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COMPARATIVE STUDY OF INTRODUCED SWEET CORN VARIETIES

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Abstract

Sweet corn is a crop highly sensitive to climatic conditions, which raises scientific interest in its productive indicators under climate change conditions. This study presents a comparative analysis of four promising hybrids for Bulgaria – Zeaton F1, Turbo F1, HMX5389 F1, and HMX59YS832 F1. The experiments were conducted in 2023 and 2024 on the territory of the Agricultural University of Plovdiv. The results show significant differences between the hybrids, with Zeaton F1 exhibiting the best biometric indicators and a maximum plant height. Plant development and especially critical periods coincided with stressful summer conditions. The second year was characterized by more extreme climatic events, but late sowing reduced the negative impact on yield. It was established that growing sweet corn in the dry conditions of Plovdiv is impossible without irrigation, while drip irrigation significantly improved moisture reserve. Hybrids with a shorter growing season showed better growth parameters when sown late. A strong correlation was observed between plant height and the number and length of leaves.

Key words: *productivity parameters, sweet corn, meteorological conditions, biometric indicators*.

INTRODUCTION

Sweet corn is significant nutritionally and economically. Numerous studies highlight its dual role as a nutritious food source with health benefits and as a commercially valuable crop in the agricultural and food industries. Sweet corn is a specialized type of maize, distinguished by its high sugar content during the milk stage (Singh et al., 2014). It is widely cultivated for fresh consumption, canning, and freezing, making it a key component of the vegetable industry. Additionally, sweet corn plays a crucial role in producing natural sweeteners, which serve as alternatives to synthetic sugars, thereby contributing to the food processing sector. The crop's market demand and adaptability to different agro-climatic conditions further establish its profitability.

The nutritional benefits of sweet corn position it as a future staple in human diets. Swapna et al. (2020) highlight its rich content of essential nutrients, including vitamins, minerals, and antioxidants, which contribute to improved digestion, eye health, and chronic disease prevention. Its tenderness and taste make it a versatile ingredient in various culinary traditions. Furthermore, the development of new varieties is essential to meet growing consumer demand and enhance its nutritional quality.

Agricultural factors play a critical role in determining the yield and quality of sweet corn (Sidahmed et al., 2024). Beyond its high sugar content and tender kernels, sweet corn is valued for its broad market appeal. Factors such as temperature, soil fertility, irrigation practices, and nutrient management directly influence its growth, development, and yield potential. Selecting varieties suited to specific agro-climatic conditions is essential for sustainable production. Additionally, advancements in agronomic techniques can lead to improved crop performance and greater profitability for farmers. Global research efforts have significantly advanced sweet corn cultivation in recent years. Revilla et al. (2021) discuss the crop’s significance as a nutrient-rich food source containing essential vitamins, minerals, and antioxidants beneficial for human health. Innovations in breeding techniques have improved disease resistance, stress tolerance, and nutritional content. Research also addresses challenges posed by biotic and abiotic stresses, such as pests, diseases, and climate variability, with modern agricultural practices and genetic improvements mitigating these issues. The growing global demand for sweet corn is driven by consumer preferences for healthier food options and its versatility in fresh and processed forms.

Recent studies provide valuable insights into sweet corn improvement. Revilla, Anibas, and Tracy (2021) offer a comprehensive review of research from 2015 to 2020, emphasizing genetic advancements, breeding strategies, and crop management innovations. Ziqi Li et al. (2024) explore the nutritional quality of sweet-waxy corn across three regions in China, demonstrating the influence of local environmental conditions on varietal responses. Tracy, Shuler, and Dodson-Swenson (2020) focus on genetic improvements, particularly the role of endosperm genes in enhancing kernel sweetness and texture.

Evaluations of vegetative and physiological traits have provided insights into the adaptability and productivity of sweet corn varieties. Elayaraja et al. (2018) emphasize the importance of combining ability and genetic factors in influencing growth, yield, and quality in hybrid sweet corn. Similarly, Tracy et al. (2020) examine physiological responses, such as photosynthesis and stress tolerance, offering guidance for breeding programs and agronomic practices. Collectively, these studies underscore the need to identify superior varieties with enhanced vegetative and physiological performance for sustainable cultivation across diverse ecological zones.

A synthesis of recent research underscores advancements in genetic improvements, market trends, and crop management strategies (Revilla et al., 2021). Studies demonstrate how regional environmental conditions influence the nutritional quality of sweet-waxy corn (Ziqi Li et al., 2024) and provide insights into varietal differences, physiological behaviours, and environmental interactions essential for sustainable production (Elayaraja et al., 2018; Tracy et al., 2020). Investigations into the role of endosperm genes continue to enhance sweetness and texture.

Building on these findings, this research aims to contribute to the broader knowledge of sweet corn improvement. The outcomes will support sustainable cultivation practices, inform breeding strategies, and aid in developing superior genotypes, benefiting stakeholders across the agricultural value chain. By analyzing growth parameters, photosynthetic efficiency, and stress tolerance, this study seeks to identify genotypes with enhanced adaptability and productivity. Integrating recent literature with field-based assessments, this work bridges scientific research and practical applications to advance sweet corn cultivation.

MATERIALS AND METHODS

The experimental work was conducted 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. The plants were sowed according to the scheme 70/20 cm on 1 June. 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 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 fertilized with Gold Forte-organomineral fertilizer 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. Fertilization 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.

By conducting biometric measurements, the vegetative behaviour in the consumptive maturity of 12 plants of the variant was monitored. The following indicators were recorded: plant height (cm); number of leaves per plant; leaf length (cm); leaf width (cm); height of ear placement (cm); number of branches per tassel; Ear length (cm); ear diameter (cm):

Meteorological data. For this study, an automatic meteorological station was installed in the experimental field. During the potential growing season, the following meteorological parameters were measured: average, maximum and minimum air temperature (°C), relative air humidity (%), and daily precipitation, (mm). The plants were cultivated under drip irrigation conditions.

A non-invasive field screening of four corn hybrid varieties was performed by leaf chlorophyll content index (CCI) measurement with device CCM200+, manufactured by Opti Science UK.

The data were analysed using one-way analysis of variance (ANOVA), Fischer's least significant difference (GD) test, and correlation analyses.

RESULTS AND DISCUSSIONS

The measured meteorological values give reason to define 2024 as one of the warmest years since the beginning of meteorological observations in the region. A lower average temperature is observed before seed sowing, with the only negative deviation in 2024 being in May (Figures 1 and 2). Hydrothermal conditions for sweet corn cultivation are favourable after mid-April. However, for testing stress factors according to the set objectives of the experiment, sowing was carried out in early June. During the initial period of corn development - June, the average temperature in 2024 is 4.1°C higher than in 2023.

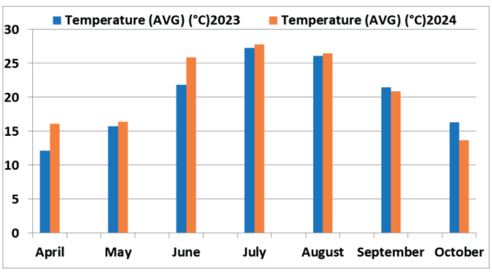


Figure 1. Average air temperature by month for 2023 and 2024

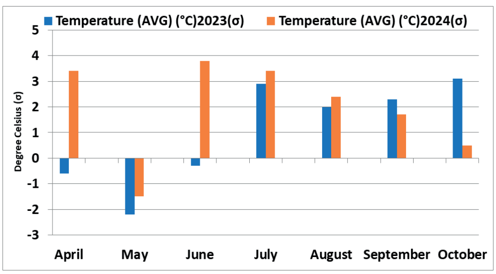


Figure 2. Deviation in average monthly air temperature from the climate norm 1991-2020

The number of days required for sweet corn seeds to germinate strongly depends on the average soil and air temperature. In June 2023, temperatures above 20°C combined with optimal soil moisture allowed germination to occur in about 5 days, and even higher average temperatures in 2024 led to seed germination within just a few days. The total vegetation period for Zeaton F1 suggests 78-80 days after germination, while for the Turbo F1, it is 8-10 days less. Under the conditions of the country, the period from leaf to leaf requires effective temperatures of about 30-32°C, and in dry and hot weather this amount increases to over 42°C (Hershkovich, 1975). During 2023, the plants entered the reproductive phase after 40 days, while in the warmer June of 2024 after 30 days. The duration of the critical phase of tasselling-silking is about 17 days and the period to milk maturity-10 days. In conclusion, with this later sowing, the critical periods for the plants are in the second half of July and at the beginning of August.

The second experimental year was significantly drier than 2023 (Figure 3). However, during the sowing period and leaf formation, precipitation in 2024 was higher than that in 2023.

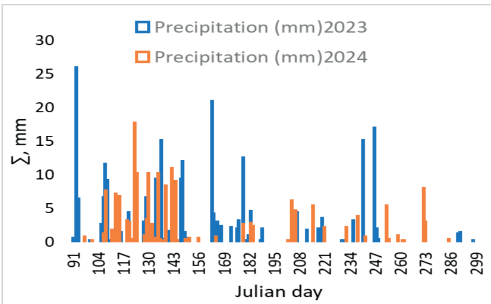


Figure 3. Precipitation amount (mm) by day in 2023 and 2024

The collected meteorological data show that the maximum temperatures in 2024 are also significantly higher compared to those in 2023 (Figure 4). In the first experimental year (2023), unfavourable conditions began in the third decade of June, with 54 days with temperatures above 32°C and 8 days with maximum values above 38°C. The record-breaking hot year 2024 began with unfavourable values already at the beginning of June, with a significantly higher number of days with maximum temperatures above 32°C (81), and (4) days with values above 38°C.

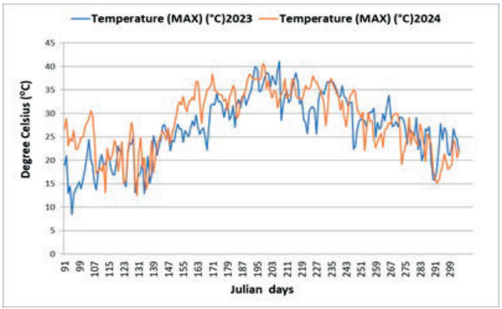


Figure 4. Maximum air temperature during the critical periods (June and July) 2023 and 2024

High RH% can alleviate the impacts of heat on maize seed set by maintaining high pollen viability and a high silk emergence ratio (Dong et al., 2024). Although irrigation reduced stress during the reproductive period, in 2024, 12 consecutive days with average relative humidity between 40% and 50% were observed in July (Figure 5).

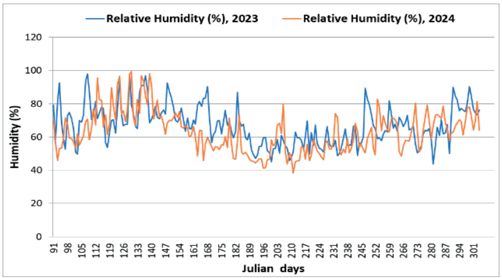


Figure 5. Average relative air humidity in % during the growing season in 2023 and 2024

However, the drip irrigation system significantly improved hydrothermal conditions and reduced abiotic stress in the experimental plots. Two periods are normally defined in the development of corn - the first of which with vegetative manifestations, and the second - the reproductive phases of the species. Corn is more resistant to extreme hydrothermal conditions during the vegetative stages of development, when growth and formation of the optimal leaf area occur. Early sowing is usually a prerequisite for shifting the critical phases forward to less stressful hydrothermal factors. However, there are studies both in favour of earlier (Tomorga et al. 1985; Imholte and Carter 1987) and in favour of later sowing (Herbek et al., 1986). In this case, meteorological data show that the most stressful conditions occurred very early - already in June. The reproductive stage of maize plants between tasseling and silking is the most sensitive stage to temperature fluctuations, as high temperatures accelerate the tassel life cycle (Siebers et al., 2017). Some studies have shown that corn yield decreases linearly with each degree of temperature increase above 30°C (Lobell et al., 2011), and Zhao et al. (2017) reported an estimated 7.4% loss in corn yield with each degree of temperature increase.

The pollen germination starts to decline at 32°C (Herrero and Johnson, 1980; Schoper et al., 1987) and is sharply reduced when the temperature increases up to 38°C (Carberry et al., 1989; Wang et al., 2021). Maize female reproductive organs are wrapped in the husk leaves, which regulate the temperature inside the ear to about 2-3°C lower than the ambient temperature (Khabba et al., 2001). However, temperatures above 38°C can delay the silk emergence time and reduce the silk emergence ratio, which greatly reduces the seed set (Liu et al., 2022). Results from both field and greenhouse experiments have revealed that heat stress during flowering significantly reduces silk receptivity and the silk emergence ratio (Cicchino et al., 2010; Alam et al., 2017; Wang et al., 2021). The data collected during the two experimental years show that the development and especially the reproductive phases of maize plant development occur after conditions of temperature stress. The second year, 2024, is saturated with more extreme events and suggests lower yields in maize plants. However, we believe that late sowing has shifted the critical phases after the most extreme values and in this case has a rather positive effect. Therefore, yields are good, and the chlorophyll index does not reflect significant stress. Another important conclusion is that in the dry summer conditions of Plovdiv, sweet corn cultivation is not possible without irrigation. However, the role of drip irrigation is well demonstrated by improving moisture conditions in both years studied. Negative deviations in the monthly air temperature values were observed only in May and during both experimental years. The days with stress factors covered almost the entire period of the critical phases of maize, which poses a problem for pollination. The sowing date determines whether the critical phenophase of tasseling and flowering coincides with the most stressful factors, which in the region occur in July. Hybrids with a shorter growing season exhibit better growth parameters when sown later under irrigation conditions.The averaged two-year results for the morphological indicators recorded during the milk maturity phase are presented in Table 1. The control variety Zeaton F1 has the tallest stem, with a significant difference from all other varieties. The varieties HMX5389 F1 and HMX59YS832 F1 showed a significant difference from the shortest variety Turbo F1. The highest leaf number is recorded in the HMX59YS832 F1 variety and the control variety Zeaton F1, which also has the tallest stems. Additionally, HMX59YS832 F1 exhibits a significant difference compared to Zeaton F1. Meanwhile, the Turbo F1 and HMX5389 F1 varieties have a statistically significantly lower number of leaves compared to the control.

The parameters of leaf length and width have close values, with the length naturally varying more than the width. The Zeaton F1, HMX5389 F1, and HMX59YS832 F1 varieties have the longest leaves and belong to the same group. The variety Turbo F1 has the shortest leaves, showing a significant difference from the others. The varieties with the longest leaves also have the widest leaves, but unlike length, the width values are very close, and no significant difference is observed.

The parameter for ear placement height varies from 53.44 cm in the Zeaton F1 variety to 35.33 cm in the HMX59YS832 F1 variety, with a significant difference only between these two. The results for this parameter follow a similar ranking to plant height. For the mentioned indicators, we can conclude that the presence of significant differences indicated that sufficient genetic variation among the hybrid genotypes was present. Similar relationships are reported by Ilker, 2011 in a study with other corn hybrids.

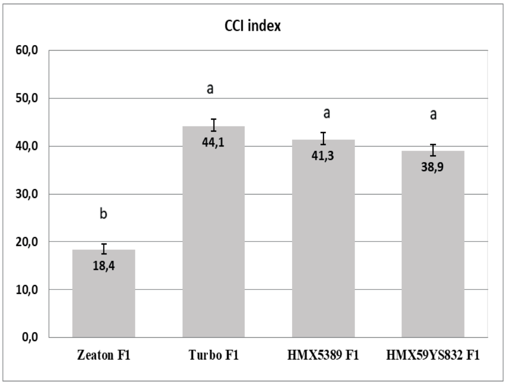
Regarding the number of tassel branches, the variation in results is minimal, and the average values do not show statistical significance.

The recorded ear morphometry does not indicate a significant advantage for any particular variety, either in length or width. The ear length ranges from 25.0 cm in the HMX59YS832 F1 variety to 23.6 cm in the Turbo F1 variety, while the highest ear width is observed in the control variety Zeaton F1.

Figure 6 presents the measured average CCI values from two years of field measurements taken during the tasseling and grain-filling (milk maturity) phases. No structural changes in the leaves due to abiotic or biotic stress were detected during the measurements, indicating that the recorded CCI reflects the normal potential of each variety. The data processing provides a clear and statistically significant separation of the varieties into two groups. The first group consists of three varieties Turbo F1, HMX5389 F1 and HMX59YS832 F1, which have a chlorophyll content index above 38 units. The control variety Zeaton F1 is distinctly separated from this group, with a chlorophyll index below 20 units, and this trend remains consistent between the two measurements. Similar ratios have been observed in field trials for other maize genotypes in previous studies (Dwi Purbajanti et al., 2024; Frommer et al., 2019).

Additionally, all varieties show a growth increase in the chlorophyll content index within the range of 20-25% over the same period. Regarding the relationship between the chlorophyll index and most morphological indicators, no strong correlations were found. However, a stronger negative relationship was identified between the parameters of stem height, ear placement height, and the relative chlorophyll index of the leaves.

Table 2 presents the calculated correlation dependencies between the recorded biometric parameters. The highest correlation coefficients are observed in the interactions between plant height the parameters of leaf length and the number of leaves per plant. The relationship between the number of leaves per plant and leaf length is moderately positive. All mentioned correlation interactions so far are statistically significant at the 1% and 5% levels. These relationships indicate that taller plants lead to a greater number and larger size of leaves.



The different letters mean significance difference at 5%

Figure 6. Average results of the leaf chlorophyll content index during periods 2023 and 2024

Moderately positive correlation coefficients, though not statistically significant, are observed in the relationships between the number of leaves and leaf width, the number of leaves and cob diameter, as well as leaf length with the indicators of cob setting height and cob length. The positive interactions with unproven statistical significance between a greater number and larger leaves and longer ear lengths are expected as a result of improved photosynthetic activity.

On the other hand, the strongest and most significant negative correlation is between leaf length and ear diameter. Moderate negative correlations, though not statistically significant, are observed between the number of leaves and cob diameter, plant height and cob diameter, and the number of leaves and the number of tassel branches. Therefore, in terms of ear diameter, a larger leaf mass not only does not lead to a larger diameter but actually reduces it. Zaluski et al. (2021) reported stronger positive interactions between plant height and the morphometric indicators of the ear, while in our case, the relationships are weakly positive or negative.

The behaviour of four sweet corn varieties under hydrothermal stress conditions was studied. During the first and second experimental years, there were 54 and 81 days, respectively, with maximum temperatures exceeding 32°C. Therefore, the vegetation occurs faster and with shortened interphase periods. Plants were most resilient during their vegetative stages.

Among the four tested hybrids, the control Zeaton F1 demonstrated the highest plant height, leaf width, ear height, and cob width.

The shortest hybrid variety, Turbo F1, exhibited higher morphometric parameters of the ear and the highest chlorophyll content index in the leaves compared to the control.

Experimental data confirm that temperature anomalies and stress factors during critical growth phases can affect pollination and yield. In this case, late sowing mitigated the adverse effects of extreme climatic conditions, contributing to stable yields despite unfavourable hydrothermal conditions. It has been proven that irrigation combined with proper fertilization is essential for cultivating sweet corn in Plovdiv’s dry summer conditions. The drip irrigation system effectively improves soil moisture levels, preventing drought stress in the crop.

Table 1. Average results of the biometric parameters -milk maturity phase

Variety/Parameter	Plant high (cm)	Number leaf per plant	Leaf length (cm)	Leaf width (cm)	Height of ear placement (cm)	Number of branches per tassel	Ear length (cm)	Ear width (cm)
Zeaton F1-(control)	153.11	9.44	81.33	11.50	53.44	15.89	24.00	3.06
Turbo F1	115.44 ***	7.44 **	73.00 **	10.67 n.s.	43.78 n.s	16.78 n.s.	23.56 n.s.	3.02 n.s.
HMX5389 F1	136.67 **	8.22 *	80.89 n.s.	10.22 **	49.56 n.s.	15.56 n.s.	24.11 n.s.	2.87 n.s.
HMX59YS832 F1	138.22 *	10.89 *	81.44 n.s.	11.11 n.s.	35.33 ***	15.00 n.s.	25.00 n.s.	2.88 n.s.
GD 5% *	12.08	1.18	4.93	0.95	10.14	2.75	1.69	0.28
GD 1% **	16.17	1.57	6.60	1.27	13.57	3.69	2.26	0.37
GD 0.1% ***	21.23	2.07	8.67	1.67	17.81	4.84	2.97	0.48

n.s. no significant difference

Table 2. Correlation coefficients between biometric parameters in corn hybrids varieties

Parameter	Plant height (cm)	Number leaf per plant	Leaf length (cm)	Leaf width (cm)	Height of ear placement	Number of branches per tassel	Ear length (cm)	Ear width (cm)
Plant height	1	0.55*	0.84**	0.25	0.46	-0.30	0.21	-0.35
Number leaf per plant		1.00	0.55*	0.47	-0.32	-0.17	0.45	-0.45
Leaf length (cm)			1.00	-0.03	0.42	-0.34	0.40	-0.54*
Leaf width (cm)				1.00	-0.36	0.22	0.06	0.13
Height of ear placement					1.00	0.06	-0.15	-0.04
Number of branches per tassel						1.00	-0.27	0.03
Ear length (cm)							1.00	-0.20
Ear width (cm)								1.00

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

CONCLUSIONS

Hybrids with shorter growing cycles showed increased growth productivity under irrigation and later sowing conditions. A stronger negative correlation was observed between stem height, ear height, and the relative chlorophyll index of the leaves. The observed genetic variation among the studied hybrids suggests potential for further selection and breeding programs. Strong correlations between plant height, number of leaves, and leaf length indicate that taller plants tend to develop a greater number and size of leaves. This study provides valuable insights for optimizing sweet corn cultivation strategies in regions facing similar climatic challenges.

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