Abiotic Stress Impacts on Soybean (*Glycine Max L. Merr.*) Seed Viability

Abiotikus stresszhatások a szója (Glycine max L. Merr.) csírázóképességére

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Abstract: Abiotic stress factors may have adverse impact on the growth and development of crop plants. In a crop physiology experiment at the Hungarian University of Agriculture and Life Sciences, Gödöllő, Hungary soybean seeds were exposed to various levels of temperature, salinity and water supply. Viability and initial growth were evaluated. The results obtained suggest that viability and early development of soybean plants depend on the optimum level of abiotic external factors like temperature, salinity and water availability.

Keywords: *abiotic stress; viability; soybean; waterlogging; salinity; temperature*

Összefoglalás: Az abiotikus stresszhatások eltérő módon befolyásolják a növények növekedését és fejlődését. Gödöllőn, a Magyar Agrár- és Élettudományi Egyetemen végzett kísérletben a hőmérséklet, a sókoncentráció és a vízellátottság szója magvak életképességére gyakorolt hatását vizsgálták. A kísérletben elemezték a csírázóképesség és a kezdeti fejlődést. A kapott eredmények szerint a szója magvak csírázását és a kezdeti fejlődését nagymértékben meghatározzák a vizsgált abiotikus tényezők; a hőmérséklet, a sókoncentráció, illetve a vízellátottság mértéke.

Kulcsszavak: *abiotikus stressz; csírázóképesség; szója; belvíz; szikesedés; hőmérséklet*

1. Introduction

Live organisms are exposed to various impacts that may influence the regular physiological processes in various ways. Selye (1974; 1983) proposed four variations of stress. On one hand he determined good stress (eustress) and bad stress (distress). On the other is over-stress (hyperstress) and understress (hypostress). He advocates balancing these: the ultimate goal 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.

It is essential to study the effect of abiotic stress in seed germination and have an idea about the germination rate of seeds and the tolerant and sensitive species under abiotic stress to increase the efficiency and production of crops. In the present study, our main aims were as follows: studying the effect of abiotic stress – temperature, salinity and waterlogging – on soybean seed germination, and trying to determine the optimal amount, range or threshold level of these factors for soybean seed germination.

2. Materials and Methods

The present trial was conducted in the laboratory of crop production MATE in Gödöllő, Hungary (Huynh Anh Kiet, 2022). The objective of the trial was studying the effect of abiotic stresses – among them temperature, salinity and waterlogging – on soybean seed germination. We used the following materials: transparent Petri dishes; micro pipette; filter paper; distilled water; soybean seeds; climate chamber; precision scale. Soybean seeds of Martina variety used for the experimentation were as follows: the methods and the description of the trial were by general laboratory standards. Samples of 9 seeds were tested for viability under these experimental conditions in three replications, run in a Memmer-type climatic chamber.

During the experiment, soybean seeds germination was tested under three abiotic factors. The treatments were set in a randomized complete block design (RCBD), having 3 repetitions. For each factor of abiotic stress, we set 3 treatments with 3 replications.

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 of soybean 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.

3. Results and Discussion

3.1. Effect of different levels of temperature on soybean seed germination

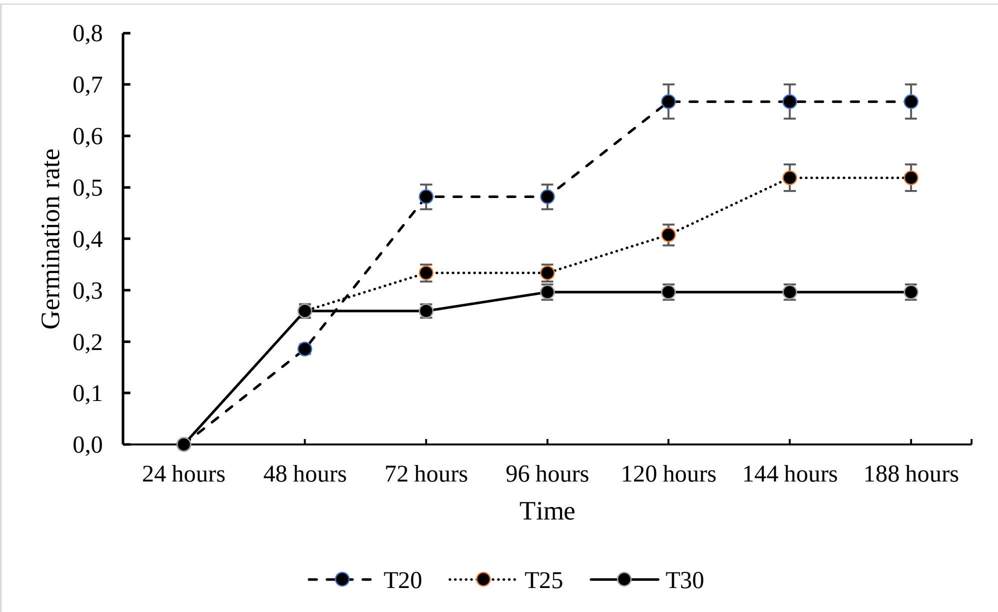

Figure 1. *Germination response of soybean seeds to temperature levels. Each point represents a mean ± SEM (n=3)*

Figure 1 presents the effects of three levels of temperature on the germination of soybean seeds during seven days. Germinated seeds varied between 1 to 6 per petri dish. The temperature of 20ºC resulted in the highest percentage of germination in all of the measured levels, while the temperature of 30ºC produced the lowest percentage of germination. The germination rate of soybean seeds decreased with increasing temperature. Total percentage of germinated seeds was 67%; 52%; and 30% at temperature 20ºC; 25ºC; and 30ºC, respectively.

A one-way ANOVA between treatments subjected to heat stress was conducted to compare the effect of different temperature levels (20°C; 25°C; 30°C) on the germination of soybean seeds. There was a significant difference effect ($p<0,05$) of different temperature levels on germinated seeds, radicle length, and plumule length of germinated seeds, presented in Table 1.

Table 1. Summary of one-way ANOVA showing a degree of freedom (Df), F, and probability for each analysis under temperature stress conditions. Significant P-values are highlighted in bold

Parameters	Df	F	P
Germinated Seeds	80	3,984	0,023
Radicle length	80	4,926	0,010
Plumule length	80	3,594	0,032

There was no significant difference between temperatures of 20°C and 25°C; 25°C and 30°C in total germinated seeds treated. The germination ratio of soybean seeds was affected by temperature. We observed a non-significant difference in seed germination between 20°C and 25°C of about -0,148 at p=0,265 and between 25°C and 30°C of about -0,222 at p=0,096 between 20°C and 25°C for germinated seeds (Table1). However, we found a significant difference in germinated seeds ratio between 20°C - and 30°C of around -0,370 at p=0,006. The ratio of germinated seeds decreased as the temperature increased.

Based on these findings, our results agreed with that of Hatfield and Egli (1974) and Gilman et al. (1973) at 20ºC the time required for a given percentage of soybean seed germination was twice of that at 30ºC. Wuebker, Mullen, and Koehler (2001) explain that at higher germination temperatures, the damaging effects of impact damage were more significant than at lower temperatures. However, our findings disagree with Szczerba et al., (2021). In their experiment, four types of soybean seed demonstrated a high ability to germinate at 25°C.

3.2. Effect of different salt levels on soybean seeds germination

Figure 2 demonstrates the effect of salt concentrations on the germination of soybean seeds. The highest percentage of germination was recorded at 0 ppm and the lowest at 1500 ppm for three salt concentrations applied. The total proportion of germinated seed was about 70%; 44%; 33%, respectively in the levels of salt 0 ppm; 1000 ppm; and 1500 ppm.

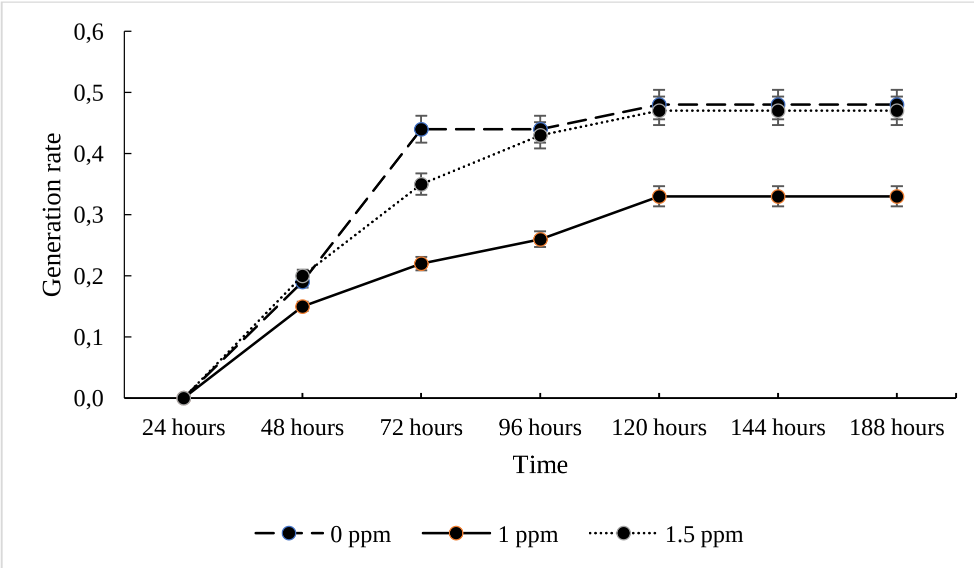

Figure 2. *Germination response of soybean seeds to salt level (x1000 ppm). Each point represents a mean ± SEM (n=3)*

A one-way ANOVA between salt stress treatments was conducted to compare the effect of different salt levels 0 ppm; 1000 ppm; and 1500 ppm on soybean seeds germination. There was a significant difference percentage of germinated seeds. The results are shown in Table 2.

Table 2. Summary of one-way Anova showing a degree of freedom (Df), F, and probability for each analysis under salt stress conditions. Significant P-values are highlighted in bold

Parameters	Df	F	P
Germinated Seeds	80	4,158	0,019
Radicle length	80	6,902	0,002
Plumule length	80	5,508	0,006

The results suggest that the percentage of soybean seed germination was reduced with increasing salt concentration. This decrease can be due to the increase in external osmotic pressure, which affects the rate of water absorption by seeds, and limits their germination (Ashraf, 2012). Our results are similar to Shu et al., (2017), the germination rate of the soybean seeds under salt stress conditions was about two to three-folds less than normal during the germination processes. Other results also supported that the delayed-germination phenotype was caused by the NaCl treatment. (Xu et al., 2011), the concentration of 100 mmol/L NaCl affected the ability of soybean seed germination. On the other hand, moderate salt stress intensity just delayed germination time and had no significant effect on the final germination percentage.

3.3. Effect of different water levels on soybean seeds germination

A water-stress experiment was carried out with three levels of water supply. Our study indicates that soybean seeds germination ratios are highest at two levels, namely 6 ml and 9 ml of water, with seeds germination percentages of 40.74 and 22.22 for 12 ml of water, respectively. After a few days at the 12 ml water treatment, however, waterlogged soybean seeds were blocked in further germination and development (Figure 3).

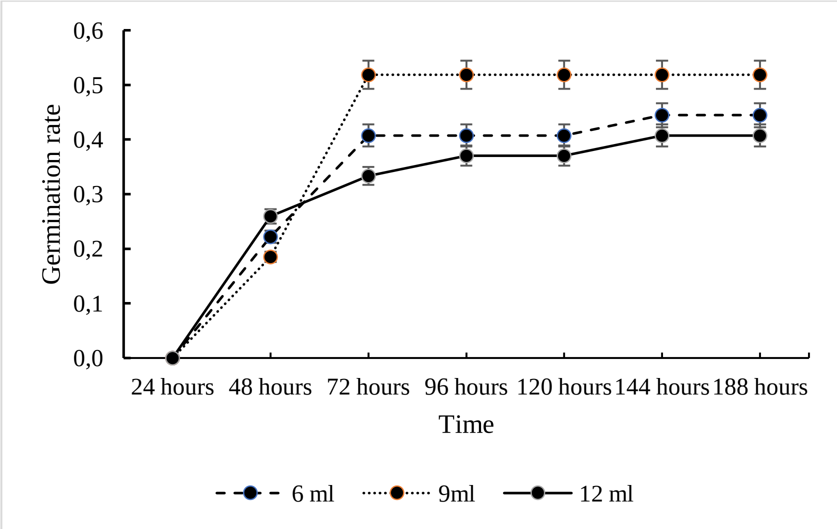

Figure 3. *Germination response of soybean seeds to water level. Each point represents a mean ± SEM (n=3)*

One-way ANOVA between treatments was conducted to compare the effect of levels of water 6 ml water; 9 ml; and 12 ml on soybean seed germination (Table 3). There was a significant difference effect of levels of water on the radicle length and plumule length of seeds germinated, as Table 2 and 3 show.

Table 3. Summary of one-way Anova showing a degree of freedom (Df), F, and probability for each analysis under water stress conditions. Significant P-values are highlighted in bold

Parameters	Df	F	P
Germinated Seeds	80	0,338	0,714
Radicle length	80	3,495	0,035
Plumule length	80	2,226	0,115

The germination ratio of soybean seeds was not significantly different between levels of water. On the other hand, the waterlogging condition damaged the soybean seedling 7 days after sowing at a water level of 12 ml. Similar results were obtained in a pea crop seed long-term waterlogging experiment (Zaman et al., 2019), where the lack of oxygen, caused membrane degradation and leakage of cellular contents, resulting in seed mortality and/or germination failure. Carrera et al (2021) reported that drought stress of soybean plants resulted in future yield losses. In our trial the best germination performance was recorded in the 9 ml treatments however the magnitude was not significant. The results suggest that water logging may deteriorate soybean germination activities and reduce the number of germinated seeds.

4. Conclusions

Summarising the trial, the results obtained suggest, that abiotic stress conditions caused changes of various magnitude in the viability and initial growth and development of soybean seeds and sprouts. Temperature proved to be a strong environmental factor influencing the performance of the seed. The higher is the temperature the poorer are the viability and growth values. Salinity was also an influencing factor for these parameters. Control and low level of NaCl concentrations had no or less impact on the seed development, however high salt concentrations in general have blocked germination and the growth of initial organs. Waterlogging conditions have obstructed germination after the second day, while normal and abundant but no flood water supply applications contributed to higher germination. The stress processes were detected and identified, however more detailed physiological observations are needed in the future to specify external and internal stresses of a certain crop, since that is the only way to improve stress tolerance in field crops.

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