Abiotic stress impact on the viability of seed samples of field crop varieties

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Abstract

Environmental impacts often determine plant growth and development altering physiological processes. From among abiotic influencing factors temperature and salinity are crucial regarding the viability of crop plants. An assessment study has been done at the Szent István University, Gödöllő to evaluate and identify the impact of various levels temperature as well as ascending concentrations of NaCl on the germination of seed samples of field crop species. Five field crop species (winter wheat *Triticum aestivum* L, maize *Zea mays* L, sunflower *Helianthus annuus* L, millet *Panicum miliaceum* L and sorghum *Sorghum bicolor* L) originated from two countries – Hungary and Pakistan - were involved in the study.

The results obtained support the known evidence, that the five examined species performed well under optimum conditions for germination, e.g. 20 °C temperature and 0 salinity. On the other hand, low temperature and high salt concentration resulted in no germination regardless to the crop species. From among the field crop species wheat proved to be the most tolerant to NaCl affects, with millet next to that. Sorghum was found to be the most vulnerable crop in the study. The geographic origin of the crops was remarkable. Pakistani and Hungarian wheat crops both performed well. Similar results were obtained with both sunflower crops. Pakistani sorghum and millet proved to be better than the Hungarian ones. Hungarian maize had better performance than the Pakistani hybrid.

Keywords: abiotic stress, temperature, salinity, viability, field crop species

Összefoglalás

A környezeti tényezők hatással vannak a termesztett növények élettani folyamataira, befolyásolva növekedésüket és fejlődésüket. Az abiotikus környezeti tényezők közül a hőmérséklet és a sókoncentráció meghatározó lehet termesztett növényeink életképességére. A gödöllői Szent István Egyetemen kutatásokat végeztünk a hőmérséklet és a növekvő NaCl koncentráció különböző szántóföldi növényfajok megmintáinak csírázóképességére gyakorolt hatásának megállapítására. A kísérletet öt növényfaj (őszi búza *Triticum aestivum* L, kukorica *Zea mays* L, napraforgó *Helianthus annuus* L, köles *Panicum miliaceum* L és cirok *Sorghum bicolor* L) különböző országokból – Magyarországról és Pakisztánból származó fajtáival végeztük.

A kapott eredmények igazolják azt az ismert élettani jelenséget, miszerint termesztett növényfajaink a legjobb csírázási értékeket optimális körülmények között 20 ^{o}C hőmérsékleten, sóterheléstől mentesen adták. Másrészről az alacsony hőmérséklet és a nagy sókoncentráció fajtól függetlenül gátolta a csírázást. A vizsgált növényfajok közül a legjobb NaCl toleranciát az őszi búza, illetve a köles mutatta. A kísérlet során a cirok bizonyult a legérzékenyebbnek. A földrajzi eredet alapján is mutatkoztak értékelhető különbségek. Mind a pakisztáni, mind a magyar búzaminták csírázóképessége kiemelkedő volt. Hasonló eredményeket kaptunk napraforgó esetében is. A pakisztáni köles és cirok magvak csírázási eredményei meghaladták a magyar mintákét. A magyar kukoricahibrid eredményei viszont jobbak voltak a pakisztáni mintáénál.

Kulcsszavak: abiotikus stressz, hőmérséklet, szikesség, életképesség, termesztett növényfajok

Introduction

Environmental impacts of a certain crop site often determine plant growth and development altering physiological processes (Hohls, 1995). From among abiotic influencing factors temperature and salinity are crucial regarding the viability of crop plants in most countryes in the World (WAPDA, 1985; FAO, 2017).

The relative growth of *plants* in the presence of *salinity* is termed by their *salt* tolerance. A high *salt* level interferes with the *germination* of seeds. *Salinity* acts like drought on *plants*, preventing roots from performing their osmotic activity where water and nutrients move from an area of high concentration (Bojović et al, 2010).

Temperature is another determining factor for seed germination. All crop species in accordance with their geographic gene pool require optimum temperature to provide efficient germination. In order to study low temperature stress effect on wheat cultivars germination, an experiment was carried out in a seed technology laboratory by Tobeh and Somarin (2012).

Evaluating various wheat cultivars of different geographic origin, they concluded to the statement that suboptimal low temperature significantly obstructed germination. Pepo et al (2010) have studied adaptive capacity of wheat and maize crops. According to their results environmental factors highly influence crop growth and development. In earlier studies of our team (Jolánkai et al 2008) on the basis of a long-term experiment an evidence was presented on the mathematical functions of temperature and moisture content in relation with the growth and development of crop plants.

Salinity and water availability are closely related factors from an aspects of plant physiology. Due to the failure of osmotic processes the membrane activity of live cells may be blocked (Rana Munns, 2006; Khalid, 2019). Salinity if a complex phenomenon due to the chemical properties and the water transport patterns of a certain soil. From the various types sodic solonetz and solonchak seem to be the most obstructive to plant growth and development (Szabolcs, 1974).

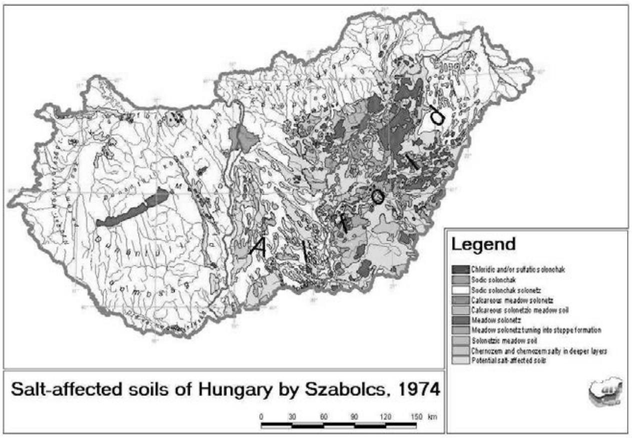

Figure 1. Types and spatial distribution of salinity in Hungary. Source Szabolcs 1974

The present study is dealing with the identification of seed viability of various field crop species originating from geographically different countries and exposed to abiotic stress conditions represented by diverse temperatures and salt concentrations.

Material and method

The materials and methods of the present study cover a rather broad field studying abiotic stress conditions for field crops. An assessment study has been done at the Szent István University, Gödöllő to evaluate and identify the impact of various levels temperature as well as ascending concentrations of NaCl on the germination of seed samples of field crop species. Five field crop species (winter wheat *Triticum aestivum* L*,* maize *Zea mays* L, sunflower *Helianthus annuus* L, millet *Panicum miliaceum* L and sorghum *Sorghum bicolor* L) originated from two countries – Hungary and Pakistan - were involved in the study.

Germination tests were done at the Research Laboratory of the SIU Crop Production Institute. All seed samples were placed and incubated on tissue paper floor in sealed Petri dishes in a climatic chamber with 3 replications. In the trial two temperatures - 20 ^{o}C and 5 ^{o}C were provided to the samples and five levels of NaCl concentrations – 0, 2, 4, 6 and 8 % were applied. Germination values were recorded after 7 days including viability of the seeds and development characteristics of the radicles and plumules.

Analyses were done by statistical programmes with respect to the methodology by regular methods (Sváb, 1981; Windows Office 2017).

Results and discussion

The results of the study show that the evaluated crops may have significant differences in their viability records under various temperature and salinity conditions. Table 1 summarizes the behaviour of crop species of different geographic origin.

Table 1. Effect of temperature and salinity on germination ranges of the examined crops (%)

	0 % NaCl	**various levels of NaCl**
20 °C	Pakistani wheat 100	Pakistani wheat poor
	Hungarian wheat 100	Hungarian wheat 40-90
	Pakistani maize 30-40	Pakistani maize 0
	Hungarian maize 90-100	Hungarian maize poor
	Pakistani sunflower 60-70	Pakistani sunflower 30
	Hungarian sunflower 70-90	Hungarian sunflower poor
	Pakistani sorghum 80-100	Pakistani sorghum poor
	Hungarian sorghum 0	Hungarian sorghum 0
	Pakistani millet 100	Pakistani millet poor
	Hungarian millet 50-100	Hungarian millet 0
5 °C	Pakistani wheat 10	Pakistani wheat 0
	Hungarian wheat 40-60	Hungarian wheat 0
	Pakistani maize 0	Pakistani maize 0
	Hungarian maize 0	Hungarian maize 0
	Pakistani sunflower 0	Pakistani sunflower 0
	Hungarian sunflower 20-80	Hungarian sunflower 0
	Pakistani sorghum 0	Pakistani sorghum 0
	Hungarian sorghum 0	Hungarian sorghum 0
	Pakistani millet 0	Pakistani millet 0
	Hungarian millet 0	Hungarian millet 0

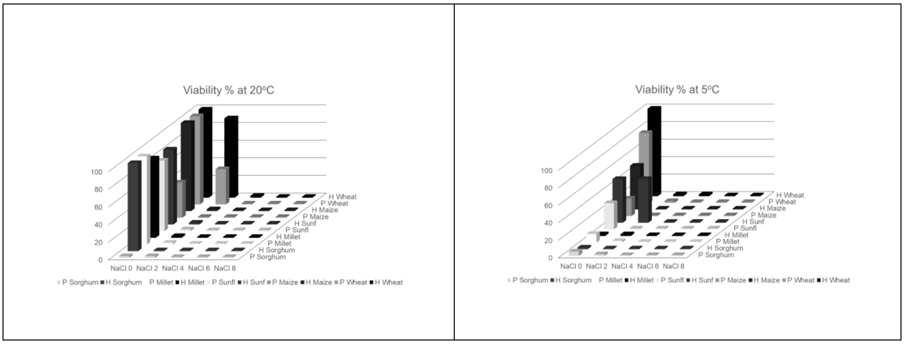

Figure 2. Effect of temperature and salinity on germination of the examined seed samples (%)

Figure 2 presents germination records of the certain crop seed samples of all experimental variants. It can be seen, that at 20 °C temperature most crops proved to be efficient regarding their germination. With the elevation of NaCl concentration levels there was poor viability in general with a few exceptions only. At 5 °C temperature in all treatments exceeding 4 % of salt content there was no germination detected.

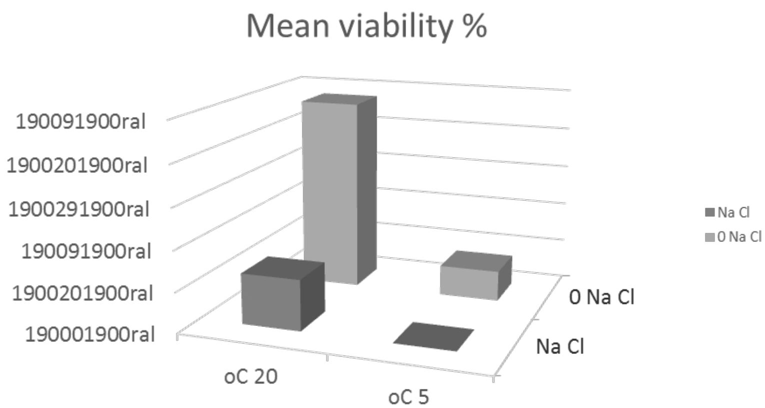

Figure 3. The mean effect of temperature and salinity on germination in the average of all crop species examined in the trial (%)

Figure 3 highlights the mean effect of temperature and salinity on germination. In the average of all species studied the results seem to support an evidence that while under optimum conditions (e.g. 20 °C and no salt stress) most of the seed samples produced high germination, the reduction of temperature and the elevation of NaCl concentration induced decline in the viability.

Table 2 presents the mathematical equations and their probability values regarding the impact of various salt concentration levels at the two temperatures applied. The exponential functions seem to prove, that the increment of NaCl concentrations were blocking the germination of all seed samples regardless to the crop species and the geographic origin. The results obtained can be summarized as follows:

1. Germination tests proved to be a highly reliable method for testing abiotic conditions for the initial development of crop plant species.

2. From among the crops, wheat proved to be the most successful. Under optimum conditions 100 % germination was detected, but viability occurred in some salt applications as well as at low temperature exposure.
3. Millet was the second most successful crop in optimum conditions but had a rather poor performance in salt applications and did not germinate in any of the low temperature treatments.
4. Maize crop was highly variable even under optimum conditions. Salt tolerance was poor, and no germination could be detected in any of the low temperature versions.
5. Sunflower had a diverse performance. There was good germination in optimum treatments, but it was a crop that has germinated – however poor – in some salt applications as well as at low temperature.
6. Sorghum seems to be the most vulnerable crop of the trial. Some of the sorghums performed well in optimum conditions, even in some of the salt affected treatments they had poor germination. All the other treatments and cultivars had no viability in any of the applications.
7. The geographic origin of the crops was remarkable. Pakistani and Hungarian wheat crops both performed well. Similar results were obtained with both sunflower crops. Pakistani sorghum and millet proved to be better than the Hungarian crops. Hungarian maize had better performance than the Pakistani one.
8. The abiotic conditions of the trial had regular known physiological effects. In general, 20 ^{o}C provided optimum viability conditions for most of the crops. At 5 ^{o}C plausible germinations could be detected only in wheat and sunflower. Slight salt tolerance could be seen at most crops under normal temperature. Salt applications at low temperature have always resulted in no viability records.

Table 2. Impact of ascending levels of NaCl concentration on the viability of seed samples of various field crops at two temperatures

Crop	Treatment	Equation	R^2
H wheat	20 ºC	$y = 95,873e^{-0,686x}$	$R^2 = 0,7556$**
P wheat	20 ºC	$y = 79,621e^{-0,645x}$	$R^2 = 0,8692$**
H maize	20 ºC	$y = 20,913e^{-0,495x}$	$R^2 = 0,6102$*
P maize	20 ºC	$y = 12,068e^{-0,404x}$	$R^2 = 0,6356$*
H sunflower	20 ºC	$y = 14,376e^{-0,444x}$	$R^2 = 0,5025^{NS}$
P sunflower	20 ºC	$y = 18,292e^{-0,473x}$	$R^2 = 0,6155$*
H millet	20 ºC	$y = 19,632e^{-0,485x}$	$R^2 = 0,6126$*
P millet	20 ºC	$y = 20,913e^{-0,495x}$	$R^2 = 0,6102$*
H sorghum	20 ºC	$y = 2e^{-0,104x}$	$R^2 = 0,7500$**
P sorghum	20 ºC	$y = 15,849e^{-0,461x}$	$R^2 = 0,5100^{NS}$
H wheat	5 ºC	$y = 20,913e^{-0,495x}$	$R^2 = 0,6102$*
P wheat	5 ºC	$y = 18,292e^{-0,473x}$	$R^2 = 0,6155$*
H maize	5 ºC	$y = 3,4657e^{-0,196x}$	$R^2 = 0,7613$**
P maize	5 ºC	$y = 1,5157e^{-0,069x}$	$R^2 = 0,5075^{NS}$
H sunflower	5 ºC	$y = 5e^{-0,241x}$	$R^2 = 0,7500$**
P sunflower	5 ºC	$y = 7,6961e^{-0,34x}$	$R^2 = 0,5150^{NS}$
H millet	5 ºC	$y = 2e^{-0,104x}$	$R^2 = 0,7500$**
P millet	5 ºC	$y = 5,2531e^{-0,265x}$	$R^2 = 0,7040$*
H sorghum	5 ºC	$y = 2e^{-0,104x}$	$R^2 = 0,7500$**
P sorghum	5 ºC	$y = 3,4657e^{-0,196x}$	$R^2 = 0,7613$**

* LSD 0.95

** LSD 0.99

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