The Effect of Tobacco Monoculture and Crop Rotations on Tobacco Leaf Composition

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SUMMARY

This paper presents the long-term results relating to the influence of different crop rotations and tobacco monoculture upon the chemical composition of flue-cured tobacco leaf. As a key crop, tobacco is included in all crop rotations. Considering the obtained results in the particular year's tobacco growing in monoculture or in crop rotation mainly had significant effect on nicotine content in tobacco leaf including a 10-year average. A similar trend was also determined for the content of proteins. The content of total nitrogen and reducing sugars was mainly affected significantly by crop rotation as regards the particular years. Calcium and potassium ratio was also unfavorable, although both of them were significantly influenced by crop rotation. The same is true for magnesium in the particular years.

KEY WORDS

tobacco monoculture, crop rotations, tobacco leaf composition

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INTRODUCTION

While numerous research papers deal with the chemical composition of tobacco, the key crop in these investigations, studies addressing this problem under the integral influence of crop rotation are very rare. Moreover, they are mainly directed towards crop sequence.

Speaking about the chemical composition of tobacco leaf in tobacco monocropping, as compared with alternative cropping frequencies and sequences, mention should be made of research done by Littlemore et al. (1991). No significant long-term changes of the flue-cured tobacco chemical composition, except for alkaloids and magnesium, were determined in its growing in monoculture, two- and four-year rotations with various preceding crops (millet, soybean, greengram, weed cover). Alkaloid concentrations increased in the first six years, and then went down with the introduction of a new, *Pseudomonas solanacearum* resistant cultivar in the last two years. Application of ethylene dibromide had only a slight, but not significant, influence on the content of macroelements in tobacco leaf.

Representative values for contents of particular chemical components of flue-cured tobacco leaf were reported by Marlan and Moseley (cit. after Akehurst, 1968). Investigating the content of nicotine and reducing sugars in flue-cured Virginia tobacco, Umamaheswara and Tripathi (1988) established a considerably high nicotine content in tobacco grown after weed cover, castor and greengram, while reducing sugars were high after gingelly and korra. Crops that the mentioned authors, as well as Prasad Rao and Gopalachari (1981, 1982), included into crop rotation along with tobacco are of less importance for interpreting our results, for which it is significant that changes occurred in the leaf chemical composition of tobacco grown in different crop rotations. Higher nitrogen content was determined in tobacco leaves when flue-cured tobacco succeeded legumes.

According to Krishna Murty et al. (1978), tobacco chemical composition was improved in all crop rotations where tobacco was grown in crop sequence with rice, maize and sorghum. As it may be assumed that the different crop rotations studied affect the chemical composition of tobacco leaf, it is likewise expected that they also influence the chemical composition of other crops included in the same crop rotations. Thus, Copeland and Crookston (1992) investigated how crop sequence affected nutrient composition of corn and soybean grown under high fertility. Bruulsema and Christie (1987) and Harris and Hesterman (1990), though without directly providing data on the chemical composition of maize grain, and the latter two also barley, dealt with the nitrogen contribution from alfalfa and red clover to the succeeding corn as well as with quantifying the nitrogen contribution from alfalfa to soil and two succeeding crops using N^{15}.

MATERIALS AND METHODS

Since this paper deals only with the part of long-term investigations of growing flue-cured tobacco in monoculture and in different types of crop rotations that refers to their effect on the chemical composition of tobacco only methods indispensable for understanding the obtained results are described. Research methods are dealt with in more detail in our previous paper (Butorac at al., 1998). Experiments were set up on luvic semigley on multi-layered Pleistocene sands, on the experimental field of the Tobacco Institute Zagreb at Pitomača (Northern Croatia), according to the method of randomized block design, with a systematic lay-out of trial plots within blocks. The trial includes seven different crop rotation types as well as a tobacco in monoculture, which is the key crop in these investigations. Participation of crops per crop rotations is as follows: 1. two-year rotation A: winter wheat+Rauola or Phacelia-tobacco; 2. two-year rotation B: winter wheat-tobacco; 3. three-year rotation: winter wheat-tobacco-maize; 4. four-year rotation A: winter wheat-tobacco-maize-soybean; 5. four-year rotation B: winter wheat-oil seed rape-tobacco-maize; 6. five-year rotation: winter wheat-oil seed rape-tobacco-maize-soybean; and 7. six-year rotation: winter wheat-tobacco-red clover-red clover-maize-soybean.

Due to the possible influence of fertilization on the chemical composition of tobacco leaf and the soil chemical properties fertilizer rates of, respectively, N, P_2O_5 and K_2O are indicated in kg ha^{-1} per crops: flue-cured tobacco 30, 60 and 160; winter wheat 160, 160 and 140; maize 180, 150 and 170; oil-seed rape 160, 100 and 250; soybean 50, 90 and 100; red clover 150, 180 and 220.

For the problems treated in this paper it should be mentioned that the soil is at the borderline between very acid and acid reaction (pH 4.5 to 4.7) in Ap and E/Bt horizons, with pH of 6.2 in Bt horizon. There is poor to very poor humus supply (1.6% to 1.0%) and good to very good phosphorus (18.4 to 25.0 mg 100 g^1 soil) and potassium availability (24.6 to 34.1 mg 100 g^1 soil). Ploughlayer $NH_{4-}N$ content ranges from 0.35 to 0.49 mg 100 g^1 soil, while that of $NO_{3-}N$ from 0.28 to 0.45 mg 100 g^1 soil.

The tobacco leaf analyses were done by Coresta (1969) – nicotine and AOAC methods (1984) – proteins, total N, CaO, MgO, K_2O as well as by the modified method after Gaines (1971) – reducing sugars.

The results were processed by the analysis of variance and Duncan's Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

It is common knowledge that tobacco leaf chemical composition depends on the internal, hereditary factors, which in turn largely depend on the type, and within the type on the tobacco cultivar as well as on a number of external factors. Among the latter, our attention is directed towards tobacco monocropping and its growing in different crop rotations. In this case, crop rotation, as a complex ecological and biological category, should be considered in terms of the crop rotation value and sequence of crops grown, cropping practices applied, particularly fertilization, its duration and physiognomy. Investigations are focused on nicotine, proteins, total nitrogen, reducing sugars, calcium, magnesium and potassium.

First, the average 10-year values of tobacco leaf nicotine are relatively high for most crop rotations considering that the optimal value to Marlan and Moseley (cit. after Akehurst, 1968) for flue-cured tobacco is 1.93% (Table 1). This is certainly a result of high discrete values that appeared in the course of several years, irrespective of the crop rotation type and all that each particular crop rotation implies. The lowest value, which is also significant to tobacco monoculture, was recorded in four-year rotation involving winter wheat, tobacco, maize and soybean. This was followed by the values recorded in tobacco monoculture and six-year rotation, etc. The highest value was recorded in three-year rotation. It appears, however, that the values for particular years are more illustrative than the mean values for particular crop rotations, since they show that leaf nicotine level was very often conditioned by meteorological characteristics of a particular year. In this respect, there is a general trend of higher nicotine contents in crop rotations of fewer fields, which includes their physiognomy and duration, in contrast to multi-year crop rotations which is partly in agreement with the results obtained by Umamaheswara and Tripathi (1988). Crop rotations stretching over a larger number of years imply also more intensive fertilization, particularly that with nitrogen for crops such as maize, and potassium for maize, oil-seed rape and red clover as well.

It is a known fact that droughts favor nicotine accumulation and decrease reducing sugars, which is characteristic of insufficiently ripe tobacco. This, in fact, disturbs the ratio of these two, for tobacco quality important components. Compared with monocropping, the ratio of these components is better in tobacco grown in crop rotation after winter wheat and oil-seed rape.

Talking about protein content in flue-cured tobacco leaf, it should be kept in mind that their excessive content has a negative effect on burning, causes a bitter taste in smoking, and develops an unpleasant smell. Proteins should be considered in terms of the same factors as nicotine. According to the average long-term values as well as values for particular years, the content of proteins was favorable with respect to the optimal value of 5.68% for flue-cured tobacco according to Marlan and Moseley (cit. after Akerhurst, 1968), (Table 1). Influence of crop rotation showed a similar trend to that for nicotine. Differences determined between particular years within the same crop rotation obviously result from changeable meteorological conditions, especially if they were manifested by strongly expressed climatic aberrations. Considering a 10-year average, significantly higher value relative to tobacco monoculture, two-year rotation A, four-year rotation A and six-years rotation was recorded in three-year rotation. In the respect to the particular year's significant differences among different crop rotations are more pronounced considering leaf protein content.

Trends analogous to the two preceding parameters were recorded also for total nitrogen (Table 1). Average values were slightly above the optimal value of 1.97% for flue-cured tobacco according to Marlan and Moseley (cit. after Akehurst, 1968) and more or less at the same level for tobacco monoculture and all types of crop rotations. In some years, however, nitrogen content was considerably higher than the optimal value while in some other years it was below this value regardless of the crop rotation type, depending on the amount of precipitation, which is in agreement with the results of Prasad Rao and Gopalachari (1981). Considering the well-known positive correlation between total nitrogen and nicotine, it can be said that total nitrogen in flue-cured tobacco leaf was not significantly affected by crop rotation and all the factors implied by crop rotation with regard to a 10-year average, but in view of the particular years the opposite is very often true.

Balance of discrete components is more important for a correct assessment of tobacco quality than the content of each component separately. This should be specially kept in mind when estimating the content of reducing sugars. In this case, reducing sugars are important primarily from the aspect of tobacco monoproduction and the crop rotations tested. Average values indicate that their content was much below the optimal value of 22.09% according to Marlan and Moseley (cit. after Akehurst, 1968) (Table 1), which is more clear in view of the fact that reducing sugars were in negative correlation to nicotine, the content of which was much above the optimal value. The reducing sugars:nicotine ratio was generally very narrow, while it should normally range from 6-9:1. Regarding a 10-year average lowest content of reducing sugars was recorded in tobacco grown in four-year rotation involving also winter wheat, oil-seed rape and maize, in which it succeeded oil-seed rape or more precisely, considerably lower

Table 1. Content of nicotine, proteins, total nitrogen and reducing sugars in tobacco leaf according to the crop rotation type, %

Type of crop rotation	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Average
Nicotine											
Tobacco monoculture	2.88de	4.14a	3.39bc	3.09b	1.51e	3.03e	3.07d	3.53c	3.21b	1.56f	2.94ab
Two-year rotation-A	3.00	3.96b	3.17d	3.16a	1.92b	3.40cd	3.02de	4.33a	2.26d	1.96de	3.02ab
Two-year rotation-B	3.18b	3.78cd	3.21cd	2.98c	1.77c	3.34cd	3.43c	3.73b	2.83c	2.41a	3.07ab
Three-year rotation	3.49a	3.60e	3.70a	3.03bc	1.64d	4.00a	3.74a	3.24de	3.04bc	2.26b	3.17a
Four-year rotation-A	2.79e	3.34f	2.50e	2.99c	2.14a	2.98e	3.38c	3.42cd	2.08d	1.87e	2.75b
Four-year rotation-B	2.99c	3.67de	3.40bc	2.69e	2.21a	3.48c	3.63ab	3.46c	2.89c	2.07cd	3.05ab
Five-year rotation	2.95cd	3.86bc	3.42b	2.89d	1.91b	3.82b	3.49bc	3.01f	3.04bc	2.08cd	3.05ab
Six-year rotation	2.98cd	3.78cd	2.57e	2.84d	1.96b	3.25d	2.88e	3.10ef	3.52a	2.09c	2.89ab
Proteins											
Tobacco monoculture	6.20c	6.01cd	5.56b	6.23c	5.06d	5.62c	5.85c	5.28c	4.71bc	4.38c	5.49b
Two-year rotation-A	6.01de	6.01cd	5.50b	6.58b	5.56bc	6.00b	5.15d	5.52b	4.03e	4.38c	5.47b
Two-year rotation-B	6.04d	6.51a	5.56b	6.72a	6.00a	6.87a	5.24d	5.76a	4.49d	4.93b	5.81ab
Three-year rotation	6.45a	6.31b	5.81a	6.79a	5.50c	7.06a	6.18a	5.56b	4.58cd	4.94b	5.92a
Four-year rotation-A	5.95e	5.98cd	5.93a	6.69a	5.56bc	5.12d	5.31d	5.21c	4.52cd	4.39c	5.47b
Four-year rotation-B	6.31b	5.95d	5.06c	6.23c	6.00a	6.12b	5.96bc	5.45b	4.90b	5.71a	5.77ab
Five-year rotation	6.29b	6.54a	6.00a	6.71a	5.56bc	6.18b	6.12ab	4.85d	5.29a	4.23c	5.77ab
Six-year rotation	6.02de	6.09c	4.50d	6.80a	5.69b	5.31cd	5.12d	5.44b	5.38a	4.24c	5.46b
Total nitrogen											
Tobacco monoculture	2.33bc	2.54c	2.21c	2.48d	1.89e	2.19cd	2.36bc	2.01c	1.67c	1.38e	2.11a
Two-year rotation-A	2.38ab	2.53cd	2.29bc	2.77a	2.19bc	2.40b	1.91f	2.22a	1.35d	1.41de	2.15a
Two-year rotation-B	2.31c	2.60b	2.31bc	2.70b	2.12d	2.32bc	2.46a	2.13b	1.64c	1.63b	2.22a
Three-year rotation	2.42a	2.44e	1.98d	2.65b	2.10d	2.74a	2.39ab	2.10b	1.59c	1.66b	2.21a
Four-year rotation-A	2.20d	2.39f	2.06d	2.59c	2.24b	1.98e	2.18d	2.00c	1.42d	1.43cde	2.05a
Four-year rotation-B	2.33bc	2.39f	2.39ab	2.47d	2.32a	1.53f	2.32bc	1.99c	1.59c	1.76a	2.11a
Five-year rotation	2.30c	2.68a	2.46a	2.69b	2.14cd	2.49b	2.29c	1.92d	1.81a	1.49c	2.23a
Six-year rotation	2.05e	2.49d	1.79e	2.79a	2.15cd	2.08de	2.08e	1.99e	2.00b	1.45cd	2.08a
Reducing sugars											
Tobacco monoculture	13.32e	12.07de	17.40c	13.10d	21.04a	20.56a	16.94c	15.17a	19.76c	24.87b	17.46a
Two-year rotation-A	13.82de	11.61e	19.15b	12.65de	15.11e	15.59cd	16.79c	10.52e	22.52b	26.80a	16.45a
Two-year rotation-B	14.75bc	12.57bc	15.69d	14.23b	16.49d	14.39d	14.11e	13.03c	21.84b	27.06a	16.42a
Three-year rotation	14.37cd	13.00b	21.03a	13.68c	15.30e	11.50e	16.30c	11.45c	21.90b	24.80b	16.33a
Four-year rotation-A	15.40b	12.81b	14.76d	14.28b	19.73b	16.60c	19.11b	12.11d	25.30a	22.66c	17.27a
Four-year rotation-B	15.13b	12.29cd	17.45c	12.36e	18.54c	12.54e	15.21d	12.18d	20.08c	21.84c	15.76a
Five-year rotation	17.23a	11.11f	15.59d	15.68a	17.30d	14.28d	16.87c	15.67a	19.47c	22.94c	16.61a
Six-year rotation	17.46a	14.52a	17.19c	14.36b	17.51d	18.94b	20.17a	14.07b	17.79d	20.08d	17.22a

in comparison with tobacco monoculture, four-year rotation and six-year rotation. It was followed by three-year rotation, both two-year rotations, and other crop rotations with a highest content of reducing sugars of 17.46% in tobacco grown in monoculture. Of course, in the particular years significant differences amongst certain crop rotations are, at any rate, present regarding reducing sugars content. Regardless of crop rotation, there were years in which sugar content was by half lower than optimal, but also years in which it was near or equal to the optimal value. On the contrary, results of Umamaheswara and Tripathi (1988) speak about of a marked influence of some crops (gingelly and korra) on a content of reducing sugars in tobacco leaf.

Calcium values considerably exceeded the optimal value of 2.22% (Marlan and Moseley; cit. after Akehurst, 1968) in tobacco monoculture and in all crop rotation types (Table 2). On an average, oppositely to the results of Littlemore et al. (1991) in which no significant long-term changes regarding calcium content of the flue-cured tobacco under the influence of different crop rotations were obtained, in our experiments significantly lower value was recorded in six year rotation in relation to two-year rotation A and B, and four year rotation B. The highest value was recorded in two-year rotation in which tobacco was grown along with green manure (Rauola or Phacelia). This might be explained by the ability of green manure crops to intensively activate soil calcium, which mainly occurs after their ploughing into soil when more carbon dioxide is released by their decomposition, which in turn activates the soil liquid phase. Oil-seed rape can also contribute to activation of soil nutrients, including calcium, which is in a sense indicated by the leaf calcium value of tobacco grown in four-year rotation in which it succeeded oil-seed rape. Mention should be made of another fact. Several years before the trial was set up, liming by dolomite was applied to the trial area, which resulted in an exceptionally high calcium content in tobacco leaf in the first two years, though significant differences between crop rotations appeared in these years. This also happened in later years, while a more pronounced trend of calcium decrease in all crop rotations and tobacco monoculture was observed only in the last investigation year. However, what is certainly unfavorable from the aspect of tobacco quality is the almost identical, in some cases even higher, content of calcium than of potassium, which has a negative effect on its combustibility and lowers its value as a raw material for production of cigarettes.

According to the 10-year averages, magnesium content almost ideally corresponds to the optimal value of 0.36% for flue-cured tobacco (Marlan and Moseley, cit. after Akehurst, 1968) in tobacco monoculture and all crop rotations (Table 2). As a rule, magnesium generally decreases from the initial much higher values, a consequence of residual effects of previously conducted liming by dolomite, towards later trial years. Owing to this fact, it is understandable that all crop rotations and tobacco monoculture in their overall ecological, biological and agrotechnical entirety remained subordinated, which disagree with the long term changes obtained by Littlemore et al. (1991). Of course, during the particular year's statistically significant differences are present among different crop rotations by themselves and tobacco monoculture.

Finally, according to average values for all crop rotations and tobacco monoculture, potassium content of flue-cured tobacco leaf was much higher than the optimal 2.47% (Marlan and Moseley; cit. after Akehurst, 1968). It was highest in six-year rotation and lowest in monoculture (Table 2). In general, it was higher in multi-year crop rotations than in two-year rotation, very often significantly higher when we are speaking of the particular year, in distinction from the results of Littlemore et al. (1991). Namely, their results showed inconsistently trends between cycles, before all due to varietal change. This trend was observable throughout the whole investigation period. In some cases, high potassium concentrations might be justified by plant ability of luxury consumption of this bioelement, provided the soil abounds in it. In this trial, this happened in the years when abundant moisture prevented potassium blocking in the soil, i.e. it's binding to illites. Also, intensified potassium fertilization for certain crops in rotations with a larger number of fields (maize, oil-seed rape, red clover) might have contributed to it through residual fertilizer effects. As already mentioned, despite all that, leaf calcium content was approximately at the same level as that of potassium, which is undesirable for tobacco quality since leaf potassium has a decisive influence on its combustibility. Ratio of these two nutrients should be balanced, naturally with preponderance of potassium, because the balance of components is more decisive than their individual contents. Owing to the previously applied liming by dolomite as well as better potassium availability, this adverse ratio was certainly not caused by mutual antagonism between potassium, on the one side, and calcium and magnesium on the other.

Although these investigations did not comprise different varieties of tobacco because it was not their aim, but tobacco in different crop rotations influences more or less the chemical composition. These investigations show that we are far away from "the ideal" varieties regarding the chemical composition of tobacco. Tobacco is still considerable under the influence of meteorological conditions than crop rotations. Naturally, it was not the aim of our investigation.

Table 2. Content of calcium, magnesium and potassium in tobacco leaf according to the crop rotation type, %

Type of crop rotation	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Average
Calcium (CaO)											
Tobacco monoculture	5.00a	5.38b	3.37c	2.79d	3.17d	3.54cd	2.85g	3.13bc	3.99a	2.47c	3.57bc
Two-year rotation-A	4.83bc	5.83a	3.49bc	3.26a	3.90a	4.61a	3.57b	3.74a	3.66b	2.87a	3.98a
Two-year rotation-B	4.80c	5.61ab	3.98a	3.18b	3.69b	3.72c	2.93fg	3.26b	3.30d	2.64b	3.71ab
Three-year rotation	4.66d	4.77c	3.02e	2.96c	3.45c	4.69a	3.22cd	2.72f	3.28d	2.29d	3.51bc
Four-year rotation-A	4.84bc	4.51d	3.57b	3.18b	3.97a	3.35d	3.82a	3.04cd	2.64e	2.56bc	3.55bc
Four-year rotation-B	4.41e	5.66a	3.45bc	3.12b	3.33c	4.22b	3.32c	3.63a	3.55bc	2.57bc	3.73ab
Five-year rotation	4.95ab	4.92c	3.40c	2.82d	3.96a	4.16b	3.02ef	2.94de	3.43cd	2.88a	3.65bc
Six-year rotation	4.17f	4.39d	3.18d	2.99c	3.43c	3.29d	3.14de	2.77ef	3.58bc	2.33d	3.33c
Magnesium (MgO)											
Tobacco monoculture	0.55b	0.60b	0.39de	0.31e	0.37e	0.27b	0.29e	0.38bc	0.27b	0.23a	0.37a
Two-year rotation-A	0.55b	0.53d	0.42c	0.44b	0.41cd	0.27b	0.34a	0.41a	0.24c	0.22b	0.38a
Two-year rotation-B	0.54b	0.63b	0.49b	0.37d	0.50a	0.26b	0.32bc	0.37c	0.25c	0.21c	0.39a
Three-year rotation	0.55b	0.48e	0.41cd	0.45b	0.42c	0.30a	0.32bc	0.37c	0.33a	0.20d	0.38a
Four-year rotation-A	0.59a	0.62b	0.52a	0.37d	0.39de	0.18c	0.30de	0.31e	0.33a	0.20d	0.38a
Four-year rotation-B	0.48c	0.57c	0.42c	0.50a	0.47b	0.26b	0.31cd	0.39b	0.27b	0.19e	0.39a
Five-year rotation	0.49c	0.48e	0.47b	0.51a	0.50a	0.30a	0.33ab	0.33d	0.27b	0.21c	0.39a
Six-year rotation	0.40d	0.66a	0.38e	0.41c	0.51a	0.19c	0.26f	0.29f	0.33a	0.20d	0.36a
Potassium (K_2O)											
Tobacco monoculture	5.14ab	4.14d	2.75e	3.18e	4.37e	2.69e	2.59de	3.19c	2.14cd	2.08f	3.23c
Two-year rotation-A	5.00b	3.86e	3.31c	3.62bc	5.17b	3.18cd	2.53e	3.84b	1.92d	2.46de	3.49bc
Two-year rotation-B	4.53c	4.13d	3.90a	3.53cd	5.04bc	2.70e	2.80cd	3.39c	2.11cd	2.32e	3.45bc
Three-year rotation	4.30d	4.21d	3.64b	4.10a	4.82cd	4.69a	2.88c	4.93a	2.33c	2.80bc	3.87ab
Four-year rotation-A	5.02b	5.09b	2.73e	3.22e	5.91a	3.44c	3.84a	3.97b	2.30c	2.95b	3.85ab
Four-year rotation-B	5.04b	4.21d	2.99d	3.42d	4.84cd	3.94b	3.23b	4.07b	2.93b	2.68cd	3.74ab
Five-year rotation	5.02b	4.57c	3.60b	4.16a	4.68d	3.49c	3.03bc	3.96b	2.74b	3.43a	3.87ab
Six-year rotation	5.27a	5.38a	3.82ab	3.78b	4.93c	3.03d	3.71a	4.09b	3.62a	3.40a	4.10a

CONCLUSION

In tobacco leaf investigations are aimed on nicotine, proteins, total nitrogen, reducing sugars, calcium, magnesium and potassium. First, as regards nicotine content, values are relatively high for most crops rotations. Analogously to the nicotine content, influence of crop rotation showed a similar trend upon the content of protein. The same trends were recorded also for total nitrogen and mainly at the same level for tobacco monoculture and all types of crop rotation. Reducing sugars were in negative correlation to nicotine, the content of which was much above the optimal values. For all values, differences determined between separate years within the same crop rotation evidently result from changeable meteorological conditions. It appears that the values for particular years are more illustrative than the mean values for particular crop rotations, more or less for all parameters which were investigated.

Calcium values in a high degree exceeded the optimal values in tobacco leaf and what is certainly unfavorable from the aspect of tobacco quality is the almost identical or even higher content of calcium than of potassium. High potassium content might be justified by plant ability of luxury consumption of this element and intensified potassium fertilization for some crops in rotations. On average, magnesium content almost ideally corresponds to the optimal values, although the initial values are considerably higher than the values of the last years of the investigations.

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