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Stability of Yield and Quality Parameters in Maize Hybrids Cultivated at Different Sowing Dates

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ABSTRACT

In the context of ongoing climate change, marked by rising air temperatures and recurrent drought episodes throughout the maize growing season, identifying hybrids capable of optimizing unfavorable environmental conditions to achieve stable yields over time and space has become essential. A field experiment was conducted at the Agricultural Research and Development Station (ARDS) Turda over five years with varying climatic conditions (2020-2024). The biological material included seven hybrids from different FAO groups developed at ARDS Turda: Turda 248, Turda 165, Turda 201, Turda Star, Turda 332, Turda 344, and Turda 335. The hybrids were sown at three different sowing dates (6°C, 8°C, and 10°C), based on soil temperature recorded at 8 a.m. The results demonstrated significant yield stability in the Turda 332 hybrid. As expected, cultivar responses to different sowing dates varied based on genetic factors. Nonetheless, the importance of sowing maize at the optimal time remains evident. Quality parameters, however, showed variation primarily depending on the genotype.

Keywords: maize, sowing date, stability, quality, yield capacity.

INTRODUCTION

It is evident that climate change has and will continue to have a negative impact on agriculture worldwide. It is therefore imperative to study plant responses to these changes to limit the effects of biotic and abiotic factors on production, quality, and stability. The productivity and stability of a crop are closely linked to technological inputs; however, crop growth is also affected by climate change in addition to production factors (Lobell and Asner, 2003).

Since maize (*Zea mays* L.) has a wide range of uses and the highest global production (Ranum et al., 2014; Wang et al., 2019), it is among the main crops affected by climate change. Maize production depends on the genetic potential of the genotype used, soil characteristics, soil management practices, and agro-climatic factors (Barşon et al., 2021; Kovačević et al., 2024). Improving drought and heat tolerance provides production stability (Petcu et al., 2018), representing one of the main methods for reducing yield losses caused by climate change. Meteorological and environmental conditions during the crop growth period have a direct influence on plant growth and development and, consequently, ultimately affect crop yield (Khushu et al., 2008) as well as quality (Zakaria et al., 2020; Rahimi et al., 2021).

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) indicated that climate change has negatively affected maize production in many regions worldwide. Therefore, it is necessary to identify solutions to avoid climatic stress during the vegetation period to improve crop stability.

Although maize is typically considered a warm-season crop, it is actually more sensitive to high-temperature stress during the vegetation period compared to other crops (Tesfaye et al., 2015). The impact of meteorological conditions on maize growth and development can be intensified by extreme environmental conditions, primarily the occurrence of heat and water stress episodes at different physiological stages of the crop (Beruski et al., 2020).

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Short-term extreme temperature changes can be critical, especially if they coincide with key developmental stages, as just a few days of extreme temperatures (above 32°C) during the flowering phase can drastically reduce production (Wheeler et al., 2000).

As a rule, maize should not be sown until soil temperatures approach 10°C, because in cold soil conditions (below 10°C), the seeds will easily absorb water but will not initiate root or shoot growth, leading to seed rot and poor emergence (Hall et al., 2016).

Previous studies conducted by authors such as Rolle et al. (2022) have shown that changing the sowing time is increasingly used as a strategy to adapt to climate change.

In this context of climate change, characterized by rising temperatures and precipitation variability, the main objective of the study was to evaluate the influence of three different sowing dates and climatic conditions on the production stability and quality of seven maize hybrids.

MATERIAL AND METHODS

A polyfactorial field experiment was conducted over five years (2020-2024) at the Agricultural Research and Development Station (ARDS) Turda to evaluate the effect of different sowing dates and climatic conditions on maize yield stability and the stability of the most important quality parameters (protein, fat, starch). The experiment involved seven maize hybrids from various maturity groups (*Turda 248, Turda 165, Turda 201, Turda Star, Turda 332, Turda 344, Turda 335*), arranged in a randomized block design with three replications and 7 m² plots. Each hybrid was sown in two rows, 5 meters long, with a 70 cm spacing between rows.

Three factors were investigated:

➢ The experimental year, with five levels: 2020, 2021, 2022, 2023, and 2024;

➢ The sowing date, with three levels, depending on soil temperature:

▪ 6°C (03.04.2020, 12.04.2021, 14.04.2022, 21.04.2023, 11.04.2024);

▪ 8°C (13.04.2020, 22.04.2021, 02.05.2022, 05.05.2023, 26.04.2024);

▪ 10°C (23.04.2020, 07.05.2021, 17.05.2022, 22.05.2023, 13.05.2024).

➢ The maize genotype, with seven levels: *Turda 248, Turda 165, Turda 201, Turda Star, Turda 332, Turda 344, Turda 335.*

The statistical analysis of the production data was performed using stability parameters based on the method proposed by Eberhart and Russell (1966), which evaluates stability based on environmental indices. The obtained data were also presented through cluster analysis using the Past4 statistical program. For the graphical representation of the experimental results, the Bray-Curtis distance was selected. This method uses a colour gradient, from dark blue to red, where red indicates higher values and blue indicates lower values.

From a climatic perspective, during the five years of study, conditions varied from year to year and from month to month in the experimental area (longitude 23°47’E, latitude 46°35’N, altitude 427 m). Average temperatures fluctuated greatly, and precipitation distribution was highly uneven.

The sowing of maize hybrids was carried out on different calendar dates from one year to another. In certain years, substantial day-to-night temperature differences led to a delay in soil warming, as indicated by soil temperature measurements taken at 8 AM.

In 2020, with the exception of May, the average monthly temperatures were higher than normal; however, this did not have a significant negative effect on the crop because excess precipitation was recorded in June and July, creating favourable conditions for maize cultivation.

The year 2021 was also favourable for maize cultivation, with values close to the multiannual average for both temperatures and precipitation. Although the amount of precipitation in June was lower than normal, the excess rainfall in July supported the achievement of very good maize yields.

The year 2022 was considered unfavourable for maize cultivation, particularly due to the shortening of certain developmental phases. Processes such as grain formation and filling were the most affected by the precipitation deficit in June and July, which, combined with high temperatures during this period, resulted in significant production losses.

The year 2023 was also considered favourable for maize cultivation due to the surplus precipitation in June, July, and August, which supported good plant development and the achievement of significant yields.

The year with the most unfavourable conditions for maize cultivation was 2024, when the precipitation regime was deficient in all months of the vegetation period. Drought set in as early as spring and, combined with extreme temperatures, led to significant production losses.

The most important climatic aspect observed during the research period was the average monthly temperature in April and May (the maize sowing period), which recorded values lower than the multiannual average. This had a negative effect on maize emergence and development in the early stages of the vegetative cycle.

Overall, during the five years of research, the average monthly temperatures recorded at Turda were higher, which is part of a global warming process. Although precipitation was often sufficient in quantity, it was unevenly distributed, preventing plants from fully benefiting from it.

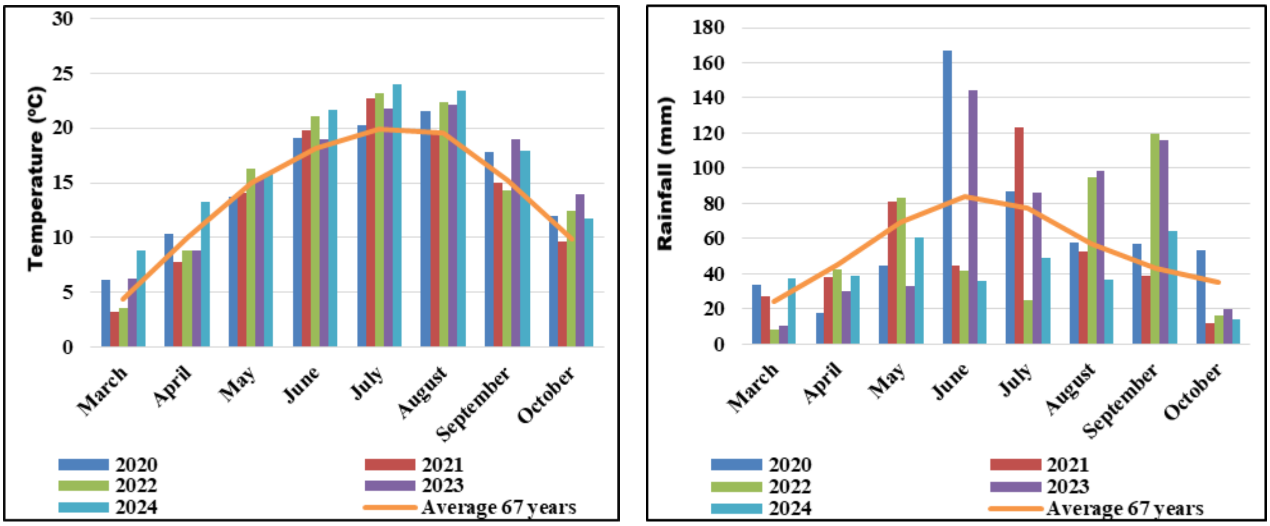

Figure 1. Temperature and rainfall distribution at Turda (2020-2024)

It is important to note that, based on the analysis of yields obtained over the past five years, yields greater than 8400 kg/ha were achieved only in 2020 and 2021. Normal temperatures and precipitation in July and August significantly contribute to pollination and proper grain formation (Vana et al., 2024), a very important aspect for achieving high maize yields.

In the last three years, maize yield has suffered due to increasingly pronounced climate changes (Figure 2), with climate change manifesting through rising air temperatures above the multiannual average, with deviations between 1-3°C (Tărău et al., 2024). Studies conducted by Wang et al. (2016) indicate that the negative effects of climate change on maize production are primarily associated with warming and the increased frequency of drought during growth periods. Based on the stability of maize production capacity relative to sowing date, a clear superiority is observed for sowing at 8°C and 10°C compared to the early sowing date.

Aedin et al. (2024) stated that the climatic evolution in recent years in Romania has shown large variations in temperature and precipitation, which negatively influenced maize yield stability, a trend also observed in our study. The stability of production capacity across the seven hybrids sown at three different soil temperatures, confirmed by cluster analysis, indicates better performance of the hybrids Turda 332, Turda 344, Turda 248, and Turda 335, which achieved the highest yields regardless of the sowing date. The maximum yield of 9947 kg/ha was obtained with the hybrid Turda 335 sown at 10°C, while the lowest yield of 6239 kg/ha was recorded for the hybrid Turda 201 sown at 6°C. Given that maize requires warm soil to germinate and grow (Duncan, 1975), these results were expected, considering that in most research years, spring temperatures were lower than normal. Turda Star shows an independent pattern, with similar yields regardless of sowing date, and is considered a hybrid with high stability regarding the relationship between soil temperature at sowing and yield.

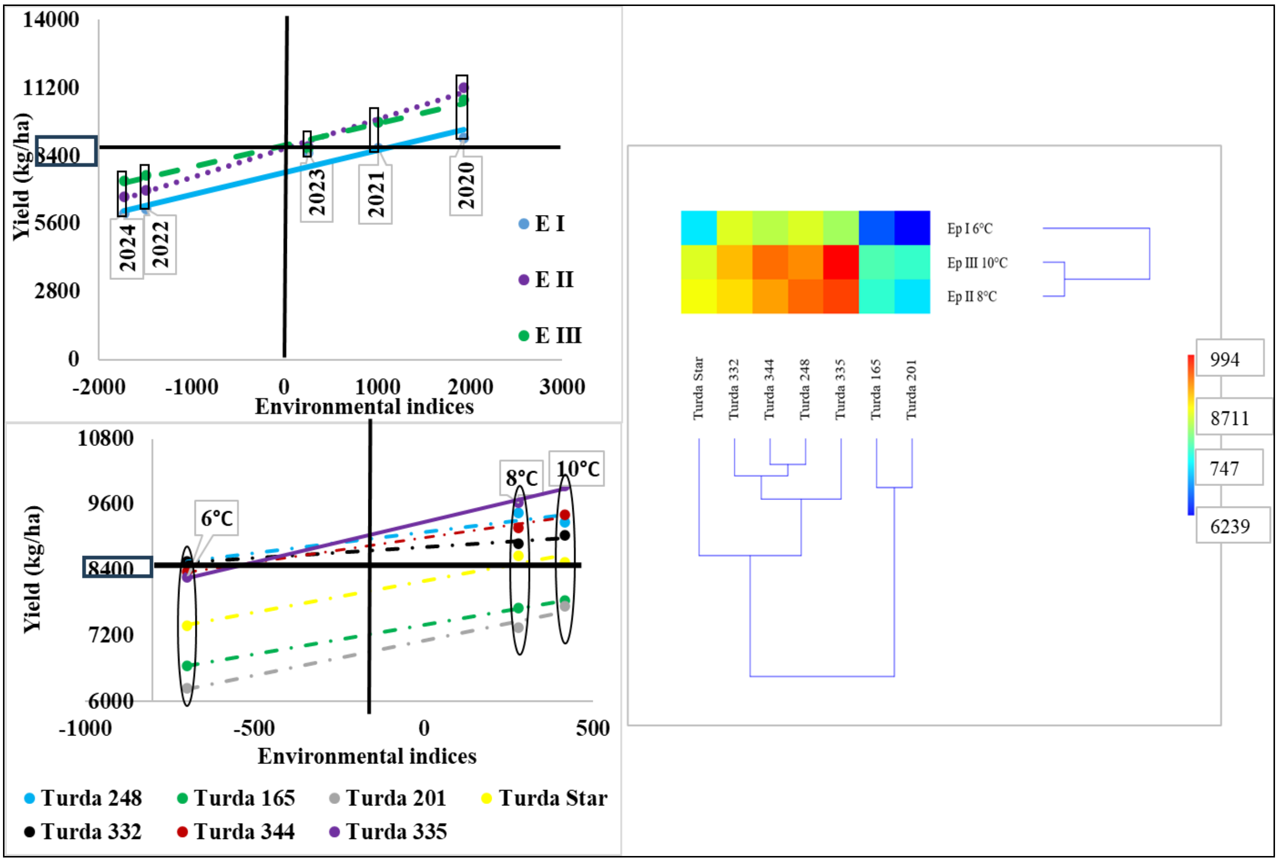

Figure 2. The stability of the yield capacity in 7 maize hybrids grown over 5 years and at three different sowing dates

TKW is a production component significantly influenced by environmental conditions (Zhang et al., 2023, Domokos et al., 2024) and by the hybrid (Barşon et al., 2021). In a year with favourable conditions for maize cultivation, such as 2020 in our case, the 1000-grain weight (TKW) exceeded 278 g, regardless of the sowing date. Based on the average performance, a decrease of nearly 80 g in this parameter was identified in the treatment sown at 6°C compared to that sown at 10°C (Figure 3). Once again, the superiority of the last two sowing dates is evident compared to the first, regardless of climatic conditions.

Regarding the performance of the seven hybrids, the highest TKW was observed in the hybrid Turda 335, both in terms of average behaviour and as the maximum of the experiment, reaching a value of 362 g when sown at 10°C. Cluster analysis clearly shows that this hybrid occupies an independent position due to its consistently good results. On average, in the years 2021 and 2024, good results for oil content were achieved when maize was sown at 10°C (Figure 4).

Regarding the performance of the seven hybrids, a marked stability was identified within the same experimental variant, with the best results obtained for the hybrids Turda 201, Turda 165, and Turda 248 sown at 10°C. These results are confirmed by the statement made by Djalovic et al. (2024), according to which maize hybrids from FAO groups 200–400 have a higher content (≈4%) than those from other maturity groups.

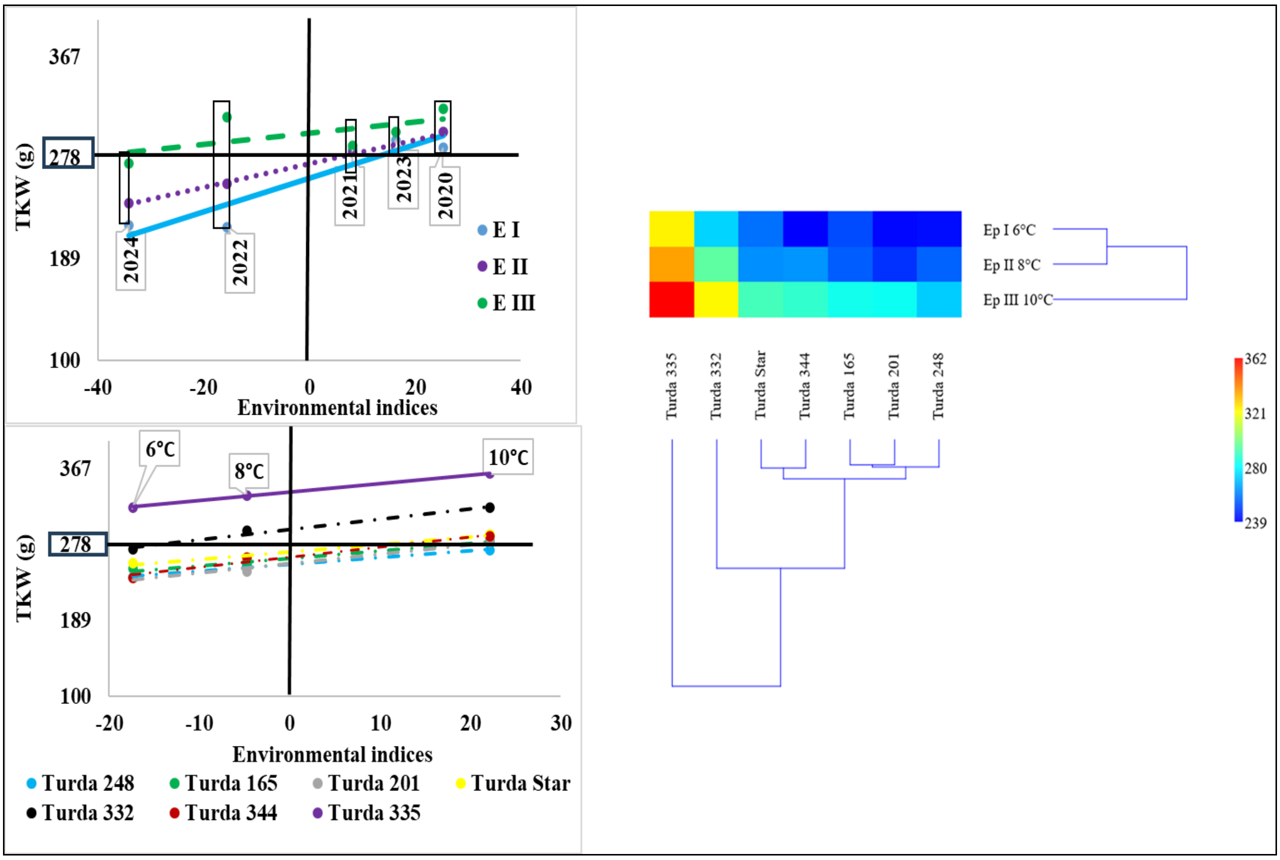

Figure 3. The stability of the TKW in 7 maize hybrids grown over 5 years and at three different sowing dates

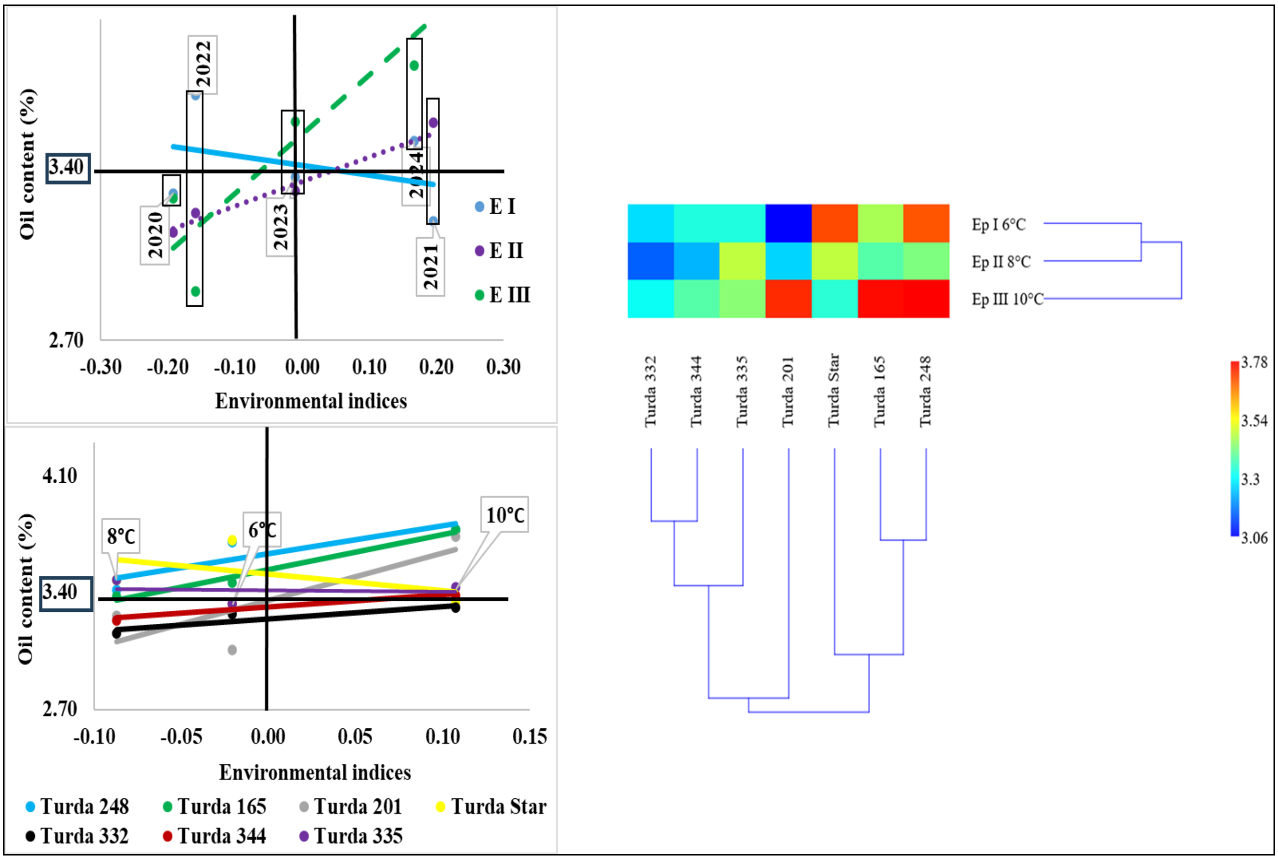

Figure 4. The stability of the oil content in 7 maize hybrids grown over 5 years and at three different sowing dates

Favourable conditions for the accumulation of fibre content were identified in the years 2020 and 2022. However, under less favourable conditions for this parameter, such as in our case in 2024, a superiority of maize sown at 6°C is observed compared to the optimal or slightly delayed sowing dates (Figure 5).

It is worth noting the hybrids Turda 248 and Turda 332, which exhibit both a pronounced stability in fibre content, regardless of sowing date, and high values for this parameter, as highlighted by the cluster analysis.

Following studies conducted by Liu et al. (2023), it was concluded that late-maturing hybrids have a higher fibre content than early maturing hybrids. The highest protein content, 7.97%, was identified in the hybrid Turda 201 sown at a temperature of 6°C. However, a pronounced stability in protein content was observed in the hybrid Turda 165, with stability evident from the shallow slope of the regression line, which is nearly parallel to the OX axis (Figure 6).

The results obtained during the 2020-2024 period show that in years with unfavourable climatic conditions for maize production, protein content improves compared to favourable years. A similar conclusion was reached by Canvin (1965), who stated that with an increase in average temperature, nitrogen is primarily converted into protein content, followed by other quality indices. Studies conducted by Barutçular et al. (2016) observed that water stress during the grain-filling period did not have a significant effect on protein content.

Regarding the average protein content obtained in the seven hybrids, the best conditions for this parameter were observed in the years 2022 and 2024, with better performance at the sowing dates of 10°C and 6°C compared to the 8°C variant.

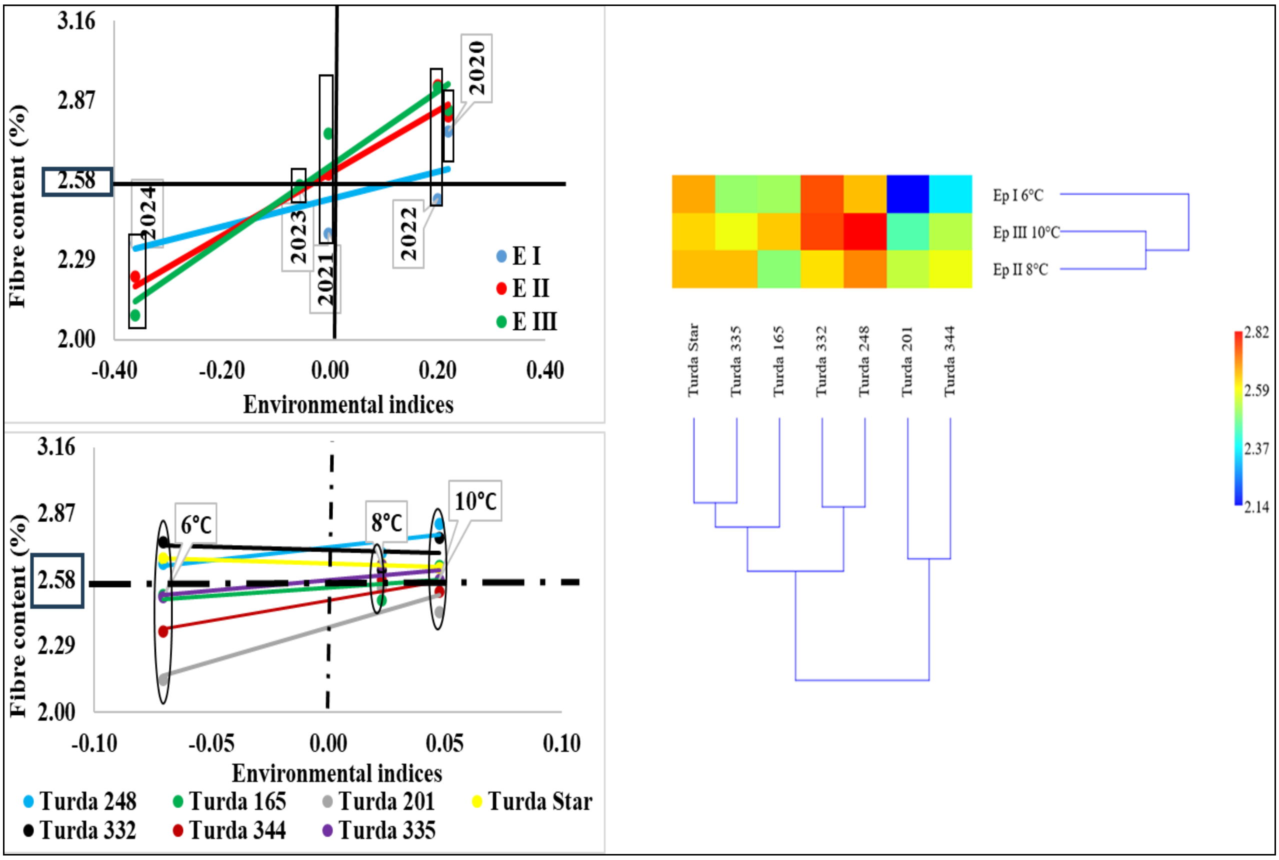

Figure 5. The stability of the fibre content in 7 maize hybrids grown over 5 years and at three different sowing dates

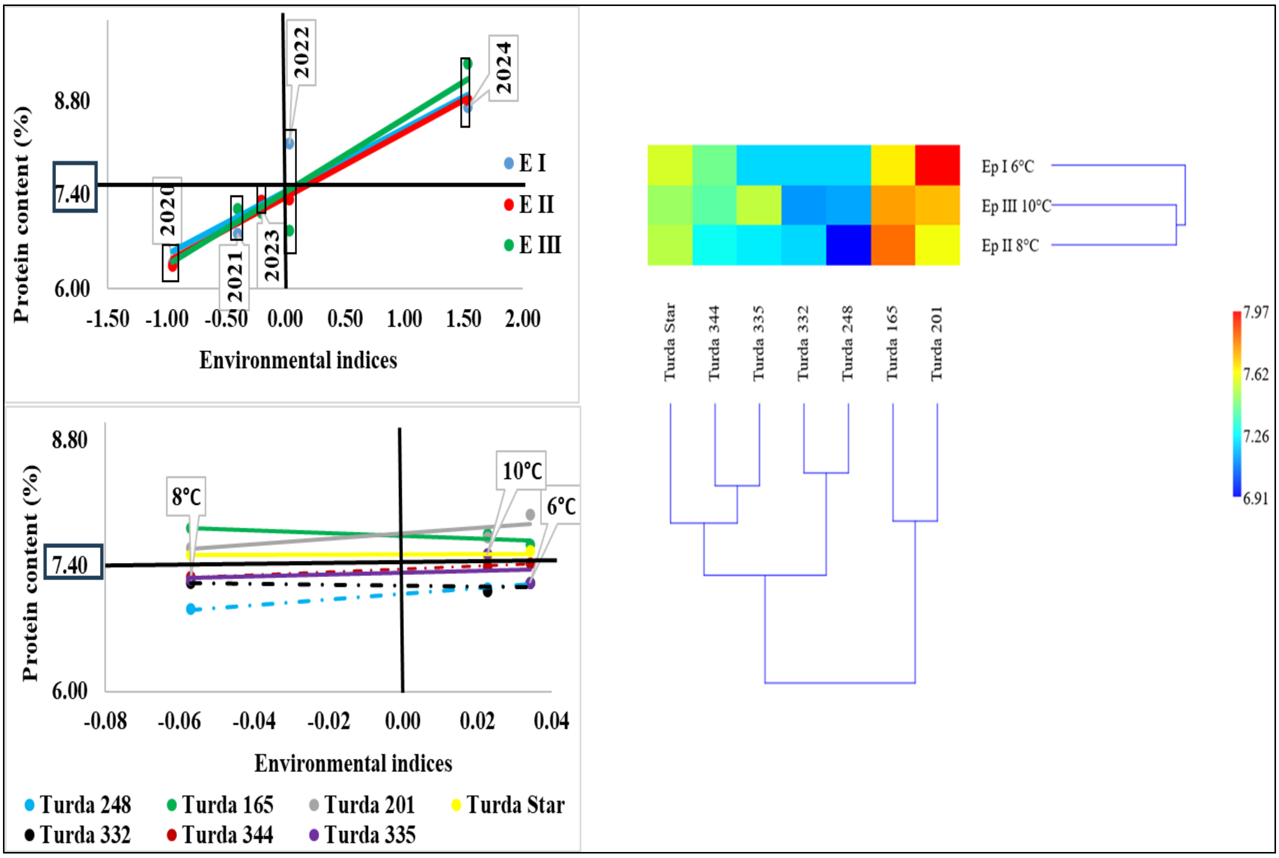

Figure 6. The stability of the protein content in 7 maize hybrids grown over 5 years and at three different sowing dates

CONCLUSIONS

Choosing the adequate maize hybrids with high yield and good stability can be an effective solution for increasing maize grain yield, regardless of sowing time or variations in environmental conditions.

In the conditions of the five years of experimentation, the optimal sowing date, when 8°C in soil with an increase trend is recorded, showed superiority over early sowing for all maize hybrids.

Looking at the overall influence of climatic conditions on maize yield, changing the sowing date, depending on soil temperature, cannot be considered a viable alternative in the fight against water stress.

Scientific research, particularly breeding activities, must focus on developing hybrids adapted to the current conditions in Romania.

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