CORESTA Congress 1994 – HARARE, ZIMBABWE

Weather Conditions and Nitrogen Supply on Ripening Rate, Yield and Quality of Flue-Cured Tobacco

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INTRODUCTION

Traditionally, tobacco has been grown without irrigation in Hungary. Irregularity of rainfall and temperature during the growing season has resulted in great year-to-year variation in yield and quality with the cropyear effect exceeding the influence of cultural practices and differences among cultivars. With irrigation increasing during the past few years, about 25 % of the total tobacco area is irrigated at present. No information is available on the responsiveness of irrigated flue-cured tobacco to the yearly variation of climatic conditions in Hungary. The objective of the present study was to characterize the year-to-year variation of ripening rate, yield, quality and some selected chemical components of irrigated flue-cured tobacco, grown under different N fertilization treatments.

MATERIALS AND METHODS

Small plot experiments were conducted during six years on a loamy sand soil, using two flue-cured cultivars at the Kápolna experiment station of the Tobacco Research Institute. The experiment was set up in a split plot design with N fertilizer rates as whole plots and cultivars (Hevesi 5 and Hevesi 6, F_1 hybrids) as subplots. The treatments were replicated four times. The nitrogen fertilizer, ranging from 0-120 kg/ha as active nitrogen, was applied in the form of ammonium nitrate prior to transplanting tobacco to the field. The experiment was run in different sites of the same field in the consecutive years. The main soil characteristics and nutrient levels, except for N, show little year-to-year variation in soil samples taken in March or April depending on the year (**Table 1**).

Table 1 Main characteristics of the soil at the experimental site, in the 0-20 cm ploughed layer.

Characteristic/year	1985	1986	1987	1988	1989	1991
pH (KCl)	4.78	5.47	4.53	4.64	4.93	4.58
$CaCO_3$ %	0	0	0	0	0	0
Organic matter %	0.97	0.59	1.28	1.12	0.91	1.18
$NO_3 + NO_2$ – N mg/kg	0,8	2,9	8,5	7,1	3,2	4,3
P_2O_5 mg/kg (AL)*	182	212	297	210	198	228
K_2O mg/kg (AL)*	205	222	395	299	299	321
Mg mg/kg (KCl)*	118	83	160	61	57	124

*The readily soluble P_2O_5 and K_2O content of the soil were determined using ammonium-lactate as extrant

As shown in **Table 2**, the nitrate – N content of the upper 60 cm soil layer varied considerably among years, which is the result of differences in N uptake by the preceding crop and in climatic conditions prior to soil sampling.

Table 2 $NO_3 + NO_2$ – N content of the soil at the experimental site, measured in spring prior to N fertilization, in the 0-60 cm layer.

Year	1985*	1986	1987	1988	1989	1991
$NO_3 + NO_2$ – N	6.2	17.4	80.2	53.9	35.1	28.9

*0-50 cm soil layer

Tobacco was transplanted in early May. Cultural practices and harvesting were in accordance with those recommended for flue-cured tobacco. The crop was irrigated whenever it was considered necessary, using 20 to 30 mm water each time.

The cured leaves were weighed for yield by plot and primings, and leaf samples were composited by grades and primings for chemical analysis. Total nitrogen, total alkaloids and reducing sugars were determined by the method of Kjeldahl, UV spectrophotometric and colorimetric method, respectively. Data were analyzed in a three-way analysis of variance wherein years, cultivars and nitrogen rates were main effects. The rate of ripening is expressed as the percentage of yield harvested before September 4th. Visual quality is referred to as the percentage of the best three cured leaf grades.

Table 3 Meteorological data for the growing season at the experimental site.

Characteristic	Months						
	April	May	June	July	August	September	total/average
Rainfall (mm)							
1985	32	143	82	40	76	33	406
1986	19	38	88	33	42	0	220
1987	57	82	35	31	42	27	274
1988	19	37	53	30	121	54	314
1989	48	93	169	23	58	14	405
1991	59	85	47	130	26	7	354
50 years average	40	60	66	55	57	46	324
Monthly mean temperature (°C)							
1985		16.0	15.9	20.1	20.3	15.1	17.5
1986		17.8	18.6	19.6	20.8	15.8	18.5
1987		13.8	18.8	22.5	17.7	17.9	18.1
1988		16.0	17.8	21.9	20.3	15.6	18.3
1989		15.3	16.8	20.4	19.5	13.1	17.0
1991		12.5	18.4	21.9	19.8	16.7	17.9
50 years average		15.8	19.2	21.1	20.5	16.4	18.6

Climatic conditions of the growing season differed considerably among the years (**Table 3**). In 1985 and 1989 the monthly mean temperature for June and July was lower than the long term average. Rainfall was high, so weather was cool and rainy in these two years during the elongation period of the plants. While there was a drought all through the season in 1987, abundant rain was registered late in the season in 1988. On the whole, it was the 1986 season that suited best the needs of flue-cured tobacco.

RESULTS AND DUSCUSSION

The ANOVA F values show significant main effects for the characteristics studied, with the only exception of visual quality between the two cultivars (**Table 4**).

Table 4 Summary and significant aspects of ANOVA F values.
Kápolna, 1985-1991
n = 336

Source of variation	F value						
	DF	Yield	Rate of ripening	Visual quality	Total alkaloids	Total N	Reducing sugars
Year	5	126.29***	679.26***	116.07***	145.03***	166.6***	8.50***
Cultivar	1	30.43***	404.21***	1.19 NS	13.28***	27.55***	48.39***
N fertilizer	6	16.82***	13.87***	14.18***	12.96***	17.43***	17.13***
Replications	3	2.31 NS	0.40 NS	2.04 NS	4.50**	4.86**	0.49 NS
Year x Cultivar	5	3.98**	58.35***	17.76***	0.57 NS	1.51 NS	0.94 NS
Year x Fertilizer	30	2.67***	3.06***	2.00**	1.28 NS	1.89**	1.71*
Cultivar x Fertilizer	6	2.16*	5.30***	3.68**	2.98**	1.24 NS	1.63 NS

NS – not significant
*significant at P = .05
**significant at P = .01
***significant at P = .001

The two-factor interactions are highly significant for yield, ripening rate and quality. The level of significance is much lower for chemical components, indicating that differences between cultivars are only slightly affected by environmental factors and N fertilization. The effect of cropyear and N fertilization on each of the characteristics is shown in **Table 5** and **Table 6**, respectively.

Cropyear effect

Differences between years exceeded differences between both N rates and cultivars for most characteristics.

Table 5 Crop characteristics as influenced by years, averaged over N rates and cultivars.

Year \ Parameter	Yield (t/ha)	Rate of ripening %	Visual quality %	Total alkaloids %	Total N %	Reducing sugars %
1985	1.99 *	90.0 *	53.2 *	2.68 *	1.77 *	5.80 * *
1986	1.96 *	75.9 *	69.3 *	2.82 *	2.17 *	5.72 * *
1987	3.15 *	38.9 *	67.2 *	5.33 *	2.92 *	5.11 *
1988	2.23 *	56.7 *	42.8 *	3.94 *	3.17 *	5.17 *
1989	1.82 *	100.0 *	67.5 *	2.93 *	2.56 *	6.63 *
1991	2.26 *	30.8 *	24.6 *	2.41 *	2.49 *	8.36 *
L.S.D. .05	0.12	3.0	4.6	0.26	0.11	1.17

*Multiple range analysis: homogenous groups according to 95 percent L.S.D. intervals

Cured leaf yield

Low yield was obtained in years with low soil nitrate nitrogen content in spring and/or with high rainfall in June (1985, 1986, 1989). The cool and rainy weather in the early part of the season resulted in shallow rooting on the one hand, and in leaching available nitrogen on the other. It is a common experience in Hungary that final yield and quality are decisively influenced by weather prevailing in the early portions of the growing season. The high yield obtained in 1987 is a good indicator of the responsiveness of tobacco to the available N present in the 0-60 cm soil profile at the beginning of the season.

The response of yield to N fertilization is reflecting similar pattern as does the average level of yield for a particular year (**Fig. 1**). The response was sharp in 1985 and in 1989, years with abundant rainfall in June, but it was slight in 1987 and 1988 when rainfall was low.

Ripening rate

The rate of ripening tended to show an inverse relationship to yield with yearly variation being highly significant. Early ripening in 1985, 1986 and 1989 is accounted for by the depletion of available nitrogen by the time of harvest, resulting from the low initial nitrate-N content in the soil and/or high amount of rainfall in June. Ripening was retarded by the high initial nitrate-N content and drought in 1987, and again by the high amount of rainfall in late July that followed a long spell of drought in 1991.

Ripening did not respond to N fertilization in 1985 and 1989 (**Fig. 2**). In these two years the application of higher levels of N fertilizer, while exerting no adverse effect on ripening rate, was essential for yield improvement. As expected, ripening rate was retarded by higher rates of N fertilizer in the other years of the study.

Visual quality

The percentage of the best three grades was low in 1985, 1988 and particularly in 1991, not reflecting the soil nitrate-N content and early season rainfall. It can be observed, however, that mid-season dry periods were followed by high rainfall in late July and August in each of these years. Nitrate-N that had been neither leached nor taken up before harvest time became now available to the plants, thus lowering quality. As it was the case for ripening rate, quality did not respond to N fertilization in 1985 and 1989 (**Fig.3**).

Chemical components

Yearly variation of total alkaloids and total nitrogen follow the same pattern, with total alkaloids being more responsive to cropyear effect (**Table 5**). The change in these two components from one year to the other is parallel to the changes in yield and is accounted for by the same factors.

The response of reducing sugars to year effect is less pronounced than that of the other characteristics.

Effect of N fertilization

Increasing the rates of N fertilizer resulted in a significant increase in yield and nitrogenous components, and a significant decrease in the ripening rate, visual quality and reducing sugars.

Table 6 Crop characteristics as influenced by N fertilization, averaged over years and cultivars.

Parameter / N kg/ha	Yield (t/ha)	Rate of ripening %	Visual quality %	Total alkaloids %	Total N %	Reducing sugars %
0	1.95 *	73.5 *	62.7 *	2.60 *	2.20 *	8.98 *
20	2.07 **	65.4 **	59.0 **	3.25 *	2.41 *	8.40 *
40	2.19 **	67.1 *	55.7 **	3.54 *	2.50 **	6.04 *
60	2.22 **	66.2 **	56.6 **	3.43 * *	2.51 ***	5.50 **
80	2.34 **	63.0 **	53.7 *	3.63 *	2.57 **	5.45 **
100	2.42 *	61.6 *	48.3 *	3.41 * *	2.62 *	4.43 **
120	2.46 *	60.7 *	42.7 *	3.60 *	2.77 *	4.12 *
L.S.D. .05	0.13	3.2	5.0	0.28	0.12	1.26

Effect of cultivar

Differences between the two cultivars are significant for all characteristics except for visual quality (**Table 7**).

Table 7 Crop characteristics as influenced by cultivar, averaged over years and N rates.

Parameter / Cultivar	Yield (t/ha)	Rate of ripening %	Visual quality %	Total alkaloids %	Total N %	Reducing sugars %
Hevesi 5	2.14 *	56.6 *	53.4 *	3.22 *	2.43 *	7.32 *
Hevesi 6	2.33 *	74.2 *	54.8 *	3.49 *	2.60 *	4.94 *
L.S.D. .05	0.07	1.7	2.7	0.15	0.06	0.67

CONCLUSIONS

Significant differences were obtained among years for all the characteristics studied.

The effect of cropyear was greater than that of N fertilization and cultivars.

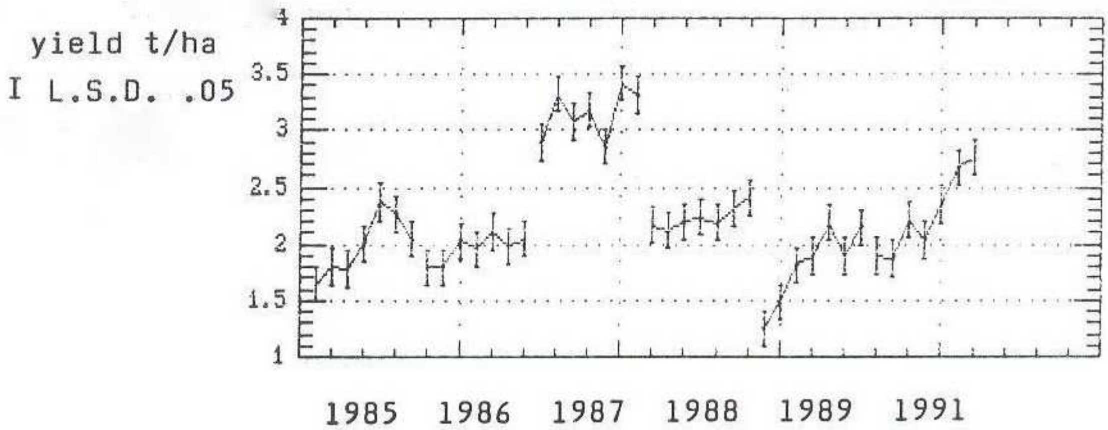
Two factor interactions were significant for yield, visual quality and ripening rate, indicating that differences between cultivars are highly affected by environmental factors and N fertilization, and also, the effect of N fertilization is influenced by the environmental factors.

Nitrate – N content of the 0-60 cm soil layer in spring and rainfall distribution are the most important environmental factors accounting for the yearly variation of crop characteristics.

The results of this study are further supporting the general experience that high variation in crop characteristics can be expected from one year to the other, even when plot site, cultural practices and cultivars are the same and irrigation is applied.

Figure 1. Response of yield to N fertilization

Kápolna



N fertilizer from 0 to 120 kg/ha as active nitrogen in each year

Figure 2. Rate of ripening as affected by N fertilization

Kápolna

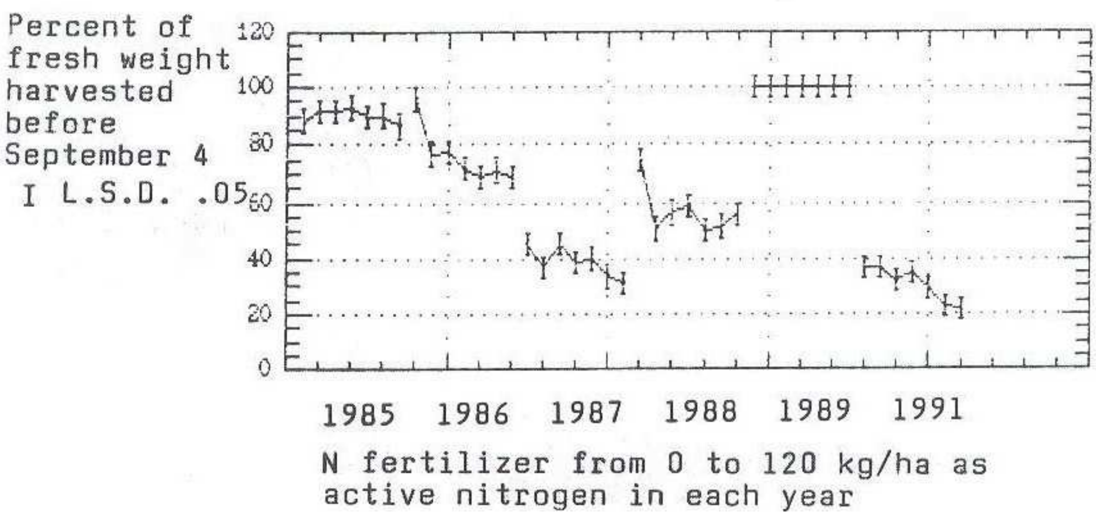


Figure 3. Effect of N fertilization on visual quality

Kápolna