DOI: 10.31577/ahs-2021-0022.01.0013

ACTA HYDROLOGICA SLOVACA

Volume 22, No. 1, 2021, 113 – 117

VIABILITY OF MAIZE (Zea mays L) SEEDS INFLUENCED BY WATER, TEMPERATURE, AND SALINITY STRESS

Noriza Khalid, Ákos Tarnawa, Zoltán Kende, Katalin M. Kassai, Márton Jolánkai*

The crops site provides a wide range of abiotic stresses to field crops. Successful protection against these impacts can be the use of adaptable cultivars. At the Crop Production Laboratory of the University of Hungarian Agricultural and Life Sciences, Gödöllő Hungary, maize Zea mays L genotypes of different geographic origin were exposed in an in vitro trial to various abiotic stress conditions (water supply representing poor and flooded state, temperature with suboptimal, optimal and high exposure, and saline and neutral environment). Samples of Hungarian and Malaysian hybrids were tested for viability, radicle and plumule growth under these conditions in four replications. The results obtained have proven that the various abiotic applications had altering effects on the germination performance of the seed samples studied.

KEY WORDS: water stress, temperature stress, salinity stress, viability, maize genotypes

Introduction

Germination of seeds is a biological process that is influenced by biotic and abiotic factors including water, oxygen, and temperature for sufficient viability. 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 started as the seed absorbs water (seed imbibition), resulting expansion of the seed and elongation of the embryo. Favourable growing conditions will allow ATP regeneration hence, allowing activation of hormones and enzymes responsible for germination such as abscisic acid (ABA), gibberellins, ethylene, and auxin (IAA). Germination ends when the radicle has grown out of the seeds coating layers and with the protrusion of the coleoptile (Miransari and Smith, 2014).

There are studies reporting that temperature elevation can cause thermoinhibition on seeds germination. A study on Nigeria's main crops which include maize, rice and sorghum, shows the impact of increases in temperature on seed germination and seedling development. The germination rate decreases for seeds cultivated at a higher temperature. The high temperature also affects the root development of the seedlings. Furthermore, the temperature elevation also caused a significant reduction in the length of stem and leaf length reduction in various crops (Iloh et al., 2014).

Salinity of crop sites represent a profound problem for plant growth and development. High soil salinity level eventually creates soil conditions with physiological drought, simultaneously may causes ion toxicity, nutrient imbalance, and oxidative stress to the seed (Nayidu et al., 2012). According to Kaymakanova (2009), high salinity in soil solutions may result in high osmotic pressure that restricts the seed imbibition by preventing water absorption and entry into the seed. The inability to absorb water resulted by high salt concentration will also prevent the mobilisation of essential nutrients needed for germination. Besides that, a saline condition during the early growth stage also caused Na^+ and Cl^- toxicity to the embryo and young seedlings that result in stunted development of the plants (Khajeh-Hosseini et al., 2003; Kaymakanova, 2009). Salt stress caused by NaCl also decreases the content of essential hormones for germination, such as gibberellins while increasing the ABA levels (Atia et al., 2009).

Water availability is essential during germination for the seed imbibition process thus, no germination will occur in the absence of water. Nonetheless, excess water may cause waterlogged soil conditions, which will deprive the seeds from oxygen supply. Oxygen is utilised by imbibed seeds as the rapid respiratory metabolic process begins and carbon dioxide (CO_2) is released as a by-product. Prolonged 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. In cereals seeds, starch stored in the endosperm of the seeds is converted to soluble sugars such as sucrose during germination through combined actions of enzymes such as α-amylase, β-amylase, and α- glucosidase (Zhou et al., 2020).

It is common for one agricultural land to represent 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., 2017). High temperatures cause more detrimental effect on germination under salinity stress than germination in saline conditions under optimum temperatures. It was observed that the combination of these stresses reduced the germination rate, shoot length, and dry weight of wheat seedlings compared to the effect of one stress alone. The combined stresses also reduced the photosynthetic rate in the same crop due to a decline in pigmentation (Neelambari et al., 2018). In a physiology trial the high temperature may have increased the moisture evaporation causing salt content elevation by capillary movement and slowing down the activation of metabolic processes thus reducing the activity of different enzymes responsible for germination (Luan et al., 2014).

The aim of the study was to determine the impact of water availability, temperature variations and salinity on the viability of maize seeds. The hypothesis of the research focused on the possible stress tolerance abilities of maize hybrids of different geographic origin. Since maize (*Zea mays* L) crop have dispersed throughout the globe during the past half of a millennium spreading from tropical and subtropical grain belts via temperate zones up to polar regions nowadays, due to direct and indirect breeding and selection processes certain genotypes may have gained specific abilities for stress tolerance.

Material and methods

In a laboratory germination trial at the Crop Production Institute of the University of Agriculture and Life Sciences, Gödöllő, Hungary, maize *Zea mays* L genotypes of different geographic origin were exposed to various abiotic stress conditions (water supply representing poor and flooded state, temperature with suboptimal, optimal and high exposure, and saline and neutral environment).

The methods and the description of the trial were in accordance with general laboratory standards. Seed samples of Hungarian and Malaysian hybrids were tested for viability, radicle and plumule growth under these experimental conditions in four replications, run in a Memmer type climatic chamber.

During the germination trial three levels of temperature were applied: 10, 25 and 35ºC respectively. Water stress during the germination was applied in two variants – simulating a dry and a flooded state – using 5 ml and 30 ml water added to each petri dish. Testing salinity was observed in two variants: zero and 2% of NaCl solutions were applied.

The viability trials were run for 6 days after exposure, and after germination an additional 10 days were given for measuring shoot and root growth.

The results were obtained by recording germination followed by the daily measurement of radicle and plumule growth in mm. The results were evaluated by correlation and the level of significance was determined with *t* probe.

Results and discussion

According to the research hypothesis the following result has been obtained. The viability experiment has covered a wide range of abiotic stress factors in relation to the impact of temperature, water availability and salinity. Three levels of temperatures – 10, 25 and 35ºC – were applied during germination to test maize hybrids of different geographic origin. At 10ºC no maize hybrids germinated, at 25ºC both Hungarian and Malaysian hybrids produced their best germination performance, however at the highest 35ºC temperature the viability of Hungarian maize was very poor, but the Malaysian one, however with a reduced viability, still germinated over 50% (Fig. 1).

The development of plumules and radicles was in accordance with the germination figures. It is worth to state that at 35ºC neither hybrids developed roots, only shoots were detectable in this application.

Saline conditions during the germination period were strictly consequent. NaCl treated seed samples have produced diverse responses. The Hungarian maize hybrid did not germinate at all, while the Malaysian maize has shown a rather low, but consequent viability in an average of 47.5%. The shoot development of the germinating hybrid was poor, but the root development proved to be satisfactory (Fig. 2).

Water stress trials have shown consequent results (Fig. 3). Simulated dry conditions – 5 ml water – and flooded conditions – 35 ml water – resulted in diverse effects. Both maize hybrids performed better in dry conditions in comparison with the flooded version. However, the Malaysian hybrid proved to be more tolerant to both dry and moist conditions that the Hungarian hybrid. Concerning root and shoot development, Hungarian maize hybrid had a rather poor performance in both applications, while the Malaysian hybrid's phenological development was in accordance with the viability figures.

The last germination trial was focusing on the temperature x salinity interaction. The results of this observation are presented in Fig. 4. At 2% salt concentration combined with 35ºC temperature only 2.5% of the Hungarian maize hybrid seeds proved to be viable.

Figure 5 presents the data of the Malaysian hybrid that had an 52.5% viability record. The plumule and radicle development values were in accordance with these findings.

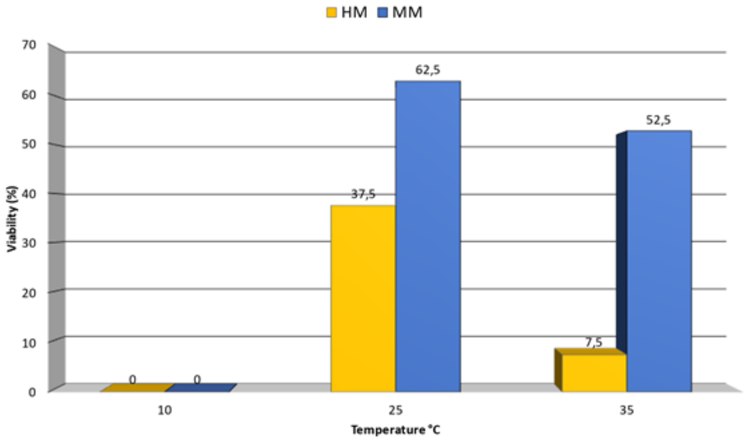

Fig. 1. Viability of seeds of maize hybrids at different temperatures.

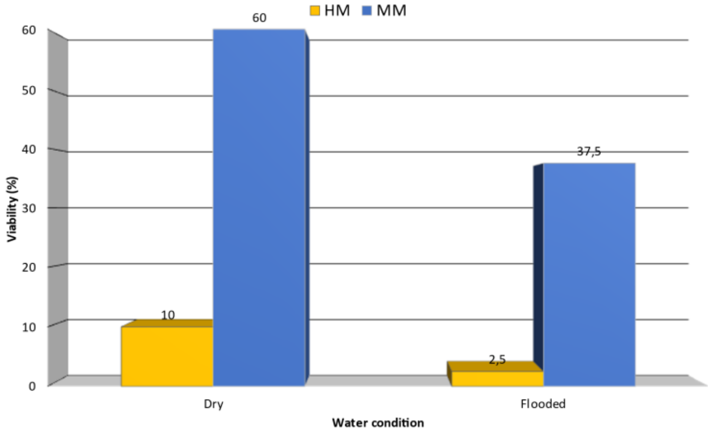

Fig. 2. Viability of seeds of maize hybrids at different NaCl levels.

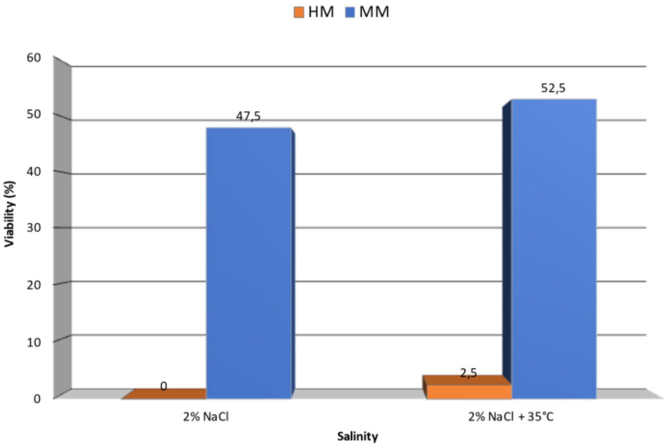

Fig. 3. Viability of seeds of maize hybrids at different water supply conditions.

Table 1 presents the correlation values of between the experimental figures. The correlation between the experimental variants was diverse. The strongest relations (0.99% significance) were found in the cases of hybrid x salinity, temperature x viability and plumule length x viability.

Strong correlations (0.95% significance) were obtained in the cases of water x radicle growth, salinity x viability and radicle growth x viability. The rest of the interrelations were not significant.

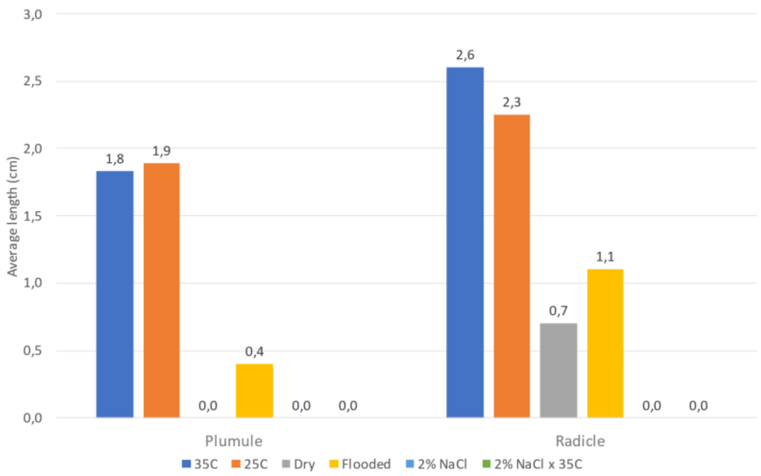

Fig. 4. Impact of various stress factors on the growth of plumules and radicles of the Hungarian maize hybrid.

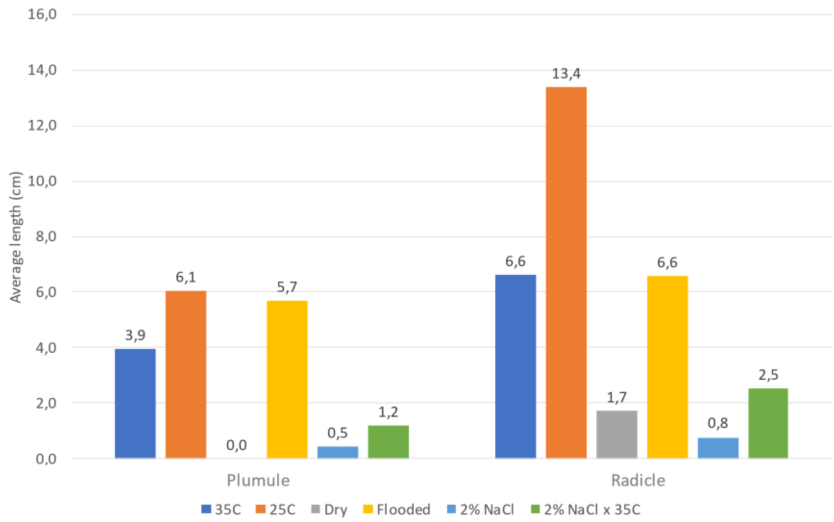

Fig. 5. Impact of various stress factors on the growth of plumules and radicles of the Malaysian maize hybrid.

Table 1. Correlation between experimental figures

r_{corr}	water	temperature	salinity	hybrid	viability	radicle	plumule
water	1						
temperature	na	1					
salinity	0.026	-0.057	1				
hybrid	na	na	-0.886**	1			
viability	-0.643	0.825**	-0.753*	0.534	1		
radicle	-0.689*	-0.467	-0.556	0.432	0.787*	1	
plumule	-0.742*	-0.511	-0.434	0.334	0.889**	0.723	1

* $LSD_{0.95}$
**$LSD_{0.99}$

Conclusion

In accordance with to the research hypothesis various results have been obtained. The viability experiment has covered a wide range of abiotic stress factors in relation with the impact of temperature, water availability and salinity.

The overall result of the experiments is the proof of the use of the appropriate plant variety in certain crop site conditions. It turned out that the Malaysian maize hybrid was much more adaptive to the extreme conditions represented by salinity, water stress and temperature stress. The conclusion of the research can be summarized that the crop site conditions are to be harmonized with the crop variety applied.

On the basis of this experiment further research should be done in favour of answering some questions that may emerge from some uncertain interactions like the behavioural patterns of radicle and plumule growth, the salinity x temperature interactions and finally the magnitude of viability. A broader screening of more varieties may provide a basis for novel statements in this field.

Acknowledgement

The authors of the article are indebted regarding the support received from NVKP and VKSZ funds of the Government of Hungary.

References

Atia, A., Debez A., Barhoumi Z., Smaoui A., Abdelly C. (2009): ABA, GA(3), and nitrate may control seed germination of Crithmum maritimum (Apiaceae) under saline conditions. Comptes rendus biologies, 332(8), 704–710.

Iloh, A., Omatta, G., Ogbadu, G. H., Onyenekwe, P. C. (2014): Effects of elevated temperature on seed germination and seedling growth on three cereal crops in Nigeria. Scientific research and essays, 9(18), 806–813.

Jolánkai, M., Kassai, M. K., Tarnawa, Á., Pósa, B., Birkás, M. (2018): Impact of precipitation and temperature on the grain and protein yield of wheat (Triticum aestivum L) varieties. Időjárás. 122. 1. 31–40.

Kaymakanova, M. (2009): Effect of salinity on germination and seed physiology in bean (Phaseolus vulgaris L.). Biotechnology and Biotechnological Equipment, Volume 23, 326–329.

Khajeh-Hosseini, M., Powell, A., Bingham, I. (2003): The interaction between salinity stress and seed vigour during germination of soyabean seeds. Seed Science and Technology, 31(3), 715–725.

Luan, Z., Xiao, M., Zhou, W., Zhang, H., Tian, Y., Wu, Y., Guan, B., Song, Y. (2014): Effects of Salinity, Temperature, and Polyethylene Glycol on the Seed Germination of Sunflower (Helianthus annuus L.). The Scientific World Journal, Volume 2014, 1–9.

Miransari, M., Smith, D. (2014): Plant hormones and seed germination. Environmental and Experimental Botany, Volume 99, 110–121.

Nayidu, N., Bollina, V., Kagale, S. (2012): Oilseed Crop Productivity Under Salt Stress. In: P. Ahmad, M. M. Azooz & M. N. V. Prasad, eds. Ecophysiology and Responses of Plants under Salt Stress. New York: Springer, 249–265.

Neelambari, Singh, A. K., Kumar, S. (2018): Effect of Individual and Combined Salinity and High Temperature Stress during Germination Stage of Different Wheat (Triticum aestivum L.) Genotypes. International Journal of Current Microbiology and Applied Sciences, 7(7), 1723–1730.

Shahid, S., Hadipour, S., Wang, X., Shourav, S. A., Minhas, A., Ismail, T. (2017): Impacts and adaptation to climate change in Malaysian real estate. International Journal of Climate Change Strategies and Management, 9(1), 87–103.

Zhou, W., Chen, F., Meng, Y., Chandrasekaran, U., Luo, X., Yang, W., Shu, K. (2020): Plant waterlogging/flooding stress responses: From seed germination to maturation, Plant Physiology and Biochemistry, Vol. 148, 228–236.

Noriza Khalid, MSc
Ákos Tarnawa, PhD
Zoltán Kende, PhD
Katalin M. Kassai, PhD
Márton Jolánkai, DSc (*corresponding author, e-mail: jolankai.marton@szie.hu)
Hungarian University of Agriculture and Life Sciences
2100 Gödöllő
Hungary