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Macroelement content and chemical composition of oriental tobacco varieties grown under the same agro-ecological conditions

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Abstract

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In field experiments and under the same agro-ecological conditions, the chemical composition and content of macroelements of local Bulgarian oriental tobacco varieties (Dzhebel basma 1, Elenski 817) and introduced oriental tobacco varieties (Prilep 23, Prilep 79-94) were studied. The soil on which the study was carried out was humus-carbonate (Rendzic Leptosols), with an alkaline soil reaction, medium humus content, and heavy sandy clay loam texture. Total content and mobile forms of the elements N, P, K, Ca, and Mg in the soil were determined, as well as their concentration in mature leaves from the middle section of the plant (commercially known as seco leaves). The chemical composition (total nitrogen, nicotine, and soluble carbohydrates) of the tobacco plants was analyzed. The response of the studied varieties to the agro-ecological conditions was ascertained. The results obtained can be used as criteria for raw material quality assessment and smoke flavour characterization. Grouping of the varieties by macroelement content and chemical composition was performed.

Keywords: oriental tobacco; soil; macroelements; nicotine; soluble carbohydrates

Introduction

Mineral substances directly affect tobacco combustion properties. They determine the ability of tobacco to smoulder and burn flamelessly, and act as catalysts for combustion of organic compounds with low flammability. The impact of individual elements on overall tobacco raw material quality and flammability is varied. Higher potassium content is the key for improved tobacco burning qualities. Magnesium has a catalytic effect on tobacco fermentation. Data on the effects of calcium are contradictory. What has been determined as crucial is the ratio between calcium and potassium content. Total nitrogen is defined as the sum of all nitrogen compounds in the tobacco plant. Low-grade and rough tobacco has higher total nitrogen content. The main alkaloid in tobacco is nicotine. Nicotine and soluble carbohydrate amounts vary greatly depending on the type and variety of tobacco, and are strongly influenced by agro-ecological conditions. High soil moisture, and high potassium and phosphorus content cause higher concentrations of soluble carbohydrates, whereas lower soil moisture and higher nitrogen content lead to lower carbohydrate content (Gyuzelev, 1983).

The main soil factors influencing macro- and microelement absorption by tobacco plants are soil pH, humus content, soil texture, the content of the elements in the soil, the presence of competing elements, and the agro-technology applied (Collins et al., 1961; Radojičić et al., 2003). Macroelement absorption is further influenced by the type and variety of the tobacco plant (McCants and Woltz, 1967). Data on nutrient concentration in different tobacco types and in tobacco leaves at all stages of growth are published by Campbell (2000) and Jones et al. (1991), respectively. Tso (1990) summarizes the results for macro- and microelements in tobacco plants growing in different countries under different agro-environmental conditions. Studies on macro- and microelemental content of tobacco plants grown in Bulgaria are focused on several different aspects. Stoilova and Zapryanova (2003) determine the content of macro- and microelements in the main groups of tobacco varieties. Yancheva (2002, 2009) studies the changes in macroelement content in tobacco leaves caused by mineral fertilization. Stamatov and Bozhinova (2016) investigate the chemical and mineral composition of new varieties of oriental tobacco, and assess the effects of mineral fertilization, too. Stoilova (2008a, 2008b) studies the impact of tobacco's mineral composition on the burning and smoldering properties. Bozhinova and Zapryanova (2004) study the absorption of nutrients in Virginia and Burley varieties. Zapryanova (2015) ascertained that there are great differences in the macroelement content of Virginia varieties grown under the same agro-ecological conditions. In recent years, changes in the oriental tobacco varieties have been introduced. This necessitates further studies on the differentiation of variety groups, and the response of tobacco varieties to climatic and soil conditions in relation to various indicators.

The objective of the study was to investigate the macroelement content and chemical composition of Bulgarian and introduced oriental tobacco varieties grown under the same agro-ecological conditions. The results obtained can be used as criteria for assessing tobacco raw material quality and tobacco smoke flavour characterization.

Materials and Methods

The study on oriental tobacco was carried out on humus-carbonate soil at the Institute of Tobacco and Tobacco Products, Markovo (Plovdiv), from 2011 to 2013. The soil reaction was alkaline, humus content was medium and the soil texture was heavy sandy clay loam (Table 1).

The Kjeldahl method was used to determine total nitrogen content in the soil. The total content of phosphorus, potassium, calcium, and magnesium were determined in accordance with to BDS ISO 14869-1 using thermal pretreatment and predigestion with HF, $HClO_4$ and HNO_3 acids. Mineral nitrogen (ammonium and nitrate) was determined using the distillation method of Bremner and Keeney. Mobile P_2O_5 was ascertained by the Egner-Rheem method, mobile K_2O – using 2 n HCL, and mobile forms of Ca and Mg were determined by extraction with 1 n KCl.

Subjects of the study were Bulgarian oriental tobacco varieties (Dzhebel basma 1, Elenski 817) and introduced ones (Prilep 23, Prilep 79-94). The main agro-technical practices: planting distances, digging, and watering, were carried out in the same way for all varieties. For plant analysis, mature leaves from the middle section of the plant were collected (so-called seco leaves).

Preparation of the plant samples for determination of P, K, Ca, and Mg included dry ashing and dissolution in 3 M HCL. Phosphorus content was determined using the vanadate-molybdate method.

To measure the content of other elements of interest, atomic absorption spectrometer (Spektra AA 220, Australia) was used at the following wavelengths: K – 766.5 nm, Ca – 422.7 nm, Mg – 285.2 nm.

The chemical composition of dried tobacco was studied. Total nitrogen content in the leaves was determined in accordance with BDS 15836-88, nicotine content – as specified in ISO 15152:2003, and soluble carbohydrates – according to ISO 15154: 2003.

Statistical treatment (ANOVA, Duncan) was performed using SPSS for Windows.

Table 1
Soil characteristics

Soil	pH	Humus, %	Silt+Clay (< 0.02 mm), %
Humus-carbonate (Rendzic Leptosols)	8.00	2.88	47.3

Results and Discussion

Soils

Data on the total content of macroelements in the studied soils is shown in Table 2. Total nitrogen content was determined to be medium, and CaO content was high. In relation to mobile forms of the macroelements, the humus-carbonate soils were well-stocked with phosphorus and had a very high content of potassium, calcium, and magnesium.

Table 2
Macroelements content in soil

Total content [%]				
N	P_2O_5	K_2O	CaO	MgO
0.16	0.15	1.36	5.43	1.83
Mobile forms				
Nmin [mg/kg]	P_2O_5 [mg/100g]	K_2O [mg/100g]	CaO [mg/100g]	MgO [mg/100g]
6.4	12.9	66.3	304.8	39.3

Tobacco

Phosphorus

Phosphorus is an element that plays a role in carbohydrate, lipid, and protein syntheses in biochemical reactions. It has been commonly held that phosphorus does not increase the yields, however, it does improve raw tobacco material quality (Donev and Zlatev, 1974). Phosphorus content in tobacco leaves varies between 0.1 and 1%, depending on the stage of leaf development (Jones et al., 1991).

The concentrations established in mature tobacco leaves of all Bulgarian and introduced varieties studied fell within these limits, and corresponded with values reported in other reference sources (Sekin et al., 2002; Yancheva, 2002; Stamatov et al., 2015). Higher phosphorus content is typical for Macedonian oriental tobacco varieties, which fell within Group 2 (Table 3).

Table 3
Phosphorus content in oriental tobacco leaves. Grouping of the varieties (Duncan's method)

Varieties	Homogenous groups Subset for α = 0.05	
	1	2
Dzhebel basma 1	0.182	
Elenski 817	0.196	0.196
Prilep 79-94		0.208
Prilep 23		0.211
Significance	0.196	0.177

Potassium

According to McCants and Woltz (1967), the overall potassium content in tobacco leaves depends mainly on the content of mobile forms of K in the soil, and on the tobacco type and variety. Campbell (2000) points out that during years when leaves from the middle section of the plants are harvested, potassium content ranges between 1.5-2.5%. According to Sekin et al. (2002), the potassium concentration ranges from 1.23 to 2.32%, depending on the region in which tobacco is grown.

Table 4
Potassium content in oriental tobacco leaves. Grouping of varieties (Duncan's method)

Varieties	Homogenous groups Subset for α = 0.05		
	1	2	3
Dzhebel basma 1	1.177		
Elenski 817	1.414	1.414	
Prilep 23		1.877	1.877
Prilep 79-94			1.916
Significance	0.284	0.055	0.852

Under the conditions for this study, potassium content in the leaves of the investigated tobacco varieties was determined to fall within these ranges. It was ascertained that the Bulgarian varieties Dzhebel basma 1 and Elenski 817 contain smaller amount of the element. A better potassium absorption capacity was observed in the introduced tobacco varieties Prilep 23 and Prilep 79-94 (Table 4).

Calcium

For all tobacco varieties studied, calcium content in mature ripe leaves collected from the middle section of the plant (seco leaves) was very high, therefore they fell within one Duncan group. This could possibly be attributed to high content of mobile Ca in the soil and alkaline soil reaction. According to Mylonas (1984), the concentration of Ca in tobacco leaves depends on the mobile forms of calcium in the soil and on the pH.

Despite the higher content of mobile potassium in the soil, under the conditions for the study, all oriental tobacco plants absorbed more calcium than potassium (Table 5). According to Apostolova (1990), when tobacco is grown on carbonate soils, large amount of calcium enters the plant, and subsequently the concentration is 4 to 5 times that of potassium. In such cases, tobacco raw material has inferior elastic and bulk properties.

Table 5
Calcium content in oriental tobacco leaves. Grouping of varieties (Duncan's method)

Varieties	Homogenous groups Subset for α = 0.05
	1
Dzhebel basma 1	3.224
Prilep 23	3.415
Elenski 817	3.604
Prilep 79-94	3.778
Significance	0.252

Magnesium

Symptoms of magnesium deficiency appear when the content in leaves is below 0.15% (Tso, 1990). Campbell (2000) points out that target magnesium concentration in both young and mature leaves is between 0.2-0.6%. According to Yancheva (2002), magnesium content in mature leaves of oriental tobacco changes within a narrow range – from 0.33 to 0.69%.

The determined magnesium content in mature leaves of the studied varieties fell within these limits. The lowest magnesium concentration was observed in the leaves of the Bulgarian variety Dzhebel basma 1 (Table 6). In the grouping of the varieties using Duncan's method, this variety fell within Group 1, and the rest fell within the second group.

Table 6
Magnesium content in oriental tobacco leaves. Grouping of varieties (Duncan's method)

Varieties	Homogenous groups Subset for α = 0.05	
	1	2
Dzhebel basma 1	0.383	
Elenski 817		0.551
Prilep 79-94		0.555
Prilep 23		0.561
Significance	1.000	0.851

Chemical composition

The chemical composition of both tobacco plant and smoke directly determine tobacco's consumable properties and the physiological effects on the human body.

Total nitrogen

Nitrogen is a constituent in a large group of compounds that have a negative impact on tobacco smoke properties – the smoke becomes sharp-tasting and pungent. However, in the case of nitrogen deficiency, dry tobacco leaves are structureless and the smoke produced is dull and tasteless.

Under the conditions for the study, nitrogen concentration in dry leaves of the oriental tobacco varieties ranged from 1.85 to 2.18% (Table 7). This content corresponds to values reported in other reference sources (Gyuzelev, 1983). Table 7 shows the varieties grouped by significance of the differences between them, and all studied varieties fell within the same group.

Table 7
Total nitrogen content in oriental tobacco leaves. Grouping of varieties (Duncan's method)

Varieties	Homogenous groups Subset for α = 0.05
	1
Dzhebel basma 1	1.853
Elenski 817	2.003
Prilep 23	2.093
Prilep 79-94	2.183
Significance	0.302

Nicotine

Nicotine content in dry tobacco leaves depends on the type and variety of the plant. It ranges from 0.4 to 6.0% for commercial and industrial tobacco crops produced globally. With regard to nicotine content, tobacco can be differentiated into three groups: low-nicotine (below 0.6%), medium-nicotine (0.6-2.5%) and high-nicotine (more than 2.5%) (Gyuzelev, 1983).

Under the conditions for this study, all oriental tobacco varieties fell within the medium-nicotine group. The lowest nicotine content was determined in Dzhebel basma 1, which fell within Duncan group 1. The difference between this variety and the Macedonian variety Prilep 79-94 was not statistically significant. Prilep 79-94 also fell within group 2, as its differences with Elenski 817 and Prilep 23 varieties were not statistically significant either (Table 8).

Table 8
Nicotine content in oriental tobacco leaves. Grouping of varieties (Duncan's method)

Varieties	Homogenous groups Subset for α = 0.05	
	1	2
Dzhebel basma 1	1.217	
Prilep 79-94	1.640	1.640
Elenski 817		1.903
Prilep 23		1.977
Significance	0.063	0.138

Soluble carbohydrates

Soluble carbohydrates are among the most important constituents of light tobaccos. They determine the characteristic pleasant taste of these tobaccos. The average content of soluble carbohydrates in oriental tobaccos is 10-18% (Gyuzelev, 1983). For the varieties studied, under the conditions of the experiment, soluble carbohydrate content ranged from 13 to 16%. The introduced tobacco varieties were determined to have lower soluble carbohydrate content, whereas in Bulgarian varieties the content was higher. Based on this indicator, differences between the studied varieties were not statistically significant, and they all fell within one group (Table 9).

With high soluble carbohydrate content (over 16%) and low nitrogen content, a plain taste lacking density is obtained, with an enhanced stinging sensation of the smoke (Gyuzelev, 1983). To characterize tobacco smoke taste, a quantitative

Table 9
Soluble carbohydrate content in oriental tobacco leaves. Grouping of varieties (Duncan's method)

Varieties	Homogenous groups Subset for α = 0.05
	1
Prilep 79-94	13.067
Prilep 23	14.400
Dzhebel basma 1	16.200
Elenski 817	16.233
Significance	0.207

ratio of soluble carbohydrates to nicotine content can be used. Optimal values fall within the range of 6.0-10.0. Table 10 contains calculated ratios for the studied varieties. The results were sorted in ascending order. As can be seen from the table, Dzhebel basma 1 variety was the only one with ratio above 10, which is a prerequisite for inharmonious taste.

Table 10
Ratio of soluble carbohydrates to nicotine

Varieties	Soluble carbohydrates/nicotine
Prilep 23	7.284
Prilep 79-94	7.968
Elenski 817	8.530
Dzhebel basma 1	13.311

Conclusions

It has been determined that for any given tobacco variety, absorption capabilities differ with respect to individual elements. Phosphorus, magnesium, and total nitrogen content in all varieties studied are consistent with the data reported in other reference sources.

For all varieties studied, calcium concentration in mature leaves harvested from the middle section of the plant was very high. It exceeded the concentration of potassium, which is not favorable for the quality of the raw tobacco material.

In terms of nicotine content, all studied varieties belong to the medium-nicotine group of varieties. The lowest nicotine content was determined in Dzhebel basma 1, which fell within a separate group by the Duncan method.

Under the conditions of the study, soluble carbohydrate content ranged from 13 to 16% for all varieties. Differences between the studied varieties based on this indicator were not statistically significant, and they all fell within one group.

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