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Influence of Sowing Date and Fertilisers on Productive Properties and Antioxidant Capacity of Sweet Corn

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ABSTRACT

Sweet corn (*Zea mays* L. var. *saccharata*) is one of the popular varieties of corn in the human diet. Its quality is influenced by various properties such as grain moisture, colour, ear weight, ear length, texture, and sugar content, while its health benefits are attributed to its total phenolic content and antioxidant activity. The aim of this research is to determine the impact of N fertiliser application and sowing date on yield indicators, total phenol content and antioxidant capacity of sweet corn. The treatments of the experiment consisted of a combination of two factors, two different nitrogen regimes and two different sowing dates. The results show that the applied treatments significantly influenced the researched traits of sweet corn. Dehusked and husked ear mass, ear length, and yield were higher when sown earlier (385 g, 264 g, and 21 cm, respectively) than later sowing (364 g, 242 g, and 20 cm, respectively). Additionally, higher values of dehusked and husked ear mass, ear length, were recorded with a higher dose of fertiliser. Furthermore, total phenol contents ranged from 57.0 to 80 mg GAE 100 g^{-1} and depended on sowing date, fertilisation, and year of study.

Keywords: sweet corn, sowing date, nitrogen, ear mass, total phenol content, antioxidant capacity.

INTRODUCTION

Sweet corn (*Zea mays* L. var. *saccharata*) is one of the popular varieties of corn in the human diet. Although its morphological characteristics and cultivation technology are similar to other varieties of corn, there are still some differences. Sweet corn kernel is more prosperous in sugar, protein and fat than other corn varieties (Budak et al., 2018). Furthermore, sweet corn is a good source of bioactive phytochemicals. It contains polyphenols, flavonoids, phenolic acids, carotenoids, anthocyanins, and other substances of medicinal importance (Cruz et al., 2022). Sweet corn has a soft, juicy, sweet and delicious kernel in the milk stage (Gavrić and Omerbegović, 2021). Due to these properties, it is very popular in the human diet of people in fresh form (ear at milk stage) and as processed food (Rattin et al., 2018).

Recently, in many countries, the demand for sweet corn and its consumption has constantly increased (Ugur and Maden, 2015), which puts new requirements on farmers. On the one hand, it is necessary to produce additional quantities of sweet corn ear. Currently, nitrogen fertilisers are the simplest and fastest way to create additional quantities of sweet corn ears. Namely, nitrogen is an essential macronutrient for corn that has the most significant effect on plant development, and it is added to the plant side-dressing to reach high yields. Corn plants with a high level of available nitrogen increase CO^2 assimilation, photosynthesis rate, sugar concentration in leaves and dry mass formation, i.e. yield increase (Zucareli et al., 2018). Also, some studies have shown that additional amounts of nitrogen increase the protein content in the grain, which increases the quality of certain varieties of corn.

The quality of sweet corn is influenced by various physical and chemical properties, such as kernel moisture, color, ear weight, texture, sugar content, and aroma profiles (Gavrić and Omerbegović, 2021; Chen et al., 2024). Its health benefits are attributed to the content of total phenols and antioxidant activity (Ledenčan et al., 2022). Phenolic compounds are present in all parts of plants, including leaves, flowers, seeds, stems, and roots. The quantity of phenols depends mainly on the plant species. In addition,

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environmental factors such as aridity, salinity, ultraviolet radiation, altitude, and weather significantly influence the production of these components (Sharma et al., 2019; Del Valle et al., 2020). Furthermore, cultural practices directly impact the environment, affecting plants' quality and productivity (Gavrić et al., 2022). One common cultural practice is the application of fertilisers, which significantly affects the growth, development, and yield of plants and the synthesis of bioactive compounds.

Scientific knowledge about the influence of sowing date and fertilisation on the productivity and content of phenolic compounds of sweet corn remains largely unresearced. Considering the above, the aim of this research is to determine the impact of N fertiliser application and sowing date on yield indicators, total phenol content and antioxidant capacity of sweet corn.

MATERIAL AND METHODS

Field experiments. Field experiments were carried out in the 2020 and 2021 growing seasons at a private farm ″Gavrić″ in Kakanj. The soil analysis indicated the following chemical characteristics for the experimental plots: pH 7.4, organic matter 5.50%, P_2O_5 = 20.1 mg 100 g^{-1}, K_2O = 31.4 mg 100 g^{-1}. The soil type was classified as Eutric Cambisol.

Meteorological data. Meteorological data was sourced from the Federal Hydrometeorological Institute, Sarajevo, Bosnia, and Herzegovina (FHMZ, 2024). The data was collected from regional meteorological stations, specifically Zenica (44°12'07″ N, 17°54'01″ E). This data included average monthly air temperature and precipitation levels and was used in the study.

Treatments and experimental design. The treatments of the experiment consisted of a combination of two factors, two different nitrogen regimes (150 and 250 kg N ha^{-1}) and two different sowing dates. The sowing of sweet corn was done manually. It was performed on May 08 and 18, 2020, while in 2021, it was performed on May 11 and 21. Sowing was done at a spacing of 70 x 25 cm.

Crop management. Soil fertilisation was the same in both years. Fertilisation was split into two applications: fertiliser at the rate of 250 kg ha^{-1} (NPK 15:15:15) was applied with deep plowing before sowing. The rest of N fertiliser (150 or 250 kg ha^{-1}) was given at the stage of 4-6 leaves. During the vegetation, weeds were removed manually. Harvest of sweet corn were done manually. Ears were harvested at the milk stage.

Data collection. All data were recorded at harvest time. Optimum harvest time was determined by daily control of ear after early stage of grain development. All measurements were performed on 10 randomly selected plants per treatment. The mass of the dehusked and husked ear, and the length of the dehusked ear were collected. After measuring the weight of the ears, the ears were frozen for 24 hours, after which the kernel was separated and frozen again until the content of bioactive components was determined.

Preparation of extracts. Plant extracts were prepared using the cold extraction method. In brief, 5 g of crushed grain was transferred to a bottle and mixed with 50 mL 40% ethanol. After 24 h, extracts were filtered through the quantitative filter paper. Obtained extracts kept in sterile sampling tubes were stored at 4°C.

Determination of bioactive components and antioxidant activity. The total phenolic content in extracts was determined by the modified Folin-Ciocalteu method (Gavrić et al., 2018). Antioxidant activity was measured using the ferric-reducing antioxidant power (FRAP) method (Benzie and Strain, 1996).

Statistical methods. All experimental measurements were statistically analysed by ANOVA (analysis of variance) method at a level of significance set up at 0.05. The statistical analyses were made using the SPSS 22.0 software program (IBM, Armonk, New York, USA).

RESULTS AND DISCUSSION

The weather conditions during the research period are depicted in Figure 1. The amount of precipitation and average monthly temperature varied depending on the year of the study. Additionally, the rainfall was distributed unevenly across the months. The highest amount of precipitation was observed in May (117 mm) and August (142 mm) of 2020, which was more than double the amount compared to 2021 (39 mm and 40 mm, respectively). July was the warmest month during the cultivation of sweet corn in both research years, with recorded averages temperatures of 21.1°C (2020) and 23.7°C (2023).

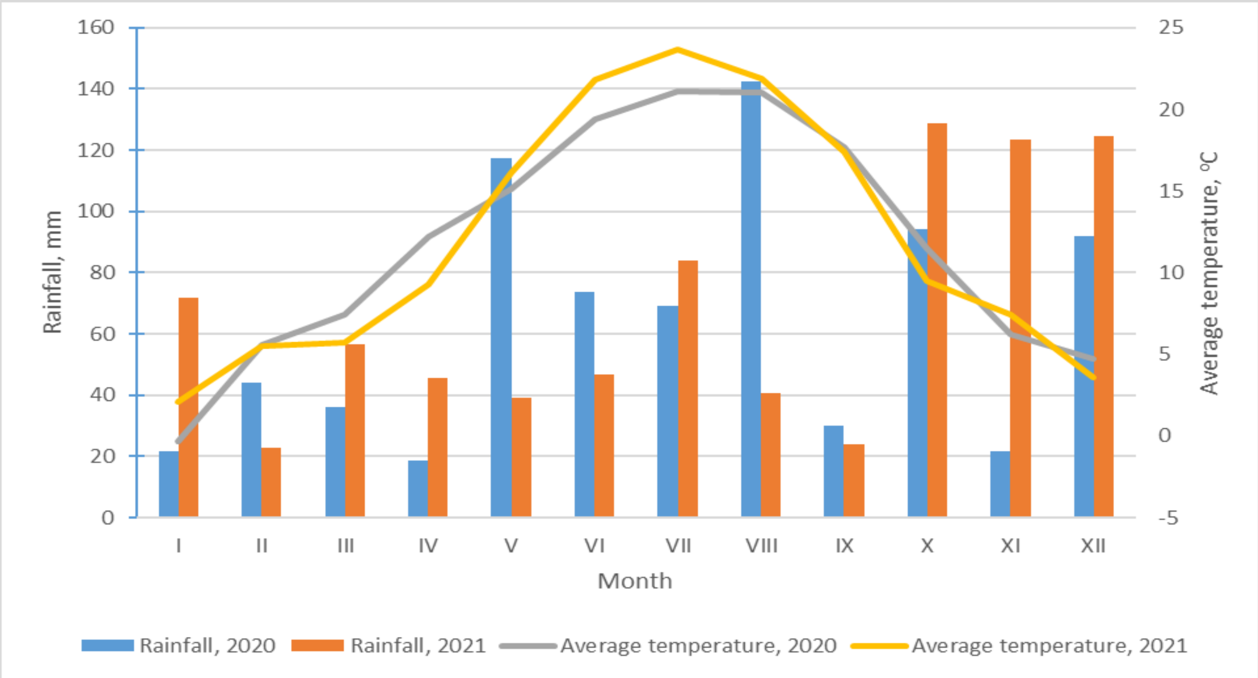

Figure 2. Average monthly temperatures (°C) and monthly rainfall (mm)

The traits researched were influenced by sowing date, fertilisation, and the year of the study. Specifically, dehusked and husked ear mass, ear length, and yield were higher when sown earlier (385 g, 264 g, and 21 cm, respectively) compared to later sowing (364 g, 242 g, and 20 cm, respectively) (Table 1). The sowing date also affected the content of total phenols and antioxidant capacity, with higher values recorded for the first sowing date. The yield components and quality indicators are higher in the first sowing date. Dekhane and Dumbre (2017) confirmed these findings in sweet corn, while Khan et al. (2018) that delaying sowing date decreased yield components, such as ear weight, due to a shorter plant growth period and reduced photosynthetic production.

Table 1. Effect of sowing date on researched traits

Sowing date	Husked ear mass	Dehusked ear mass	Ear lenght	Total phenolics	Antioxidant capacity
	g	g	cm	mg GAE $100g^{-1}$	μM Fe^{2+} $100g^{-1}$
First	385a	264a	21a	78.0a	16.2ns
Second	364b	242b	20b	59.0b	15.7ns
Average	**375**	**253**	**20**	**68.5**	**16.0**

Different letters indicate significant differences at the 0.05 level; ns: nonsignificant differences.
GAE - gallic acid equivalent, CAE - cathetin acid equivalent.

The results presented in Table 2 show that the traits under study were significantly affected by using fertilisers. The highest values for dehusked and husked ear mass, ear length, and yield were observed with 250 kg ha^{-1} of mineral fertiliser, compared to the treatments with 150 kg ha^{-1} of fertilisers. Conversely, significantly lower values for total phenols and antioxidant activity were obtained when a larger amount of fertiliser was applied compared to a smaller amount. Therefore, the additional amount of nitrogen increased the growth of plants. These results are consistent with earlier research (Oktem et al., 2010; Zucareli et al., 2018). Sinclair and Jafarikouhini (2022) found that applying N fertiliser increases the yield of fresh grains. Also, the same authors recorded a highly positive, linear correlation between the yield of fresh grains and the number of grains formed per ear. These changes in the plant come about because nitrogen plays a crucial role in increasing plant yield by influencing photosynthesis rates, growth rates, and plant productivity in most ecosystems (Yuan-Yuan et al., 2021; Shah et al., 2024). Additionally, nitrogen application also affects the quality of the crop, as it is essential for nucleic acids, proteins, growth hormones, and chlorophyll (Anas et al., 2020; Shah et al., 2024). Insufficient nitrogen application can reduce nitrogen concentration in leaves, chlorophyll content, and photosynthetic capacity, while excessive application can inhibit growth and cause wilting. Therefore, determining the optimal application of nitrogen is crucial for improving the yield and quality of sweet corn.

Table 2. Effect of N fertiliser on researched traits

Fertiliser	Husked ear mass	Dehusked ear mass	Ear lenght	Total phenolics	Antioxidant capacity
kg N ha^{-1}	g	g	cm	mg GAE 100g^{-1}	µM Fe^{2+} 100g^{-1}
150	350b	237b	20b	70.0ns	16.4a
250	398a	269a	21a	67.0ns	15.5b
Average	**375**	**253**	**20**	**68.5**	**16.0**

Different letters indicate significant differences at the 0.05 level; ns: nonsignificant differences.
GAE - gallic acid equivalent, CAE - cathetin acid equivalent.

In the study, the research year significantly impacted the mass, ear length, total phenol content, and antioxidant capacity (Table 3). Specifically, sweet corn grown in 2021 had a lower mass of husked and dehusked ears (394 g and 225 g, respectively) than those grown in 2020 (394 g and 281 g, respectively). These differences are likely due to the varied weather conditions, particularly the distribution of precipitation between the two years. As illustrated in Figure 1, 2020 registered more precipitation at the beginning of the growing season (May) than in 2021. However, in 2021, more precipitation was recorded during the kernel development (July) compared to 2020. This increased rainfall positively influenced plant growth and grain formation. Our findings are consistent with those of Gavrić and Omerbegović (2021), who found that the mass of sweet corn and its yield increase significantly with greater precipitation. They attribute this to decreased available water, reduced plant turgor, and diminished cell growth and development, evident in reduced plant height and yield. Several other studies have also highlighted the positive impact of water availability on plant height, yield, and sweet corn quality (Viswanatha et al., 2002; Ertek and Kara, 2013). However, some authors (Kim et al., 2024) argue that excessive rainfall can lower crop yield and quality, attributing this to creating favourable conditions for plant diseases by excess water.

Table 3. Effect of year of study on researched traits

Year	Husked ear mass	Dehusked ear mass	Ear lenght	Total phenolics	Antioxidant capacity
	g	g	cm	mg GAE $100g^{-1}$	µM Fe^{2+} $100g^{-1}$
2020	356b	225b	19b	80.0a	16.0ns
2021	394a	281a	21a	57.0b	16.1ns
Average	**375**	**253**	**20**	**68.5**	**16.0**

Different letters indicate significant differences at the 0.05 level; ns: nonsignificant differences.
GAE - gallic acid equivalent, CAE - cathetin acid equivalent.

The total phenol content in the grain and the antioxidant capacity are essential factors in sweet corn's health value (Ledenčan et al., 2022). The results of our research indicate that the sowing date, fertilisation, and year of study significantly influenced the levels of total phenols and antioxidant capacity. Average total phenol contents ranged from 57.0 to 80 mg GAE 100 g^{-1} (Tables 1, 2, and 3). It was recorded that the first sowing date has a significantly higher phenol content and antioxidant capacity (78.0 mg GAE 100 g^{-1} and 16.2 µM Fe^{2+} $100g^{-1}$, respectively) compared to the second sowing date (59.0 mg GAE 100 g^{-1} and 15.7 µM Fe^{2+} $100g^{-1}$, respectively) (Table 1). Also, there were significant differences in content between the years of research (Table 3). Different content of total phenols and antioxidant capacity in certain years were also recorded by other researchers (Ledenčan et al., 2022). The mentioned authors believe that these differences arose due to different weather conditions.

Although our research provided insight into the influence of nitrogen fertilisation and sowing date on yield indicators and the content of total phenols in sweet corn grains, it has certain limitations. The research only utilised a limited number of doses of nitrogen fertiliser and two sowing dates. Therefore, future research should consider the potential influence of different nutrients and amounts on the yield and quality of sweet corn. Despite these limitations, our research has shown certain benefits that can be applied in practice. More precisely, choosing an earlier sowing date and using a higher dose of nitrogen fertiliser can positively affect ear weight, ear length, and quality indicators.

CONCLUSIONS

This research showed that using N fertiliser and sowing date affect sweet corn's yield indicators and antioxidant capacity. Using fertilisers increased the masses of husked and dehusked ear and ear length. Therefore, using this method of fertilisation could be a practice for improving sweet corn yield indicators. The sowing of sween corn later has a negative effect on yield indicatorsas well as on the content of total phenols and antioxidant capacity.

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