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Regime of Soil Temperature During the Sowing Period of Spring Crops in the Some Stations of South-Eastern Bulgaria

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Abstract. Object of this study is the regime of soil surface temperatures down to 20 cm depth during the period of sowing and initializing stages of spring crops development. The area to the west of Burgas is on the border of the Black Sea sub region of the Continental-Mediterranean region. The annual course of rainfall is characterized by maximum during November and minimum in August. Less pronounced is the continental influence with a secondary maximum in June. The area is generally classified as dry but mitigated compared to the interior of southern Bulgaria and with higher relative air humidity. In terms of temperature conditions, the spring is a cooler and the sharp decreases are lower. The agro-ecological resources of the region during the last 30 years have defined it as dry, moderately hot. Increasing tendencies last 30 years in air temperature have been established compared to 1961-1990. In recent years, scientists have focused their research mainly on air temperature. It is known that soil temperature is very important, and in the initial stages-the main for development of spring cultures. Are there any trends in the climatic conditions of the depth of sowing of spring cultures (above the surface of the soil, 0.00 m, 0.02 m, 0.05 m, 0.10 m and 0.20 m) is also an issue of scientific interest? The aim of the research is to study the regime of the soil temperature during the spring months in relation to the precision of sowing and the start and development of some spring crops grown in the South-Eastern Bulgaria.

Key words: climate change, spring crops, ten days soil temperatures, sowing period.

Introduction

The analysis of the data on the main meteorological elements during the last century shows tendencies of air temperature increasing and decreasing or changed distribution of rainfall during the seasons (KAZANDJIEV *et al.*, 2008; KOLEVA & ALEXANDROV, 2008). Regarding the temperature conditions is clear that for the period 1971-2000 compared to the current climate the average annual air temperature has increased by 1.5°C in northern Bulgaria (KAZANDJIEV *et al.*, 2008; 2009; EITZINGER *et al.*, 2008). The new publications for the period 1988-2017 show that the average annual temperature in the region raised with 1.5°C compared to the period 1961-1990 (MARINOVA *et al.*, 2017). Changes in temperature and precipitation affect the development of spring crops. In the region of Karnobat, in recent years there have been changes in the thermal conditions during the

vegetation period. Studies show that the area has turned from an agro-climatic region with a lower temperature (warm) to a higher-temperate one (moderately hot) (GEORGIEVA *et al.*, 2018).

From the spring crops in the studied area, mainly maize, sunflower and some beans are grown. Many of the waste products are also used as concentrated feed in livestock. Some crops are also grown as second crops. In the studied region, in the last years, the production of sunflower is 13% of the entire country; grain corn - 3%, and silage fodder- 19%. In the recent years, growing in the natural humid conditions has become risky. During the first 15 years from recent century on the territory of Bulgaria are registered at least 3 years with summer agricultural drought. The average maize grain yield in Bulgaria dropped to less than 1.8 t ha-1. Growing of rain fed maize is associated with great yield variability (POPOVA *et al.*, 2015).

Sunflower is commonly viewed as a drought-tolerant crop and consequently as a cropping opportunity for regions where water resources (used for irrigation) are decreasing and in situations where soil water deficit is expected to increase dramatically (GARCIA *et al.*, 2012). So, there is a growing interest in the cultivation of sunflower at the expense of corn. The region of south eastern Bulgaria is characterized with frequent summer droughts (GEORGIEVA *et al.*, 2017a; b) which lead to yield loses. In this case can using the agroclimatic resources of the region and carried out of earlier sowing. The both kind of crops are exacting to soil temperature at the sowing. Does the increasing air temperature leds to changes of the regime of soil temperature in the area as a matter to be explored in relation to the cultivation of different groups of spring crops?

The aim of the research is to study the regime of the soil temperature during the spring months in relation to the precision of sowing and the start and development of some spring crops grown in the area.

Material and Methods

Average daily air temperature (˚C) and the soil temperature at 0.02 m; 0.05 m; 0.10 m; 0.20 m; minimum radiative temperature from weather stations Karnobat and Yambol from the network of National Institute of Meteorology and Hydrology (NIMH) are used. Long term phenological data for the sowing and germination period of spring crops such as sunflower and maize from the archive of the Agrometeorology Division of NIMH are used. The dates of sowing (D1), germination (D2) and the interphase period (D2-D1) were analyzed in Julian days. The data are collected from the agrometeorological network according to the NIMH methodologies. Monthly values of the soil temperatures are obtained by average daily soil temperatures. The Man-Kendall test was used to detect trends in temperature variation. All results are visualized using Microsoft Excel. The study period is 1986-2015.

Results and Discussion

Agrophysical properties of the soil types depend on the season, weight, humidity, etc. Vertisols is the predominant soil type is (typical and leached) in the area. Generally, this type of soil is fertile, with a broad humus horizon, warm and very suitable for growing wheat, spring and vegetable crops. Their temperature coefficient of conductivity is low 3.0*10-7m2.s-1 (MARINOVA, 1993). We compared the data from two thirty-year-olds periods shows an increase in soil temperature in the shallow soil layers during the period 1986-2015 compared to the period 1961-1990 in all months, with the exception of November and December when the deviations were negative (Fig.1). A similar trend was observed in the air temperature in the study of some stations in the region of Southern Bulgaria (GEORGIEVA *et al.*, 2017b). Highest are the summer deviations from May to August when their values are between 1.0°C and 1.5°C (Fig.1).

Sunflower is a culture with a large ecological plasticity and is grown in most of the country's regions. It is resistant to cold as the young plants tolerate spring frosts of about minus 5.0° C. It has been found that, when the soil temperature rises above 5.0°C (KIRYAKOV & GUROVA, 1969), a satisfactory growth rate of the seeds is observed. Optimum conditions for sowing the crop are observed when the soil is warmed to 8.0°C. The main agrometeorological indicator for maize sowing is the increase in soil temperature at drilling depth above 10.0°C (KIRYAKOV & GUROVA, 1969). In the study of ten days soil temperatures the focus is placed on the spring period when the sowing and the initial development of sunflower and corn take place.

Although the seeds are placed at a depth of about 0.05 m, the authors consider it appropriate to look at the values at adjacent depths due to the known physical laws of heat distribution. During the first ten days of March, the average temperature of the air is 4.6°C, the second ten days - 5.6° C, and the third is 7.8°C. The soil temperature is slightly higher at 5.0°C, respectively; 6.2°C and 8.7°C (Fig.2).

In April the ten days air temperature are 9.9°C; 10.7°C; 12.3°C as the soil are 11.2°C 12.5°C and 14.5°C respectively.

In May, ten days values of air temperatures were 14.0°C, 16.0°C and 17.0°C, and on the ground 17.0°C, 19.3°C and 20.8°C. By the end of March conditions were favorable for maize sowing, but due to the possible late spring frosts and the adverse impact of soil amplitude, sowing was postponed until April (Fig. 2).

Data on the average ten days temperature above soil indicates that it is colder in the Karnobat region. In the first and second ten day period of March, temperatures are negative below minus 2.5°C as the average value for the third ten days period of March is negative. In Yambol the value in the first ten days is minus 1.4°C but in the second ten-days the value is lower minus 1.6°C. This fact is important during the sowing of medium and late crops such as maize, which are affected by late spring frosts. During the third ten days in Yambol the average temperature over soil is close to 0.0°C, but positive (Fig. 3).

The phenological development of sunflower and maize should be related to agro-meteorological conditions. Data show that maize sowing in both regions is at the end of the second ten days period of April. Sunflower sowing is delayed compared to the recommended limits and occurs during the same period (Table 1). According to the phenological data maize seeds at Karnobat germinate on average for the 12 days, the fastest 8 days, and the slowest for 16 days. At Yambol the duration is average 13 days, 9 days and 27 days (Fig. 4.). The sunflower in the region of Karnobat grows on average for 15 days, the shortest for 9 days and the longest-23 days. The sunflower in the region of Yambol grows on average for 11 days, the shortest for 4 days and the longest -24 days (Fig.5.). There is a 19 days difference in sowing period between the two stations.

Optimal sowing dates define the optimal development and productivity of spring crops. At the same time they are passive method of impact against the adverse effects of weather factors such as summer droughts typical for Southeast Europe and the research area. Sowing times are determined by the combination of heat and humidity.

Generally, winter precipitation is a prerequisite for good wetting conditions in early spring. Recent air temperature studies show statistically significant increases over the growing season (MARINOVA *et al.*, 2017; GEORGIEVA *et al.*, 2017a; b; GEORGIEVA *et al.*, 2018). For the initial development of plants, soil temperatures are essential. In this sense, the authors aim to verify that there are similar changes in the soil temperature at the depth of sowing. Ggraphical presentation (Fig.1) shows positive deviations in monthly soil temperature values.

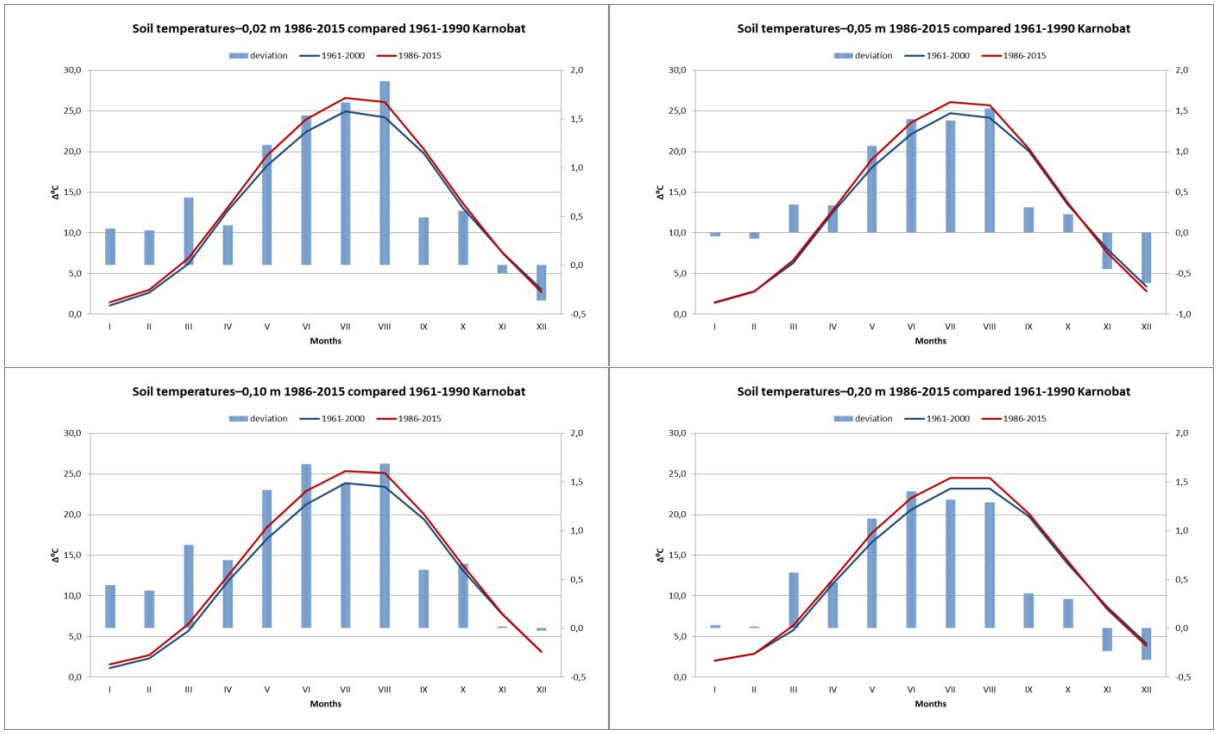

Fig. 1. Comparison of the annual course of soil temperature during 1986-2015 and 1961-1990 in station Karnobat for different soil depths.

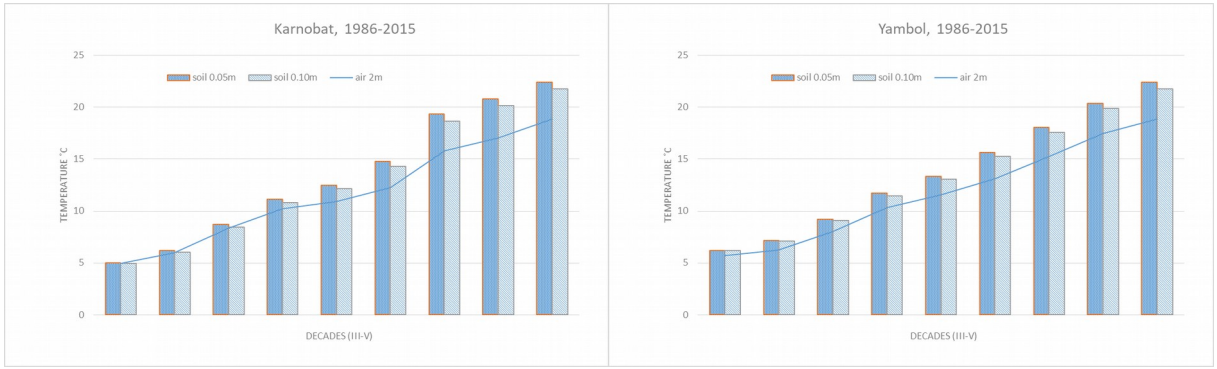

Fig. 2. Ten-days air and soil temperatures during the period of 1986-2015 for two soil depths – 0.05 and 0.10 cm in stations Karnobat and Yambol.

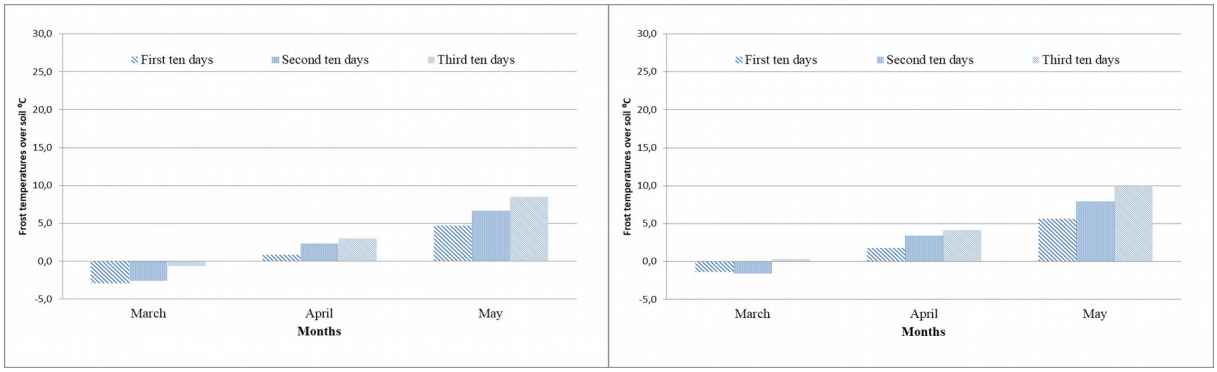

Fig. 3. Minimum radiation temperature (frost) in Karnobat and Yambol.

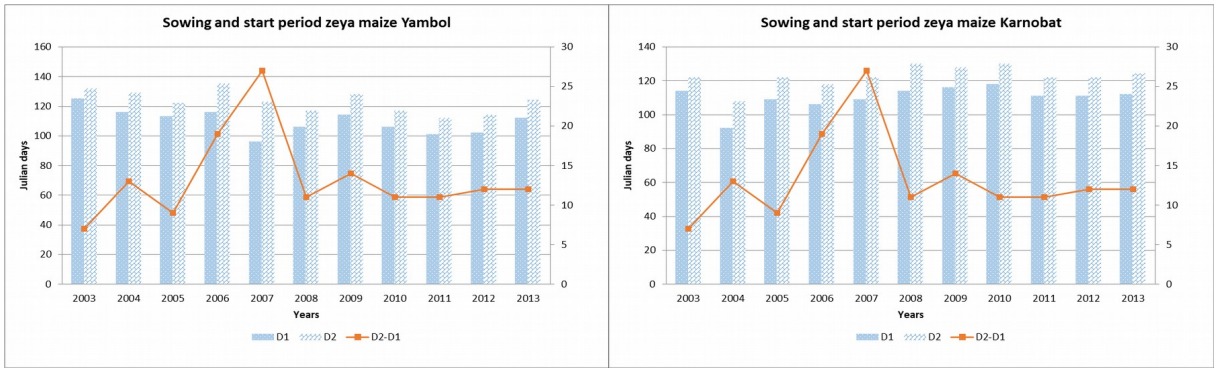

Fig. 4. Initial phenological development of maize in stations Karnobat and Yambol.

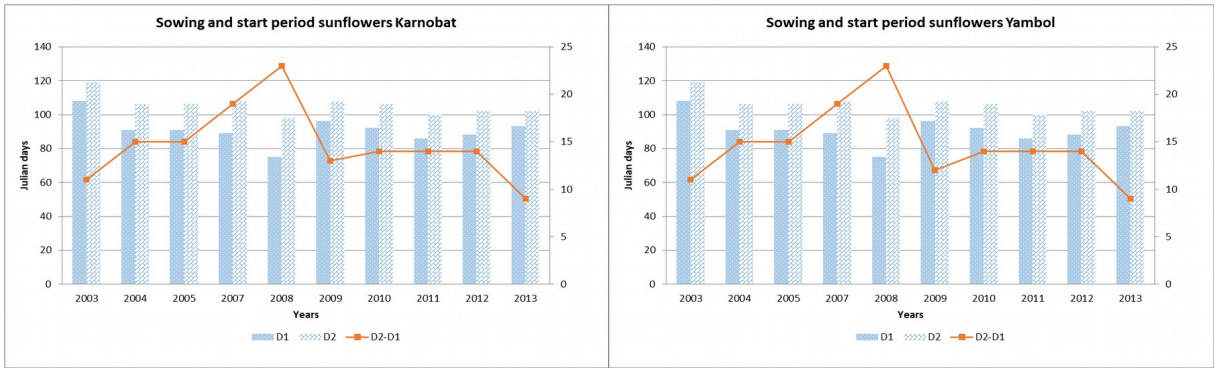

Fig. 5. Initial phenological development of sunflower in stations Karnobat and Yambol.

The analysis of the phenology data for the last 15 years in the region shows a significant delay in sowing dates compared to the emergence of favorable meteorological conditions. In terms of soil and air temperature and ecological requirements of crops, the best conditions in the area for sowing sunflower are observed in the first ten days of March in Yambol and the second in Karnobat. The data show that the conditions in Karnobat and Yambol are similar but in Karnobat is a bit cooler (Fig. 2) from Yambol. The same dependence is observed at the ten daily air temperatures.

According to Table 1, the earliest dates are as close as possible to the optimal periods, which for sunflower are the second ten days of March, and for the corn - mid-April. Spring frosts are essential for the sowing of corn as the plants are damaged at negative temperatures. So if the soil's temperature conditions are suitable for planting in early April, the risk of frost shifts it later. However, positive trends in radiation minimum temperatures suggest a detailed study of the frosts and a shift of the sowing period early. Thus, the plants will have better development conditions later, through a reproductive phase, will complete their early development and will enable the cultivation of second crops. The authors believe that the right link between science and practice and the monitoring of short-term forecasts will be useful for better organization and higher yields.

The statistical analysis show positive trends in the ten-day temperature of different depths during the spring period (Table 2 and 3). Positive trends in the minimum temperature above soil, which is in relation with the frost, are essential for spring crops. These are observed mainly in March and May in Karnobat which should affect early and late spring cultures.

The established tendencies in the increasing soil and air temperature during the

vegetation season and positive trends in minimum radiation temperature favor the sowing of the spring crops. As a recommendation for the region of South-Eastern Bulgaria, it can be said that sunflower sowing can be done early in the third ten days of March, when the conditions are already favorable. This will pull phenological development forward and reduce the negative impact of summer droughts. Sowing maize is also delayed compared to the period of favorable weather conditions in the area. During the sowing period of maize, the limiting factor is the spring frost.

Table 1. Dates of sowing and germination of maize and sunflower.

	Average	**Earliest**	**Latest**	**Average**	**Earliest**	**Latest**
			Maize			
Karnobat	20.IV	2.IV	28.IV	2.V	18.IV	10.V
Yambol	19.IV	6.IV	5.V	4.V	22.IV	15.V
			Sunflower			
Karnobat	1.IV	16.III	18.IV	15.IV	8.IV	29.IV
Yambol	20.IV	25.III	16.V	1.IV	6.IV	26.V

Table 2. Significance of average soil temperatures trend by Mann-Kendall test in the 1986-2015 on Yambol station. Legend: *** α=0.001; ** α=0.01;* α=0.05; + α=0.1

Period	**n**	**Values**	**Test Z**	**Significant**	**Q**
1992-2015	24	Rad-min. T ^{0}C Mart	2.16	*	0.11
1992-2015	22	0.20 m ^{0}C March II	2.32	*	0.12
1992-2015	22	0.20 m ^{0}C April II	2.00	*	0.09
1992-2015	22	0.20 m ^{0}C April III	1.75	+	0.06
1992-2015	24	0.05 m ^{0}C May II	2.06	*	0.10
1992-2015	24	0.00 m ^{0}C May	1.95	+	0.07
1992-2015	24	0.02 m ^{0}C May	2.05	*	0.07
1992-2015	24	0.05 m ^{0}C May	2.30	*	0.06
1992-2015	24	0.10 m ^{0}C May	1.81	+	0.05

Table 3. Significance of average soil temperatures trend by Mann-Kendall test in the 1986-2015 on Karnobat station. Legend: *** α=0.001; ** α=0.01;* α=0.05; + α=0.1.

Period	**n**	**Values**	**Test Z**	**Significant**	**Q**
1986-2015	30	Rad-min. T ^{0}C Mart I	2.21	*	0.14
1986-2015	30	Rad-min. T ^{0}C Mart II	2.15	*	0.10
1986-2015	30	Rad-min. T ^{0}C May I	2.96	**	0.12
1986-2015	30	Rad-min. T ^{0}C May II	3.05	**	0.13
1986-2015	30	0.00 m ^{0}C May III	2.17	*	0.12
1986-2015	30	0.02 m ^{0}C May III	2.17	*	0.11
1986-2015	30	0.10 m ^{0}C May III	3.05	**	0.11
1986-2015	30	0.05 m ^{0}C May I	1.71	+	0.07
1986-2015	30	0.10 m ^{0}C May III	2.37	*	0.10
1986-2015	30	0.05 m ^{0}C May III	2.37	*	0.10
1986-2015	30	0.20 m ^{0}C May III	2.42	*	0.08

Conclusions

The average values of the air and soil temperature from 0.02 m to 0.20 m as well as minimum radiation temperature above soil during the spring period were calculated.

The deviations of the monthly values of the soil temperatures for the study period compared to the period 1961-1990 are positive. Exceptions are November and December when the deviations are negative.

Positive, statistically significant trends in the soil temperature in ten days periods during the sowing season of crops were observed. The positive trend in minimum radiation temperature in Yambol in March is important for the sowing and start development of spring crops.

According to the results obtained and the phenology analyzed, it is appropriate to bring forward the sowing periods in the area.

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