Response of field crop species to abiotic stress impacts during early development

Szántóföldi növények fajspecifikus abiotikus stressz-reakciója a kezdeti fejlődés során

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Abstract: Field crops are exposed to various abiotic stresses at all crop sites. The use of adaptable species may reduce the risk of production. In an *in vitro* laboratory trial at the Agronomy Institute of the Hungarian University of Agriculture and Life Sciences, Gödöllő, field bean *Phaseolus vulgaris* L. and maize *Zea mays* L seeds were exposed to various abiotic stress conditions (water supply representing normal and flooded state, temperature with optimal and high exposures, and increasing salinity conditions). Seed samples of both species were tested for viability. The results of the trial suggest that the various abiotic applications had altering effects on the germination performance of seed samples. Bean seeds proved to be more vulnerable in comparison with maize.

***Keywords**: bean, maize, water stress, temperature stress, salinity stress, viability*

Összefoglalás: A szántóföldi növények minden termőhelyen számos abiotikus stressznek vannak kitéve. A termesztés kockázatát az alkalmazkodó fajok használata csökkentheti. A MATE Agronómiai Intézetében Gödöllőn *in vitro* laboratóriumi kísérletben bab *Phaseolus vulgaris* L és kukorica *Zea mays* L magvak csírázását vizsgálták különféle abiotikus stressz körülmények között (vízellátás normál és elárasztott állapot, optimális és magas hőmérséklet, valamint növekvő sótartalom). A kísérletek eredményei arra engednek következtetni, hogy a különböző abiotikus körülmények hatással voltak a magvak csírázására. A bab magvak érzékenyebbnek bizonyultak a kukoricához képest.

***Kulcsszavak:** bab, kukorica, víz-stressz, hőmérséklet-stressz, só-stressz, csírázás*

1 Introduction

Germination of seeds is a physiological process which is influenced by biotic and abiotic factors including water, oxygen, and temperature for a successful germination process. A combination of conducive environmental factors and various cellular processes will allow physiological and morphological changes within the seed which will result in activation of the embryo. Germination starts when the embryo and water (seed imbibition), resulting expansion of the seed and elongation of the embryo, and ends when the radicle has grown out of the seeds coating layers and with the protrusion of the coleoptile (Miransari & Smith, 2014).

Various impacts that may influence the regular physiological processes of live organisms are manifested in stress conditions. Selye (1974; 1983) determined four variations of stress. On one hand he identified good stress (eustress) and bad stress (distress). Regarding the magnitude both may be over-stress (hyperstress) or understress (hypostress). The optimum would be to balance hyperstress and hypostress perfectly and have as much eustress as possible. Viability of plant seeds and the development of germinated plants require certain environmental conditions. The most fundamental factors of these processes are the optimal presence of moisture, temperature, and the availability of oxygen. Any of them whenever missing or the presence of that is out of the optimum range may induce stress impacts on the germination and sprouting processes.

Temperature elevation can cause thermoinhibition on seeds germination. The germination rate decreases for seeds cultivated at a higher temperature. The high temperature also affects the root development of the seedlings (Iloh, et al., 2014).

Soil salinity level may create soil conditions with physiological drought, simultaneously may causes ion toxicity, nutrient imbalance and oxidative stress to the seed (Nayidu, et al., 2012). Kaymakanova (2009) reported that high salinity in soil solutions will result in high osmotic pressure that restricts the seed imbibition by preventing water absorption into the seed. Salt stress caused by NaCl may also decrease the content of essential hormones for germination, such as gibberellins (Atia, et al., 2009).

Water is essential during germination for the seed imbibition process thus, no germination will occur in the absence of water. Nonetheless, excess water will cause waterlogged soil conditions, which will deprive the seeds from oxygen supply. Permanent flood during germination stage resulted by extreme weather conditions, for example torrential rain, or planting in an area with high water table, can threaten crops with low water-logged tolerance by restricting the respiratory activity essential for germination (Zhou, et al., 2020).

It is common for one agricultural land to handle more than one abiotic stress at the same time. Water and temperature interactions often determine yield quantity and quality performance (Jolánkai et al. 2018). A combination of two or more abiotic stress will aggravate the impact of each stress and farmers may need to spend more input to remove or lessen the impacts. High temperature simultaneously with salt stress is a common condition, especially in semiarid and arid regions in the world (Shahid, et al., 2018). The combined stresses may reduce the photosynthetic rate in the same crop due to a decline in pigmentation (Neelambari., et al., 2018).

The aim of the present experiments was to determine the impact of some abiotic factors on seed germination of two crops. Bean *Phaseolus vulgaris* L as a dicotyledonous and maize *Zea mays* L a monocotyledonous plants were studied to determine the impact of water availability, temperature variations and salinity on the viability of seeds.

2 Materials and Methods

The present trial was conducted in the laboratory of MATE Agronomy Institute in Gödöllő, Hungary within an experimental series related to seed viability (Huynh Anh et al, 2024). The objective of the trial was studying the effect of abiotic stresses – among them temperature, salinity and waterlogging – on seed germination. Transparent Petri dishes; micro pipette; filter paper; distilled water; bean and maize seeds; Memmer-type climatic chamber; precision scale were used. Field bean *Phaseolus vulgaris* L. and maize *Zea mays* L seeds were exposed to various abiotic stress conditions (water supply representing normal and flooded state, temperature with optimal and high exposures, and increasing salinity conditions). The methods and the description of the trial were by general laboratory standards. The applications were as follows:

Temperature treatment. We carried out a study on the effect of three levels of temperature (T20; T25; and T30) on the germination of seeds as follows: 20°C, 25°C and 30°C respectively.

Salinity treatment. Two levels of NaCl concentrations on seeds germination (1000 ppm) and (1500 ppm) compared to control seeds (0 ppm) as follows: S0: control seeds. S1: seeds tested to germinate under 1000 ppm of salt. S2: seeds tested to germinate under 1500 ppm of salt.

Water treatment. In this trial, we tried to test three amounts of water in each seed using Petri dishes. The treatments were as follows: W0: seeds soaked in 6 ml of water, W1: seeds soaked in 9 ml of water, W2: seeds soaked in 12 ml of water.

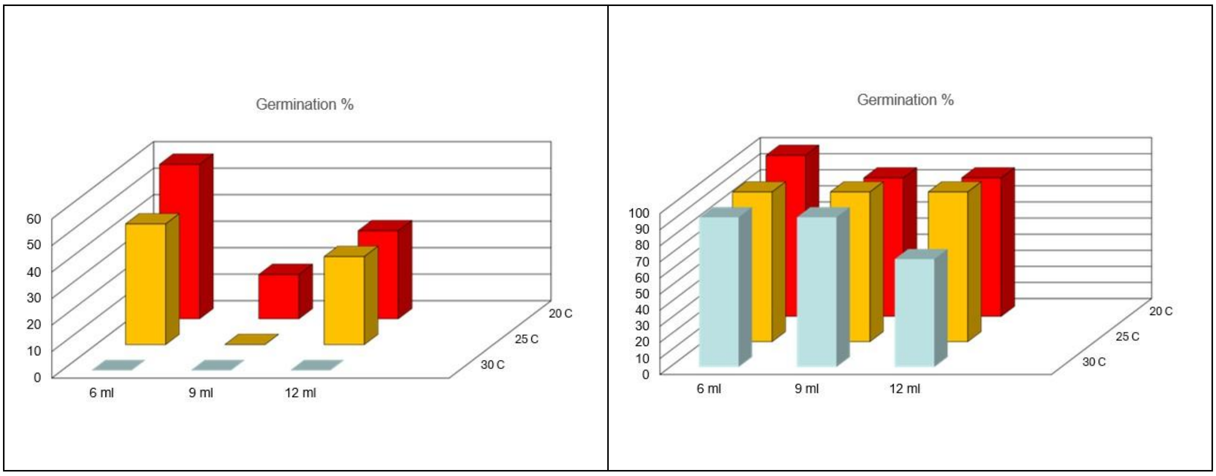

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Figure 1 *Bean (a) and maize (b) germination performance, water supply x temperature assessment*

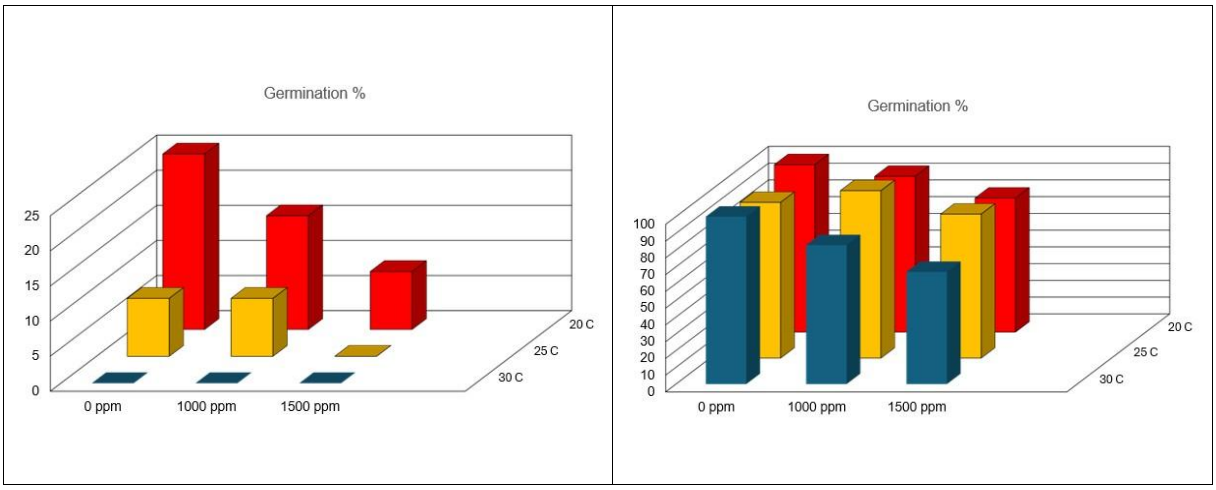

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Figure 2 *Bean (a) and maize (b) germination performance, salinity x temperature assessment*

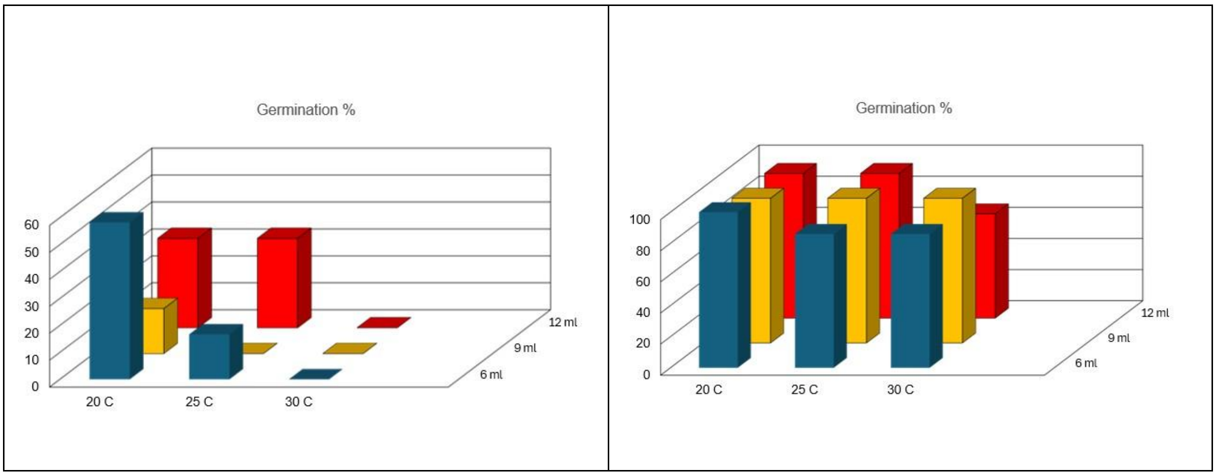

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Figure 3 *Bean (a) and maize (b) germination performance, temperature x water supply assessment*

3 Results and Discussion

3.1 Bean trial

Water supply had a consequent impact on seed germination. The smallest amount (6 ml) resulted in the highest values while bigger doses (9 and 12 mm) flooded seeds and reduced germination (Fig. 1a).

Salinity had strong impact on germination. The higher the salt concentration (1000 and 1500 ppm), the poorer the germination was observed (Fig. 2a).

The most definite impact was detected in the case of temperature. At 30 ºC there was no germination, the best values were obtained in the case of 20 ºC (Fig. 3a).

The ascending values of all treatments resulted in the decrement of the magnitude of all the observed parameters. From among them temperature proved to be significant, while water supply and salinity had detectable but not significant trends.

3.2 Maize trial

Maize germination was affected by the amount of water. The highest germinations were observed in the smaller amount treatments, while flooded seeds produced poorer germination (Fig. 1b).

Salt concentration had definite impact on germination. The 0 ppm control resulted the highest germination figures, while increased salt concentration reduced the viability of maize seeds (Fig. 2b).

Temperature was the least influencing factor affecting maize seed viability. At 30 ºC poorer germination was recorded, while 20 and 25 ºC applications were almost similar in all treatments (Fig. 3b).

The higher levels of all treatments resulted in poorer viability values. However, the strongest significant decrement was detected in the case of salinity.

Table 1 Regression of various stress factors regarding seed viability in case of bean and maize seed germination

Treatment	equation	R^2
Bean		
water	y = - 11x + 46	0,4286
salinity	y = - X + 11,333	0,3324
temperature	y = - 18x + 56,667	0,9982
Maize		
water	y = - 6,5 x + 104,67	0,5841
salinity	y = - 10x + 109,33	0,9494
temperature	y = - 4x + 97	0,5414

4 Conclusions

The aim of the experiments was to determine the impact of some abiotic factors on seed germination of two crops. Bean *Phaseolus vulgaris* L as a dicotyledonous species proved to be more vulnerable than maize *Zea mays* L a monocotyledonous plant regarding seed viability.

The ascending levels of all treatments – water supply, salinity and temperature – were in negative correlation with germination. In case of bean crop temperature proved to be the strongest stress factor resulting no germination at 30 °C. Maize crop was less affected by abiotic stress factors, however higher salinity resulted in the decrement of viability (Table 1).

In the experiment various interactions were observed. The higher levels of all applications resulted in poorer viability values however their interactions suggest that the combination of any high stress treatment with lower applications of other factors could reduce the magnitude of the harmful effects.

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