

Examination of drought stress of two genotype maize hybrids with different fertilization

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SUMMARY

In the growing season of 2019, we analysed stress resulting from climatic factors on maize hybrids of different genotypes, with the aim of gaining a better understanding of the physiological responses of each hybrid, which might support the elaboration of a cost-effective irrigation plan.

Our experiments were carried out at the Látókép Experimental Station of the University of Debrecen on calcareous chernozem soil in a small-plot long-term field trial with strip plot design. In the scope of the experiment, N-fertilizer doses were applied as basic fertilizer and top-dressing in addition to the non-fertilized (control) treatment. The 60 and 120 kg N/ha doses applied as basic fertilizers in the spring were followed by top-dressing in the V6 phenophase with a +30 kg N/ha dose. Measurements were carried out with the involvement of the Renfor early (FAO 320) and Fornad (FAO 420) late maturity hybrids-

The stomata of the plants became more and more closed with the progression of the phenological phases; their stomatal conductance decreased. However, the hybrids responded differently to environmental stress. In the case of the Renfor hybrid, the highest conductance (669 mmol/m²s) was recorded in the V12 phenophase with the 150 kg N/ha treatment. The stomata were more open due to the high turgor pressure, allowing plants to evaporate properly. The plant was in its worst physiological condition on 2nd July, at the time of the appearance of the last leaf in the case of the 120 kg N dose (224 mmol/m²s). The value measured in the V12 phenophase has already shown that the stomata were closing due to the self-regulating system of the plant. It would have been necessary to dispense irrigation water following the measurement. This confirms the finding that water stress can be prevented by measuring stomatal conductance.

In the case of the Fornad hybrid, stomatal conductance was the highest on 12th June (630 mmol/m²s) in the 90 kg N/ha treatment and it was the lowest (183 mmol/m²s) in VT (emergence of the last leaf) phenophase in the 60 kg N/ha treatment. In this case, the appropriate time for applying irrigation water would have been early July, when the conditions for the plants were still adequate. Subsequently, the stomata began to close due to a reduction of the water resources available to them.

There was a significant correlation between soil moisture and stomatal conductance, as well as between temperature and stomatal conductance.

Keywords: climate change, maize, stomatal conductance

INTRODUCTION

Adverse weather extremes caused by climate change, drought and water shortage have significant negative effects on the yield and quality of maize (Mukesh et al., 2017). Water shortage during tasseling (Nagy, 2007) and high temperature during fecundation (Butler and Huybers, 2015) result in significant yield reduction. One of the solutions to adapting to extreme weather is to choose stress-resistant hybrids that withstand drought. These hybrids tolerate high temperatures (Islam et al., 2012; Marton et al., 2012; Jolánkai et al., 2016) and provide adequate yield and quality (Izsáki, 2006; Győri, 2010; Pepó, 2017). At the same time, prevention and timely detection of drought play a key role in cultivation (Jolánkai and Birkás, 2010).

The average water content of the plants is 60–80% (Martinez et al., 2010) and in order to maintain this water content, the plant needs continuous water uptake throughout the entire vegetation period. Only 1–2% of the absorbed water is used by the plant, while 98–99% is evaporated (Jones et al., 2013).

By measuring stomatal conductance, plant stress can be detected even before the onset of symptoms (O'Toole and Cruz, 1980), since water supply, heat and

light conditions have a decisive influence on stomatal openness and position (Boldizsár, 2007; Anda and Löke, 2002; Anda et al., 2010) and stomatal conductance (Miyashita et al., 2005; Yunpu et al., 2013). The aim is to investigate how hybrids of variable genotypes react to the reduction of soil moisture and heat stress. In addition, to prove that the effects of stress can be demonstrated by examining stomatal conductance before the onset of plant symptoms.

MATERIALS AND METHODS

Production site description: The examinations were carried out in Hungary, at the Látókép Experimental Station of the University of Debrecen (47° 33' N, 21° 26' S, altitude: 111 m), on loess-based, lowland calcareous chernozem soil. The trial is a striped small-plot long-term field trial. The measurements were carried out in 2019 with natural precipitation, using Renfor (FAO 320) early maturity and Fornad (FAO 420) late maturity maize hybrids.

Based on the results of soil analysis in 2012, it can be stated that the average pH_{KCl} value of the soil is 6.6, which is considered to be slightly acidic; it is optimal for the nutrient uptake of plants. In the upper layer (20 cm) of the soil, Arany's plasticity index is 39 and the

total amount of water-soluble salts is 0.04%, which means low salt content. The carbonated lime content in the upper 80 cm of the soil is around 0%, which means that the soil is considered to be lime deficient, but below 100 cm there is 12% lime, which indicates that the soil is moderately calcareous. The upper 20 cm of the soil has a 2.3% organic matter content, which does not exceed 1.0% at a depth of 120 cm. The potassium supply of the soil is good and its P content can be considered moderate.

Experimental details: Field examinations were performed with the Sc-1 Leaf Porometer. It determines air flow from originating from the leaves and stomatal conductance of leaves as a function of the density, size and degree of opening of the stoma. Measurements are made over a period of 30 seconds in the range 0–1000 mmol/m²·s. Measurements were made on the lower, middle and upper leaves, respectively. The average of the values obtained was used to infer the physiological state of the specimens. The TDR soil moisture-measuring probe was used to determine soil moisture. From the average of three measurements per plot, we could infer the soil moisture status. In the field experiment, in addition to non-fertilized (control) treatment, the N-fertilizer doses were distributed as basic fertilizers and top-dressing. The 60 and 120 kg N/ha doses applied as basic fertilizers in spring were followed by top-dressing in the V6 (six leaf stage) phenophase with a +30 kg N/ha dose. The green crop was maize. The maize was sown on 10.04.2019. Measurements were performed on seven separate

occasions between 4th June and 16th July, 2019, in non-fertilized (control), A₆₀, (60 kg N applied as base fertilizer) A₁₂₀, (120 kg N applied as base fertilizer) V₆₉₀, (A₆₀+ at 6 leaf stage 30 kg N) and V₆₁₅₀ (A₁₂₀+ at six leaf stage 30 kg N) treatments. Evaluation of data was carried out with the SPSS for Windows 21.0 statistical software package by means of linear regression correlation test.

RESULTS AND CONCLUSIONS

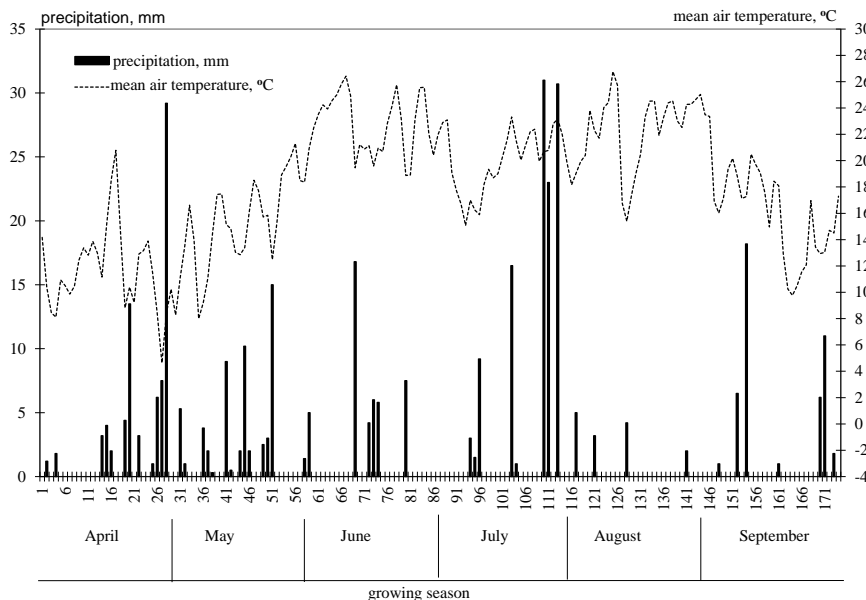
Climatic characterisation of the crop year

Weather was evaluated on the basis of data measured and recorded by an automatic weather station located in the experimental site. The values were compared to the mean values over the period 1981–2010 (Nagy, 2019).

In the winter period preceding the 2019 growing season, there was little rainfall (only 93.7 mm), which was 113.3 mm below the average. As a result, the replenishment of the deeper soil layers was not satisfactory. The total amount of precipitation in the 2019 growing season (365 mm) was 19 mm above the average (346 mm).

In June, precipitation was 19 mm below the mean values (66 mm). The mean monthly temperature was 21.9 °C; especially the middle of the month was warm (Figure 1). Maize is less susceptible to drought and extreme high temperatures during this period than before and later during the silking and ripening periods.

Figure 1: Air temperature and the amount of rainfall during the growing season of maize, 2019



The dry period continued in early July, with colder than normal weather in the middle of the month, which mitigated the adverse effects of the already reduced level of soil moisture. According to Gombos and Nagy (2019), the mean temperature in July (21.1 °C) has never been this low in the last 10 years. There was

significant rainfall in the second half of the month. Nearly half of the precipitation fell in 2 days at the end of July (30 and 31 mm), the total amount of precipitation of the month was 116 mm. This amount was significantly higher than the average of multiple years. However, in terms of the phenological



development of maize, this amount of precipitation arrived somewhat late. August was extremely dry, with only 14 mm of rainfall, much below the average (49 mm).

Development of the stomatal conductance of different genotype hybrids

Within the period of 4th June and 16th July the conductance varied over a wide range. The lowest value of the interval was 183 mmol/m²-s while the highest value was 669 mmol/m²-s. Based on the first stomatal conductance measurement (4th June), the environmental conditions were adequate for maize

hybrids in terms of plant stress. Lower stomatal conductance was observed in the case of the 60 kg N/ha treatment, but it was recorded at differed nutrient levels for each examined hybrid. In the case of the Fornad hybrid it was recorded in the 150 kg N/ha treatment (413 mmol/m²-s) while for the Renfor hybrid in the control (406 mmol/m²-s). However, the highest value developed inversely, because the most appropriate environmental condition at the time for the Fornad hybrid was in the non-fertilized treatment (590 mmol/m²-s) while for the Renfor hybrid in the 150 kg N/ha treatment (544 mmol/m²-s) (Figure 2–3).

Figure 2: Stomatal conductance of the Fornad (FAO 420) maize hybrid, 2019

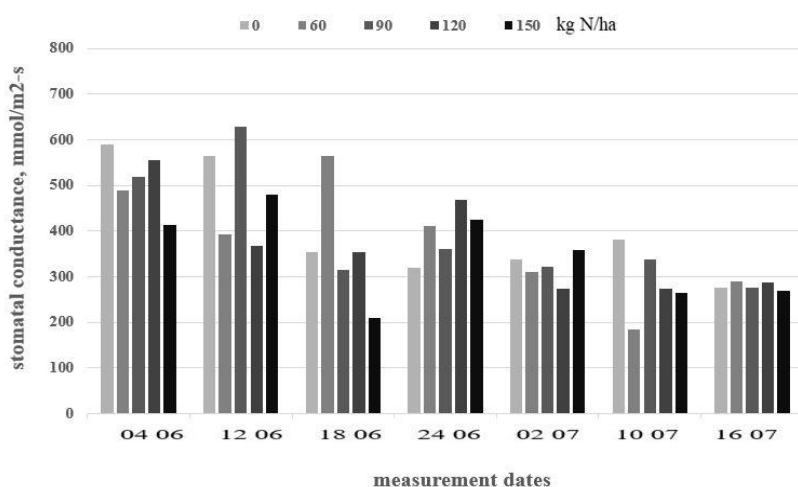
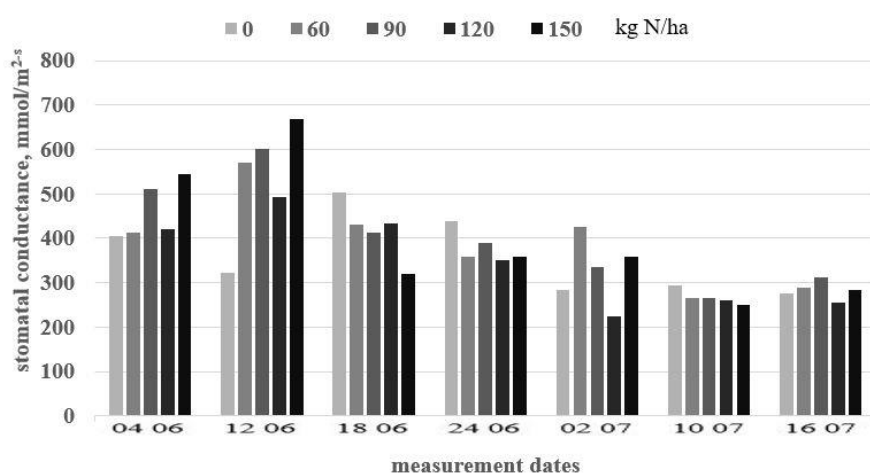


Figure 3: Stomatal conductance of the Renfor (FAO 320) maize hybrid, 2019



On the second measurement date (12th June), the lowest value (323 mmol/m²-s) for the Renfor hybrid was recorded in the control treatment, while the highest stomatal conductance was measured in the 150 kg N dose treatment. The Fornad hybrid reacted differently

to environmental conditions, because its highest stomatal conductance (629 mmol/m²-s) was measured in the case of the 90 kg N treatment.

The measurement that took place six days later (18th June) showed that there was a stress situation for both



hybrids in the 150 kg N/ha treatment, which is indicated by low stomatal conductance. (the plant was exposed to heat and water stress due to decreasing soil moisture and high temperatures). However, the data also show that the Renfor hybrid, which has a shorter breeding period had a better stomatal conductance (319 mmol/m²-s) than the Fornad hybrid (210 mmol/m²-s, which has a longer breeding period. The best physiological condition of the plants was recorded in the control (503 mmol/m²-s) for the Renfor hybrid and in the 60 kg N/ha treatment for the Fornad hybrid.

Different properties of the hybrids showed themselves on the basis of the conductance measured in the V12 (12 leaf) phenological phase of maize (24th June). The Renfor hybrid had the least stress (heat and water stress) in the control treatment, whereas the Fornad hybrid had the most stress in the same treatment. The most suitable environmental condition was in the 120 kg N/ha treatment (468 mmol/m²-s).

The stomatal conductance measured at the time of the appearance of the last leaf (2nd July) showed that both hybrids had the highest stress in the 120 kg N/ha treatment. The extent of the stress situation varied between hybrids. The plant stress situation was higher in the case of the Renfor hybrid (243 mmol/m²-s) than in the case of the Fornad hybrid (274 mmol/m²-s).

In the VT (last leaf appears) phenological phase by the emergence of the last leaf, the Fornad hybrid was under the most stress in the 60 kg N/ha treatment with a conductance value of 183 mmol/m²-s. This was the lowest stomatal conductance value during the examined period. The stomatal activity showed that the most optimal condition for both hybrids was in the control treatment.

Following the R1 phenophase, the two hybrids had approximately the same stomatal conductance, ranging from 255 mmol/m²-s to 313 mmol/m²-s.

In summary, it can be stated that the stomata of the plants became more and more closed with the progression of the phenological phases and thus their stomatal conductance decreased. However, the hybrids

responded differently to environmental stress. In the case of Renfor (an early maturity hybrid), the highest conductance was recorded in the 150 kg N/ha treatment of the V12 phenological phase (669 mmol/m²-s). The plant was in its worst physiological condition on 2nd July, when the last leaf appeared (224 mmol/m²-s) in the 120 kg N dose treatment. However, closing of the stomata was detectable already on the basis of the values measured in the V12 phenophase. Following the measurement, it would have been necessary to apply irrigation water to avoid water stress. All of the above confirm the finding that water stress can be prevented by measuring stomatal conductivity.

The late maturity Fornad hybrid had the highest conductance on 12th June (630 mmol/m²-s) in the 90 kg N/ha treatment, while the lowest value (183 mmol/m²-s) was measured in the VT phenophase in the 60 kg N/ha treatment. In this case, the appropriate time for the irrigation water to be applied would have been early July, when the conditions for the plants were still adequate. Subsequently, the stomata began to close due to a reduction of available water resources.

Effect of soil humidity and air temperature on stomatal conductance

Linear regression was used to examine the correlation between soil humidity and stomatal conductance, which showed a significant correlation (Figure 4). The obtained results are in accordance with Miyashita et al. (2005) who found that the responses of stomata are closely related to soil moisture content. Water deficiency of soil causes the closing of the stomata. As the phenological phases progressed, soil humidity decreased and became a limiting factor, the plant became under water stress, and stomatal conductance decreased. In both hybrids, stomata were closed to reduce plant transpiration.

There was also a significant correlation between temperature and stomatal conductance (Figure 5). As the temperature increased, the stomata of the plants were closing, resulting in a lower conductance value.

Figure 4: Effect of soil humidity on stomatal conductance

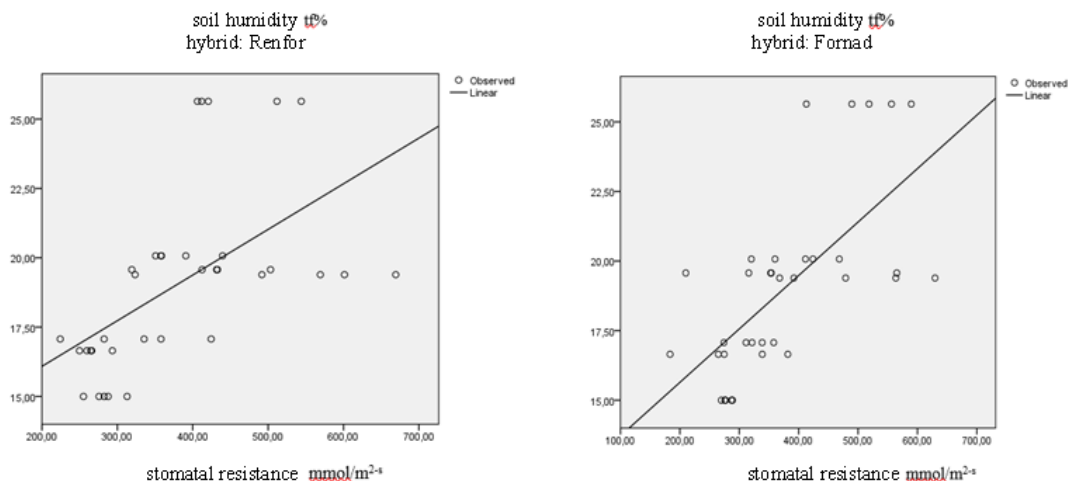
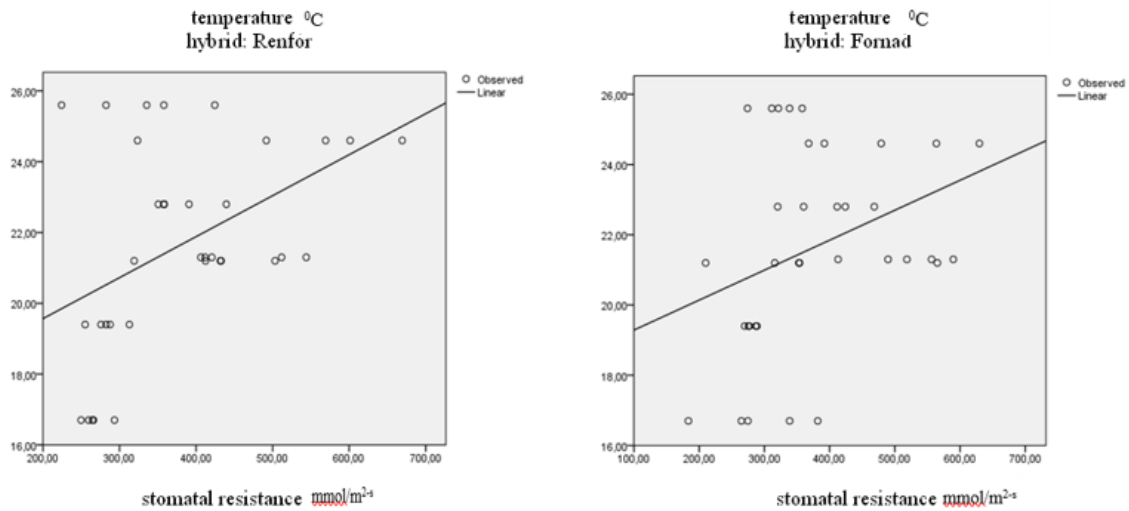


Figure 5: Effect of temperature on stomatal conductance



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