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AGRO-CLIMATIC CONDITIONS FOR GROWING OF SUNFLOWER IN DIFFERENT CLIMATIC AREA IN BULGARIA

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Abstract

Assessment of agro-climatic resources of the agricultural regions relates to the biological requirements of the crops and the applied agricultural techniques. Agro meteorological conditions determine 65-80% of the potential productivity of agricultural crops. In the years after 2000, unfavorable tendencies in the values of meteorological elements, as well as an increase in the frequency of extreme weather events, are a fact. These features of the weather create risky conditions for the cultivation of sunflower in some areas of traditional producers of this crop. The aim of this study is the assessment of the agro-climatic conditions for the cultivation of sunflower in Bulgaria. A comparative analysis and evaluation of the agro-climatic conditions for growing sunflowers in three locations - Chirpan, Karnobat and G. Toshevo and their influence on the growth, development and productivity of sunflowers was made. The experimental fields are located in two climatic sub-regions of the European-continental climatic region - moderately continental (G. Toshevo) and transitionally continental (Chirpan and Karnobat) regions. The new climatic norms of the meteorological elements for the period 1991-2020 were used in the comparative analysis.

Key words: *sunflower, hydrothermal conditions, principal component analysis (PCA), phenology, yield.*

INTRODUCTION

Sunflower is the main oil-producing crop in our country and in most countries of Central and Western Europe. It is grown mainly for the production of sunflower oil, which is distinguished by varied unsaturated acids content (rich in linoleic acid and protein). According to the content of oil in the seeds, the sunflower occupies the second place after the soybean – 55% against 62.4%, among the oleaginous (oil-bearing) crops in our country. Sunflower seed and oil have been considered as a part of the healthiest diets as they could be a rich source of various phytochemicals, tocopherols, sterols or microelements (Rauf et al., 2020).

Because of these qualities, its production rapidly increased in the second half of the 20th century. The largest amount of sunflower is produced in Europe, and among the countries producing this crop in the EU, Romania ranks first with 3450 thousand tons, followed by Bulgaria 1940 thousand tons, Hungary 1830 thousand tons, France 1325 thousand tons, Spain 960 thousand tons and Italy 250 thousand tons. In the 70s of the 20th century, Bulgaria occupied the first place in the world in sunflower production per capita, averaging over 55 kg.

In conditions of climate change, and climate variability, especially during last decade at southern latitudes, temperature increases, precipitation decreases as well as increases in climatic inter-annual variability, and a higher frequency of extreme events are to be expected (IPCC, 2014). These combined changes will lead to a shorter growing season (especially grain filling phase), increased water deficit and heat stress, which will reduce yields, lead to higher yield variability, and probably reduce the agricultural area of this traditional crop in regions as Romania, and Bulgaria.

Over the last several years, the Bulgarian oilseeds industry has invested in expanding capacities, diversifying and adding value to sunflower crop. The country was a net exporter of sunflower seeds and during last several years has increased its crushing capacity. As a result of these developments, Bulgaria is on a trend to consume most of its sunflower crop and become a net exporter of processed products. The planting areas have increased because of higher profitability, low input requirements and better exporting possibilities. Nevertheless, some factors still limited the sunflower production (Valkova et al., 2016). Sunflower is considered as a moderately drought resistant plant. Its cultivation is dependent on global climate change marked by sudden enhanced temperatures, hailstorms, strong wind or erratic rainfall (Debaeke et al., 2020). High temperatures led to increase of leaves evapotranspiration, soil water extraction as well as the irrigation water demand. Sunflower crop is sensitive to drought and heat stresses from early flowering to grain filling stages due to inadequate availability of soil moisture. This conducted to significant reduction of yield and quality of seeds (Hussain et al., 2018). In sunflower, environmental factors have a great influence on the seed yield, as it is a polygenic character. Abiotic stresses especially supra-optimal temperature affect the viability of pollen, thus affecting the size and number of seeds produced by the plant (Razzaq et al., 2019; Mehmood et al., 2023). Significant results have been recently achieved in sunflower breeding program in DAI-General Toshevo. Some new sunflower hybrids, such as Krasela, Enigma and etc., with high productivity and resistance to abiotic and biotic stress factors were registered and distributed in Bulgaria (Georgiev et al., 2018; Nenova et al., 2019).

Climate change is causing changes in the conditions under which ecosystems grow and develop. This leads to changes in their growth, development and productivity. To the greatest extent, this applies to the cultivation of agricultural crops, as changes create conditions that lead to the reduction of plant productivity, mainly caused by biotic and abiotic stress factors.

The assessment of agrometeorological conditions in Bulgaria over the last 30 years and their changes compared to the previous period (Georgieva et al., 2022) show an increase in average monthly air temperatures in all regions of the country from January to September. The trend of advancing the beginning of the growing season compared to the reference period is also confirmed in the transition through 10°C. The period with temperatures above 5°C in the agricultural regions of the country lasts 235-300 days.

During the October-March period, an increase of more than 10% was found in the amount of precipitation in North-Eastern Bulgaria. A decrease in precipitation amounts is observed in Central North, East and South-West Bulgaria. The previous studies for the period 1971-2000 show that in the central part of the Danube Plain, full saturation is reached in the root zone. Second period, April-June, the deviations of the sums of precipitation are mostly negative, and reach 10-15% in Central and North-Eastern Bulgaria. The greatest decline is observed in the extreme north-western regions and in the extreme southern regions. The third period, June-August, is characterized by a significant decrease in precipitation in central southern Bulgaria and part of the Danube region. The deviation varies between 7 and 25%. An increase of more than 10% in the amount of precipitation is observed in individual stations in North-Eastern Bulgaria. The sunflower has a relatively long growing season. The hybrids that were created in our country or were introduced to our conditions belong, according to the duration of their vegetation period, to the group of mid-early mature with duration up to 130-145 days. For their full development, sunflower crops in our country need a sum of active temperatures of 2600-2850°C. According to the research of some authors, the best production results are obtained if average temperatures in July-August are 21-22°C and optimal humidity levels. In correspondence to the heat conditions, the sunflower maturity considered is occurs around August 10-15 in the Danube Plain and around August 15-20 in Dobrudja.

Regarding moisture conditions, it is considered that the need fluctuates in 9-13 l/m² during the vegetative development and reaches up to 50-60 l/m² during the formation of the yield and pouring of the grain. Because sunflower plants developing a powerful central root that reaches a depth of 2-3 m. Under such conditions yields of 2800-3900 kg/ha are considered very well.

Similar studies have been conducted in some European countries (Debaeke et al., 2017) in France, (Kalenska and Rizhenko 2020) in Ukraine, (Eloisa Aguera, 2021) in Spain. In these studies, the authors pay attention to climate changes and conditions for sunflower development in their countries.
There are also many other studies related to the growth and productivity of this culture, but they are more or less intertwined with other goals of their authors, such as monitoring methods (López-Granados et al., 2008; Buzna et al., 2023), different norms of fertilization, etc.
The aim of this paper is to assess hydrothermal conditions for sunflower cultivation and their impact on the yield in three experimental fields located in two climatic sub-regions.

MATERIALS AND METHODS

For this study, the data from the planned experiment carried out within the National Research Programme "Smart crop production" in three locations - Chirpan, Karnobat and G. Toshevo during the period 2020-2023. Data from standard meteorological and agrometeorological observations in the network of National Institute of Meteorology and Hydrology for the period 1991-2020 are used also. Observations include data on temperatures - average, maximum and minimum, total precipitation, relative humidity, wind speed, sowing dates, dates of occurrence of the main phonological stages, yield and water content in the soil. All observations and measurements were carried out in production areas. Observations include data on temperatures - average, maximum and minimum, total precipitation, relative humidity, wind speed, sowing dates, dates of occurrence of the main phenophases, yield and water content in the soil. All observations and measurements were carried out in production areas.
The regions of Karnobat and Chirpan are located in the Transitional-Continental climatic sub-region, the climatic region of Eastern middle Bulgaria, which is characterized by a mild climate - warm winters and hot summers.
General Toshevo is located in the Eastern climatic region of the Danube Plain, which is part of the Moderately Continental climatic sub-region. Cold winters and hot summers are characteristic of this region.
During the experiment from 2021 to 2023, the occurrence of the phenological phases was observed - second and fourth pair of leaves, inflorescence formation, flowering and technical maturity. In 2022 and 2023, the Krasela hybrid was grown in all three locations, and in 2021, P 64 HE 114 was grown in Chirpan, in Karnobat PL25, and in G. Toshevo - LE 25. During the experimental period biometric measurements was made. There were calculated some agrometeorological indices.
The main phenological phases were observed, the sowing dates and the interphase periods were recorded during the experiment. For comparison, the same data for the period 1991-2020 were used, Table 1. Meteorological conditions during the period 2021-2023 are characterized by average temperatures. Periods of severe and extreme drought over the years are at different times and of different duration and intensity, Table 2.

Table 1. Average multi annual dates of main phenological stages of Sunflower (*Heliantus annuus* L.) occurrence and duration of interphase periods in different regions of Bulgaria

Experimental fields	Sowing (date)	Inflores cence (date)	Flowering (date)	Maturity (date)	Sowing-Inflores cence (days)	Inflores cence-Flowering (days)	Flowering-Maturity (days)	Vegetation season
G. Toshevo	15.04	18.06	13.07	27.08	59	25	43	129
Karnobat	10.04	16.06	9.07	16.08	68	18	38	129
Chirpan	6.04	14.06	2.07	14.08	73	18	43	130

Table 2. Periods and duration with strong and extreme drought in 2021-2023

Station/ Year	2021	2022	2023
Chirpan	July, August and September ~90 days	May, July, August, October and November ~150 days	July, August, September, October and November ~150 days
Karnobat	July, August and September ~90 days	July, August, September, October and November ~150 days	July and August ~60 days
G. Toshevo	September ~30 days	July, August, October and November ~120 days	June, July, August and September ~120 days

RESULS AND DISCUSSIONS

The regions of Karnobat and Chirpan are located in the Transitional-Continental climatic sub-region, the climatic region of Eastern and Central Bulgaria, which is characterized by a milder climate - mild winters and warm summers, Figure 1. From the climatograms it can be seen that the average temperature during the winter months remains positive, and the highest and monthly values are in July. The amount of precipitation has a spring-summer maximum and a minimum in February and August.

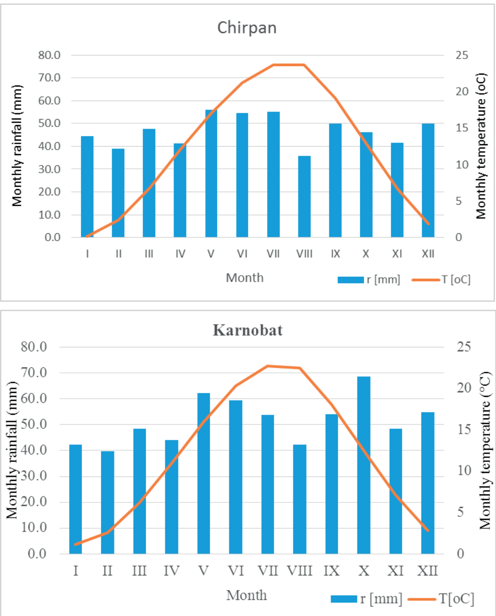

Figure 1. Climatograms for the regions of Chirpan and Karnobat (1991-2020)

General Toshevo is located in the Eastern climatic region of the Danube Plain, which is part of the Moderately Continental climatic sub region. This region is characterized by colder winters and hot and dry summers, Figure 2. The climatogram well shows these values characteristic of the region with minimum temperatures in January and maximum in July. The maximum of precipitation is in June and September, and the minimum in February and August, which is a prerequisite for prolonged periods with insufficient moisture.

A comparison was made of the conditions during the years of the experiment (2021-2023) compared to the period 1991-2020, the values of the average monthly temperatures were calculated, Figure 3 a-c and the rainfall totals for the three locations, Figure 4.

Deviations of air temperature in all three stations during the experiment, were positive. The largest positive deviations are in 2023. The deviations were positive in all three stations in January, February, July, August and November. During the growing season of the sunflower, the months of April, May and June are characterized by both positive and negative. The deviations in April 2021 and 2023 and in June 2021 in the three locations are negative. The Chirpan deviation in 2023 is negative. Figure 3 a-c.

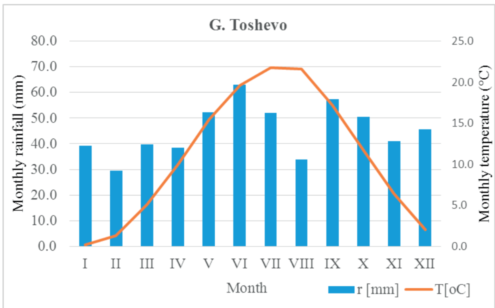

Figure 2. Climatogram for G. Toshevo in the period 1991-2020

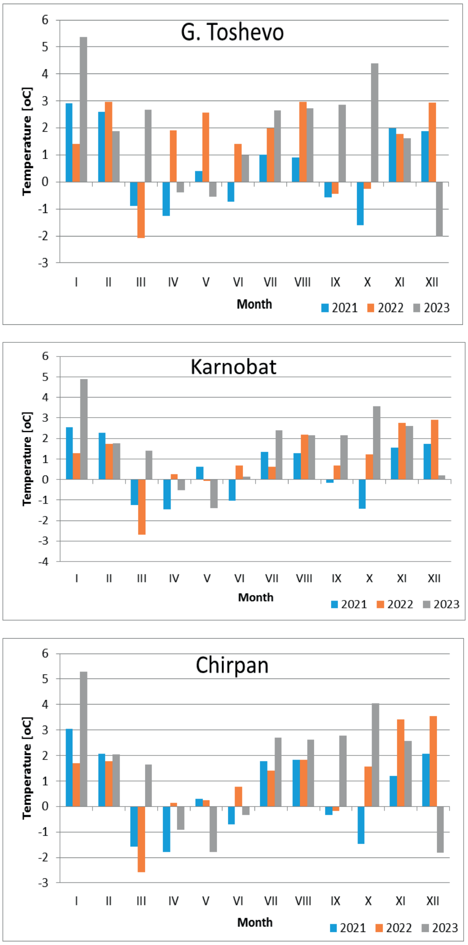

Figure 3. Deviations of average monthly air temperatures for the period 2021-2023 compared to the norm 1991-2020 in: a) G. Toshevo; b) Karnobat; c) Chirpan

The annual amount of precipitation had a positive deviation in 2021 in all three stations and a significant negative deviation in 2022. In 2023 in Karnobat and G. Toshevo deviations were also negative, but insignificant, while in Karnobat the precipitation was significantly below the climatic norm.

To study the influence of agrometeorological conditions, we conventionally divided the vegetation period into three sub-periods – from sowing to the formation of an inflorescence; from inflorescence formation to flowering and from flowering to ripening. During these periods, we tracked the dynamics of the sums of active temperatures and the sum of precipitation. The average duration of the growing season in the three locations is 129-130 days, Table 3.

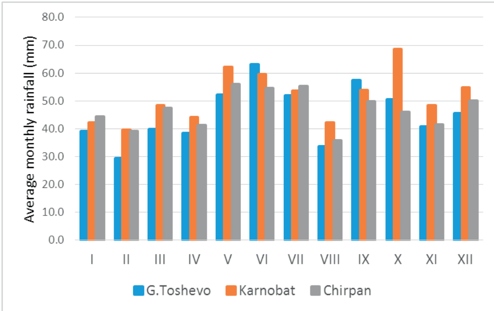

Figure 4. Monthly values of the amount of precipitation for the period 2021-2023

For the years of experiment the sum of active temperatures during the growing season, in Karnobat reaches 3445°C-4132ºC, in Toshevo this sums are 3197°C-4068°C, and in Chirpan 3960°C to 4230ºC. The amount of precipitation in Karnobat during the growing season is 216-375 mm, in Chirpan it reaches 278-352 mm, and in Toshevo this value is about 179-354 mm.

To characterize the humidification conditions, the precipitation amounts for the periods October-March and April-August in the three locations were determined (Figure5).

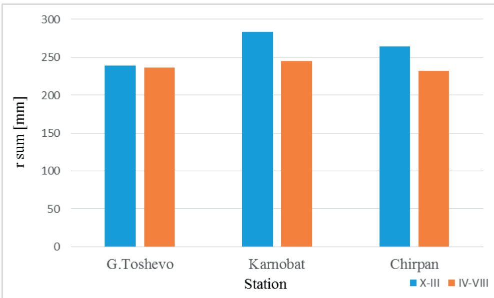

Figure 5. Multi annual rainfall sums during periods October-March and April-August for the periods 1991-2020

The amounts of precipitation during the period X-III in G. Toshevo are lower than those necessary to reach full saturation of the one-meter soil layer at the beginning of the growing season. In the rest two stations, the precipitation totals exceed 250 mm, which is a prerequisite for favorable humidification conditions at the start of the vegetation in the spring (Figure 5).

The sums of precipitation during the vegetation period for the years of the experiment are characterized by a positive deviation in 2021, negative deviations in 2022 and insignificant positive deviations in G. Toshevo and Chirpan and negative in Karnobat (Figure 6).

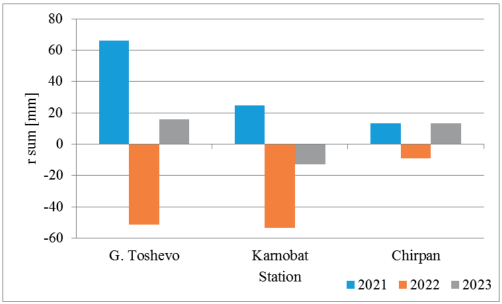

Figure 6. Rainfall sums deviations during sunflower vegetation period for experimental years and climatic norm (1991-2020)

The average yield of grain for the period 1991-2020 is respectively - in Karnobat 1.57 t/ha, in G. Toshevo 2.3 t/ha and in Chirpan 2.33 t/ha. The maximum yields are – Karnobat 2.7 t/ha, G. Toshevo 3.84 t/ha and Chirpan 3.6 t/ha.

The phenological development of the sunflower during the period of experiment was monitored in the following phases - sowing, inflorescence formation, flowering and maturity, Table 3. For assessment of development of sunflower development during the experiment was used the average dates of occurrence of phases and the duration of interphase periods, Table 3. The earliest sowing dates have been registered in Chirpan and Karnobat - during the first decade of April, except 2021 in Karnobat. In G. Toshevo the sowing date have been realised one month later, during the first decade of May. In relation to average dates significant deviation is finding in G. Toshevo. The base date here is 15 April. The earliest dates of maturity have been registered in Chirpan, during the second decade of August, after that in Karnobat, during the third decade of August and the latest in first decade on September in G. Toshevo.

To assess the relationship between yields and temperature-humidity characteristics of the regions, we applied multiple analysis using the method of principal components, where the components were the sums of effective temperatures for the periods from sowing to flowering - tef_sum1 and from flowering to ripening tef_sum2, as well as the sum of precipitation for these periods – r_sum1 and r_sum2 (Figure 7).

Table 3. Dates of main phenological stages of Sunflower (*Heliantus annuus* L.) occurrence and duration of interphase periods during the experiment (2021-2023) in the experimental sites

Location	Observed dates for phenol stages occurrence				Development periods duration			Vegetation Season Duration (days)
	Sowing (date)	Inflorescence (date)	Flowering (date)	Maturity (date)	Sowing-Inflorescence (days)	Inflorescence-Flowering (days)	Flowering-Maturity (days)	
G. Toshevo	6.05	1.07	30.07	9.09	86	29	41	126
G. Toshevo	10.05	5.07	28.07	8.09	57	22	42	121
G. Toshevo	8.05	20.06	21.07	13.09	73	31	54	128
Karnobat	16.04	30.06	11.07	25.08	75	11	45	131
Karnobat	10.04	8.07	18.07	28.08	89	10	41	140
Karnobat	5.04	30.06	15.07	25.08	86	15	41	142
Chirpan	8.04	17.06	30.06	15.08	70	13	46	129
Chirpan	6.04	15.06	29.06	11.08	73	14	43	127
Chirpan	4.04	16.06	3.07	15.08		17	42	132

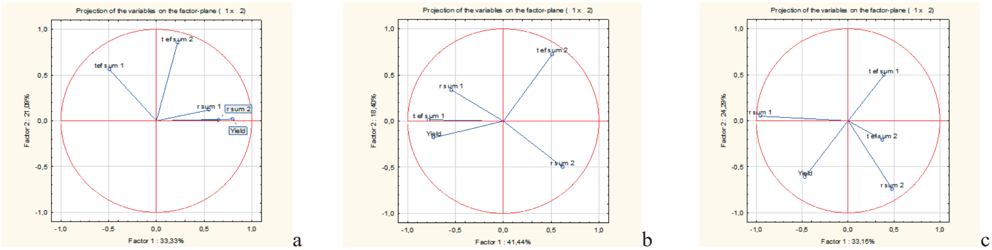

Figure 7. Principal Components Analysis for Karnobat a), G. Toshevo b) and Chirpan c)

The dates of phenological stages occurrence reported by us in comparison with the average dates of occurrence of the same stages for the last 30 years shows a deviation in the real vegetation period in Karnobat, but no more than 10%. Analysis of the duration of inter-stages periods shows deviations corresponding to differences in agrometeorological conditions. In G. Toshevo (2021 and 2023) and Karnobat (2022 and 2023) an extension of the leaves formation was observed.

The analysis of the results indicates that the yield of grain in Karnobat is most strongly influenced by the amount of precipitation during the entire vegetation period, as precipitation has a positive effect on the growth and development and productivity of the crop, and by the sum of the effective temperatures during the period from flowering to maturation. In General Toshevo, the impact of the sum of effective temperatures and the sum of precipitation on yields from sowing to flowering is decisive, their role is positive, and from flowering to maturity, there is a possibility that they have a negative effect during flowering. In Chirpan, as in Karnobat, yields depend on the amount of precipitation during the growing season, as the amount from sowing to flowering is decisive.

As a result of the conducted research and numerical experiments, we established the role and importance of temperatures, respectively the temperature sums of the effective temperatures and the sum of precipitation during the vegetative and reproductive periods of the development of sunflower crops in our country.

CONCLUSIONS

The temperature conditions in our country in all three locations are favorable for sowing and growing sunflower;

The mode of atmospheric humidification largely determines the productivity of sunflower crops, and the analysis indicates that in all three locations the amount of precipitation during the period from sowing to flowering is decisive;

In General Toshevo, the role of the sum of the effective temperatures from sowing to flowering is firstly decisive, and then the sum of precipitation during this period;

The differences of the main components in G. Toshevo compared to Karnobat and Chirpan are natural and are due to the fact that they are located in different climatic areas;

Due to the possibility of prolonged drought in Chirpan from July to September, and not infrequently until October-November, irrigation measures should be taken during the period of yield formation, and also a precise selection of hybrids should be made in view of their durability of drought.

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