Effects of Topping Height, Maturity and Cultivar on the Yield and Chemical Characteristics of Flue-cured Tobacco

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Summary

Effects of topping height, maturity and cultivar on the yield and chemical characteristics of flue-cured tobacco were studied in 2004-2005 and 2007. Investigations were carried out in the main tobacco growing region of Croatia according to the split-split plot method. The trial involved the following treatments: (1) topping height (17 and 20 harvesting leaves), (2) leaf maturity at harvesting (unripe, ripe and overripe) and (3) cultivar (HVT 1, VJ 1, DH 17).

Effects of topping height were obtained in this study only in interaction with maturity and cultivar. Topping height in interaction with leaf maturity affected the yield and nicotine content in dry years, and in interaction with cultivar in the year with sufficient precipitation the content of reducing sugars. Leaf maturity at harvesting affected the content of total nitrogen, proteins and reducing sugars in interaction with cultivar in 2007, marked by a forty-day water stress and retrovegetation from the second decade of August.

Leaf maturity at harvesting in 2004 and 2005 had no impact on yields. The highest yield was achieved by harvesting ripe tobacco topped to 20 leaves in 2007. Delayed harvesting increased the nitrogen content. In 2004, total nitrogen in overripe tobacco was significantly higher compared to ripe tobacco. Protein content increased until optimum maturity in 2005 and then decreased. In 2005, higher topping of cultivar VJ 1 resulted in a higher content of reducing sugars. Intensity of the decrease in the content of proteins and reducing sugars, as well as changes in total nitrogen caused by delayed harvesting in 2007 depended on cultivar characteristics. A weak positive correlation was established between yield and total nitrogen.

Key words

flue-cured tobacco, yield, nicotine, total nitrogen, proteins, reducing sugars

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Introduction

Topping height, estimation of harvest time and cultivar selection under the growing conditions without irrigation are factors that have a significant impact on the yield and quality of flue-cured tobacco. The mechanism of the effect of topping on tobacco has not been fully clarified yet. However, removal of flowers with or without removing top tobacco leaves delays the beginning of ripening (Thomas and Stoddard, 1980; Crafts-Brandner, 1991). Leaf ripening is a genetically controlled process and is independent of flowering (Thomas and Stoddard, 1980). Knowledge of genetic variability of cultivars enables their selection as well as application of agricultural management practices that can reduce the adverse effects of environmental conditions on the requirements regarding targeted yields and chemical characteristics of dried tobacco leaves (Chaplin, 1975; Gwynn, 1968; Gaines et al., 1983). Precipitation deficit in the growing period, a factor that cannot be influenced without irrigation, disturbs continuity in the process of plant growth and development as well as the tobacco ripening processes. If it is accompanied with retrovegetation, it can have irreparable consequences, particularly on the chemical composition of tobacco leaf (Weybrew et al., 1983).

Investigations done so far have shown that high yields with desirable chemical composition can be achieved only in cases of complete exhaustion of soil nitrogen reserves in the initial flowering stage and its incorporation into nitrogen compounds, followed by accumulation of starch (Weybrew and Woltz, 1975; Weybrew et al., 1983). This implies that the uptake and metabolism of nitrogen and carbohydrates determine the usability of tobacco and that their leaf content after harvest and drying reflect the stage of maturity at harvest time. Maturation processes are characterized by changes in plants, without final death. This development stage is actually marked by the transition from nutrient assimilation to their remobilization from older into younger top leaves of the plant (Weybrew and Woltz, 1975; Masclaux et al., 2000).

Literature data, though not unambiguous, generally show that higher yields can be achieved by higher topping (Campbell i sur., 1980; Kasturi Krishna et al., 2004) and harvesting in the stage of optimum maturity (Moseley et al., 1963; Suggs, 1986; Weybrew et al., 1984). Summarizing the results of investigations done to date, it can be concluded that delaying the harvest from the stage of immaturity to overmaturity leads to an increase in nicotine content (Mosely et al. 1963; Gwynn, 1968; Weybrew et al., 1984), decrease in total nitrogen (Long and Weybrew, 1981; Moseley et al., 1963; Weybrew et al., 1984) and N-proteins (Moseley et al., 1963; Long and Weybrew, 1981), and increase in reducing sugars until the stage of optimum maturity, which is then followed by an appreciable drop (Moseley et al., 1963; Long and Weybrew, 1981). However, Weybrew et al. (1984) and Suggs (1986) obtained highly inconsistent and contradictory results. Interactions between the cultivar and leaf maturity at harvesting and between cultivar and topping height in nicotine content may enable selection of suitable cultivars, in dependence on the growing purpose (Collins et al., 1965; Gwynn, 1968; Campbell et al., 1982).

Walker (1968) has found a significant strong, positive correlation between leaf weight and total nitrogen. In six-year-long investigation of the same cultivars, Gaines et al. (1983) determined no correlations between yield and nicotine, total nitrogen and reducing sugars.

The goal of these investigations was to determine the impact of topping height, maturity at harvest time and cultivar on (1) yield and contents of nicotine, total nitrogen, proteins and reducing sugars, and (2) correlation between yield and the studied chemical characteristics of flue-cured tobacco.

Materials and methods

Investigation was conducted at the production areas of the tobacco enterprise Agroduhan d.o.o. at Slatina, in 2004, 2005 and 2007, on luvisol on loess and Pleistocene sand. No investigations were done in 2006 because optimum tobacco growing density was not attained on the trial field. Due to abundant precipitation, tobacco laid in water, which caused crop failure. The soil had slightly acidic reaction, was very poorly supplied with humus and moderately supplied with nitrogen in the plough layer and poorly in the sub-plough layer, very well supplied with available potassium and averagely supplied with available phosphorus. Trial treatments included: (1) topping height (17 leaves and 20 leaves for harvesting), (2) leaf maturity at harvest (unripe, ripe, overripe), and (3) cultivar (HVT 1, VJ 1 and DH 17). Trials were set up according to the split-split-plot method with four replications. The trial plot was represented by one row with 25 tobacco plants. Spacing between rows, which were trial treatments, was 100 cm; intra-row spacing of plants was 40-45 cm, while that between replications was 200 cm. Fertilizers were applied two times. Basic fertilization involved broadcasting of 400 kg ha^{-1} of complex mineral fertilizer NPK (0:5:30) at bed preparation, and topdressing in bands in the first or second growth cycle of 250 kg ha^{-1} of calcium nitrate (14.4% N). Common tobacco production technology was applied for the control of stipule growth and for leaf drying. Tobacco topping, estimation of harvest time, classification and sampling were carried out according to the set methodology.

Flowers and top leaves were removed in the early flowering stage (appearance of flowers on about 25% of trial area) with simultaneous removal of the first two lower leaves, which were not included in the calculation of agronomic indicators. Tobacco was harvested manually in six harvests. Two leaves were removed at the first harvest, three leaves at the second, third, fourth and fifth harvest each, and the leaves remaining on the stalk at the sixth harvest.

Leaf maturity for harvesting was estimated according to the generally accepted visual signs for harvesting (Moseley et al., 1963; Weybrew et al., 1983). Tobacco leaves removed in all treatments were dried in the same dryer by the ripe tobacco drying method. Consequently, yellowing was not optimal for unripe and overripe tobacco.

Samples of dried tobacco leaves, about 100 g, from the fourth harvest (leaves 9, 10 and 11) were used for chemical analyses. In the Tobacco Institute laboratory, samples were dried to constant weight for 96 hours at a temperature of 70°C and ground.

Nicotine and reducing sugars were analysed according to HRN ISO 15152 (2004) and HRN ISO 15154 (2004). Total nitrogen and proteins were determined by Kjeldahl process (Gunning-Arnold method, AOAC, 1970). To calculate correlations between the yield and chemical characteristics of tobacco, use was made of all the trial factors for a particular property (18 treatments with four replications).

Data were analysed according to the trial set up method using the mixed procedure of SAS statistical software, while Pearson's correlation coefficient was calculated for correlations (SAS Institute Inc., 2004). The results were tested by Fisher's t-test.

Results and discussion

Climatic conditions in the three-year trial period were mainly defined by the amount of precipitation and especially by its distribution (Table 1). Considering the impact of water stress upon the growth of tobacco plants (*Maw* et al., 2009), data are presented only for critical phases of tobacco development.

Climatic conditions during the growing season, with special reference to precipitation distribution in the stages of intensive tobacco growth and maturing, had a strong influence on the expression of the studied factors, on the yield and chemical composition of the tobacco cultivars tested. 431. 2 mm of precipitation was recorded in the climatically most favourable year 2005, 177.6 mm in the driest 2004, and 205.8 mm in 2007. Rainfall of 48.1 mm was recorded in the stage of intensive tobacco growth and development, stalk elongation, butonization, flowering and onset of ripening in 2004, while only 24.5 mm in 2007. However, the dry period continued in the second half of the growing season in 2004, while from the second decade of August 2007 to the end of the growing season, the soil moisture regime suitable for nutrient uptake was re-established and the so called retrovegetation ("regreening") occurred.

Statistically significant differences in tobacco yield under the influence of topping height and cultivar (Table 2), that is, THxM interaction, were recorded only in 2007 (Table 3).

When tobacco topped to 17 leaves for harvesting was harvested, differences in yield between tobacco leaves of different maturity were not significant. However, the highest yield of tobacco topped to 20 leaves for harvesting was achieved by harvesting ripe tobacco; differences in yields between unripe and overripe tobacco were not significant. Results of other authors for the effect of leaf maturity upon yield are not unambiguous. No differences in yield were found when tobacco was harvested at the time of its visually estimated maturity or a week before it (Moseley et al., 1963; Suggs, 1986), or yield was higher if tobacco was harvested a week prior to optimum maturity (Weybrew et al., 1984). However, delayed harvesting after optimum maturity, namely, harvesting of overripe tobacco, led to yield decrease (Moseley et al., 1963; Suggs, 1986;

Table 1. Temperature and precipitation for the months of intensive growth and senescence of tobacco, Virovitica, 2004-2005 and 2007

Month	Mean monthly diurnal temperature (°C)			Decade	Precipitation (mm)		
	2004	2005	2007		2004	2005	2007
July	21.3	21.3	22.3	I	23.0	47.6	13.1
				II	0.7	41.6	2.0
				III	18.7	76.0	4.7
August	21.0	18.9	21.1	I	5.7	91.3	4.7
				II	16.0	53.0	38.2
				III	18.7	33.4	33.3
September	15.6	16.7	13.7	I	3.8	1.4	64.8
				II	25.9	56.5	31.1
				III	65.1	30.4	14.1
					177.6	431.2	205. 8

Table 2. Effect of topping height, maturity and cultivar on yield and nicotine, 2004-2005 and 2007

Treatment	Yield (kg/ha)			Nicotine (%)		
	2004	2005	2007	2004	2005	2007
Topping height (TH)						
17 leaves	2183 a	2489a	2350 b	1.94a	1.80a	4.12a
20 leaves	2209 a	2376a	2560 a	2.08a	1.90a	3.94a
Maturity (M)						
Unripe	2285 a	2528a	2404a	2.12 a	1.59 b	3.44 b
Ripe	2174 a	2425a	2506a	1.86 b	1.75 b	4.40 a
Overripe	2129 a	2345a	2455a	2.05 a	2.22 a	4.25 a
Cultivar (C)						
HVT 1	2268 a	2464a	2615 a	2.20 a	1.72a	3.74 b
VJ 1	2114 a	2478a	2412 b	1.91 b	1.97a	4.48 a
DH 17	2207 a	2355a	2338 b	1.92 b	1.87a	3.87 b

Average values marked by the same letter are not significantly different at P=0.05

Table 3. Interactions between topping height and maturity on yield and nicotine, and between topping height and cultivars on reducing sugars

Topping height	Yield (kg/ha) 2007			Nicotine (%) 2004			Reducing sugars (%) 2005		
	Maturity (M)			Maturity (M)			Cultivar (C)		
	Unripe	Ripe	Overripe	Unripe	Ripe	Overripe	HVT 1	VJ 1	DH 17
17 leaves	2312 Aa	2279 Ab	2459 Aa	2.18 Aa	1.92 Ba	1.73 Bb	22.75 Aa	18.09 Bb	22.81 Aa
20 leaves	2497 Ba	2732 Aa	2450 Ba	2.07 Ba	1.81 Ca	2.36 Aa	20.57 Ba	21.67 Aba	24.16 Aa

Average values marked by the same uppercase letter are not statistically different within the same topping height, Average values marked by the same lowercase letter are not statistically different within the same maturity and cultivar.

Weybrew et al., 1984). Non-significant differences between yields of tobacco topped to 17 leaves for harvesting suggest that the degree of optimum maturity of tobacco leaves was not reached at any harvest date. The re-established regime of favourable soil moisture that enabled nutrient uptake from the soil, from the second decade of August to the end of harvest, prolonged leaf maturation and remobilization of nutrients from older to younger top leaves (Weybrew and Woltz, 1975; Weybrew et al. 1983; Masclaux et al., 2000). Such results are in agreement with investigations done by Thomas and Stoddard (1980) and Crafts-Brandner (1991), who report that topping prolonged tobacco maturation. In case of higher topping, only harvesting of ripe tobacco produced a statistically significant difference in yield, that is, higher yield compared to lower topping. No such effect was recorded in harvesting unripe and overripe tobacco. A large number of authors achieved higher yields with higher topping (Campbell et al., 1980; Kasturi Krishna et al., 2004). However, Brown and Terril (1979) and Čavlek et al. (1991) obtained such results only in years with insufficient precipitation.

In 2007, cultivar HVT 1 gave a higher yield compared to the yields of cultivars VJ 1 and DH 17, between which there were no significant differences (Table 2). Cultivar variability, reflected in the manner of maturation during tobacco growth in the investigations done to date, resulted in differences in economic traits and interactions with investigated factors (Chaplin, 1975; Gwynn, 1968; Gaines et al., 1983).

According to the results of analysis of variance, maturity of tobacco leaves at harvest time had a significant effect on nicotine in all the three trial years, and on cultivars only in 2004 and 2007 (Table 2). The effect of cultivar was not consistent in any trial year. In 2004, nicotine content was under the influence of THxM interaction (Table 3).

In tobacco topped to 17 leaves for harvesting, harvest delayed from unripe to ripe and overripe leaves in 2004 led to a significant decrease in nicotine content. In tobacco topped to 20 leaves for harvesting, harvest delayed from unripe to ripe leaves resulted in a decrease and from unripe to overripe leaves to an increase in nicotine content. Further, an increase in topping height for overripe tobacco resulted in higher nicotine content, which effect was not recorded for tobacco leaves removed in their unripe and ripe stages.

It is obvious that tobacco leaves topped to 17 leaves for harvesting, though removed as overripe, were not of the same maturity as tobacco leaves topped to 20 leaves. This result suggests slower maturation of tobacco topped to a lower height. The effect of topping upon maturity has not been fully clarified yet. Topping was found to enhance drought tolerance and to retard leaf senescence, thereby prolonging processes going on in leaves. According to Crafts-Brandner (1991), loss of chlorophyll and activity of the enzyme ribulose 1.5 bisphosphate carboxylase-oxygenase indicate slower maturation of topped plants compared to untopped plants.

In the climatically most favourable year 2005, nicotine content was significantly increased by delaying harvesting at optimum maturity to harvesting of overripe tobacco, and in 2007, with marked water stress and re-established regime of favourable soil moisture, from the harvesting of unripe to harvesting ripe tobacco (Table 2). Increase in nicotine content due to delayed harvesting was reported by Gwynn (1968), Mosely (1963) and Weybrew et al. (1984). The highest nicotine content in 2007 was recorded in the leaves of cultivar VJ 1.

King (1986) topped mammoth tobacco to 14, 18, 22 and 26 leaves for harvesting and found that the yield increased with increasing the number of leaves for harvesting. The highest nicotine content was obtained by topping to 14 leaves and significantly decreased with increasing the number of leaves.

Total nitrogen in dried tobacco leaves varied in 2004 under the influence of leaf maturity at harvest time and of the cultivar (Table 4), while joint action of maturity and cultivar was observed in 2007 (Table 5). Harvesting of overripe tobacco in 2004 resulted in a higher nitrogen content compared to ripe tobacco; the highest nitrogen was found in the leaves of cultivar HVT 1. Increased total nitrogen content in overripe tobacco leaves in 2004, compared to ripe leaves, is contrary to the results of other authors (Long and Weybrew, 1981; Moseley et al., 1963; Weybrew et al., 1984). It is obvious that no remobilization and translocation of nitrogen into upper younger leaves occurred until tobacco harvest (Weybrew et al., 1984; Masclaux et al., 2000), that is, tobacco was not overripe.

Effect of the degree of tobacco maturity on total nitrogen content in cultivars was not consistent in 2007 (Table 5). In harvesting unripe tobacco, cultivar HVT 1 had significantly the highest total nitrogen, in contrast to harvesting ripe and overripe tobacco where total nitrogen contents of tested cultivars did not differ significantly.

Protein content with regard to the degree of maturity was not consistent and was influenced by the amount and distribution of precipitation. In the first trial year, marked by insufficient precipitation, no significant differences were recorded for protein

Table 4. Effect of topping height, maturity and cultivar on total nitrogen, proteins and reducing sugars, 2004-2005 and 2007

	Total nitrogen (%)			Proteins (%)			Reducing sugars (%)		
	2004	2005	2007	2004	2005	2007	2004	2005	2007
Topping height (TH)									
17 leaves	1.80 a	1.90 a	3.41a	5.06a	6.00a	8.59a	25.27a	21.22a	6.91a
20 leaves	1.74 a	1.91 a	3.36a	4.84a	5.95a	8.32a	24.19a	22.13a	7.43a
Maturity (M)									
Unripe	1.77 ab	1.96 a	3.33a	4.91a	5.99 b	9.18 a	23.37a	21.67a	9.47a
Ripe	1.69 b	1.85a	3.53a	4.72a	6.49 a	8.19 b	27.15a	22.90a	6.36b
Overripe	1.84 a	1.90a	3.29a	5.22a	5.45 c	7.99 b	23.67a	20.45a	5.68b
Cultivar (C)									
HVT 1	1.84 a	1.88a	3.41a	5.06a	6.05a	8.83 a	24.07a	21.66 ab	7.11b
VJ 1	1.73 b	1.92a	3.39a	4.93a	5.94a	8.27 b	24.80a	19.88 b	6.23c
DH 17	1.73 b	1.91a	3.35a	4.85a	5.93a	8.26 b	25.32a	23.48 a	8.16a

Average values marked by the same letter are not significantly different at P=0.05

Table 5. Effect of interactions between maturity and cultivar on total nitrogen, proteins and reducing sugars in 2007

	Total nitrogen (%) Cultivar (C)			Proteins (%) Cultivar (C)			Reducing sugars (%) Cultivar (C)		
Maturity (M)	HVT 1	VJ 1	DH 17	HVT 1	VJ 1	DH 17	HVT 1	VJ 1	DH 17
Unripe	3.53 Aa	3.30 Bb	3.16 Bb	9.93 Aa	8.77 Ba	8.85 Ba	8.1 Ba	8.50 Ba	11.8 Aa
Ripe	3.44 Aa	3.61 Aa	3.55 Aa	8.44 Ab	8.15 Aa	7.97 Ab	7.10 Aab	5.30 Bb	6.60 ABb
Overripe	3.27 Aa	3.27 Ab	3.34 Aab	8.11 Ab	7.9 Aab	7.96 Ab	6.10 Ab	4.90 Ab	6.10 Ab

Average values marked by the same uppercase letter are not statistically different within the same maturity, Average values marked by the same lowercase letter are not statistically different within the same cultivar.

content, whereas in the following year, with sufficient precipitation, the lowest protein content was found in overripe tobacco leaves, which is in agreement with the results of Moseleya et al. (1963) and Long and Weybrew (1981) (Table 4).

In 2007, with forty-day long water stress in the period of intensive growth, stalk elongation, flowering and onset of tobacco maturation, MxC interaction was recorded (Table 5). In harvesting unripe tobacco, protein content in the leaves of cultivar HVT 1 was higher compared to cultivars VJ 1 and DH 17, while differences in protein contents were not significant when harvesting ripe and overripe tobacco. Protein content was decreased in all cultivars by delaying harvesting from unripe to ripe tobacco. Cultivar differences are noticeable in the different intensities of protein decrease.

According to the results of analysis of variance, the effect of topping height on reducing sugars was recorded only in 2005 in interaction with the cultivar (Table 3). Interaction between maturity and cultivar was also recorded in 2007 (Tables 4 and 5). When tobacco was topped to 17 leaves in 2005, a significantly higher content of reducing sugars was determined in cultivars HVT 1 and DH 17 compared to VJ 1, and in topping to 20 leaves for harvesting in DH 17 compared to HVT 1. Topping to 20 leaves for harvesting led to higher content of reducing sugars in cultivar VJ 1 compared to tobacco topped to 17 leaves for harvesting, while no such response was recorded for cultivars HVT 1 and DH 17. These results are in agreement with those of other authors, who report that higher topping in years with favourable moisture resulted in higher contents of reducing sugars (Minner, 1980; King, 1986), namely, without differences in years with insufficient and unfavourable distribution of precipitation (Court and Hendel, 1989)

When harvesting unripe tobacco, the significantly highest content of reducing sugars was achieved in 2007 by cultivar DH 17, while the difference between cultivars HVT 1 and VJ 1 was not significant (Table 4). In case of ripe tobacco harvesting, the content of reducing sugars in VJ 1 was significantly lower compared to HVT 1, indicating a change in cultivar response compared to unripe harvesting. In case of overripe tobacco harvesting, there were no significant differences between the cultivars. Obvious decrease in the content of reducing sugars by delayed harvesting in 2007 was strongly affected by leaf maturity at harvest time as well as by the hereditary traits of cultivars (Table 4). Decrease in the content of reducing sugars in cultivar HVT 1 was detected only by its overripe harvesting and by ripe harvesting of VJ 1 and DH 17, without any further significant decrease.

Also other authors report significant differences in reducing sugars at different stages of leaf maturity at harvest date. Decreased contents of reducing sugars due to delayed harvesting are reported by Mosely et al. (1963), Gwynn (1968), Long and Weybrew (1981), while Mosely et al. (1963) emphasize cultivar differences as well. However, Suggs (1986) and Weybrew et al. (1984) obtained highly inconsistent and contradictory results in their studies.

Chemical composition of tobacco leaves in this study supports the assumption that precipitation distribution impairs tobacco quality (Weybrew et al., 1983). Weybrew and Wolz (1975) maintain that precipitation and chemical composition are not directly related but that the interaction of moisture and soil nitrogen supply is responsible. Content of nitrogen components in tobacco leaf increases after an expressly dry period, and the content of reducing sugars decreases irretrievably (Weybrew and Wolz, 1975; Ismail and Long, 1980; Weybrew et al., 1983), which was confirmed by this study in 2007. In the intensive growth stage of that year, nitrogen supplies were not used up until the tobacco flowering stage due to drought, and the rainy period at a later stage delayed nitrogen uptake as well as synthesis of nicotine and other nitrogen compounds. Starch accumulation did not start in the tobacco flowering stage but starch served as a source of energy for reduction of nitrates and their incorporation into nitrogen compounds, as well as for remobilization of nitrogen from older to younger upper leaves during leaf senescence (Weybrew and Wolz, 1975; Masclaux et al., 2000). This resulted in a very high content of nitrogen compounds and very low content of reducing sugars in dried tobacco leaves.

Correlation coefficients for the interrelationship between yield and the studied components of leaf chemical composition that characterize leaf quality are given in Table 6.

Table 6. Correlation coefficients between yield and chemical constituents, 2004-2005 and 2007

Year	Nicotine	Total nitogen	Proteins	Reducing sugars
2004	0.032	-0.073	0.002	0.100
2005	-0.062	0.067	0.203	0.146
2007	0.113	0.286*	0.118	-0.197

No correlations between yield and the studied chemical components of tobacco leaf were found in the first two trial years. In the third year, marked by a forty-day dry period followed by establishment of moisture favourable for protracted nutrient uptake from soil, statistical analysis rendered a weak positive correlation for total nitrogen. Non-significant correlation between yield and nicotine content as well as a positive correlation with total nitrogen content is in agreement with the results of Walker (1968), and partly with those of Gaines et al. (1983).

Conclusions

The three-year investigation results point to the following conclusions:

1. Effects of topping height, maturity and cultivar on the studied traits depended on the amount and distribution of precipitation from the stage of initial intensive growth to the end of the tobacco growing period. This is undoubtedly corroborated by inconsistencies in the three-year investigation results for all the traits studied.
2. Topping height in interaction with leaf maturity at harvesting time in the years with precipitation deficit (2004) and water stress (2007) affected the yield and nicotine content, and the content of reducing sugars in interaction with the cultivar (2005).
3. In 2005, leaf maturity at harvesting affected protein and nicotine contents, and in 2007 in interaction with cultivar the content of total nitrogen, proteins and reducing sugars.
4. In 2007, the highest yield was achieved by topping to 20 leaves and ripe harvesting.
5. Nicotine content increases with increasing the degree of maturity at harvesting time. In 2004, the highest nicotine content was achieved by topping to 20 leaves and overripe harvesting.
6. In 2004, total nitrogen content of overripe tobacco was significantly higher compared to ripe tobacco. In 2005, protein content increased until optimum maturity, and then decreased. In that year, only increased topping height of cultivar VJ 1 resulted in an increase in reducing sugars.
7. Intensity of the decrease in the content of proteins and reducing sugars, as well as changes in total nitrogen due to delayed harvesting in 2007 depended on cultivar characteristics.
8. Weak positive correlation was established between yield and total nitrogen.

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