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PRODUCTIVITY PARAMETERS OF SWEET CORN CULTIVATED UNDER METEOROLOGICAL CONDITIONS OF PLOVDIV

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Abstract

Sweet corn falls into the group of vegetable crops with great sensitivity to environmental conditions. In climate change conditions, the manifestations of its productive parameters arouse high scientific interest due to the wide application of this crop. Therefore, the purpose of this study is a comparative analysis of four promising sweet corn varieties for Bulgaria - Zeaton F1, Turbo F1, HMX5389 F1 and HMX59YS832 F1. The experiments were carried out under the meteorological conditions of 2023 and 2024 on the Agricultural University of Plovdiv territory. The results obtained provide information about the productive and morphological parameters of the varieties. The variety with the shortest vegetation period, Turbo F1, has the best productive parameters: ear mass, number of rows in the ear, number of grains per ear, grain weight per ear, weight of 1000 grains and length of the grain. The correlation analysis calculated the strongest relationship between ear mass and both the kernel weight per ear and the mass of 1000 kernels.

***Key words**: productivity parameters, sweet corn, heat stress.*

INTRODUCTION

Sweet corn (*Zea mays* var. *saccharata*) is a staple crop of significant economic and nutritional importance. It is a vital crop globally, valued for its sweetness, tender kernels, and nutritional benefits. The growing demand for sweet corn in fresh, canned, and frozen forms underscores the importance of improving productivity parameters to meet consumer needs. Its unique flavour, high sugar content, and versatility in both fresh and processed markets highlight the necessity of enhancing productivity. The productivity of sweet corn cultivation is influenced by multiple factors, including genetic traits, agronomic practices, and environmental conditions, with meteorological factors playing a crucial role in determining crop performance and yield outcomes (Morton et al., 2017; Popova et al., 2021). Productivity parameters are significantly affected by climatic and meteorological conditions, which shape growth, development, and yield potential. Plovdiv, Bulgaria, is characterized by its diverse weather patterns, making it an ideal case for studying the effects of these variables on sweet corn cultivation. Climate variability and change have an increasing impact on agricultural productivity worldwide. The influence of meteorological factors on crop productivity has been extensively studied.

The effects of temperature and rainfall variability on maize yields globally are examined (Smith et al., 2020). Changes in climate patterns influence phenological development and productivity, providing a comparative basis for understanding regional impacts.

Focusing on the Balkan region, it is identified that key climatic factors influence sweet corn production (Petkova et al., 2018). The changes and agrarian reform in Bulgaria since 1989 bring many risks and challenges to agriculture and irrigation opportunities (Kolcheva, 2024).

The interaction between irrigation practices and climatic conditions has been explored, demonstrating the significance of water management in mitigating the effects of climate variability on sweet corn yields (Chen et al., 2019).

Agrometeorological models tailored to Bulgarian conditions have been developed, offering insights into optimizing crop productivity under specific environmental scenarios (Georgieva et al., 2021). The phenological responses of sweet corn to climatic stressors such as heat waves and drought have been investigated, highlighting the need for adaptive strategies to sustain yields (Rahman et al., 2017).

Research into future climate scenarios shows how maize yields in the Midwest may be affected, emphasizing the role of climate variability in yield fluctuations and offering insights applicable to sweet corn (Southworth et al., 2000).

The effects of climate variability on maize yields, particularly drought episodes and their impact on productivity, have been analyzed, providing a comparative framework for assessing sweet corn's sensitivity to similar conditions (Omoyo et al., 2015).

Temperature and rainfall have been shown to significantly influence seasonal maize yields, offering valuable insights into seasonal climate impacts on sweet corn (Wang et al., 2022). Climatic stress factors such as rainfall variability and temperature extremes have been identified as key determinants of maize yields, shedding light on how sweet corn might respond to similar meteorological conditions (Cudjoe et al., 2021).

A methodological framework for assessing these effects on sweet corn in regions like Plovdiv has also been proposed (Mumo et al., 2018). The influence of temperature and rainfall variability on yields has been emphasised, underlining their importance for sweet corn cultivation (Attia et al., 2022).

Projections of future maize yield scenarios under climate change offer a long-term perspective relevant to developing adaptive strategies for sweet corn (Jones et al., 2003). Using a generalized least squares model, it is examined how climate variables influence maize yields over time, providing insights for modelling sweet corn productivity (Wu et al., 2021).

Maize yield vulnerability under various climate scenarios has been explored, contributing to a better understanding of adaptive measures applicable to sweet corn (Shi & Tao, 2014). The interaction of rainfall and temperature changes on maize yields, the need for adaptive measures in agricultural practices (Oseni & Masarirambi, 2011).

Changes in rainfall patterns are serious challenges (Liu et al., 2023). Heat and drought have been reported to increase osmotic stress and seed germination, plant growth, leaf expansion and ear development (Revilla et al., 2021). When heat stress is present during ear differentiation, there is a reduction in ear length and kernel row number. When heat stress is present during tasseling, there is a significant reduction in ear weight (Nemeskéri et al., 2019).

Climate change and weather variability have affected the growth and development of vegetable crops worldwide (Abewoy, 2018). The impact of weather variability is further enhanced by the frequent use of supersweet corn varieties, which have the highest potential yield but are most sensitive to drastic changes in daily air temperature and soil water availability (Nemeskéri et al., 2019).

There are studies about how environmental factors, particularly temperature and relative humidity, influence key productivity parameters such as cob size, kernel weight, and overall yield in sweet corn (Tas and Mutlu, 2021).

The importance of understanding these relationships is emphasised as key to optimising cultivation practices and ensuring sustainable production under varying climatic conditions.

The need for region-specific studies is also highlighted to develop tailored cultivation practices that maximise yield potential across different climate scenarios. This study aims to evaluate the productive parameters of several sweet corn hybrids grown in Plovdiv under temperature stress conditions at a later sowing date. Understanding of critical phases and appropriate hydrothermal windows during the hot summer period is discussed. The study will help farmers to select suitable hybrids, optimal sowing dates, as well as good agronomic practices. Understanding plant responses to environmental conditions and selecting the most adaptable variety is the first step in developing the best management practices for sweet corn production in the region.

MATERIALS AND METHODS

The experimental work was undertaken in the period 2023-2024. In the field of AU-Plovdiv, with four sweet corn hybrid varieties: Zeaton F1, Turbo F1, HMX5389 F1 and HMX59YS832 F1, with a sowing date of June 1. The plants were sown according to the scheme 70/20 cm. The experiment was carried out according to the block method in 4 variants with four repetitions, with 50 plants per repetition, and the size of the experimental plot was 7 m^2. Watering was carried out with a drip system. The following variants were tested: 1. Zeaton F1 - Control; 2. Turbo F1, HMX5389 F1; 3. HMX5389 F1; 4. HMX59YS832 F1. The plants were fertilised with Gold Forte – organo-mineral fertiliser containing N 48%, P 8%, K 4%, Mg 2%, Mn 0.4%, Mo 0.02%, Zn 2%, Free acids 6%, Alginic acid 0.2%, Gibberellic acid 150, pH: 4.5-6.5. Fertilisation was applied at a rate of 1000 ml/da, four times in vegetation- 2-leaf stage, 6-leaf stage, before tasselling, and during grain filling. The productivity of the plants was determined on 12 plants of a variant in consumer maturity in September by taking into account the total yield. The morphological characterization of the ears was done by determining the parameters ear length (cm), ear diameter (cm), ear mass (g), number of rows in the ear, number of grains in the ear, weight of grains in the ear (g), weight of 1000 grains (g), length of grain (cm), width of grain (cm).

Meteorological data. For this experiment, observations were organised on the hourly values of basic meteorological parameters. The data were collected using an automatic station located next to the experimental field. Data were processed for: maximum air temperature (°C), relative air humidity (%), wind speed in m/s meters per second at 2 meters above the ground surface, and humidity of the root-dwelling soil layer. The base temperature for corn development was assumed to be 10° C. The plants were grown under drip irrigation.

Statistical analysis of the data was performed using one-way analysis of variance (ANOVA), Fisher's least significant difference (LSD) test and correlation analyses.

RESULTS AND DISCUSSIONS

Sweet corn is very sensitive to high temperatures. Its entire cycle from sowing to harvest is significantly influenced by weather conditions. Some studies (Dhaliwal et al., 2022) show that temperatures during the growing season above 30 °C were detrimental to crop yields. Each additional degree day spent above 30°C during flowering reduces yields by 0.5% and 2% in irrigated and rainfed fields, respectively. Sweet corn is most vulnerable to heat waves during its reproductive period. In the first year, the most stressful conditions are observed in the last ten days of July, when air temperatures above 40°C, relative humidity below 25% and wind speeds at 2 meters above the ground surface of about 5 m/s are recorded. Air temperatures above 35°C prevail throughout the month (Figure 1).

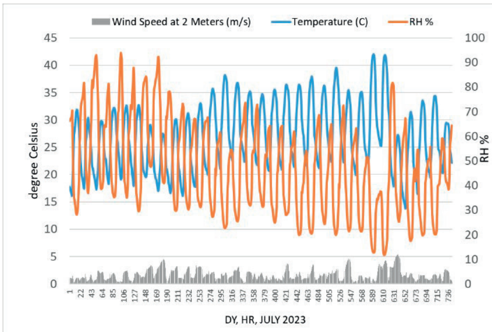

Figure 1. Distribution of Maximum Air Temperature (°C), Relative Humidity (%), and Wind Speed (m/s) by Hour in July 2023

Slightly lower values, around 30°C-32°C but with humidity between 85% and 95%, were recorded at the beginning of the month. In 2023, the least unfavourable period for the reproductive period of sweet corn was the last days of the first and last ten days of the month.

Conditions in July 2024 remain highly stressful, with better periods for the critical phases of sweet corn cultivation observed at the beginning and end of the month (Figure 2). A significant number of hours with air temperatures above 32°C and 35°C were recorded, mainly in the middle of the period.

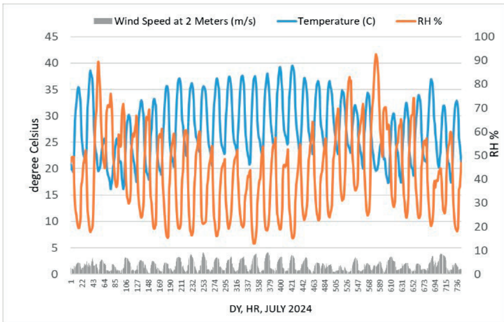

Figure 2. Distribution of Maximum Air Temperature (°C), Relative Humidity (%), and Wind Speed (m/s) by Hour in July 2024

In August, the hydrothermal conditions in the experimental area are slightly more favourable compared to those of the previous July (Figure 3). The middle of the period is most suitable for pollination. Throughout August 2024, there are a significant number of hours with relative air humidity below 25% (Figure 4).

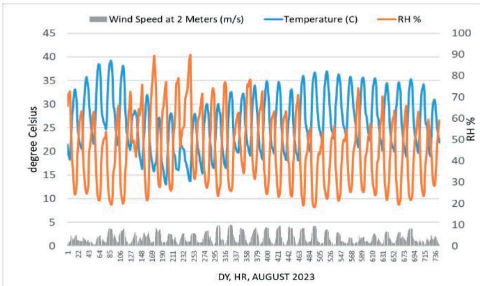

Figure 3. Distribution of Maximum Air Temperature (°C), Relative Humidity (%), and Wind Speed (m/s) by Hour in August 2023

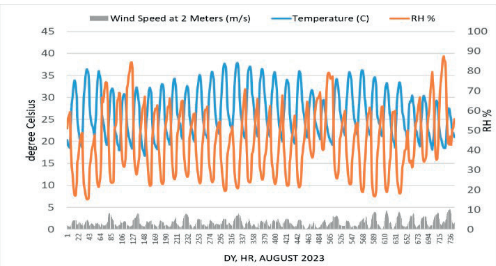

Figure 4. Distribution of Maximum Air Temperature (°C), Relative Humidity (%), and Wind Speed (m/s) by Hour in August 2024

During the critical phases at the end of the second decade, temperatures are slightly lower, and the wind is weakest.

During the two experimental years, a significant number of days with maximum temperatures > 32°C were observed, with more cases in 2024 than in 2023 (Table 1).

The cumulative accumulation of effective temperatures is shown in Figure 5.

Table 1. Number of days with maximum temperatures > 32°C in different intervals during the period June-August

Period/Temp.° C	32-34	34-36	36-38	38-40	>40
(VI-VIII) 2023	19	17	11	1	1
(VI-VIII) 2024	30	28	19	3	1

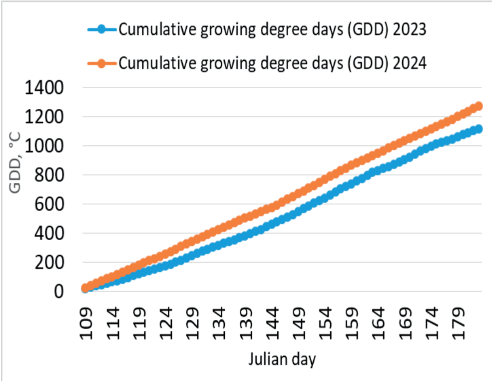

Figure 5 Cumulative growing degree days during experimental period

Growing degree days (GDD) are calculated by subtracting a base or threshold temperature from the average daily temperature. For corn, this base temperature is 10 degrees Celsius. The cumulative GDD10 shows year-to-year variability. The critical phenophases occurred around mid-July, depending on the hybrid.

The vulnerability of maize to drought in the Plovdiv region is very high due to the lower total available water (TAW = 116 mm) (Popova, 2015). The same authors determined net irrigation requirements (NIR, mm) for maize relative between 280 mm and 400 mm depending on the moisture conditions. Unlike grain corn, sweet corn is a vegetable crop, and irrigation is mandatory for yield. Soil moisture in the experimental plot was maintained in an optimal mode during both experimental years through the capabilities of a drip irrigation system (Figure 6).

The additional water provided significantly mitigated the adverse effects of heat waves on the studied plants.

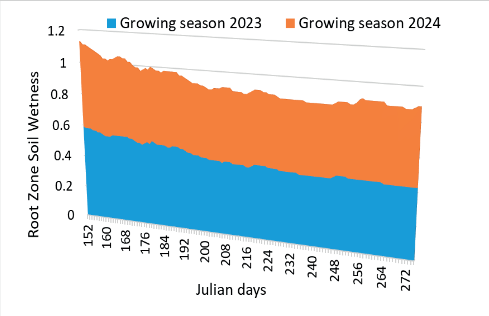

Figure 6. Root zone soil moisture wetness from June

Table 2 presents the two-year average values of biometric parameters of ear, grain and productivity recorded after maturation. The length and diameter of the ears vary slightly. The variety HMX5389 F1 has the longest ear, while the control variety Zeaton F1 has the shortest, with no statistically significant difference between them. For the other parameter, a significant difference of up to 5% is observed only between HMX5389 F1 and Turbo F1, but compared to control Zeaton F1, there is no significant difference.
For all other productivity parameters, the differences among the varieties are more pronounced and statistically significant. Regarding ear mass with grain, Turbo F1 has the highest mass and, along with HMX5389 F1, belongs to the same group. The control variety Zeaton F1 has the lowest ear mass, with a statistically significant difference from the above-mentioned varieties. The results for the parameter number of rows per ear, number of grains per ear, and grain weight per ear give advantage to Turbo F1, which exceeds the next varieties, HMX5389 F1 and HMX59YS832 F1, by an average of 15%. The greatest difference between Turbo F1 and the least productive variety Zeaton F1 is observed in the number of grains per ear, where all other varieties have a statistically significant difference of up to 5% compared to the control variety Zeaton F1.
For the indicator mass of 1000 grains, the trend in values is maintained, but with the difference that in HMX59YS832 F1, the higher number of seeds per ear leads to a lower mass of 1000 grains, which is the opposite of HMX5389 F1. In the most productive variety, Turbo F1 and the least productive control variety Zeaton F1, this inverse relationship is not observed.
The morphometric parameters of the grain indicate an advantage in grain length for the higher-yielding varieties Turbo F1, HMX5389 F1, and HMX59YS832 F1. Regarding grain width, HMX59YS832 F1 has the highest value, followed by Zeaton F1. Interestingly, there is a statistically significant difference between HMX59YS832 F1 and the high-yielding Turbo F1, which has the smallest diameter.
Table 3 presents the correlation dependencies between productivity parameters recorded after maturation. Parameters characterizing the ear, namely length, mass with kernels, and the number of rows, show a moderate to strong positive correlation with productivity indicators. The strongest relationship is calculated between ear mass and the kernel weight per ear and the mass of 1000 kernels. A similar strong correlation is reported by Agapie and Sala (2023).
A moderate correlation is observed between ear length and the indicators kernel weight per ear and mass of 1000 kernels, as well as between ear mass and the number of kernels per ear and the number of rows with kernel weight per ear. Agapie and Sala (2023) report correlations of the same strength. All of the above interactions are statistically confirmed at the 5% and 1% significance levels.
For the morphometric indicator kernel diameter, no significant positive correlation is calculated with the elements of productivity.
The strongest positive correlations among the morphometric indicators of the ear are calculated for ear length with ear mass and ear mass with the number of rows per ear. Among the productivity indicators, the most notable relationships are between kernel weight per ear and the mass of 1000 kernels, as well as the number of kernels with kernel weight per ear.
From the calculated correlation dependencies for the morphometric parameters of the kernels, only kernel length shows a strong positive and statistically significant impact on productivity and ear morphometry. The other indicator, kernel width, similar to ear diameter, does not influence any of the productivity indicators examined in the study.

Table 2. The productivity parameters of corn hybrids varieties

Parameters	Ear length (cm)	Ear width (cm)	Ear mass (g)	Number of rows in the ear	Number of grains in the ear	Weight of grains in the ear (g)	Weight of 1000 grains (g)	Length of grain (mm)	Width of grain (mm)
Zeaton F1-control	19.83	4.37	112.33	16.00	595.67	91.33	142.67	9.93	5.00
Turbo F1	20.67 n.s.	4.67 n.s	175.33 **	17.67 n.s	737.33 **	158.00 **	211.00 *	12.38**	4.07 n.s.
HMX5389 F1	21.33 n.s	3.97 n.s	153.00 *	16.00 n.s	698.67 *	128.67 n.s.	185.33 n.s.	11.00n.s.	4.87 n.s.
HMX59YS832 F1	21.00 n.s	4.37 n.s	143.00 n.s	16.00 n.s	722.67 **	111.00 n.s.	156.00 n.s.	11.67 *	6.17 n.s.
GD 5% *	2.23	0.51	36.93	1.69	98.46	39.96	59.35	16.4	1.46
GD 1% **	3.09	0.70	51.25	2.35	136.66	55.46	82.38	22.8	2.03
GD 0.1% ***	4.30	0.98	71.28	3.27	190.08	77.14	114.58	31.7	2.82

n.s. no significant difference

Table 3. Correlation coefficients between productivity parameters of corn hybrids varieties

Parameters	Ear length (cm)	Ear width (cm)	Ear mass (g)	Number of rows in the ear	Length of grain (mm)	Width of grain (mm)	Number of grains in the ear	Weight of grains in the ear (g)	Weight of 1000 grains (g)
Ear length (cm)	1.00	0.21	0.59*	0.05	0.52*	0.07	0.28	0.52*	0.59*
Ear width (cm)		1.00	0.32	0.29	0.51	-0.46	0.24	0.33	0.28
Ear mass (g)			1.00	0.54*	0.89**	-0.29	0.56*	0.98**	0.93**
Number of rows in the ear				1.00	0.60*	-0.49	0.51	0.63*	0.46
Length of grain (mm)					1.00	-0.35	0.52*	0.88**	0.82**
Width of grain (mm)						1.00	-0.20	-0.39	-0.28
Number of grains in the ear							1.00	0.53*	0.28
Weight of grains in the ear (g)								1.00	0.94**
Weight of 1000 grains (g)									1.00

*-correlation is significant at the 5%; **- correlation is significant at the 1%

CONCLUSIONS

The productive indicators of sweet corn in the Plovdiv region, grown at a late sowing date under conditions of high thermal stress, were studied. The experiment was conducted in two of the warmest years since 2020. During the growing season, 41 days with maximum temperatures > 32°C were recorded in 2023 and 81 days in 2024. Although 2024 is hotter and drier, pollination conditions are in a more favourable window compared to those in 2023. Under irrigation conditions, all observed hybrids have given good results. The variety with the shortest vegetation period, Turbo F1 has the best productive parameters: ear mass, number of rows in the ear, number of grains per ear, grain weight per ear, weight of 1000 grains and length of the grain. Irrigation has significantly mitigated the unfavourable hydrothermal conditions in the reproductive phases of sweet corn development. Therefore, temperature stress and increased evaporation lead to the need for higher irrigation rates.

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