IMPACT OF CLIMATE CHANGE ON THE PRODUCTION OF TOBACCO IN THE REGION OF PRILEP

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ABSTRACT

Tobacco production as a field of agriculture is one of the most vulnerable sectors to the effects of climate change. Changes in temperatures and rainfall, as well as frequent weather extremes have negative effects on productivity. This paper provides an insight into the effects of temperatures and rainfall during the past ten years on the tobacco production in Prilep production area. This study clearly indicates that tobacco production deserves more attention when it comes to both climate change threats and opportunities. Tobacco production needs adaptation measures in order to achieve better yield and quality. By presenting this study, we aim to advance the understanding and promotion of practical approaches to the challenges posed by climate change to tobacco production.

Key words: *temperature, rainfall, climate parameters, climate change, yield, quality of tobacco*

Introduction

Republic of Macedonia is in the central part of the Balkan Peninsula with total area of 25,713 km^2. Agricultural area covers 550 000 ha, from which 82 % is arable land and gardens (6). The agricultural sector is one of the most important sectors of the Macedonian economy. This sector employs more than 19% of the population and accounts for 12% from the GDP.

Tobacco production is very important agricultural filed in Macedonia. In 2011 33234 contracts were concluded and 26537 tones of tobacco were produced. More than 33000 families in the country are involved in the tobacco production.

This culture is the main occupation of the rural population. Tobacco is high profitable crop for manufacturers and for our country at all. This crop grows on areas where production of other crops is impossible and unsustainable. Tobacco participates with 22.2 to 29.6%, in the export of agricultural and food products and with 4 to 5% of the total export in the Republic of Macedonia. For producers, there is no such crop that can replace tobacco in achieving financial profits. This is even more pronounced with climate factors that have a trend of increasing temperatures and drought periods (9).

As climate is fundamental not only for quality but also for quantity of produced tobacco, there is a need for permanent study (2, 3, 8). Historical data indicate that Macedonia is characterized by high climate variability shown by: increasing temperature, lower humidity and occurrence of extreme phenomena, such as droughts, heat waves and forest fires (5). In this paper we will try to summarize the fifty- years data on the basic climate factors (temperature and precipitation) in Prilep and also to analyze their impact on yield and quality of tobacco produced in the field of Tobacco Institute – Prilep.

MATERIAL AND METHODS

10-year data were analyzed for the following parameters: average monthly air temperature, absolute minimum and maximum, average maximum temperature in warmer period, average minimal temperature in coldest months, last spring and first autumn frost, number of days without frost, total amount of rainfall by months and years. Based on the analysis, an overview picture will be obtained on the basic climatic factors in Prilep tobacco producing area. For comparison with the last decade, average data are presented for the period 1962-2011 for temperature and precipitation. The data are obtained from the meteorological station located at the Experimental field of the Scientific Tobacco Institute – Prilep. In order to determine the impact of climate and climate change

on the yield and quality of tobacco, results of a ten-year study of oriental tobacco grown in the field of Tobacco Institute are presented in this paper. For this purpose, data are taken from varieties where tobacco is grown with proper agro-technical measures and control variants in which climatic factors have a decisive influence on formation of their yield and quality.

RESULTS AND DISCUSSION

Tobacco production is a long, specific and very complex process consisted of several connected and interdependent stages.

The first stage is production of tobacco seedlings, which starts at the second half of March and ends at the beginning of June. All cultural practices in this stage (preparation of soil and seed beds, sowing), as well as duration of the vegetation period depend on temperature and humidity of the soil and air.

According to Donev (1972), minimal temperature for seedling development is 10-11°C, and optimal temperature is 20-25°C. The temperature also affects the length of seed germination period, which on the other hand determines the period when tobacco seedlings are ready for transplanting.

It was found that at a temperature of 10 °C, the seed germinates in 16 days, at temperature of 8°C germination occurs in 22 days, and at temperature of 6 °C in 28 days (7). The average monthly air temperature (°C) for the last ten years, as well as average data for the 50-years period (1962-2011) for Prilep tobacco producing area are presented in Table 1.

Table 1. Average monthly air temperature (°C) in Prilep tobacco producing area

Year	Months												Average	Average
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I-XII	V- IX
2002	-2.7	5.9	8.6	10.5	16.3	21.0	23.0	21.2	15.8	11.7	8.0	2.6	**11.8**	**19.5**
2003	2.7	-2.0	4.9	8.4	18.5	22.0	23.5	23.9	16.3	12.2	7.6	1.1	**11.6**	**20.8**
2004	-0.8	2.6	6.6	11.6	13.4	19.2	21.8	21.1	17.8	14.3	6.3	2.6	**11.4**	**18.7**
2005	0.9	-1.5	5.5	10.7	16.7	18.9	22.9	21.1	17.9	11.7	5.3	1.9	**11.0**	**19.5**
2006	-2.7	0.1	6.2	11.8	16.1	19.5	21.5	22.4	17.7	13.2	4.8	0.9	**11.0**	**19.4**
2007	4.8	5.0	7.9	12.1	16.9	21.6	25.3	23.7	16.9	11.8	4.8	-0.2	**12.6**	**20.9**
2008	1.0	3.8	8.2	11.9	16.7	19.9	22.3	23.6	15.8	12.5	7.7	3.0	**12.2**	**19.7**
2009	1.1	2.3	5.4	11.3	15.8	18.5	21.9	21.4	17.1	11.3	7.6	5.7	**11.6**	**18.9**
2010	1.7	3.5	6.8	11.3	15.3	18.8	21.3	23.1	15.9	9.8	10.3	9.8	**11.7**	**18.9**
2011	0.5	3.0	6.0	9.9	13.9	18.5	21.3	21.9	19.6	9.6	3.9	2.1	**10.9**	**19.1**
X_{02-11}	**0.7**	**2.3**	**6.6**	**10.9**	**16.0**	**19.8**	**22.5**	**22.3**	**17.1**	**11.8**	**6.6**	**2.9**	**11.6**	**19.5**
X_{62-11}	**0.3**	**2.6**	**6.7**	**11.1**	**16.1**	**19.9**	**22.2**	**22.1**	**18.2**	**12.8**	**6.9**	**2.0**	**11.7**	**19.5**

According to the data presented, the average air temperature in March is 6.6 °C. This temperature is unfavorable for normal germination of tobacco seeds. Sowing the seeds at these temperatures brings few days prolonged seedlings vegetation period. In April, the average monthly temperature is more favorable and it is 10.9 °C. Complete picture of the climatic factors cannot be done by average temperature data. During the spring months, large fluctuations of temperature are recorded: night temperatures are very low, and day temperatures are much higher. Certain agro-technical operations depend on these fluctuations. Characteristic of this period is the occurrence of late spring frosts that cause serious damage to the field production of tobacco seedlings. Data on the beginning of sowing and transplanting in field in the period 2003- 2012 are presented in Table 2. It can be concluded that early sowing is not a precondition for earlier seedling growth.

The shortest period of seedling growth was observed in 2008 (52 days) and the longest in 2012 (68 days). These variations are closely linked to climatic factors that determine beginning of the filed activities and biochemical and physiological changes of the tobacco seed.

Table 2. Duration of tobacco seedlings growing period (2003-2012)

No.	Year	Sowing date	Planting date	Duration of the growing period
1	2003	03.04	27.05	55
2	2004	07.04	09.06	64
3	2005	06.04.	03.06	59
4	2006	04.04	29.05	55
5	2007	14.03	11.05	58
6	2008	31.03	22.05	52
7	2009	29.03	27.05	59
8	2010	31.03	03.06	64
9	2011	26.03	25.05	60
10	2012	29.03	05.06	68

Table 3. Meteorological data for the period 2002 - 2011

Year	Absolute maximum		Average max. *T* of the warmest month °C	Absolute minimum		Average min. *T* of the coldest month °C	Last spring frost	Fist autumn frost	Total days without frost
	Date	°C		Date	°C				
2002	13.08.	35.0	29.3	5.01.	- 20.0	- 6.8	25.03.	31.10.	219
2003	17.07.	37.0	31.0	8.04.	- 10.7	- 5.2	9.04.	11.11.	215
2004	9.07.	35.8	28.2	14.02.	- 14.0	- 4.1	9.03.	17.11.	252
2005	3.08.	37.0	29.4	11.02.	- 20.1	- 5.6	4.04	18.10.	196
2006	20.08.	39.5	29.2	8.02.	- 18.2	- 6.0	14.03.	19.10.	218
2007	24.07.	41.0	32.8	22.12.	- 10.1	- 2.6	23.03.	15.10.	205
2008	14.07.	37.8	33.3	18.02.	- 13.3	- 2.5	26.03.	12.11.	230
2009	25.07.	38.5	30.6	01.01.	- 13.8	- 2.5	28.03.	15.10.	200
2010	14.08.	36.5	32.0	17.12.	- 16.7	- 1.5	20.03.	9.10.	202
2011	25.08.	38.3	32.5	25.12.	- 11.7	- 2.8	14.04.	18.10.	186

Tobacco production in field begins with completion of the first stage – seedlings production and usually ends with the occurrence of the first autumn frost (Table 3). 2011 is a year with the lowest number of unfrosted days (186), with the last frost being observed on 14 April and the first autumn frost on 18 October. Early autumn frost ended the vegetation and a part of the most quality tobacco was left in filed. Table 4 gives the average and absolute minimum and maximum temperatures in the observed period. In the last few years, the absolute maximum temperature has been recorded in July and August, ranging from 35 to 41°C. It can be seen in Table 1 that the average temperature in these months in the last decade has been 0.3, 0.2 °C higher than in the last 50 years, as a consequence of the global warming. The absolute minimum varied from -10.1 on Decembar 22th, 2011 to -20.1 on February. 4th, 2003. In the last 5 years, the maximum air temperature was high and averaged 32 to 33 °C.

Precipitation amount in the last 10 years, as well as the average precipitation in the last 50 years, is given in Table 4. According to the data presented in the table, a climadiagram is made to create a comprehensive graphical survey of the investigated climate parameters.

The amount of precipitations in the last several decades is presented in Table 5. May and June are the months with the highest amount of precipitation, which coincides with the beginning of soil preparation for tobacco transplanting.

The frequent and heavy rains in this period make impossible the use of mechanization in preparation of soil. Because of the excess of water, the quality of ploughing is poor, seedlings are overgrown and not well-established, and all this is reflected in yield and quality of the produced tobacco. In comparison with the multi-year average, precipitation in May in the last decade was 13.2 mm lower and in June it was 5.4 mm higher.

Table 4. Precipitation in Prilep area (1962-2011)

Year	Month												Sum	Sum
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I-XII	V- IX
2002	50.1	12.1	46.5	84.2	75.7	8.2	68.0	56.0	121.8	86.9	32.4	112.6	**754.5**	**329.7**
2003	37.7	12.4	4.8	39.5	9.4	49.8	26.0	35.0	45.9	139.5	22.9	30.0	**452.9**	**166.1**
2004	43.3	13.6	17.8	50.0	53.6	103.2	58.6	50.3	54.5	37.0	51.7	29.1	**526.7**	**320.2**
2005	42.9	49.9	27.9	24.0	47.8	56.8	19.3	80.0	7.8	43.5	30.8	77.0	**507.7**	**211.7**
2006	29.8	25.8	69.8	48.7	30.1	25.9	52.1	33.2	22.8	68.2	---	---	**406.4**	**164.1**
2007	---	---	---	15.2	74.3	79.5	5.3	54.2	16.6	112.4	82.4	44.6	**484.5**	**229.9**
2008	9.0	16.1	43.4	65.5	41.3	10.0	11.0	11.0	110.0	23.0	31.0	48.0	**419.3**	**183.3**
2009	75.0	5.0	27.0	39.0	55.0	75.0	8.0	43.0	15.0	78.0	95.0	63.0	**578.0**	**196.0**
2010	24.0	73.0	37.0	50.0	64.0	87.0	55.0	45.0	47.0	154.0	78.0	75.0	**789.0**	**298.0**
2011	20.0	22.0	26.0	19.0	63.0	51.0	17.0	11.0	38.0	33.0	2.0	59.0	**361.0**	**180.0**
X_{02-11}	**33.2**	**23.0**	**30.0**	**43.5**	**51.4**	**54.7**	**32.0**	**41.9**	**48.0**	**77.6**	**42.6**	**53.8**	**531.7**	**228.0**
X_{62-11}	**38.6**	**36.0**	**41.9**	**49.0**	**64.6**	**49.3**	**34.2**	**39.4**	**41.4**	**60.2**	**59.6**	**52.2**	**566.4**	**228.9**

In order to have normal growth and development of tobacco plant, the most favorable temperature is 20-30 ^{o}C. According to Atanasov (1965), the most favorable for oriental tobacco growth are the areas with average day temperature of 22 ^{o}C and precipitation of 120 to 150 mm.

During the vegetation period, Prilep area has 19.5 ^{o}C mean monthly air temperature and 228.9 mm precipitation. The average data on precipitation and temperature show that climatic conditions in this area are favorable for a good quality tobacco production. Unlike temperature, which is considerably uniform, in some decades there are high fluctuations in precipitation, both by months and by years. The lowest amount of precipitation of 164.1 mm was observed in 2006 and the highest in 2002, when 329.7 mm of rain fell during the vegetation period.

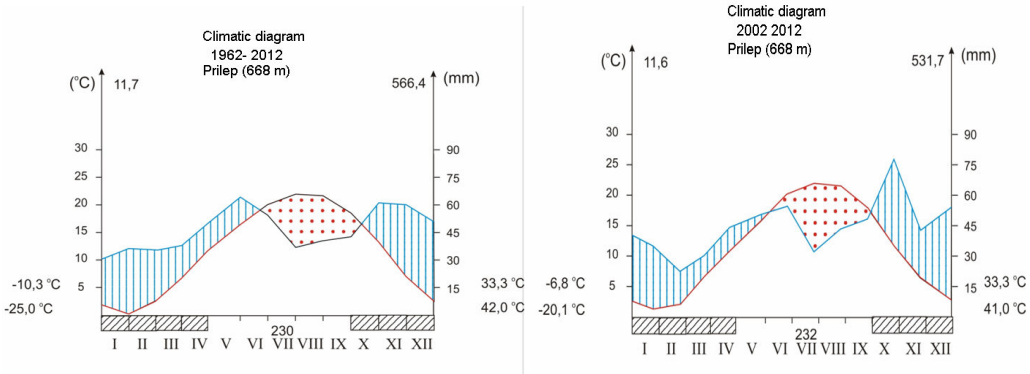

Fig. 1 Climatic diagrams

Precipitation distribution during the vegetation period has a very important role in formation of yield and quality of tobacco. From the detailed data on distribution and amount of precipitation by days (not presented here because of their extensiveness), we can see a high unevenness of these

parameters especially during the vegetation period. Average amounts of precipitation are sufficient for normal tobacco growth, but due to its uneven distribution, as well as unproductive rain (high amounts of rain in the short period of time), they are insufficient for the needs of tobacco plant. Under these conditions, nutrients are inaccessible to the root system; the plants are malnourished, with small growth, with a small number of leaves resulting in strongly reduced yield. Effects of the climatic conditions during the dry periods (control variant) can be seen in Figures 2 and 3. Irrigation is one of the effective measures for mitigation of harmful effects of the climate.

Fig 2. Control variant

Fig. 3. Irrigated variant

Data on tobacco yield, average price and gross income for the period 2000-2011, presented in Table 5, are obtained both from control variants where no agro-technical measures were applied during the vegetation period, and from the fertilized and irrigated variants. Experiments were performed at the Experimental field of Tobacco Institute – Prilep with oriental tobacco.

Table 5. Yield, average price and gross income of tobacco/ ha, (2000-2011)

Year	Yield(kg/ha)		Average price (den/kg)		Gross income (den/ha)	
	Control variant	Fertilized and irrigated variant	Control variant	Fertilized and irrigated variant	Control variant	Fertilized and irrigated variant
2000	2116	2937	101.01	106.67	213588	313121
2001	2439	3157	99.05	109.11	241583	344278
2002	3213	3496	78.90	98.80	253506	345405
2003	2627	3329	91.49	94.33	240344	314025
2005	2666	3460	106.88	118.03	284722	407131
2006	2571	3408	101.43	105.23	262307	360129
2007	2240	3933	100.64	120.21	226368	473367
2008	1348	3230	78.89	113.84	106603	367667
2009	2557	3596	99.54	110.90	255175	398549
2010	2911	3287	130.71	122.61	380497	403019
2011	2878	3654	135.47	128.88	389883	470928
Average	2506	3408	102.18	111.69	259507	381602
%	100	135.99	100	109.31	100	147.05

It can be seen from the table that climatic factors have negative impact to the yield, quality and the gross income of the control variants, reducing the average yield for 35.99 %, average price for 9.31 % and gross income for 47.05%. Based on the presented data for temperature and precipitation in the last decade, their influence on yield and quality and prediction of climatic change especially during the summer period, it is necessary to undertake certain measures to buffer

the negative impacts of climate. In tobacco production those measures include: selection of new tobacco varieties resistant to drought, avoidance of seeding in open seedbeds, proper preparation of seedbeds in autumn, shortening of seedlings vegetation period, timely planting which will enable plants to utilize the spring precipitation for normal rooting, compulsory irrigation during the warmest months of the year, providing new sources of irrigation (drilling wells, building micro reservoirs), etc.

The third stage in tobacco production is curing. Oriental tobacco is sun cured. This is another stage that depends on the climatic conditions. If the year is dry, tobacco will have a good curing, it will retain the color typical for the class and thereby it will have a high quality. In wet years, tobacco drying process is prolonged, the color is darker and occurrence of mold is possible, by which the quality of tobacco raw material will be impaired.

CONCLUSIONS

Based on the analyses of climate conditions in the Prilep region and the results of field trials, the following conclusions can be drawn:

- Average monthly air temperature in the last decade in the warmest months is higher for 0.3 ^{o}C in July and 0.2 ^{o}C in August compared to the five-decades period (1962-2011), as a consequence of the global warming.
- Average amount of precipitation has high fluctuations both by, months and by years. Uneven distribution as well as unproductive rain (high amounts of rain in a short period of time), strongly affects tobacco yield.
- Climatic factors reduce the gross income for almost 40%, which reduces twice the gross profit per unit area.
- For successful tackling a climate change there are few necessary adaptive measures, among which: selection of new tobacco varieties resistant to drought, avoiding sowing in open seedbeds, autumn seedbed preparation, shortening the seedlings vegetation period, timely planting which will enable the plants to use the spring precipitation for normal rooting, irrigation during the warmest months of the year, providing new sources of irrigation – drilling wells, building micro reservoirs etc.

- Tobacco is a crop that can well adaptate to climate change. This crop is cultivated on the land where the production of other crops is impossible and unsustainable. It can accomplish high gross income per unit area with minimal agro-technical measures. According to that, tobacco is highly adaptable crop that can be successfully grown in Prilep area in the future.
- Having in mind the tobacco subsidy of 1 euro per kilogram, this labor-intensive crop will continue to be unreplacable, with no alternative in the areas where it is grown.

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