

**IDENTIFICATION OF CHANGES IN THE METABOLIC PROCESSES
OF GERMINATION AND GROWTH OF MAIZE SEEDLINGS UNDER
THE INFLUENCE OF HEAT STRESS AND THE USE OF REGLALG**

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ABSTRACT

Laboratory experiments were carried out to determine the effect of pretreatment of seeds of two hybrids of maize (*Zea mays* L.) with Reglalg and subsequent exposure to heat stress (HS) of 50°C for 30 min on seed germination, seedling growth and assessment of translocation of endosperm reserve substances for these processes. The results showed a positive effect of Reglalg on seed germination and seedling growth parameters, which were affected by HS conditions. The use of Reglalg to treat the seeds of maize hybrids before expose to HS, had a beneficial effect on the formation of seedling biomass due to an increase in the mass of endosperm translocated from seeds to these processes under the conditions of stress. Also, the use of Reglalg in seed pretreatment favored the decrease in endosperm mass consumed for cellular metabolism respiration under HS.

INTRODUCTION

The effective growth and development of plants is determined by a number of environmental factors, among which the temperature regime is of great importance. Due to climate change, high temperature has become a major abiotic stress affecting crop yields in many regions of the world (Lesk et al. 2016, Khaeim et al. 2022). Stresses of high temperature induce changes in morphological, physiological, biochemical and molecular changes in plants (Hasanuzzaman et al. 2013, Shi et al 2017). At the same time the influence of stress factors, including high temperature is determined by the plant species, their development phases, the degree and duration of action of the factors.

Maize *Zea mays* L. originating from tropical and subtropical regions, which seems to be adapted to warm temperatures, is also affected by the action of temperature stress (Shi et al. 2017, Khaeim et al. 2022). The results of the NASA study show that climate change has a serious impact on the growth, development and productivity of maize, whose production as early as 2030 is expected to decrease by 24% (Jägermeyr et al. 2021). It is also known that the most important morpho-physiological traits that characterize the effect of high temperatures are the growth processes in the early stages of ontogenesis (Cheng et al. 2018, Andrade et al. 2019, Khaeim et al. 2022). Seed germination and vigorous seedlings formation may depend on their ability to use seed reserve substances more efficiently, which

is dependent on various factors, including temperature regime, genotype type and the application of different seed pretreatments before germination (Sikder 2009, Sharafi et al. 2012, Tian et al. 2014, Cheng et al. 2018, Li et al. 2022).

The aim of this work was to study germination, seedling growth and the mobilization of seed reserve substances in these processes of maize hybrids, differing in resistance to high temperatures, under the influence of heat stress and the use of the Reglalg preparation.

MATERIAL AND METHODS

Maize (*Zea mays* L.) seeds of two hybrids with different resistance to high temperatures, including resistant - Por. 374 and sensitive - Por. 427, used in the study, were provided by the Public Institution «Porumbeni» Institute of Phytotechnics. The experiments were conducted under controlled laboratory conditions. Before germination, maize seeds treated with water (control) or the optimal dose (1/200) of Reglalg (experimental) and air-dried were placed for imbibition in water at 5°C for 36 hours. Afterward part of the control and experimental seeds were exposed to heat stress (HS) of +50°C for 30 minutes, and the other part of the control and experimental seeds were treated at 26°C. Then followed the placement of the treated seeds of all variants for germination in a dark chamber at a temperature of 26°C and air humidity of 60-75%. During the experiments, the final percentage of germination was evaluated both in the controls and in the experimental variants. The 5-day-old maize seedlings were collected and used to determine the epicotyls height and radicle length. Then these individual components were weighed and placed in an oven at 105°C ± 2°C for 72 hours to determine the dry weight. Dry root mass (DRM), dry epicotyls mass (DEM), dry mass of 1 plant (DMP), dry seed biomass until germination (DSM0) and dry seed biomass after germination (seed remnant) (DSMR) were determined for all variants. In order to determine the rate of endosperm biomass translocated in formation of biomass of roots, epicotyls, seedling, unused endosperm biomass after germination and endosperm mass eliminated for respiration, first, the amount of endosperm mass consumed in respiration (DMRE) was determined by the formula:

$DMRE = DSM0 - (DRM + DEM + DSMR)$; where, DSM0 - dry seed biomass before germination, DRM - dry root biomass, DEM - dry epicotyls mass, DSMR - dry seed biomass after germination (seed endosperm residue after 120 hours from the time of seed placement in the thermostat for germination). Then, the biomass rates of endosperm allocated to the growth of roots (RMER), epicotyls (RMEE), seedlings (RMEP), and unused endosperm (RMNE), as well as eliminated for respiration (RMRE) were determined according to the formulas (Dascaluc et al. 2020).

The data were statistically processed, determining the mean value, standard deviation and credibility of the mean values using the «Statistics 7» software package for computers.

RESULTS AND DISCUSSIONS

The results on the effect of a heat stress (HS) of 50°C for 30 minutes on the germination rates of corn hybrids that differ in resistance to high temperatures are presented in table 1. Obtained results showed that HS reduces the percentage of seed germination in the studied hybrids, both for the controls (53% - Por. 374; 75% - Por. 427), as well as for the variants with the application of Reglalg (62% - Por. 374; 87% - Por. 427).

Table 1

The influence of high temperature (HT) of 50°C for 30 min and the application of the optimal dose of 1/200 of Reglalg on the germination rate of the seeds of corn hybrids that differ in resistance to high temperatures

Hybrids	Treatments	Temperature treatment	Final germination, %
Por. 374, resistant to HT	Control (C), H ₂ O	C, 26°C,	98
		HT, 50°C, 30 min	53
	Reg., 1/200	Reg., 26°C,	98
		HT, 50°C, 30 min	62
Por. 427, sensible to HT	Control (C), H ₂ O	C, 26°C,	100
		HT, 50°C, 30 min	75
	Reg., 1/200	Reg., 26°C,	100
		HT, 50°C, 30 min	87

It can be observed that pretreatment of seeds with Reglalg used in 1/200 concentration, had a beneficial effect on their germination under the action of HT stress of 50°C for 30 min.

In figure 1 are presented the data on the changes of radicle length and epicotyl height of hybrid maize seedlings Por. 374 and Por. 427, depending on the preliminary application of the Reglalg preparation, dose 1/200, and followed the exposure to the HT of 50°C action for 30 min. The obtained results demonstrate the positive effect of the Reglalg in increasing growth rates of seedlings, including the length of radicles and height epicotyls, compared with the controls.

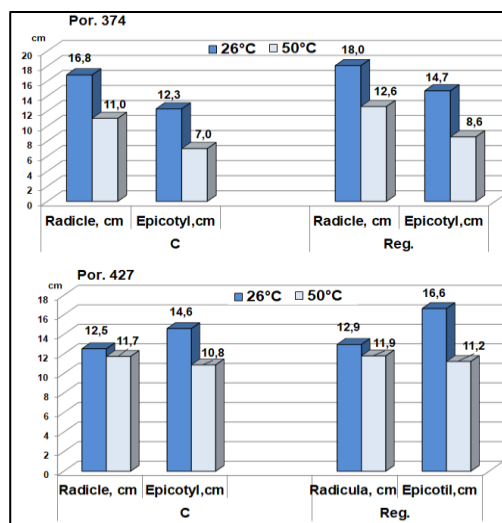


Fig. 1. Changes in biometric indices, including radicle length and epicotyl height of hybrid maize seedlings Por. 374 and Por. 427 depending on the application

of the Reglalg preparation, dilution 1/200 and the exposure to HS of 50°C action for 30 min. Age of seedlings – 5 days.

The maximum length of both radicles and epicotyl was obtained for seedlings of maize hybrid resistant to high temperature - Por. 374. In variants with Reglalg application and followed the HS treatment, the length of the radicles was significantly longer - by 14%, and epicotyls - by 22%, compared with the controls. These data demonstrate the stimulatory effect of Reglalg, used in seed under HS action conditions. And for the hybrid sensitive to high temperatures - Por. 427, the application of Regal also demonstrated the tendency to increase the growth parameters of seedlings under HS conditions.

Thus, the use of the Reglalg for the treatment of maize seeds before exposure to HS had a beneficial effect on the processes of germination and growth of seedlings, increasing the percentage of seed germination and the value of morphological parameters under the conditions of HS.

Stimulation of growth processes caused by pretreatment of maize seeds with Reglalg under HS should also be accompanied by a change in the dry mass content of seedlings components. In this regard, we conducted a study on the determination of the dry mass of seedling roots and epicotyls on the 5th days of ontogeny. The results (Fig. 2) demonstrate that the rate of dry matter removed from the endosperm during the processes of seed germination and seedling biomass

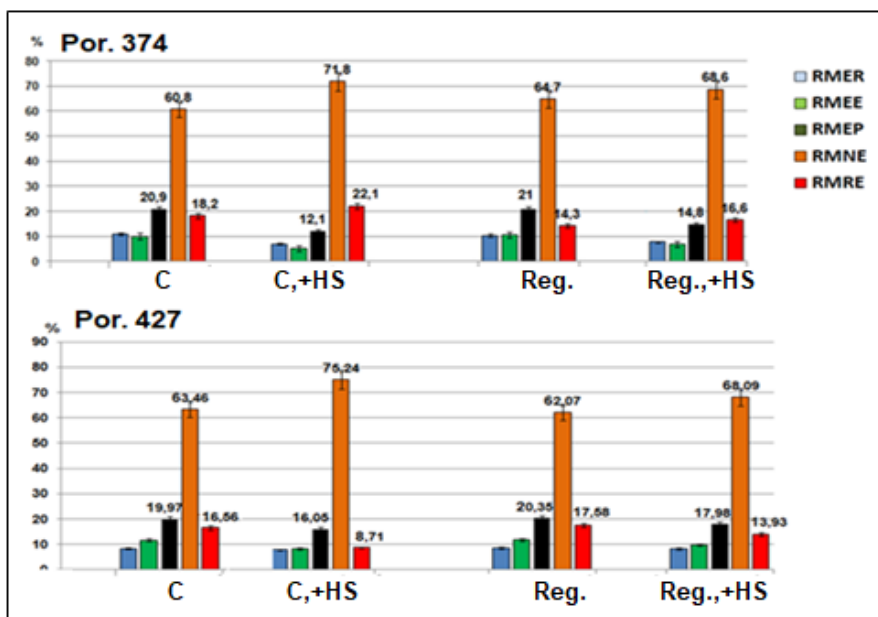


Figure 2. Influence of heat stress (HS) of 50°C for 30 min on the rates of reserve substances consumed from the endosperm on seed germination and seedling growth of maize hybrid P. 374 and P. 427. The seeds of the control and experimental variants were incubated for germination at + 26°C for 120 hours. Rates of endosperm allocated to the growth of roots (RMER), epicotyls (RMEE), seedling (RMEP), and unused endosperm (RMNE) as well as utilized for respiration (RMRE).

formation of studied maize hybrids is lower in the variants with HS of 50°C both in the control variants (C) as well as in the variants with Reglalg (Reg.). It should also be noted that HS, applied to the seeds of the high temperature resistant hybrid Por. 374, which reduce the mass of the endosperm released by the seeds during the formation of a biomass unit of the seedling, is accompanied, at the same time, by an increase in the mass of endosperm consumed in respiration. However, pretreatment of Por. 374 seeds with Reglalg (Reg.; Reg., +HS) led to a decrease in the rate of endosperm used for respiration (RMRE) by 21% and 24.9%, respectively, compared to controls (C; C, +HS).

Determination of the ratio between the rate of mass of the endosperm allocated in the formation of the biomass of roots to the mass allocated in the formation of the epicotyl (RMER/RMEE) show that for Por. 374 in the variants of controls and Reglalg with HS it consisted 1,33 and respective 1,13, and for Por.427-0,96 and respective 0,84, compared to their respective controls. Thus, in conditions of HS of both variants (C, +HS) and (Reg., + HS) the rate of endosperm mass of seeds of the hybrid resistant to high temperature (Por. 374) preponderantly is released in formation of roots biomass, whereas for sensible to high temperature hybrid - Por. 427 the value of these indices is less than of one unite. At the same time, significant differences are observed in the hybrids studied by the ratio between the endosperm mass allocated in respiration and the biomass formation of the seedling⁻¹. The values of the ratio (RMRE)/(RMEP) in the variants (C, +HS) and (Reg., +HS) for the high temperature resistant hybrid Por. 374 are 1.83 and 1.13, respectively, and for the sensitive hybrid, Por. 427 - 0.54 and 0.77, respectively. These results demonstrate that the intensity of the metabolism related to the processes of germination and growth of the seedlings of the high temperature resistant hybrid Por. 374 is higher, probable, activities induced in cells need more energy, and for the formation of a unit mass of the plant, more mass of the endosperm is spent in respiration, compared to those for the hybrid Por. 427-sensitive to high temperature.

CONCLUSIONS

Heat stress (HS) of 50°C for 30 min had a more pronounced effect on seed germination of Por 374, reducing germination by 45% compared to 25% for Por. 427, though from the point of view of resistance to high temperatures, Por.374 is considered resistant, and Por. 427 sensitive.

The use of Reglalg in the pretreatment of maize seeds showed a beneficial effect on the processes of germination and development of seedlings, by increasing the percentage of seed germination and the value of morphological parameters of seedlings under the action of HS.

The results obtained showed that, for both hybrids, HS reduces the mass of endosperm released by seeds during the formation of seedlings, reducing the biomass of seedlings⁻¹ by 20% and 12%, respectively, for Por. 374 and Por. 427. While application of Reglalg under HS conditions increases the rate of dry mass of endosperm allocated in formation of seedling⁻¹ biomass by 16% and 12%, respectively for Por. 374 and Por. 427.

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