Effect of long-term potassium fertilization on the chemical composition of Oriental tobacco

Влияние на системното калиево торене върху химичния състав на ориенталски тютюн

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Abstract

The effects of the different potassium rates (0, 75 and 450 kg K_2O ha^{-1}) on nutrient concentrations in the above-ground biomass and chemical characteristics of sun-cured tobacco have been studied in a stationary field trial. Annual fertilization with 75 kg K_2O ha^{-1} was adequate to maintain soil K concentration near the initial value. It was found that yield of cured leaves was not significantly affected by rate of K application when oriental tobacco was grown on soils with high available soil K. With the increase of K fertilization rate the content of the potassium in leaves increased from 0.65 to 4.49%. The concentration of Ca and Mg in the leaves ranged from 2.03 to 5.23% and from 0.52 to 0.71%, respectively and decreased with increases in added potassium. No effect of K rates on nicotine and protein content was noted. Only the reducing sugars' content tended to increase to 11.42% at the highest K rate. Fertilization with moderate potassium rates (75 kg K_2O ha^{-1}) on soils high in available K is necessary to maintain the good potassium reserves. When oriental tobacco was grown on alkaline soils with high available K and Ca, potassium fertilization improves K nutrition and therefore may favorably affect burning properties of tobacco.

Keywords: chemical composition, oriental tobacco, potassium fertilization

Резюме

В изследване, проведено върху стационарен полски опит е проучено влиянието на калиевото торене с различни норми (0, 75 и 450 kg K_2O ha^{-1}) върху концентрацията на N, P, K, Ca и Mg в надземната биомаса на ориенталски тютюн и химичния състав на сухия тютюн. Системното торене със 75 kg K_2O ha^{-1} е адекватно за поддържане на нивото на калия в почвата близко до изходното. Стопанският добив е повлиян слабо от калиевата норма при отглеждане на тютюна на почви с високо съдържание на подвижен калий. Съдържанието на калий в листата нараства с увеличаване на калиевата норма. Концентрацията на

Ca и Mg в листните тъкани се понижава от нарастването на торовия калий. Нормата на торене с калий не влияе върху съдържанието на никотин и белтъчини в сухия тютюн. Единствено съдържанието на разтворими въглехидрати показва тенденция към повишение при най-високата торова норма.

Ключови думи: калиево торене, ориенталски тютюн, химичен състав

Подробно резюме

Изискванията на тютюна към калия са високи. Калиевото торене допринася главно за подобряване на някои качествени признаци на сухия тютюн – горяемост, цвят, еластичност. То увеличава добива сух тютюн, пазарната му стойност и съдържанието на K и Mn в листата при отглеждане на тютюна на почви, бедни на усвоим калий (Leggett, et al., 1977). Link and Terrill (1982) установяват, че торенето с калий на почви с високо съдържание на подвижен калий води до повишаване концентрацията на калия в сухия тютюн, но добивът и качеството остават непроменени.

В настоящото проучване се проследява влиянието на калиево торене и на създадените от системното торене контрастни запасености на елемента в почвата върху добива, концентрацията на макроелементи в надземната биомаса на ориенталски тютюн и химичния състав на сухия тютюн.

Изследванията са проведени върху стационарен полски опит със системно торене и непрекъсната монокултура тютюн. Заложен е върху хумусно-карбонатна почва в Института по тютюна и тютюневите изделия в с. Марково през 1966 г.

Анализирани са почвени и растителни проби от варианти, торени с 0, 75 и 450 kg K_2O ha^{-1}. Почвените проби от слоя 0-25 cm са анализирани за: pH във вода - потенциометрично, общ хумус – по Тюрин (Totev et al., 1987), подвижен фосфор - по Егнер-Рийм, усвоим калий - в 2N HCl и подвижни форми на Ca и Mg - в извлек от 1N KCl (Tomov et al., 1999). За растителен анализ са използвани технически зрели листа от долен, среден и горен беритбен пояс, стъбла и съцветия. Общият азот в растителните тъкани е определен по метода на Келдал. Съдържанието на P, K, Ca и Mg в тютюна е определено след сухо изгаряне на растителния материал и разтваряне на пепелта в 3 M HCl. Фосфорът е определен по молибдат-ванадатен метод (Tomov et al., 1999). За отчитане концентрацията на K, Ca и Mg в почвените и растителните проби е използван атомен абсорбционен спектрометър.

Продължителното торене със 75 kg K_2O ha^{-1} води до годишно нарастване на подвижния калий с 5.0 mg kg^{-1} почва, а при торене с 450 kg K_2O ha^{-1} увеличението е с 51.2 mg kg^{-1} почва. Стопанският добив е повлиян слабо от калиевата норма при отглеждане на тютюна на почви с високо съдържание на подвижен калий. Съдържанието на калий в листата нараства с увеличаване на калиевата норма (Таблица 2). Концентрацията на Ca и Mg в листните тъкани се понижава от нарастването на торовия калий. Нормата на торене не влияе върху съдържанието на никотин и белтъчини в сухия тютюн (Таблица 3). Единствено съдържанието на разтворими въглехидрати показва тенденция към повишение при най-високата торова норма.

Системното калиево торене с умерени норми (75 kg K_2O ha^{-1}) на добре запасените с подвижен калий почви допринася за поддържане и сравнително

слабо повишаване нивото на калия в почвата. При отглеждане на ориенталски тютюн на алкални почви с високо съдържание на подвижен К и Са, калиевото торене спомага за подобряване на К хранене на растенията и следователно може да окаже благоприятно влияние върху пушателните качества на тютюна.

Introduction

The potassium requirement of tobacco is high and it is generally accepted that high potassium content is associated with good quality. Leaf color, texture, combustibility, and hygroscopic properties are improved by potassium fertilization. In the study of Leggett, et al. (1977) potassium fertilization increased the cured leaf yield, its market value and leaf K and Mn contents on soil low in available K. Concentration of potassium in the cured leaf was increased but there was no yield or quality response to applied potassium on soil high in potassium (Link and Terrill, 1982). Boshoff (2001) reported that no benefit was obtained from applied potassium and only reasonable application rates are necessary to maintain the good potassium reserves that already exist. In general farm practice, the amount of potassium used often exceeds normal requirements. According to Traynor (1980) too much potassium is not directly toxic to plants but can have adverse effects. High potassium application tends to delay leaf maturity, but improves rate of burn (Tso, 1999). High levels of K and Ca in the nutrients were observed to reduce Mg content in leaf to deficiency level (McCants and Woltz, 1967). Leggett, et al. (1977) have found a reduction of 23% in Mg and 32% in Ca below the control when tobacco plants were fertilized with 448 kg K ha^{-1}. On the other hand, Link and Terrill (1982) reported that the concentration of phosphorus, calcium, and magnesium in cured leaves were not affected by the rate of K fertilization.

The current investigation was conducted to determine the effect of long-term potassium fertilization on chemical composition of Oriental tobacco grown on alkaline soil with high available soil K.

Materials and Methods

The effects of different potassium rates (0, 75 and 450 kg K_2O ha^{-1}) on chemical composition of Oriental tobacco were studied in a stationary field trial. A long-term fertilizer experiment with continuous tobacco cropping system was established at Tobacco and Tobacco Products Institute – Markovo, Bulgaria on rendzina soil in 1966. The experimental design was a randomized complete block replicated three times. In 2008 and 2009, oriental tobacco plants (*Nicotiana tabaccum* L. cv. Plovdiv 7) were grown in the stationary field. The plot area was 6.25 m^2 (2.5 X 2.5 m). Tobacco seedlings were transplanted at a 0.5 x 0.12 m distance (166 000 plants ha^{-1}). Cultural practices such as irrigation, weeding, pest and disease control were according to the recommended practices for commercial plantations. After the last priming the plots were cleared of crop residues. The land was prepared for seedling establishment by hand cultivation. Urea, triple superphosphate and potassium sulphate were used as sources of N, P and K. Fertilizers were broadcast before transplanting and then incorporated in the top soil layer. At the beginning of the experiment, the soil had a pH value of 8.5 and contained 3.01% humus, 15 mg P_2O_5 kg^{-1} soil and 400-500 mg K_2O kg^{-1} soil (Vartanyan, 1979).

In March 2008, soils from the following treatments: $N_{50}P_{75}K_0$, $N_{50}P_{75}K_{75}$ and $N_{50}P_{75}K_{450}$ were sampled for probing the long-term effects of increasing potassium rates on soil fertility. Soil samples were collected from the upper layer (0 - 25 cm) of each plot. The following soil characteristics were determined: pH in water, humus according to Tjurin (Totev et al., 1987), available P – by the Egner-Riehm method, available K – in 2N HCl. Available Ca and Mg were determined by using 1N KCl (Tomov et al., 1999). In 2008 and 2009 mature leaves from different stalk position (lower, middle and upper leaves), stems and blossoms were collected for analyses. All samples were washed with tap water to remove any adhering soil particles and rinsed with distilled water, after which they were dried at 75^0C for 12 h and ground.

Total nitrogen in the plants was determined by the Kjeldahl method. The preparation of plant samples for analysis of P, K, Ca and Mg was made by means of dry ashing and dissolution in 3 M HCl. Phosphorus was determined colorimetrically by the molybdovanadate procedure (Tomov et al., 1999). An atomic absorption spectrometer „Spektra AA 220" (Varian, Australia) was used for determination of K, Ca and Mg content in the soil and plant samples.

In 2009 the random samples of sun-cured leaves were analyzed for nicotine (ISO 15152), proteins (BDS 9142-88) and reducing sugars (ISO 15154).

Results were analyzed using the SPSS statistical package and differences were assessed with the Duncan test at the 0.05 probability level.

Results and Discussion

The long-term fertilization with 75 and 450 kg K_2O ha^{-1} y^{-1} had no recordable influence on the soil reaction and total humus content as compared to the 0 kg K_2O ha^{-1} treatment (Table 1). The soil available K content of the plots that did not receive K declined at a rate of 1.9 mg K_2O kg^{-1} soil $year^{-1}$. Plots fertilized with 75 kg K_2O ha^{-1} exhibited annual increases of available K_2O of 5.0 mg kg^{-1}. Plots that received large amounts of K_2O (450 kg ha^{-1}) showed high rate of increase – 51.2 mg K_2O kg^{-1} y^{-1}. These results lead to the conclusion that for these experimental conditions annual application of 75 kg K_2O ha^{-1} resulted in a small available K increase and is adequate to maintain soil K content near the initial value. Different amounts of K fertilizers applied over 42 years resulted in a small differentiation in soil available P_2O_5, Ca and Mg content.

Таблица 1. Характеристика на почвата, използвана в изследването
Table 1. Selected properties of the soil used in the study

Treatments	pH	Total humus, %	Available forms, mg kg^{-1}			
			K_2O	P_2O_5	Ca	Mg
$N_{50}P_{75}K_0$	8.18	2.60	368.5	98.2	3508	331
$N_{50}P_{75}K_{75}$	8.20	2.63	660.2	96.2	3307	296
$N_{50}P_{75}K_{450}$	8.21	2.55	2600.0	94.4	3612	385
Initial soil	8.50	3.01	450.0	15.0	-	-

Yield of cured leaves was not greatly affected by rate of K application. Average yield was, respectively, 1561 kg ha^{-1}, 1635 kg ha^{-1} and 1583 kg ha^{-1} for the $N_{50}P_{75}K_0$;

$N_{50}P_{75}K_{75}$ and $N_{50}P_{75}K_{450}$ treatment. Leaf yield tended to increase by 4.7% as potassium fertilization increased from 0 to 75 kg K_2O ha^{-1}. Lack of pronounced potassium treatment effect on yield can be attributed to the high available K content in soil of the experimental site.

Table 2 shows the nutrient concentrations in the above-ground biomass as dependent on K fertilizing rate, averaged over the period studied.

Таблица 2. Концентрация на елементите в надземната биомаса на ориенталски тютюн в зависимост от калиевото торене (средно за 2 години)

Table 2. Nutrient concentrations in the above-ground biomass of oriental tobacco as depending on K fertilizing rate (2-year average)

Treatments	Lower leaves	Middle leaves	Upper leaves	Stems	Blossoms
			K concentration (%)		
$N_{50}P_{75}K_0$	0.65c*	1.16b	1.03c	1.12c	3.20a
$N_{50}P_{75}K_{75}$	2.13b	1.73b	1.82b	2.56b	3.44a
$N_{50}P_{75}K_{450}$	4.49a	3.95a	2.87a	5.67a	3.79a
			N concentration (%)		
$N_{50}P_{75}K_0$	1.67b	2.01a	3.07a	0.78a	3.62a
$N_{50}P_{75}K_{75}$	2.05a	2.14a	2.86a	0.74a	3.49a
$N_{50}P_{75}K_{450}$	1.69b	1.94a	2.78a	0.74a	3.59a
			P concentration (%)		
$N_{50}P_{75}K_0$	0.088a	0.095a	0.185a	0.057a	0.460a
$N_{50}P_{75}K_{75}$	0.095a	0.085a	0.185a	0.062a	0.470a
$N_{50}P_{75}K_{450}$	0.090a	0.095a	0.163a	0.060a	0.490a
			Ca concentration (%)		
$N_{50}P_{75}K_0$	5.23a	4.57a	2.44a	1.10a	0.59a
$N_{50}P_{75}K_{75}$	4.93a	4.22b	2.41a	1.18a	0.60a
$N_{50}P_{75}K_{450}$	3.88b	3.23c	2.03b	0.78a	0.51a
			Mg concentration (%)		
$N_{50}P_{75}K_0$	0.71a	0.67a	0.67a	0.25a	0.44a
$N_{50}P_{75}K_{75}$	0.63b	0.61a	0.54b	0.15a	0.35a
$N_{50}P_{75}K_{450}$	0.58b	0.55b	0.52b	0.20a	0.47a

* - Different letters within each column indicate that the means are significantly different ($P<0.05$)

Potassium concentration in the plants was affected by K fertilizing level. Lack of any additional K fertilizer resulted in K values in the lower and upper leaves significantly lower than in treatments receiving additional K. For middle leaves, added potassium also resulted in higher K concentrations, but there was no significant difference among plants supplied with 0 and 75 kg K_2O ha^{-1}. Potassium content in mature leaves does not depend on leaves' stalk position. Stem K concentrations were equal or higher than those of leaves. According to Drossopoulos, et al. (1999) stem K was preserved at high levels showing this organ as a considerable K reservoir. Significantly lower K concentrations in stems were observed at the 0 kg K_2O ha^{-1} treatment as compared to those receiving supplemental K fertilizer. The K concentration in the blossoms did not change significantly with increasing K level. According to Volodarskiy (1971) the concentration of K_2O in the leaves of 3-5% (2.5-4.2% K) has beneficial influence on the burning properties of tobacco. The comparison of our data with these values shows that the leaf tissue concentration is relatively low under continuous fertilization with 0 and 75 kg K_2O ha^{-1} although large quantities of mobile potassium in the soil exist in these treatments. One possible explanation for this contradiction could be found in the high content of available calcium in the soil, which is an antagonist of K and decreases potassium absorption. According to Traynor (1980) crops can show K deficiency symptoms in leaves due to drought rather than shortage of soil K and keeping a crop well supplied with water can improve K nutrition better than application of K fertilizer. It is known that except in extreme heat and drought conditions, no irrigation is recommended to quality Oriental production. The experimental plots were irrigated when the available soil moisture was limiting tobacco growth (only two irrigations were applied in 2008 and 2009). Therefore, under our experimental conditions water deficit could be another important factor which reduces potassium uptake by tobacco. The K concentration in the leaves at the 450 kg K_2O ha^{-1} treatment ranged between 2.9%-4.5% and these potassium levels are sufficient to improve the burning properties of oriental tobacco.

Nitrogen concentration in the lower leaves was significantly increased with an increase in potassium fertilizer level (up to 75 kg K_2O ha^{-1}) and further increase in potassium rate decreased this parameter. Increasing levels of K fertility had no significant effect on nitrogen concentration in the middle and upper leaves, stems and blossoms ($P>0.05$).

The concentration of P in leaves, stems and blossoms was not affected by the application of different potassium rates, and thus no relationship appeared between these elements. The results of Bruns and Ebelhar (2006) similarly demonstrate that K fertilization does not affect the concentration of P in the maize organs.

Calcium concentration in leaves was 2.03 to 5.23% (Table 2). These values are similar to those reported by Yancheva (2002). Our results show a negative relationship between Ca concentration in the leaves and K fertilizing rate, supporting the hypothesis of an antagonistic relationship between the two elements. The Ca concentration in the lower and upper leaves did not change significantly with increasing of potassium level from 0 to 75 kg ha^{-1}. Among the three K fertilizing rates, 450 kg K_2O ha^{-1} treatment led to lowest Ca concentration in stems and blossoms but the differences between different treatments were not significant.

Magnesium concentration in mature leaves was 0.52 to 0.71% (Table 2). Mg deficiency may be expected to occur when the value in the leaf is 0.2 percent or less of the dry weight (McCants and Woltz, 1967). It normally occurs on sandy soils low in exchangeable magnesium, on a few acid sols low in exchangeable magnesium, or can be induced by high levels of potassium (Wild, 1988). Observed values in our experiment were higher than the critical concentration of 0.2%. The good supply of plants with Mg was probably because tobacco was grown on a soil with adequate levels of available magnesium. The concentrations of magnesium in tobacco leaves diminished with increasing of K fertilization levels. The results of Mylonas, et al. (1981) similarly demonstrate that magnesium concentration in oriental tobacco leaves tended to decrease as applied potassium increased. In our study no significant differences were observed in Mg concentration of lower and upper leaves among treatments receiving supplemental K fertilizer. The stems and blossoms' concentrations of Mg were not affected by the application of different levels of potassium ($P>0.05$).

Table 3 shows the effect of different potassium rates on chemical characteristics of sun-cured tobacco. Values of leaf nicotine were relatively high for all treatments. According to Ghiuselev (1983) the normal nicotine content for oriental tobacco is within

0.6-2.5%. The values observed for all treatments were near the upper part of the acceptable range. The rates of potassium used had no effect on percentage of nicotine in the cured leaves. Excessive protein content in oriental tobacco is known to adversely affect burning properties, causes a bitter taste in smoking and unpleasant smell. Leaf protein content was favorable for all treatments and was not affected by K fertilizing level. According to data by Ghiuselev (1983) the optimum reducing sugars' content in oriental tobacco is between 10% and 18%. The reducing sugars' content tended to increase at the 450 kg K_2O ha^{-1} rate. Balance of chemical components is important for a correct assessment of tobacco quality. The reducing sugars:nicotine ratio was very narrow, while it should range from 6-10:1. The ratio of these components was better in tobacco from 450 kg K_2O ha^{-1} treatment. Given the above data we can point out that increasing levels of K fertilization had no pronounced effect on chemical composition of the cured tobacco.

Таблица 3. Химичен състав на ориенталски тютюн сорт Пловдив 7 (% към сухото вещество)

Table 3. Chemical composition of Oriental tobacco variety Plovdiv 7 (% of dry weight)

Treatments	Nicotine	Proteins	Reducing sugars
$N_{50}P_{75}K_0$	2.52	6.28	9.94
$N_{50}P_{75}K_{75}$	2.64	6.03	9.23
$N_{50}P_{75}K_{450}$	2.48	6.19	11.42

Conclusion

Under our climatic and soil conditions annual fertilization with 75 kg K_2O ha^{-1} resulted in a small available K increase and is adequate to maintain soil K concentration near the initial value. Long-term fertilization with 450 kg K_2O ha^{-1} leads to excess of available soil potassium.

Cured leaf yield was little influenced by K fertilization when oriental tobacco was grown on soils with high available soil K.

With the increase of K fertilization rate the content of the potassium in leaves also increased. The calcium and magnesium concentrations decrease in the leaves with increases in added potassium. Increasing levels of K fertilization had no pronounced effect on nicotine and protein content of the cured tobacco. Only the reducing sugars' content tended to increase at the highest K rate.

Fertilization with moderate potassium rates on soils high in available K is necessary to maintain the good potassium reserves. When oriental tobacco was grown on alkaline soils with high available soil K and Ca, potassium fertilization improved K nutrition and therefore may favorably affect burning properties of tobacco.

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