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THE EFFECT OF DROUGHT STRESS ON THE PHENOLOGICAL PARAMETERS OF DIFFERENT MAIZE HYBRIDS

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Abstract. *Irrigation experiments related to drought stress are important from several points of view. The first of these is to improve the quality and quantity of the yield, as it is already known, drought stress negatively affects the growth and development of plants, which can lead to a reduced average yield and a lower quality crop. Irrigation trials allow us to determine how to replace missing moisture to maximize yield and improve crop quality. Optimizing water management is also of great importance, as efficient water management is critical for plant survival and maximizing yield. The exploration of genetic differences is also an important aspect, since different plant varieties or hybrids may react differently to drought stress. Irrigation trials help identify stress-tolerant cultivars or hybrids that are better adapted to drought conditions. During our research, we tested five different maize hybrids in the year of 2023. The location was the experimental farm of the Hungarian University of Agriculture and Life Sciences Department of Irrigation and Land Improvement in Szarvas. The experiment was set up under a foil tent, in order to completely exclude natural precipitation, resulting in an even and precise water dose for all hybrids during the research. The experiment was created with three repetition with three different water dose, during the growing season we were able to monitor the air temperature of the experimental area, the leaf area (LAI) of the different hybrids, the relative chlorophyll content (SPAD) value and the plant height, while the total biomass was determined during the harvest.*

Keywords*: drought stress, irrigation, maize*

INTRODUCTION

Globally, cereals provide the majority of human food. According to Laskowski et al. (2019), these staple foods play a central role in food security. The FAO report indicates that in 2022, global cereal production increased by 8.3 million tons. The most important cereals are maize (1,151.36 million tons), wheat (783.8 million tons), rice (502.98 million tons), and barley (150.48 million tons). These crops are fundamental sources of nutrition worldwide.

Maize (Zea mays L.) has been cultivated for over 9,000 years, originating in southern Mexico. Today, its global production exceeds one billion tons annually. It exhibits remarkable adaptability to diverse agroecological and climatic regions. This adaptability enables its extensive use as food for humans, feed for livestock, and raw material for the agricultural processing industry.

In Hungary, maize is the crop with the largest cultivation area, with an annual sown area approaching 1.2 million hectares, according to the Central Statistical Office. Adequate yield security for maize can only be achieved with irrigation, however, the irrigable area in Hungary is significantly smaller, approximately 400,000 hectares. Government plans only aim to double this area. The current utilization of irrigation infrastructure is only 25%, making a significant increase in irrigable areas appear unreasonable.

According to FAO (2017), the world population is projected to reach 9.7 billion by 2050. One of the greatest challenges for humanity will be how to sustainably feed this growing population. Maximizing maize production and productivity can play a crucial role in stabilizing agri-food systems and promoting food security (Grote et al., 2021; Poole et al., 2021; Ranum et al., 2014; Shiferaw et al., 2011).

To achieve this, it is important to manage production inputs and soil fertility, adopt integrated nutrient management, and implement climate adaptation strategies.

The average water requirement for maize typically ranges from approximately 500 to 800 mm of rainfall or irrigation water during a full growing season. This value can vary depending on the location of cultivation, climate, soil type, and other factors. It is important to note that this is a general estimate, and the specific water requirement should always be adjusted to local conditions and the maize hybrid variety (Djaman et al., 2013).

The amount of water available for agricultural irrigation is decreasing worldwide due to the growing population and competition for water resources (e.g., industries, environmental functions, municipalities, recreation, biofuel production, mining, etc.), as well as deteriorating water quality. Additionally, climate change impacts the seasonal distribution and magnitude of precipitation, as well as the recharge of soil and surface water resources (Irmak, S. et al., 2012).

Irrigation plays a fundamental role in maximizing maize yield, especially in drought-prone areas. Optimizing irrigation strategies can significantly improve water use efficiency and reduce yield losses (Payero et al., 2006; Steduto et al., 2012; Tolk et al., 1999). Limited irrigation can result in significantly different productivity under various climatic conditions. Howell et al. (1995) reported that limited irrigation reduced maize yield by affecting both kernel weight and the number of kernels per ear in the Bushland region of Texas. It has been demonstrated that limited irrigation practices increase the water use efficiency of maize and other crops, as water use is reduced more than yield (Howell and Hiler, 1975; Djaman and Irmak, 2012; Payero et al., 2009).

According to AQUASTAT (2022), the global irrigated area for maize is 31.5 million hectares, which accounts for 15.6% of the world's total maize cultivation area. The largest irrigated maize areas are found in China (13 million ha), the USA (4.8 million ha), and India (2.2 million ha). In Europe, maize is irrigated on 2.4 million hectares, primarily in France, Italy, and Spain.

In summary, cereals, particularly maize, play a crucial role in global food security. Optimizing maize production and improving water use efficiency are key to developing sustainable agricultural systems, especially in the context of a growing population and increasing competition for water resources.

MATERIAL AND METHODS

The irrigation response of maize hybrids depends on many factors, such as the genetic characteristics of the hybrid, soil type, climatic conditions, and the irrigation technology applied. In our case, the most important aspect is the genetic characteristics of the hybrids. Some hybrids are genetically more resistant to drought and require less irrigation, while others utilize the available water more efficiently, producing higher yields with the same amount of water. Our experiment was set up at the experimental farm of the Hungarian University of Agriculture and Life Sciences Department of Irrigation and Land Improvement in Szarvas.

The experiment was conducted under a greenhouse to ensure that rainfall would not influence the results, allowing the plants to receive only the amount of water we intended to apply. We selected five maize hybrids which are popular in the Hungarian cultivation.

The hybrids were sown on April 11, 2023, with 8 kg of soil measured into each pot and we sown four seeds per pot. On May 31, 2023, we adjusted the number of plants and separated the water portion, after that only two plants remained in each pot.

In the experiment, three levels of water supply were established. Initially, the total water-holding capacity (TWC) of the soil was determined, which represents the amount of water the soil can retain against gravitational forces. The following treatments were implemented:

- SWS 40%: 40% of the water content of the soil saturated to its total water-holding capacity.
- SWS 60%: 60% of the water content of the soil saturated to its total water-holding capacity.
- SWS 80%: 80% of the water content of the soil saturated to its total water-holding capacity.

In the experiment, water was applied to the culture vessels every two days during the cooler spring climate and daily during the warmer summer period. The daily amount of water applied was regularly recorded, and adjustments were made as necessary based on temperature and plant evaporation rates.

During the growing season, we performed the following measurements:

- Chlorophyll content (SPAD)
- Leaf area index (cm^2) (LAI)
- Plant height (cm)
- Biomass (g)

RESULTS AND DISCUSSIONS

During the growing season the following datas were measured in the research.

Table 1.

Phenological parameters measured during the growing season in response to different water supply levels.

Treatment	Plant Height (cm)	SPAD	LAI (cm^2)	Biomass (g)
1/SWS80%	156.33	32.1	948.38	262.29
2/SWS80%	114.33	34.73	1092.88	329.6
3/SWS80%	120.67	36.03	1314.25	339.42
4/SWS80%	123.33	37.77	1356.88	459
5/SWS80%	104	37.8	951.38	393.42
1/SWS60%	125	33.2	923.88	165.31
2/SWS60%	99	36.5	1252.5	273.19
3/SWS60%	102	31.57	1083.38	293.29
4/SWS60%	99	35.53	951.63	339.97
5/SWS60%	91	37.63	824.38	327.22
1/SWS40%	101	32.43	848.88	115.18
2/SWS40%	81.67	32.57	787.13	179.24
3/SWS40%	86.33	30.73	821.13	177.29
4/SWS40%	84	31.67	736	186.33
5/SWS40%	79	31.3	708.5	194.74

Plant Height: Within the SWS80% treatment, plant height values ranged from 156.33 cm to 104 cm, with an average plant height of 123.33 cm among the five hybrids. In the SWS60% treatment, these values were significantly lower, ranging from 125 cm to 91 cm, with an average plant height of 103.2 cm. The lowest water supply level (SWS40%) resulted in plant heights ranging from 79 cm to 101 cm, with an average height of 86.2 cm across the five hybrids.

Plants under the SWS 80% treatment exhibited the greatest average height, indicating that sufficient water supply is crucial for maximizing plant stature. Conversely, the SWS 40% treatment resulted in the shortest plants, highlighting the adverse impact of water stress on growth.

SPAD (Chlorophyll Content): Higher SPAD values in the SWS 80% treatment indicate better chlorophyll content and, potentially, higher photosynthetic activity. The SWS 40% treatment showed the lowest SPAD values, suggesting reduced chlorophyll content under water-limited conditions.

Within the SWS80% treatment, the average SPAD value was 35.29 across the five hybrids. In the SWS60% treatment, this showed a decreasing trend with an average of 34.43, while within the SWS40% treatment, the value was only 31.74.

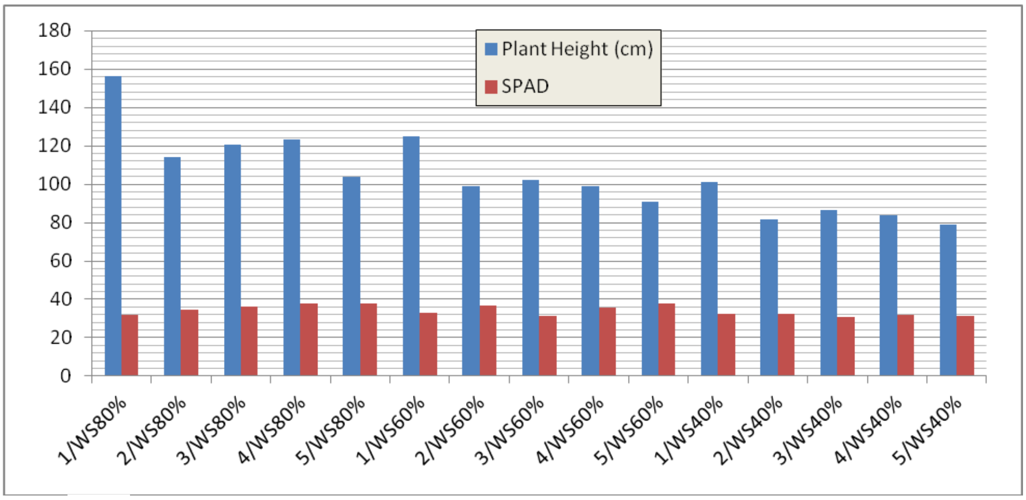

Fig 1. Changes in plant height and SPAD values in response to different water supply levels.

Leaf Area Index (LAI): The LAI was highest in the SWS 80% treatment, indicating more extensive leaf area and, consequently, higher potential for photosynthesis. The reduced LAI in the SWS 40% treatment reflects the negative impact of water stress on leaf development.

Biomass: Biomass accumulation was significantly higher in the SWS 80% treatment compared to the other treatments. This suggests that adequate water supply not only supports vegetative growth but also enhances overall plant productivity. The lower biomass in the SWS 40% treatment underscores the detrimental effects of water scarcity on plant growth and yield.

These findings are consistent with previous studies that emphasize the importance of adequate water supply for optimal plant growth and yield (Payero et al., 2006). Water stress, as evidenced by the SWS 40% treatment, negatively affects plant height, chlorophyll content, leaf area, and biomass accumulation.

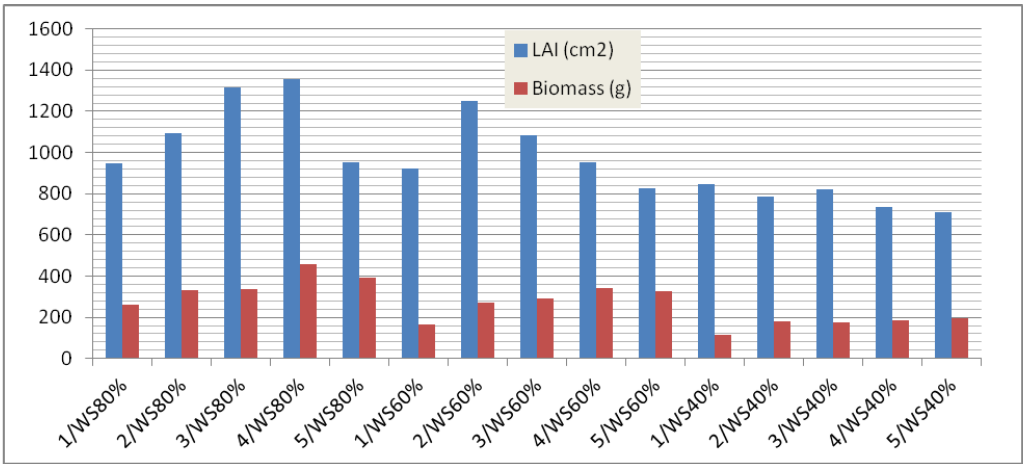

Fig 2. Changes in leaf area index and biomass values in response to different water supply levels.

CONCLUSIONS

The experiment demonstrates that higher water supply levels significantly enhance maize growth parameters, including plant height, SPAD readings, LAI, and biomass. The SWS 80% treatment resulted in the highest values for all measured parameters, indicating optimal growth conditions. In contrast, the SWS 40% treatment showed the lowest values, highlighting the negative impact of water limitation. These results underscore the importance of adequate irrigation in maximizing maize growth and productivity, and they provide valuable insights for developing effective water management strategies in maize cultivation. Further research could explore the long-term effects of these treatments on yield and other physiological responses.

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