Effect of precipitation on wheat (Triticum aestivum), maize (Zea mays), and sunflower (Helianthus annuus) yields in the district of Szentes

A csapadék hatása a búza (Triticum aestivum), a kukorica (Zea mays) és a napraforgó (Helianthus annuus) termésére a Szentesi járásban

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Abstract: Hungary's three most important arable crops are wheat, maize, and sunflower. These crops have the largest area under cultivation. In our study, we compared the average yields of a 200-ha farm on the outskirts of Szentes city with variations in rainfall conditions. We have shown that the amount of rainfall during the growing season affected the yield averages of wheat and maize and their prices on the world market. Yields of drought-sensitive maize, which prefers humid conditions, were most dependent on rainfall. However, rainfall also proved to be a significant factor in wheat yield averages. Sunflower yield averages did not correlate with rainfall, which may be because water demand is highly dependent on the phenological stage. Therefore, a good rainfall distribution over time is also important for this crop. Changes in rainfall patterns due to climate change do not favor any crop. This is because climate change is reflected in a linear trend in annual rainfall amounts and greater rainfall variability over time and space.

Keywords: *Triticum aestivum, Zea mays, Helianthus annuus, rainfall extremities, drought, Great Hungarian Plain*

Összefoglalás: Magyarország három legjelentősebb szántóföldi kultúrája a búza, a kukorica és a napraforgó. Vetésterülete ezen kultúráknak a legnagyobb. Tanulmányunkban egy Szentes település határában fekvő kétszáz hektáros gazdaság átlagos terméshozamait vetettük össze a település csapadékviszonyainak változásával. Kimutattuk, hogy a vegetációs perióduson belüli csapadék mennyisége hatással volt a búza és a kukorica termésátlagaira és ezen keresztül a világpiaci áraik alakulására is. Leginkább a humid körülményeket kedvelő, aszályjelző kukorica terméshozama függött a csapadékösszegtől. Jelentős tényezőnek bizonyult azonban a búza termésátlagaiban is a csapadékösszeg. A napraforgó termésátlagai nem mutattak összefüggést a csapadék mennyiségével, melynek oka abban kereshető, hogy a vízigény erősen függ a fenológiai fázistól. Emiatt ezen kultúra esetében a csapadék megfelelő időbeli eloszlása is lényeges. Az éghajlatváltozás okozta csapadékviszonyok megváltozása egyik növénynek sem kedvez. Azért mert az éghajlatváltozás nem csak az éves csapadékösszeg lineáris trendjében mutatkozik meg, hanem a csapadék időbeli és térbeli nagyobb változékonyságában is.

***Kulcsszavak**: Triticum aestivum, Zea mays, Helianthus annuus, extrém csapadék, aszály, Magyar Alföld*

1 Introduction

Of particular relevance among the impacts of climate change on agriculture is the increase in the frequency of extreme precipitation events and droughts (Stott, 2016). Such changes in precipitation patterns also affect crop yields in the Carpathian Basin (Jánosi et al., 2023; Hetesi et al., 2023). This is particularly true in cultivated areas where natural precipitation is the only source of water taken up by plants (Varga-Haszonits and Varga, 2005). Sufficient and timely natural precipitation is necessary for plant growth and development and achieving optimal crop yields. Depending on their phenological stage, knowledge of the water requirements of plants is also the key to the time-differentiated planning of artificial water supply.

The critical period for common wheat (*Triticum aestivum* L.) is the development of its generative organs and achieving yield potential (Nyiri, 1993). If wheat does not receive sufficient water, it will limit its further development, reduce the amount of genetic yield available, and reduce the quality of the crop (Alaei et al., 2010; Xuemei et al., 2010; Nouri et al., 2011; Ragheid et al., 2011).

For maize, the early growing season is critical. Water loss due to evaporation in rows that have not yet closed is high (Lacolla et al., 2023). Early growth, in addition to full reproduction, requires significant amounts of water. Without irrigation, this period must coincide with a natural rainfall peak. In Hungary, irrigation of maize is essential to achieve optimal yields, as the crop's water requirements are almost always more significant than the precipitation of the growing season (Tamás et al., 2022).

It is also true for maize and wheat that insufficient rainfall leads to drought stress. However, excessive precipitation and the high humidity that often accompanies it are not beneficial either, as they promote the growth and reproduction of many hydrophilic plant pathogenic fungi (Pál-Fám and Rudolf, 2014) and weed infestation (Varga, 2002; Márton et al., 2013).

In the case of sunflowers, the most important role in achieving optimal yields is played by balanced rainfall conditions. Sunflowers require the most water until plate formation. However, from plate formation to stalk maturation, high rainfall is particularly harmful because it encourages (mainly fungal) infections.

Our study aimed to investigate the precipitation conditions in the Szentes district and how the annual and growing season precipitation amounts affect the yields of wheat, maize, and sunflowers on a farm. In the broader region, the largest area (209 706 ha) is under wheat. This is followed by maize (221 541 ha) and sunflower, which has a significant area (KSH, 2020; KSH, 2022). This order is also valid for all regions of Hungary, which is why these three crops were chosen.

2 Materials and Methods

Our study was conducted in the Szentes District in the Southern Great Plain region (*Figure 1*). Szentes is the third most populous settlement in the Csongrád-Csanád county, on the River

Tisza's left bank. The Lower Tisza Water Management Directorate (ATIVIZIG, 2024) measures daily rainfall at the *Felsőveker* hydrometeorological station in the municipality. As is standard, the rainfall totals are automatically read at exactly 07:00 every day with an accuracy of tenths of a millimeter.

We investigated whether annual wheat, maize, and sunflower yields from 2006 to 2019 and rainfall totals show a linear relationship. Rainfall totals were determined by summing daily rainfall data separately for the growing season and separately for the whole calendar year. Yields were obtained from a large farm based in Szentes city, which did not use artificial irrigation water supplementation during the study period. Therefore, natural precipitation was the primary source of water for the crops.

Finally, annual yields were compared with average market selling prices for wheat and maize. We examined the extent to which yields show a negative correlation with sales prices and whether successive years of low yields could result in a rolling effect on prices.

3 Results and Discussion

Figure 1 shows how sensitive the yield of different crops is to rainfall. A medium-strong correlation is observed for maize, considered a drought indicator crop, and a medium-strong correlation for wheat. As a control, the yields of the sunflower fields occupying the third largest area of the farm were also examined. Our original hypothesis was supported by the fact that sunflower yields did not show any correlation with rainfall.

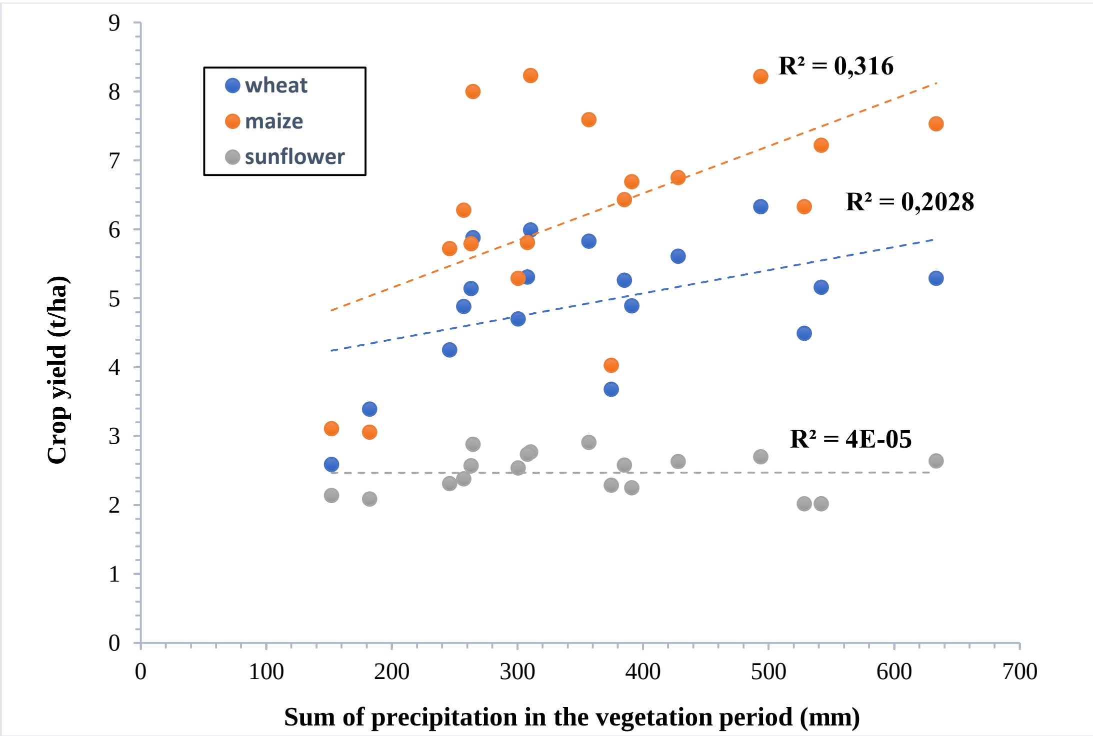

Figure 1 *Yields (t/ha) of maize, wheat, and sunflower on a farm near Szentes and the sum of precipitation in the vegetation period data in Szentes between 1978 and 2020 (Source of data: ATIVIZIG, 2024; Szentes farm, 2023).*

The lowest yields shown in *Figure 2* belong to 2003 and 2007, when the growing season rainfall did not even reach 200 mm. The year with the highest rainfall was 2014, when 633.6 mm of rainfall was recorded during the growing season. Even so, this is not the year with the highest average yields, which indicates the impact of the high rainfall not being positive (+78% compared to the growing season average). The highest yield averages typically occurred in years close to the multi-year rainfall average (2016, 2018, 2020).

Figure 2 *Trends in wheat and maize crop yields and average buying-in prices 2003–2020.*
(Source of data: KSH, 2024; Szentes farm, 2023)

A similar positive correlation was found between maize yield (=0.21) and wheat yield and annual precipitation between 2006 and 2019 in a study in Poland. Still, Poland's climate is rainier than Hungary's (*Wójcik-Gront* and *Gozdowski*, 2023).

Several factors can explain the lack of a strong correlation, the most important of which is plants' phenological, phase-dependent water demand, which varies during the growing season. The water requirements of plants are more or less constant and are a well-known varietal characteristic. Like many abiotic environmental factors, rainfall is optimal for crops within a range. Too much rainfall can lead to anaerobic soil conditions and soil erosion, as the soil has a finite capacity to absorb water. It can also increase the growth and spread of weeds, pests, and pathogens that require a wet and humid environment. Among pathogens, fungal diseases such as rust (*Puccinia sorghi, Puccinia striiformis, Puccinia triticina*) and fusarium (*Fusarium* sp.) are particularly susceptible to humid conditions. Aphids (Aphidoidea) and leaf beetles (Oulema sp.) are also important among pests.

It is also worth comparing wheat and maize crop yields with buying-in prices (*Figure 2*). It can be seen that the two driest years (2003 and 2012) had the lowest yields, which drove up buying-in prices. In the years with better yields, prices fell.

An even more accurate relationship between crop yields and buying-in prices would be obtained by inflation-adjusted prices. However, the drought year 2012 is still striking, with only 182.3 mm of rainfall in the vegetation period and prices at a record high (wheat: 60 425 HUF/t, maize: 56 697 HUF/t). The previous year, also dry, was also low, with 246.1 mm of rainfall. Thus, the high buying-in price in 2012 probably reflects the rolling effect of the drought; just as the fall in prices was delayed, the rise in yields appeared with a lag. Limited storage time also plays a role in this.

4 Conclusions

The dependence of wheat and maize yields on the amount of precipitation is shown using the example of the average yields of a large farm from 2003 to 2020. The drought-sensitive nature of maize, which prefers humid conditions, was shown by the dependence of the yield average on higher precipitation. Wheat yield averages were found to be less dependent on rainfall than maize, which is consistent with the lower water requirement of the crop. This result confirms the role of intra- and inter-annual rainfall forecasting in crop protection.

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