (ICA, 1992; Coraspe and Tejera, 1996). These samples were taken to the water and soil laboratory, at the National University of Colombia, for chemical analysis by the Agronomy Faculty.

The chemical properties analyzed and evaluated from the soil were: pH, related to soil-water 1:1 (v/v); cation exchange capacity (CEC), with ammonium acetate; electric conductivity (EC), through saturated soil paste with a 1:2 soil-water proportion (p/v); organic matter (OM), through the methods of organic carbon by Walkley Black; phosphorus (P), by Bray II; exchangeable bases such as potassium (K), calcium (Ca) and magnesium (Mg), extracted through ammonium acetate; sulfur (S), extracted through monocalcic phosphate and chloride (Cl^-), through titration with silver nitrate from the saturated soil paste.

The texture was the only physical property which was evaluated, through the methodology of Bouyoucos. This property was determined from the proportion showed among sand, silt and clay, according to the USDA, 12 kinds of texture are differentiated; nevertheless for the purpose of this study the textures were simplified in three classes: (1) light texture "coarse texture" which encompassed: sandy (S), loamy sand (LS), sandy loam (SL), sandy clay loam (SCL), textures which make then ideal for the tobacco crop (Ballari, 2005; Rodríguez, 2004); (2) heavy texture "fine texture" including: clay loam (CL), sandy clay (SC), silty clay (SIC) and clay (C) textures, which are the least suitable for tobacco crop; and (3) loamy texture "middle texture" which included: loam (L), silt loam (SL), silt (S) and clay loam (CL). The results from the analysis of soils were analyzed with the interpretation tables for the chemical and physical parameters of soil for Flue-Cured tobacco growth according to the values presented by Ballari (2005). Nevertheless, tables for the interpretation of the CEC and EC not present, so these variables are taken into account for the multivariate analysis only.

In the results from the soil analysis, the percentage of the organic carbon (OC) was reported; nevertheless the requirements for organic matter (OM) for the Flue-Cured Tobacco crop are known; and so, is necessary the conversion of the percentage in OM from the data of OC multiplied by 1.72 (ICA, 1992) (Tab. 1).

TABLE 1. Interpretation of organic matter in the soil for the Flue-cured tobacco crop (Ballari, 2005).

Interpretation	Value (%)
Unsuitable	< 1 or >3
Regular	1 - 1.5
Suitable	1.5 - 2.5
High	2.5 – 3

The pH influences physical-chemical and biological processes in relation with nutrition, because of this, it is the first parameter to keep in mind for interpreting and recommending fertilization of the soil (Bohn *et al.*, 2001) (Tab. 2).

TABLE 2. Interpretation of the soil pH for the Flue-cured tobacco crop (Ballari, 2005).

Interpretation	Value
Unsuitable, with important limitations	< 5 or >7.5
Regular, with moderate limitations	5.0-5.5 or 7.0-7.5
From very good to good, with possible limitations	5.5-6 or 6.5-7
Suitable, without limitations	6.0 – 6.5

TABLE 3. Interpretation of the levels of potassium, calcium and magnesium (cmol kg^{-1}) related to the texture of the soil for the Flue-cured tobacco crop (Ballari, 2005).

Texture	Unsuitable	Regular	Good*	Suitable
		Potassium		
Light "coarse"	< 0.25 or >0.8	0.25 – 0.35	0.35 – 0.55	0.55 - 0.8
Regularly "loam"	< 0.35 or >1.1	0.35 – 0.55	0.55 – 0.8	0.8 – 1.1
Heavy "fine"	< 0.5 or >1.4	0.55 – 0.8	0.8 – 1.1	1.1 – 1.4
		Calcium		
Light "coarse"	< 3 or >7.5	3 – 4.5	4.5 – 6	6 – 7.5
Regularly "loam"	< 4.5 or >9.5	4.5 – 6	6 – 7.5	7.5 – 9.5
Heavy "fine"	< 6 or >12	6 – 7.5	7.5 – 9.5	9.5 – 12
		Magnesium		
Light "coarse"	< 0.7 or >1.9	0.7 – 1	1 – 1.4	1.4 – 1.9
Regularly "loam"	< 1 or >2.6	1 – 1.4	1.4 – 1.9	1.9 – 2.6
Heavy "fine"	< 1.4 or >3.5	1.4 – 1.9	1.9 – 2.6	2.6 – 3.5

* with important limitations.

In the interpretation of K, Ca and Mg, the texture of the soil was considered (Ballari, 2005) (Tab. 3). The interpretation of P, S and Cl^- are described in Tab. 4, wherein the high value for phosphorus is considered very good.

In order to be able to identify the plots of tobacco which showed optimum conditions for growing the crop, the data were organized with tables and dynamic graphics, in which each plot was identified; as many parameters our of the nine reported by Ballari (2005) are ideal or adequate for the tobacco plant Flue-cured. In this way, the chemical limitations of the soil were analyzed, which can occur in each zone in this study.

TABLE 4. Interpretation of phosphorus, sulfur and chloride (mg kg^{-1}) in the soil for the Flue-cured tobacco crop (Ballari, 2005).

Interpretation	Phosphorus	Sulfur	Chloride
Unsuitable	<10 or >41	<8 or >21	<5 or >16
Regular	10-20	8-11	5-8
Suitable	20-30	11-17	8-12
High	30-40*	17-20	12-16

* very good value of phosphorus for tobacco.

Additionally, the data were organized in a processing matrix assigned for observations (sampling plots) and the resultant variables of the analysis of soils (physical-chemical parameters). All the variables were codified using the interpretation tables. The analyses were run through descriptive statistics (Excel®) and multiple correspondences analysis, with the statistics program Spad 3.5 (Cisia- Ceresta, 1998), with the purpose of determining the relation or similarity among the plots evaluated and the Flue-cured tobacco production.

Results

Individual parameters analysis

pH

In the state of Huila, 38.2% of the sampling soils were within the ideal pH for tobacco crops (values between 6.0 and 6.5), 50% of these soils were within the good to very good classification and 11.8% had a regular pH (from 5 to 5.5). In Santander, 61.3% of the soils were characterized as having unsuitable pH values (<4.5 and/or >8.0), 25.8% presented a regular pH, 9.7% presented a very good pH, and only 3.2% had an ideal pH (Tab. 5). In general, soils in Huila have an acidic pH with an expected low availability of phosphorus, nitrogen, potassium, calcium, magnesium, sulfur and molybdenum (Sposito, 2008). Instead, the soils of Santander (alkaline pH) are expected to have a low availability of iron, copper and zinc (Fassbender, 1982).

For the counties in the present study, the following were noticed: in Campoalegre, 52.9% of the soils had an ideal pH and 47.1% were between the classification of very good to good; in Garzón, 29.4% had an ideal pH, 47.1% were in the category of very good to good and 23.5% had regular pH values; in Capitanejo, 81.8% of the soils had an unsuitable pH, 9.1% presented a regular pH and 9.1% were in the ideal category; in the county of Enciso, 50% of the soils had inadequate pH values, 35% were regular and 15% of the sampled soils were located within the very good to good category (Tab. 5).

Ruíz *et al*. (1969 and 1994) reported that in Huila, the soils have and present different classifications with predominantly acid ph soils; the same situation was found in the present study; nevertheless, a modal profile in the counties of Campoalegre and Garzón showed a classification between 4.3 and 7.5 (Ruíz *et al*., 1969, 1994) and the pH for the soils evaluated for the tobacco crop in this study were found between 5.08 and 7.0, considering that this crop does not develop in all climatic zones in the state of Huila.

On the other hand, the pH modal profile for the counties of Capitanejo and Enciso showed values from 4.9 to 8.0 (Carrizosa and Vega, 1969) and the soils in this present study were classified between 5.3 to 8.4, with a predominance of alkaline soils; furthermore, these difference are derived from the soil solution due to the environmental conditions; finding acid soils at altitudes higher than 1,200 m a.s.l.

Organic matter (OM)

In Huila, 55.9% of the soils had unsuitable contents of organic matter, 17.6% had OM within a medium low category, 14.7% with an unsuitable percentage and 11.8% of the samples within the medium high category. In Santander, 71% of the soils had an unsuitable percentage of OM, 22.6% had a medium high category and 6.5% presented an ideal percentage. This indicates that, proportionally, the soil from Huila shows a greater percentage of ideal OM (Tab. 5).

The results from the evaluation in the counties are as follows: in Campoalegre, 41.2% of the soils were classified within the suitable category, 29.4% within the medium low category, 17.6% within the medium high category and the remaining soils (11.8%) showed an unsuitable percentage; in Garzón, 70.6% of the soils showed a suitable content of OM, greater with respect to Campoalegre county, 17.6% unsuitable, 5.9% medium low and 5.9% showed a medium high percentage; in Capitanejo, 100% of the sampled soils showed an unsuitable percentage of OM, whereas in Enciso, 55% of the soils were characterized by having an unsuitable percentage of OM, soils with medium high contents (35%) and suitable (10%) (Tab. 5).

The mineralization processes from the counties in Santander were bigger, with respect to and contrasting with the ones presented in Huila, due to the fact that OM contents can be affected by the temperature (from 32 to 43°C), the humidity content of the soil, which varies when compared between the Santander and Huila estates, principally due

TABLE 5. Characteristics of the soils from four municipalities, Capitanejo and Enciso, Santander; Campoalegre and Garzón, Huila, according to the soil analysis of the corresponding samples from the tobacco growing farms.

Parameter	Capitanejo	Enciso	Campoalegre	Garzón
pH	54.5% of the soils presented a slightly alkaline pH, 27.3% moderately alkaline, 9.1% slightly acid and 9.1% neutral.	35% of the soils presented a lightly alkaline pH, 30% neutral, 20% moderately alkaline, 10% strongly acid and 5% moderately acid.	52.9% of the soils presented moderately acid pH and 47.1% slightly acid.	41.2% were moderately acid soils, 29.4% slightly acid, 17.6% strongly acid and 11.8% neutral.
OM	72.7% of the soils presented medium percentages, 18.2% high and 9.1% ideal.	75% presented medium percentages, 20% high and 5% ideals.	41.2% of the soils presented suitable OM contents, 17.6% medium high, 29.4% medium low and 11.8% unsuitable.	70.6% of the soils presented suitable contents, 5.9% medium high, the same percentage with medium low and 17.6% unsuitable.
P	Presented unsuitable contents of P in 100% of the soils sampled.		58.8% were soils with very good contents, 23.5% unsuitable and 17.6% good.	58.8% were soils with unsuitable contents, 17.6% very good, 17.6% good and 5.9% regular.
K	36.4% of the soils presented regular content of K, 36.4% good, 18.2% unsuitable and 9.1% very good.	45% of K was good, 25% unsuitable, 25% regular and 5% very good.	88.2% unsuitable and 11.8% regular.	41.2% good, 35.3% regular, 11.8% very good and 11.8% unsuitable.
Ca	100% of the soils presented an excess of calcium content which was unsuitable.	95% of the soils presented an excess of Ca (unsuitable) and 5% medium content.	29.9% unsuitable, the same percentage very good, 23.5% good and 17.6% regular.	35.3% unsuitable, 29.4% good, 17.6% very good and the same percentage was regular.
Mg	54.5% of the soils presented good content and 45.5% unsuitable.	30% unsuitable, 30% very good, 20% regular and 20% good.	41.2% unsuitable, 23.5% regular, 17.6% very good and the same percentage was good.	100% of the soils presented unsuitable magnesium contents.
S	63.3% of the soils with very high contents of S and 36.4% medium.	50% of the soils were unsuitable, 25% good, 15% high and 10% regular.	52.9% unsuitable, 35.3% regular and 11.8% good.	47.1 of the soils were good, 35.3% unsuitable, 11.8% regular and 5.9% high.
Cl^-	90.9% of the soils were unsuitable and 9.1% regular.	85% presented unsuitable contents, 10% high and 5% good.	88.2% were unsuitable soils, 5.9% regular and 5.9% high.	100% of the soils presented unsuitable contents.
Texture	90.9% of the soils presented sandy clay loam textures and 9.1% were sandy loam.	65% of the soils were sandy clay loam textures, 15% clay, 15% clay loam and 5% sandy loam.	94.1% of the soils presented sandy loam textures and 5.9% sandy clay loam.	70.6% of the soils presented sandy loam textures, 17.6% clay sandy loam, 5.9% sandy loam and 5.9% clay loam.

to the texture (clay contents in the soils), precipitation, and watering or irrigation systems and other practices of agricultural handling, and the presence of volcanic ash in Huila (Ruíz *et al*., 1994; Bonh, 2001; Sposito, 2008). In addition, based on the results, the content of native nitrogen is different in the four counties in this study, intervening with and influencing the tobacco quality of Flue-cured tobacco through its direct relation with nicotine production (Hurtado *et al*., 2007), due to the quantity and different forms of Nitrogen that can be obtained through mineralization processes.

Because of the parental material of the soil in these two states, the organic matter in Huila was higher and more suitable for the sowing of tobacco, as a result of the volcanic ash (Carrizosa and Vega, 1969; Ruíz *et al*., 1969 and 1994). On the contrary, in Santander, the influence of materials such as sandstone, slate banks of limestone and granoditorites made the organic matter lower (Carrizosa and Vega, 1969). Nevertheless, the analysis of soils evaluated in the county of Capitanejo showed that these soils are unsuitable for the sowing of tobacco because the organic matter content was higher than 3%, this is possible because of the higher contents of clay compared with the ones in Huila. These very high contents are unsuitable for the tobacco crop, because of nitrogenous compounds formed by the mineralization process and also due to the implied nicotine contents (Ballari, 2005; Marchetti *et al*., 2006; Hurtado *et al*., 2007).

Phosphorus (P)

In Huila, 41.2% of the sampled soils showed unsuitable phosphorus contents, 38.2% with very good content, 17.6% good and 2.9% with a regular content of this element. On the other hand, in Santander, all soils had an unsuitable content of P. In Huila, the soils registered higher contents of phosphorus, without reaching a high availability (Tab. 5).

In the counties of Huila, Campoalegre presented soils with a very good content of P (58.8%), good content (17.6%) and unsuitable content (23.5%), whereas in Garzón county, 58.8% of soils did not have suitable contents of P, 17.6% had good content levels of P, 17.6% with suitable contents and 5.9% with regular contents of P (Tab. 5).

In these four counties, the phosphorus content was unsuitable for the sowing of tobacco crops, because the values were greater than 40 mg kg^{-1}. According to Ruíz *et al*. (1994), in Huila, the majority of the soils present low contents of assimilable phosphorus, excluding the soils of Lithic Ustorthens, Tropic Fluvanquents, Typic Troporthents, Typic Hapludands, Typic Eutropepts, Typic Tropofluvents, Typic Haplustalfs and Typic Ustipsamments; which can present contents greater than 80 mg kg^{-1}. These contents can be attributed to the apatite field deposits, presented with different thermic and storey reliefs. The contents of P in Santander were not available for the plants, neither were they found in the solution of the soil, due to the calcium content, which these contents generate the formation of calcium phosphates, adsorption and precipitation of the element (P) (Wandruszka, 2006; Sposito, 2008).

The native contents of the phosphorus element for these two zones are limited because of chemical conditions and specifically due to the calcium and volcanic ashes contents (Carrizosa and Vega, 1969; Ruíz *et al*., 1969 and 1994), which generate low phosphorus concentrations in the soil solution, limiting root growth in the crop, because a greater proportion of this element is required in the first growing stages (Crafts-Brandner *et al*., 1990; Smith and Wood, 2011; Osmond and Kang, 2008).

Potassium (K)

The soils from Huila presented unsuitable contents of K (50%), while in Santander, soils presented a good content of this element (41.9%). Nevertheless, the remaining percentage of the soil in Huila presented good, suitable and regular contents of potassium (20.6, 5.9 and 23.5%, respectively). In Santander, regular, unsuitable and suitable contents of K were found (29, 22.6 and 6.5%, respectively) (Tab. 5).

In the county of Campoalegre, 88.2% of the soils presented an unsuitable content of K and 11.8% with a regular content of this element. In Garzón, 41.2% presented good content, 35.3% regular content, 11.8% unsuitable, with an equal percentage with a suitable content. In Capitanejo county, 36.4% presented a regular content and an equal percentage with a good content for this element, 18.2% with an unsuitable content and 9.1% with a suitable content of K. Finally, in Enciso, 54.5% of the soils had good contents, 25% regular, 25% unsuitable and 5% with very good contents of potassium (Tab. 5).

In Huila, the potassium was unsuitable due to low contents found for this element, on the contrary in Santander, it presented unsuitable levels for this element but because of high contents, this situation is related directly with the texture of the soil (Ballari, 2005). The unsuitable contents for potassium are reflected in the quality of the leaf in the tobacco crop, in the physical quality principally, as a result of the modifications on parameters like: texture, consistency, and structure in the tobacco leaf (Condor and

Villagarcía, 2002; Ballari, 2005; Lu *et al.,* 2005; Moustakas and Ntzanis, 2005; Gurumurthy and Vageesh, 2007; Yang, *et al.,* 2007; Osmond and Kang, 2008).

Calcium (Ca)

According to the results of the analysis of soils, 32.4% of the soils in Huila presented unsuitable contents of calcium, 26.5% good contents, 23.5% suitable and regular contents 17.6%. While 96.8% of the soils in Santander had the tendency to present unsuitable contents for Ca and 3.2% with regular contents for this element (Tab. 5).

In Campoalegre county, of the sampled soils, 29.4% presented unsuitable contents for calcium, due to its deficiency in this zone, with values below the minimum taking into consideration the texture of the soil, 29.4% belonged to soils with a very good content, 23.5% good content and 17.6% with a regular availability of Ca. In Garzón county, 35.3% of the sampled soils presented unsuitable contents of calcium due to excess, 29.4% with good contents, 17.6% suitable and 17.6% regular contents in relation to the levels of Ca. Huila was the state that presented the greatest variability in calcium contents in the soils. In Santander, the soils with unsuitable contents were due to excess of Ca contents that are found in this zone; in Capitanejo, 100% of the soils had unsuitable contents for calcium. In Enciso county, 95% of the soils were unsuitable in relation to the contents of Ca and 5% had regular contents of this element (Tab. 5).

Ruiz *et al.* (1994) reported unsuitable contents for calcium and suitable contents for the two Huila counties of the present study. Nevertheless, the calcium contents in Huila vary because of the anthropic intervention or processes, the parental material, the weather or climatic conditions and the relief; soils with altitudes over 2,000 m a.s.l. are found to be poor in exchangeable bases, on the contrary; the soils located lower than 1,000 m a.s.l. present a high concentration of this element (Ruíz *et al*., 1994). In Santander, the excess of calcium is due to the parental material and the physical and chemical weathering processes that were found in this zone during the deposit of sedimentary materials (Carrizosa and Vega, 1969; Malagón, 1979).

Magnesium (Mg)

In Huila, unsuitable contents of magnesium prevailed (70.6%), with equal levels of soils with suitable, good and regular contents of Mg found (8.8, 8.8 and 11.8% respectively). These results agree with the ones reported by Ruiz *et al.* (1994) for Huila. 35.5% of the soil in Santander, showed unsuitable contents of Mg, 32.3% had good contents, 19.4% with suitable and 12.9% with regular contents for this element (Tab. 5).

In Huila, in the county of Campoalegre, 41.2% of the soils were characterized by having unsuitable contents of Mg, 17.6% corresponded with a suitable content, 23.5% with regular and 17.6% with good contents of magnesium; on the contrary, 100% of the soils in the county of Garzón had unsuitable contents for this element. In Santander, in the county of Capitanejo, 45.5% presented soils with unsuitable contents and 54.5% with suitable contents of Mg; in Enciso county, 30% of the soil presented suitable levels, 30% with unsuitable, 20% with regular and 20% with good contents for this element (Tab. 5).

The soils from Huila and Santander in general have the tendency to present unsuitable magnesium contents, which is a principal deficiency of this element in the soil, a condition which may generate a decrease in the quality of the tobacco leaf, producing dark cured leaves and reduction in the sugar and starch contents (Pinkerton, 1972; Smith and Wood, 2011; Rojo, 2006).

Sulfur (S)

In the state of Huila, soils with unsuitable contents of S (44.1%) prevailed according to the requirements for this element in the tobacco crop; an equal situation was found in the state of Santander (54.8%); some soils with good contents (29.4%), regular contents (23.5%) and high (2.9%) contents for sulfur were also found. Besides in Santander state, are soils which present good, high and regular contents for sulfur (29, 9.7 and 6.5% respectively). Summarizing, both states in the present study presented an excessive content for S in the majority of their soils (Tab. 5).

In Campoalegre county, 52.9% of the soils were characterized by having unsuitable contents for S, 35.3% corresponded to soils with regular and 11.8% with good contents of S. In Garzón, 47% presented good contents, 35.3% of the soils were with unsuitable contents, 11.8% with regular content and 5.9% with high contents for this element. In Capitanejo, 63.6% of the soils presented unsuitable levels and 36.4% with good content levels for sulfur. In Enciso county, 50% of the soils presented excess sulfur, 25% with good content, 15% with high and 10% with regular contents for S. For this reason, it can be said that the counties of Garzón and Enciso presented a greater variability in the content of sulfur in the soil (Tab. 5).

Chloride (Cl^-)

In Santander, 87.1% of the soils presented unsuitable contents for Cl^-, 6.5% high, 3.2% good and 3.2% with regular content. In Huila, 94.1% of the soils presented an unsuitable content for Cl^-, 2.9% high and 2.9% with regular contents for this element (Tab. 5). It was noticed that the majority of the soils sampled in both states showed unsuitable levels (>16 mg kg^{-1}) for Cl^- for the tobacco crop; it is important to emphasize that this element is harmful for the quality of the tobacco crop if it is found to be in excess, causing lower combustibility in the dried tobacco leaf (Elliot and Back, 1963; Ishizaki and Akiya, 1978; Randle, 2004; Osmond and Kang, 2008).

In Campoalegre, 87.1% of the soils were characterized by possessing unsuitable contents of Cl^-, 5.9% with a high level content and the remaining soils (5.9%) with a regular content for this element. On the other hand, in Garzón county, 100% had unsuitable contents of Cl^-. In Capitanejo, 90.9% of the soils sampled presented unsuitable contents for this element and 9.1% with regular contents. In the county of Enciso, in 85% of the soils, Cl^- was not found with suitable contents due to the excess of this element, 10% with a high level and 5% with good level contents (Tab. 5).

Texture

The states of Huila (97.1%) and Santander (80.6%) were characterized by having ideal textures for growing the tobacco crop. In Huila, in the county of Campoalegre, 100% of the soils sampled presented ideal textures (SCL and SL); while in Garzón county, 94.1% were ideal soils (LS, SL and SCL) and the remaining percentage presented unsuitable soils (CL). In Santander, Capitanejo county presented 100% soils with an ideal texture (SCL, L and/or SL). In the county of Enciso, 70% of the soils had an ideal texture (SCL, L and/or SL) and 30% of the remaining soils presented an unsuitable texture (C and/or CL) (Tab. 5).

In the four counties, it can be said that the majority of the soils were ideal considering the texture since the soils were clay sandy loam, sandy loam and loam. Light soils produce very good industrial quality tobacco. Furthermore, unsuitable soils, such as heavy ones, generate an increase in the levels of nicotine and root growth is not optimum; nevertheless, they should present with good drainage and avoid flooding (Rodríguez, 2004; Ballari, 2005).

Grouping analysis of the plots

Huila and Santander

Sixty-five soil analyses from the two states were grouped by similitude as shown in Fig. 2, through 9 variables and 24 association modalities. The variables which intervene on the grouping are: OM, P, K, Ca, Mg, S and Cl^-.

In the first division line, two groups are observed, A (23%) and B (47%). Group A is characterized by presenting unsuitable contents for OM, Ca and S and a Mg content between good and regular. On the other hand, group B presents suitable contents for OM and Mg, a good content for K, regular for S and unsuitable for Mg (Fig. 1).

In the second division line, three groups are observed, A (23%), C (6%) and D (71%). Groups C and D are subdivisions of group B. Group C is characterized by presenting suitable contents for S. Group D presents suitable contents for OM, Mg and Ca and a regular content for S (Fig. 1).

On the third division, five groups are observed A (23%), C (6%), E (6%), F (5%) and G (60%). Groups E, F and G are

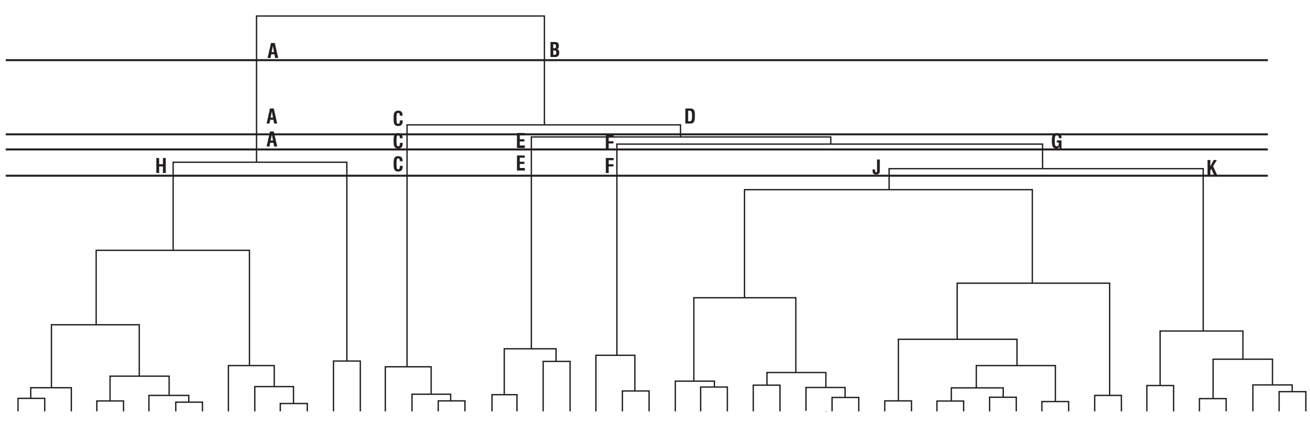

FIGURE 1. Grouping by similitude of the analyzed variables from the results and interpretation of the soil analysis. This dendogram was built with the statistics program SPAD 3.5.

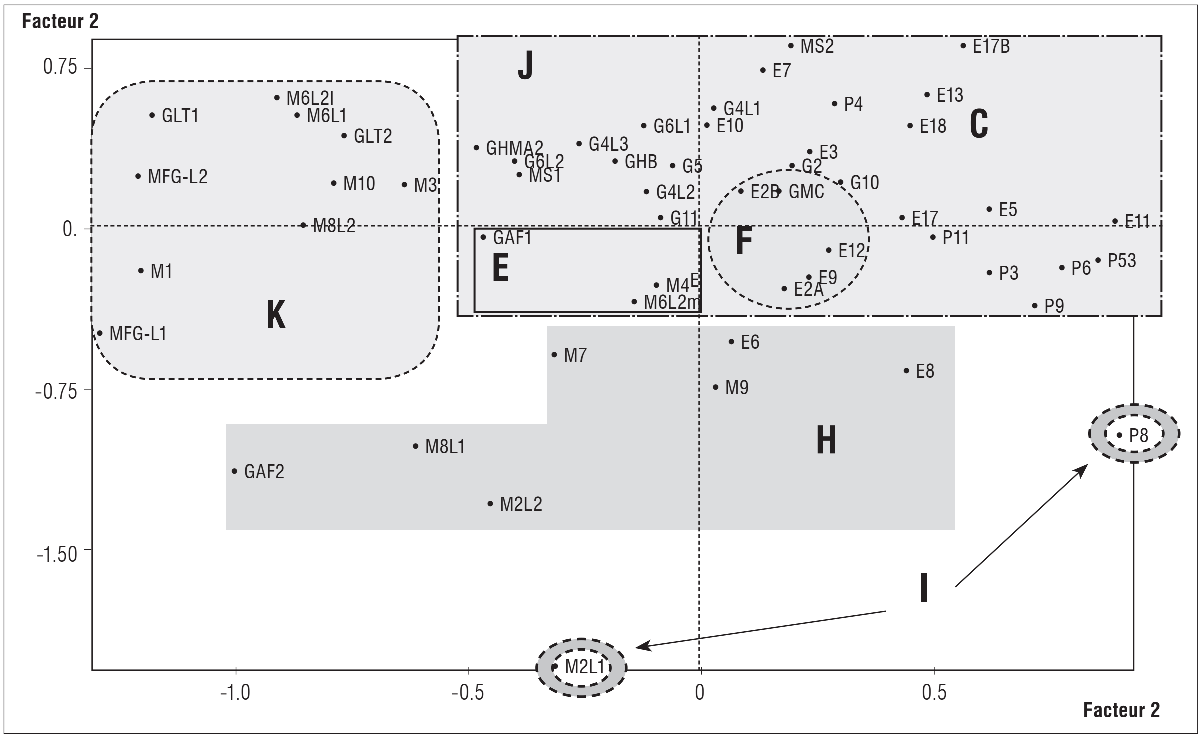

FIGURE 2. Distribution and grouping for the interpretation of the soil analysis and its results. This dendogram was built with the statistics program SPAD 3.5.

subdivisions of group D. Group E presents a regular content for Ca. Group F is characterized by presenting suitable contents for Cl^-. Group G presents suitable contents for OM and Mg, good for Ca and regular for S (Fig. 1).

The fourth classification by similitude of the plots presents seven groups H, I, C, E, F, J and K; wherein H and I are subdivisions for group A, and groups J and K subdivisions of group G. In group H, 20% is characterized by presenting unsuitable contents for OM, Ca and S and a good content for Mg. In group I, 3% is differentiated by presenting a regular content for Cl^-. Group C is the same as group E and F were described previously. In group J, 50% of the plots were found, but characteristics of separation are not presented. In group K, 11% of the grouped plots were found, it is characterized by having suitable contents for Ca and P, an unsuitable content for K and a regular content for S (Figs. 1 and 2). As seen with the multivariable analysis in Santander, the remaining divisions were not described, due to the lack of separation variables.

Conclusions

In general, the soils that were sampled in this present study in the state of Huila were characterized by having a texture, pH and percentage with suitable contents for organic matter; with unsuitable contents for P, K, Mg, S and Cl^- for the tobacco crop and calcium contents between unsuitable and good levels.

In the soils from the state of Santander, unsuitable contents and percentage for pH, OM, P, Ca, S and Cl^- prevailed, finding equally suitable textures, K had regular contents, and Mg presented contents between unsuitable and regular.

The soils from Huila presented a greater variability for pH, OM percentage and Ca contents; while the soils from Santander presented a greater variability for Mg content.

Out of the nine evaluated parameters in the grouping analysis by similitude, the textures and pH did not allow separation of the groups. Chloride was a parameter that did not take into account the grouping analysis for Huila; therefore, the contents for this element in the soil were similar for the counties of Huila (Campoalegre and Garzón).

Literature cited

Agrocadenas. 2005. La agroindustria del tabaco en Colombia: el negocio de los cigarrillos y cigarros. pp. 225-256. In: Anuario 2005 Agroindustria y competitividad, estructura y dinámica en Colombia (1992-2005). Ministerio de Agricultura y Desarrollo Rural, Observatorio Agrocadenas Colombia, Bogota.

Agrocadenas. 2006. Indicadores de competitividad para Tabaco. Ministerio de Agricultura y Desarrollo Rural, Observatorio Agrocadenas Colombia, Bogota.

Ballari, M. 2005. Tabaco Virginia, aspectos ecofisiológicos y de la nutrición en condiciones de cultivo. Talleres Gráficos de Alejandro Graziani, Córdoba, Argentina.

Bohn, H., B. McNeal, and G. O'Connor. 2001. Soil chemistry. 3rd ed. John Wiley and Sons, New York, NY.

Carrizosa, U.J. and V.M. Vega. 1969. Estudio general de suelos, para fines agrícolas de los municipios de Guaca, San Andrés, Molagavita, San José de Miranda, Málaga, Cerrito, Concepción. Carcasi, San Miguel, Macaravita, Enciso y Capitanejo, departamento de Santander. Estudios Agrotecnicos, Instituto Geográfico Agustín Codazzi, Bogota.

CCI, Corporación Colombia Internacional. 2001. Acuerdo de competitividad de la Cadena productiva del tabaco en Colombia. Bogota.

CCI, Corporación Colombia Internacional. 2008. Evaluaciones Agropecuarias Municipales Años 2006, 2007 y 2008. Ministerio de Agricultura y Desarrollo Rural; Sistema de Información Agropecuaria, Secretarías de Agricultura Departamentales, Bogota.

Cisia-Ceresta. 1998. SPAD. 3.5 integrado versión PC. Centre International de Statistique et d´Informatique Appliquées, Paris.

Condor, A. and S. Villagarcía. 2002. Evaluación de mezcla formulada de fertilizante con dosis crecientes y aplicación de materia orgánica en el rendimiento de tabaco negro en un suelo arenoso bajo condiciones de invernadero. Rev. Per. Biol. 9(2), 121-126.

Coraspe, H. and S. Tejera. 1996. Procedimiento para la toma de muestras de suelos (on line). Revista de Difusión de Tecnología Agrícola Pecuaria, Pesquera y Acuícola 54, www.sian.inia.gob.ve; consulted: October, 2012.

Crafts-Brandner, S.J., M.E. Salvucci, J.L. Sims, and T.G. Sutton. 1990. Phosphorus nutrition influence on plant growth and nonstructural carbohydrate accumulation in tobacco. Crop Sci. 30, 609-614.

DNP, Departamento Nacional de Planeación. 2009. Anuario estadístico del sector agropecuario año 2008. http://www.dnp.gov.co; consulted: October, 2012.

Elliot, J.M. and M.E. Back. 1963. Effects of potassium and chlorine on the production of tobacco seedling. Can. J. Soil. Sci. 43, 268-274.

Fassbender, H. 1982. Química de suelos con énfasis en suelos de América Latina. Instituto Interamericano de Cooperación para la Agricultura (IICA), San Jose.

Gurumurthy, K.T. and T.S. Vageesh. 2007. Leaf yield and nutrient uptake by FCV tobacco as influenced by K and Mg nutrition. Karnataka J. Agric. Sci. 20 (4), 741-744.

Hernández, S.R, C.C. Fernández and P.L. Baptista. 2003. Metodología de la investigación. 3rd ed. McGraw Hill, Mexico DF.

Hurtado, R.E., C.A. Forero, L.A. Ortiz, A.M. Fernández, J. García, and C. León. 2007. Evaluación edafoclimática del tabaco rubio: Burley y Virginia. Corporación Colombiana de Investigación Agropecuaria (Corpoica), Fedetabaco, Bogota.

ICA, Instituto Colombiano Agropecuario. 1992. Fertilización en diversos cultivos. Quinta aproximación. Technical Assistance Manual No. 25. Bogota.

IDEAM, Instituto de Hidrología, Meteorología y Estudios Ambientales. 1999. Orografía y geología del área del macizo colombiano. pp. 7-18. In: El macizo Colombiano y su área de influencia. Modulo hídrico. Bogota.

Ishizaki, H. and T. Akiya. 1978. Effects of chlorine on growth and quality of Tobacco. Jpn Agric Res Q 12(1), 1-6.

Lu, Y.X., C.J. Li and S. Zhang. 2005. Transpiration, potassium uptake and flow in tobacco as affected by nitrogen forms and nutrient levels. Ann. Bot. 95, 991-998.

Malagón, D. 1979. Fundamentos de Mineralogía de Suelos. Centro Interamericano de Desarrollo Integral de Aguas y Tierras (CIDIAT), Mérida. Venezuela.

Mantilla, G., L.S. de la Torre, C.E. Gómez, N. Ordoñez, J.L. Ceballos, C. Euscátegui, P. Pérez, S. Pérez, N. Martínez, R. Sánchez, N. Maldonado, S. Pérez, J. Gaitán, L. Chávez, C. Chamorro, and A. Flórez. 2001. Los suelos: estabilidad, productividad y degradación. pp. 228-277. In: Leyva, P., C. Cano, M. Arango, J.D. Pabón, G. Mantilla, J. Sánchez, J. Rodríguez, C. Bermúdez, L. Panizzo, M. Toro, I. Jaramillo, A. Cano, and H. Sánchez (eds.). El medio ambiente en Colombia. Instituto de Hidrología, Meteorología y Estudios Ambientales, Bogota.

Marchetti, R., F. Castelli, and R. Contillo. 2006. Nitrogen requirements for Flue-Cured tobacco. Agron. J. 98, 666-674

Moreno, C.E. and R.A. Coronado. 2006. Fertilización orgánica y manejo del suelo en el sistema de producción tabaco asociado fríjol en Santander. Corporación Colombiana de Investigación Agropecuaria (Corpoica), Ministerio de Agricultura y Desarrollo Rural (MADR). Bucaramanga, Colombia.

Moustakas, N. and H. Ntzanis. 2005. Dry matter accumulation and nutrient uptake in flue-cured tobacco (*Nicotiana tabacum* L.). Field Crops Res. 94, 1-13.

Osmond, D. and J. Kang. 2008. Nutrient removal by crops in North Carolina. In: North Carolina Cooperative Extension Service, North Carolina State University, www.soil.ncsu.edu; consulted: October, 2012.

Pinkerton, A. 1972. Recovery of flue-cured tobacco from magnesium deficiency: changes in leaf magnesium content and effects on leaf quality. Aust. J. Agric. Res. 23(4), 641-649.

Prasad, R. and J.F. Power. 1997. Soil fertility management for sustainable agriculture. Lewis Publishers, Boca Raton, FL.

Randle, W. 2004. Chloride Requirements in onion: clarifying a widespread misunderstanding. Better Crops Plant Food. 88(4), 10-11.

Rodríguez, J.A. 2004. Consideraciones medioambientales en el cultivo de tabaco en España. In: Enciclopedia básica del cultivo de tabaco. Manual práctico para todos los agricultores Junta Extremeño, Extremadura, España.

Rojo, L.W. 2006. Crop Kit specialty plant nutrition management guide tobacco. The Worldwide business formula (SQM). YARA, Atlanta, GA.

Ruiz, E., V.J. Rivillas, G.H. Villota, H.R. Jaramillo, H. Rodríguez, C. Molina, J. Fonseca, and O.E. Mosquera. 1969. Estudio general de suelos del departamento del Huila, algunas regiones como Baraya, Tello, Aipe, Neiva, Palermo, Santa María, Rivera, Campoalegre, Yaguará, Hobo, Paicol, Gigante, Agrado, Garzón, Pitalito, La Plata, Tarquí, Altamira, Elías, Teruel, Íquira, Guadalupe, Timaná, Suaza, Saladoblanco, Oporapa, La Argentina. Instituto Geográfico Agustín Codazzi, Bogota.

Ruiz, E., O. Rocha, H. Rodríguez, R. Molina, A.M. Palasino, F. Garavito, A. Bernal, D. Mendivelso, and J.J. Pinto. 1994. Estudio general de suelos del departamento del Huila. Tomo I y II. Instituto Geográfico Agustín Codazzi, Bogota.

Smith, W.D. and S. Wood. 2011. Nutrient management. pp. 67-82. In: Flue-cured tobacco guide. North Carolina State University, Raleigh, NC.

Sposito, G. 2008. The chemistry of soils. 2nd ed. Oxford, UK.

Thompson, L.M. and F.R. Troeh. 2002. Los suelos y su fertilidad. 4th ed. Editorial Reverté, Barcelona, Spain.

Urquiza, M.N. 2002. Manejo sostenible de los suelos. Centro de Información, Gestión y Educación Ambiental, Ministerio de Ciencia, Tecnología y Medio Ambiente Cuba, www.medioambiente.cu; consulted: October, 2012.

Wandruszka, R. 2006. Retención de fósforo en suelos calcáreos y el efecto de la materia orgánica en su movilidad (on line). Geochem. Trans. 7, 6-6, http://viaclinica.com/article.php?pmc_id=1483820; consulted: October, 2012.

Yang, T., L. Lu, W. Xia, and J. Fan. 2007. Characteristics of potassium-enriched, flue-cured tobacco genotype in potassium absorption, accumulation, and in-ward potassium currents of root cortex. Agric. Sci. China. 6(12), 1479-1486.