1 Introduction

Flue cured tobacco is grown on about 6000 hectares in northern Croatia where, owing to its most favourable pedoclimatic conditions for tobacco, there is a tradition of 50 years of tobacco production. Since mainly small farms have been found in this region certain problems occurred in tobacco production due to its frequent growing in a very narrow crop rotation or even in monoculture. Negative effects of such growing include spreading of diseases and pest partial exhaustion of nutrients and reduction of tobacco yield and quality (BUTORAC et al., 1995; BUTORAC et al., 1999;...
Hence, recognizing the factors mentioned above as well as some other factors (lower chemical and physical properties of the soil), there was a need to explore some types of crop rotation including tobacco under ecological conditions prevailing in this region. Crop rotation, commonly, involved crops are tobacco, winter wheat, maize, soybean, oil rape, red clover. Though our investigations focused on tobacco, they also included other crops which are important in Europe. Crop rotation is generally recognized as very comply agro-economic function, with influences on agro-technical, phytosanitary and economic effects as well (BUTORAC et al., 1999; BUTORAC et al., 2000; KARLEN et al., 1994). Crop rotation plays both a direct and an indirect role in preserving soil fertility and assuring good-quality of tobacco production. Crop rotation is a biological buffer system that disrupts the adverse biological cycles of diseases, pest and weeds, and conserves the soil organic matter more effectively than monoculture.

The aim of these investigations was to study tobacco productions in monoculture, compared with production in crop rotation on their influence on the yield and quality of tobacco.

2 Material and methods

These investigations were carried out for fifteen years on the experimental field of the Tobacco Institute Zagreb. Several types of crop rotation were tested: tobacco monoculture, two-crop (winter wheat – tobacco), three-crop (winter wheat, tobacco, maize), four-crop (winter wheat, tobacco, maize, soybean) and five-crop (maize, soybean, winter wheat, oil-seed rape, and tobacco) rotation. Tobacco is the key crop in these investigations while winter wheat and oil-seed rape were the preceding crops in trials.

Investigations started in 1987 and were carried out on semigley soil (sandy loam), which is characteristic soil of the area where flue-cured tobacco is grown in northern Croatia. The soil is of poor porosity in the eluvial (E/Bt) and illuvial (Bt) horizons.

There was an average water capacity of 34.0 %, while the air capacity was low in the sub-plough layers (8.6 %). Soil compaction increased with depth. The plough layer had acid reaction (pH = 5.4).

Tobacco was grown for fifteen-years in monoculture and in four types of crop rotation (1:2, 1:3, 1:4, 1:5). Seven two-crop rotations, five three-crop rotations, three four-crop rotations and three five-crop rotations have been completed to date.

The trial was set up according to the method of randomized block design in four replications, with a systematic layout of trial plots within the blocks. Each trial plot covers an area of 50 m² and each block 200 m². The domestic tobacco cultivar Drava which is resistant on black root rot was planted.

Standard cropping practices as well as standard fertilizations were applied to all trial crops. Fertilizer rates in kg ha⁻¹ are, for N, P₂O₅ and K₂O respectively: 30, 60 and 160 for flue-cured tobacco; 160, 160 and 140 for winter wheat; 180, 150 and 170 for maize; 50, 90 and 100 for soybean (before sowing the seed was inoculated with Bradyrhizobi um japonicum) and 160, 100 and 250 for oil-seed rape.

Tobacco was harvested in six harvests. After the cured leaves were investigated on quality and yield by classifying and weighing. The data of leaf yield and quality (% class I-III) were statistically processed by analysis of variance as well as the t-test to estimate the significance of the differences between average values in different crop rotations.

3 Results and discussion

The climate conditions during tobacco vegetation had a particular influence on the yield, especially on the quality of tobacco (LITTLEMORE et al., 1991). According to the data obtained from the meteorological station situated in the immediate vicinity of the experimental plot, there were considerable differences in the amount and distribution of precipitation (Table 1).

A minimum precipitation of 255 mm was recorded during the vegetation period in 1992, and a maximum precipitation of 476 mm in 1995. The average amount of precipitation during the tobacco vegetation period (May to September) over fifteen years amounted to 353 mm. No

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<tr>
<td>mm</td>
<td>285</td>
<td>281</td>
<td>399</td>
<td>261</td>
<td>438</td>
<td>255</td>
<td>310</td>
<td>335</td>
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negative temperatures, i.e. no late spring or early autumn frosts were registrated during the tobacco vegetation periods during the 15 years of investigations.

The results obtained for yields during the fifteen years of investigation are presented in Table 2.

The average values of flue-cured tobacco leaf yields for the 15-year period indicate a trend more or less analogous to that for particular years. Significantly higher yields were recorded in all kinds of crop rotations compared to tobacco monoculture cropping (BUTORAC et al., 1995; BUTORAC et al., 1999; TURSČIČ et al., 1997; LITTLEMORE et al., 1991). A significantly lower tobacco yield was obtained after three years of flue cured tobacco monocropping.

Tobacco grown in wider crop rotation was less infected with viruses, which resulted in better yield and quality.

Significantly higher yields were recorded in all crop rotations relative to tobacco monocropping. Thus, the advantage of crop rotation over monoculture is evident, and even that of crop rotation with a longer duration over crop rotation of shorter duration. Although the results obtained allow to conclude that a winter wheat-tobacco 2-year rotation may be quite acceptable in the main tobacco-growing area in northern Croatia. To recommend 3-year rotation including maize in addition to these two crops, as well as the other crop rotations tested, might be more justified in agricultural practice. Average long-term values show that the results of the 3-year, 4-year and 5-year crop rotations were better.

The common indicator of tobacco quality is the proportion of cured quality leaves belonging to the six particular classes. After each harvest (generally five to six), tobacco was classified into six classes according to the standard criteria for flue-cured tobacco in Croatia. In this case, our attention was focused on the influence of tobacco monoculture and the different crop rotations, also including to a certain extent, the crop rotation value and crop sequence on the tobacco quality.

### Table 2: Tobacco yield (t/ha) according to crop rotation type
**Tabelle 2: Tabakerträge (t/ha) in den unterschiedlichen Fruchtfolgen**

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<td>Monoculture</td>
<td>2.63</td>
<td>2.21</td>
<td>2.66</td>
<td>1.92</td>
<td>1.86</td>
<td>1.79</td>
<td>1.82</td>
<td>1.65</td>
<td>1.80</td>
<td>1.68</td>
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<td>1.57</td>
<td>1.61</td>
<td>1.53</td>
<td>1.39</td>
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<td>2.12</td>
<td>2.05*</td>
<td>2.29*</td>
<td>2.07*</td>
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<td>2.43*</td>
<td>2.38</td>
<td>2.56</td>
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<td>2.70</td>
<td>2.46</td>
<td>2.80</td>
<td>2.43*</td>
<td>2.40*</td>
<td>2.53**</td>
<td>2.14**</td>
<td>2.28*</td>
<td>2.20**</td>
<td>2.43**</td>
<td>2.45**</td>
<td>2.51*</td>
<td>2.48*</td>
<td>2.76*</td>
<td>2.46*</td>
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<tr>
<td>Four-year rotation</td>
<td>2.76</td>
<td>2.43</td>
<td>2.86</td>
<td>2.38</td>
<td>2.59**</td>
<td>2.39*</td>
<td>2.25**</td>
<td>2.33**</td>
<td>2.31**</td>
<td>2.48*</td>
<td>2.60*</td>
<td>2.73*</td>
<td>2.58*</td>
<td>2.83*</td>
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<tr>
<td>Five-year rotation</td>
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<td>2.45</td>
<td>2.85</td>
<td>2.70*</td>
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<td>NS</td>
<td>NS</td>
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<td>0.28</td>
<td>0.27</td>
<td>0.26</td>
<td>0.21</td>
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<td>0.32</td>
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<td>0.35</td>
<td>0.19</td>
<td>0.21</td>
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### Table 3: Influence of crop rotation on the quality of harvested tobacco leaves (% class I–III)
**Tabelle 3: Qualität der geernteten Tabakblätter (% Klasse I–III)**

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<tr>
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<td>13.9</td>
<td>12.4</td>
<td>0.0</td>
<td>19.4</td>
<td>11.4</td>
<td>20.6</td>
<td>18.0</td>
<td>17.3</td>
<td>18.4</td>
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<td>16.4</td>
<td>13.8</td>
<td>16.1</td>
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<tr>
<td>Two-year rotation</td>
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<td>11.5</td>
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<td>49.9*</td>
<td>37.7*</td>
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<td>26.8</td>
<td>21.3</td>
<td>28.1*</td>
<td>31.3*</td>
<td>18.3</td>
<td>23.4</td>
<td>25.7*</td>
</tr>
<tr>
<td>Three-year rotation</td>
<td>38.7</td>
<td>20.2</td>
<td>12.9</td>
<td>19.1*</td>
<td>48.3*</td>
<td>48.4*</td>
<td>38.6*</td>
<td>8.0</td>
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<td>34.2*</td>
<td>26.4</td>
<td>31.4*</td>
<td>32.7*</td>
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<tr>
<td>Four-year rotation</td>
<td>34.9</td>
<td>26.4</td>
<td>18.3*</td>
<td>20.3*</td>
<td>41.3*</td>
<td>48.2*</td>
<td>39.0*</td>
<td>14.3</td>
<td>40.2*</td>
<td>40.3*</td>
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<tr>
<td>Five-year rotation</td>
<td>36.4</td>
<td>23.4</td>
<td>19.6*</td>
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<td>43.5*</td>
<td>39.6*</td>
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<td>19.3</td>
<td>41.4*</td>
<td>41.5*</td>
<td>31.7*</td>
<td>41.3*</td>
<td>36.3*</td>
<td>27.4*</td>
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<td>33.8*</td>
</tr>
<tr>
<td>LSD (P=0.05)</td>
<td>NS</td>
<td>NS</td>
<td>3.6</td>
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<td>5.6</td>
<td>8.3</td>
<td>6.5</td>
<td>4.6</td>
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The percentage tobacco leaves classified as belonging to quality class I–III are presented in Table 3 according to the defined types of crop rotation and trial years.

The first three classes include better quality tobacco which has a considerable effect on the financial result of the tobacco production. A substantially lower percentage of better quality tobacco leaves was recorded in tobacco grown in monoculture, which, along with lower leaf yield, had a significant effect on the overall value of the productivity per hectare.

It is noticeable at first sight that, according to the long term investigation, the proportion of quality classes I-III showed an almost straight-line upward trend in the monoculture, with average 16.1 % respectively to average 25.7 % in the 2-year winter wheat-tobacco rotation. This was followed by a further rise to average 32.7 % in the 3-year rotation involving, besides tobacco, winter wheat and maize.

The 5-year rotation (33.8 %) average was slightly better than the 4-year rotation (32.9 %) average. Besides winter wheat, tobacco and maize, soybean and oil-seed rape were included in the 5-year rotation.

Better quality and higher yield of tobacco has resulted in better value of dried tobacco leaf.

### 4 Conclusions

Tobacco grown in crop rotation for 15 years gave a significantly higher yield than tobacco planted in monoculture. Tobacco grown in the four types (2-, 3-, 4- and 5 years) of crop rotation had a significantly higher yield and better quality leaves than grown in monoculture.

In monoculture the average yield was 1.85 t/ha with 16.1 % leaves in classes I–III, while in crop rotation the average yield was 2.36 t/ha to 2.55 t/ha with average of 25.7% to 33.8 % leaves class I–III.

An increase in yield and quality has been detected from 2-crop rotation to 3-crop rotation, while between 3,4 and 5-crop rotations the increase was not significant.

### References


**Tursić, I., A. Butorac, N. Vuletić, M. Mesić, M. Berdin and F. Bašić (1997):** The influence of crop rotation on the infection with tobacco mosaic virus in the agroecological conditions of Croatia. Coresta Agro/Phyto joint meeting. Montreux. Switzerland.

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