THE EFFECT OF ABSCISIC ACID AND BENZYLAMINOPURINE ON GASES EXCHANGE AND WATER USE EFFICIENCY IN MAIZE (*ZEA MAYS* L.) DURING WATER STRESS

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Vaclav HEJNAK

Czech University of Life Sciences Prague, Faculty of Agrobiology, Food and Natural Resources, Department of Botany and Plant Physiology, Kamycka 129, 165 21 Prague, Czech Republic

Corresponding address: hejnak@af.czu.cz

Introduction

Sustainable development of the cultivation eco-systems for maize is only possible if the stability of the circulation of water, nutrients and energy in the whole system consisting of soil, plant and atmosphere is ensured. Physiological responses at the level of stomata, which regulate the output of water as well as intake of CO_2, are very important to ensure good balance between water intake through roots and water output through leaves. Much attention is paid to the effect of growth regulators on the regulation of water management of plants. In a number of agricultural crops, including maize, the effect of abscisic acid (ABA) on the closing of stomata and the effect of cytokinins on their opening was proved.

The aim of the experiment

To identify how ABA and cytokinin benzylaminopurine (BAP) in C_4 maize plants influence the gas exchange parameters if they are applied as late as during a deepening soil drought.

Materials and methods

Young maize plants (*Zea mays* L., cv. Anjou 245) were used for the experiment. The experiments were taking place in a physiological greenhouse under controlled conditions: 14-hour photoperiod, the temperature 20–25 °C during the day and 16–20 °C at night and the relative air humidity 50–60 %. In containers filled with soil, 5 plants were cultivated on an area of 0.05 m^2. The soil moisture was maintained at the level of 60–70 % of the maximum capillary water capacity. Plants 8 weeks old were divided into 6 groups with 4 repetitions:

1. control group – plants irrigated throughout the experiment;
2. plants stressed by drought – complete interruption of irrigation;
3. plants stressed by drought + 3 days after interruption of irrigation, 100 µM ABA was applied;
4. plants stressed by drought + 3 days after interruption of irrigation, 1 µM BAP was applied;
5. plants stressed by drought + 3 days after interruption of irrigation, 10 µM BAP was applied;
6. plants stressed by drought + 3 days after interruption of irrigation, 10 µM BAP + 100 µM ABA was applied.

The growth regulators (BAP and ABA) were applied by a spray device on the leaves of the plants. The concentration levels BAP 1 µM and 10 µM and ABA 100 µM were used in the application dose, corresponding to 100 cm^3 m^{-2} when converted. The Citovett wetting agent was used.

The responses of the plants to changes of the moisture content in soil and the applications of the growth regulators on the leaves of the plants were identified by measuring the relative water content (RWC) in leaves, the photosynthesis rate (Pn), the transpiration rate (E) and the water use efficiency (WUE) as a Pn/E. Pn and E were identified in intact leaves by means of a gasometrical infrared analyser *LCA-4* (*ADC Bio Scientific Ltd.*, Hoddesdon, UK). 3 leaves were measured in each experimental container. The immediate reactions on the applications of the growth regulators were detected by measurement of Pn, E and WUE in the period 24 hours after applications. The longer-range trends were detected in the period 3–9 days after applications of the growth regulators. In the assimilation chamber, the temperature during the measuring process was 25 °C, the level of irradiance was 750 µmol m^{-2} s^{-1}, air humidity was 50 % and the concentration of CO_2 was 350 µmol mol^{-1}.

The statistical evaluation was carried out by means of a variance analysis at $\alpha = 0.05$ in the Statistica computer software, version 6.1 CZ, the ANOVA module. The mean values measured in three series of experiments have been published.

Results and discussion

Young plants of maize, cv. Anjou 245, exposed in variants 2 to 6 to gradual drying-up of soil substrate retained a high RWC > 80 % (84 through 89 %), throughout the experiment, which was not statistically different from the levels observed in the control variant 1.

However, in spite of the high RWC, stomatal limitation of the gas exchange parameters (Pn and E) occurred on the drying-up soil (Fig. 1 to 4). There were observed a statistically significant decrease of the photosynthesis and transpiration rates in the plants stressed by drought in variant 2 in comparison with the non-stressed variant 1. WUE was approximately the same or lower in comparison with the non-stressed plants (Table I).

Growth regulators applied on the plants stressed by drought at the point of time after 3 days significantly influenced the parameters of the exchange of gases between the maize leaves and the surrounding environment. When 100 µM abscisic acid (ABA) was sprayed on a leaf (variant 3), this resulted, throughout the experiment, by tighter closing of stomata and by lower levels of Pn and E in comparison with the stressed plants, not treated by growth regulators. The decrease of the gas exchange parameters was greatest shortly (in the period 24 hours) after the application when the differences were highly provably in comparison with the untreated plants. The statistically nonsignificant improvement of WUE was occurred after the application of ABA.

When benzylaminopurine (BAP) in the concentration of 1 µM (variant 4) was sprayed on the maize plants, this resulted in steady, but statistically improvably higher levels of Pn. On the contrary, E was lower than in the stressed plants, not treated by growth regulators, and it was lower to a statistically provable extent during the period 3–9 days after applications of BAP. When a stronger concentration of BAP amounting to 10 µM (variant 5) was used, Pn increased to a statistically highly provable extent in comparison with the untreated plants but it did not reach the level of Pn in the control plants that were irrigated throughout the experiment. The levels of E identified by measuring were hovering around the levels identified in the stressed untreated plants. The application of both concentration of BAP on plants stressed by drought resulted, throughout the monitored period, in improve level of WUE in comparison with the stressed plants not treated by BAP.

When the stronger concentration of BAP and 100 µM ABA were applied common (variant 6), Pn and E increased in comparison with stressed plants, not treated by growth regulators, but WUE didn´t improve.

Conclusions

The results confirmed that growth regulators supplied to C4 maize plants growing on a drying-up soil during a water stress can effectively influence its photosynthetic performance and water management capability. Reducing the gas exchange parameters by applying ABA can generally improve the ability of plants to survive an unfavourable drought because reduction of the amount of water evaporated through transpiration enables the plant to economise water, to adapt gradually as concerns osmosis and to redistribute water in its organs. Another aspect that apparently also matters are the interactions of exogenously supplied substances and the natural levels of hormones in plants, as shown by the findings obtained after application of BAP. A lower dose ultimately supported the ability of maize plants to economise water and improved water use efficiency (WUE). A higher dose supported improvement of WUE by increasing the photosynthesis rate.

Acknowledgements

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Table I. *The water use efficiency (WUE) of young maize plants, cv. Anjou 245, during water stress in the period 24 hours and 3–9 days after applications of the growth regulators. Mean ± SD (n=9).*

Variants	WUE (mmol CO_2 mol^{-1} H_2O) during water stress in the period 24 hours after application of the growth regulators		WUE (mmol CO_2 mol^{-1} H_2O) during water stress in the period 3–9 days after application of the growth regulators	
	Mean	SD	Mean	SD
1	9,02	0,46	9,88	0,59
2	9,15	0,84	9,01	0,91
3	10,15	0,75	10,05	0,67
4	10,69	0,47	11,81	0,6
5	10,26	0,52	10,38	0,72
6	9,17	0,55	8,95	0,41

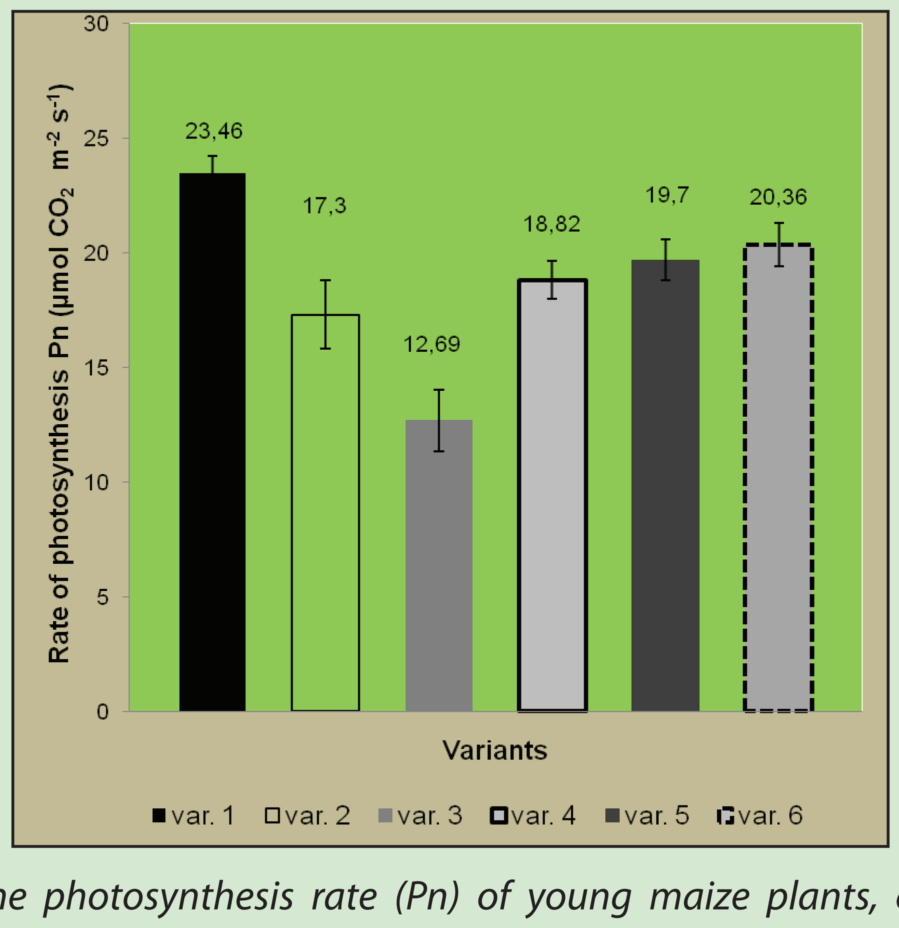

Figure 1. *The photosynthesis rate (Pn) of young maize plants, cv. Anjou 245, during water stress in the period 24 hours after applications of the growth regulators. Mean ± SD (n=9).*

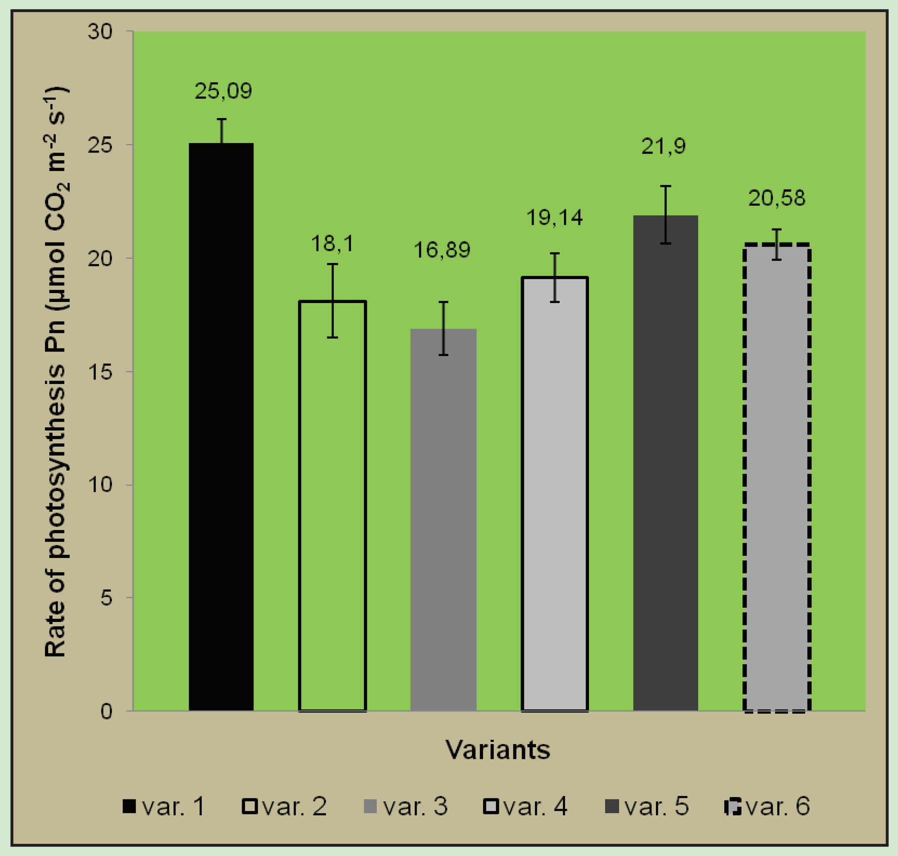

Figure 2. *The photosynthesis rate (Pn) of young maize plants, cv. Anjou 245, during water stress in the period 3–9 days after applications of the growth regulators. Mean ± SD (n=9).*

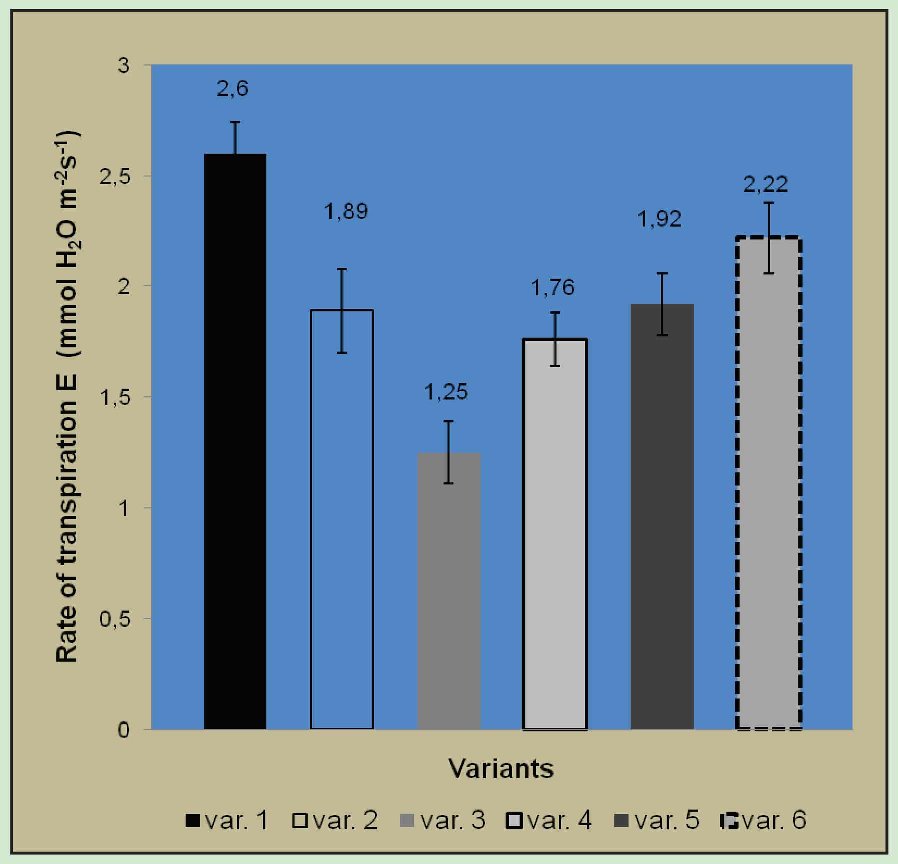

Figure 3. *The transpiration rate (E) of young maize plants, cv. Anjou 245, during water stress in the period 24 hours after applications of the growth regulators. Mean ± SD (n=9).*

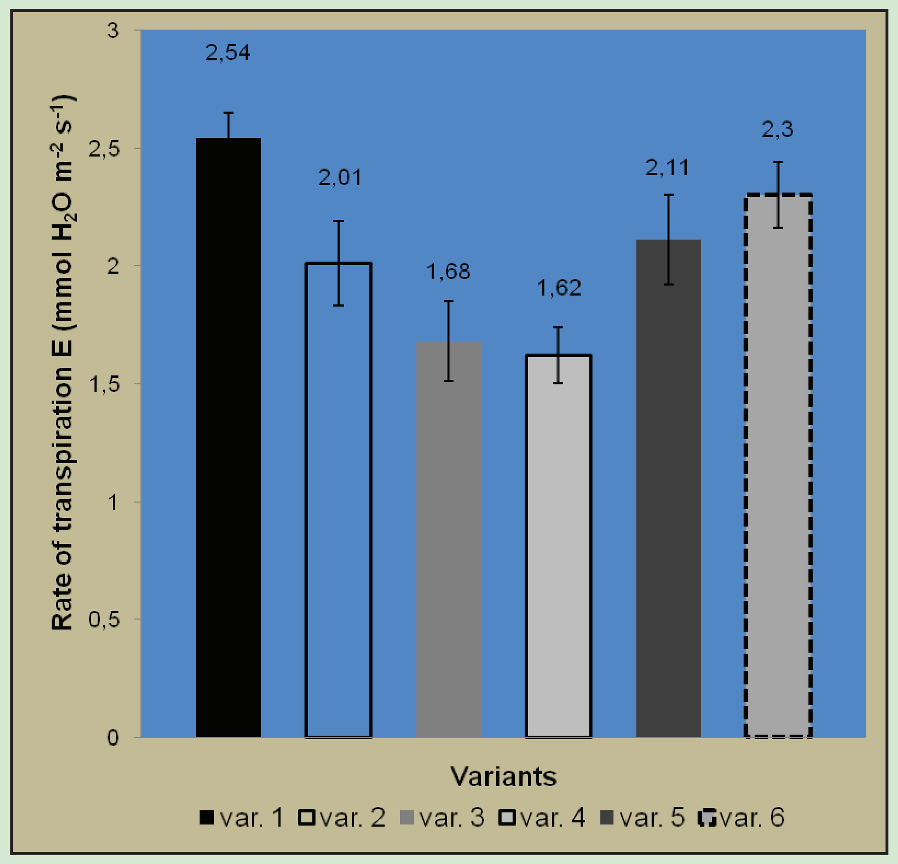

Figure 4. *The transpiration rate (E) of young maize plants, cv. Anjou 245, during water stress in the period 3–9 days after applications of the growth regulators. Mean ± SD (n=9).*