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Impacts of Drought Stress on Corn Cultivars (*Zea mays* L.) At the Germination Stage

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The importance of germination is so high that many believe it is one of the most determining stages of life for a plant, as effective yield and growth are qualities that mainly rely on this stage. This study aims to investigate the impacts of DS (drought stress) on germination-related factors in corn cultivars by a factorial experiment with an RCB layout with three replications in 2018. This experiment selected Golden West and Single Cross and evaluated their performance at six levels of drought treatment, including control (0), -2, -4, -6, -8, and -10 bars, with the primary aim of comparing them in terms of their performance under stress conditions. Results indicated significant differences among the cultivars and DS levels. Based on the results, the study stated that the following criteria decreased remarkably: germination rate (GR), (GP) germination percentage, (RL) radical length, (PL) plumule length, and (SL) seedling length, and dry matter. Findings ranked Golden West as the top cultivar with the highest stress resistance as well as the highest levels of all traits.

Keywords: drought stress, Zea Mays, germination, and PEG-6000

INTRODUCTION

Environmental stresses originating from non-living (abiotic) sources are the number-one factor responsible for more than 50% of average yield loss of major crops worldwide (Khayatnezhad and Gholamin 2012, Partheeban, Chandrasekhar et al. 2017, Gholamin and Khayatnezhad 2020, karasakal, Khayatnezhad et al. 2020, Khayatnezhad and Gholamin 2020) among which drought is known to cause the greatest level of financial and agronomic loss by hindering the growth and development of crops so much that some believe it may be one of the most destructive forms of environmental stresses (Xiong, Wang et al. 2006). Maize is a widely popular crop cultivated on a global scale (Farhad, Saleem et al. 2009, Khayatnezhad and Gholamin 2012), and a staple food that like every major commercial crop has its sensitivities to drought. Throughout the world, approximately 1000000 km^2 of land in developing countries is allocated to the cultivation of maize. Also, it is the lower-income and middle-income developing countries that produce about 70% of maize production among the developing countries (Partheeban, Chandrasekhar et al. 2017). Predictions indicate that the demand for maize will double in the developing countries by 2050 and in the developed countries by 2025 and it will rank the top crop with the highest global production in the coming decades (Rosegrant, Msangi et al. 2008, Fataei, Varamesh et al. 2018, Amirfazli, Safarzadeh et al. 2019, Mohammadi Aloucheh, Baris et al. 2019, Alayi, Sobhani et al. 2020, Gholamin and Khayatnezhad 2020, Jalili 2020). Generally, plants are negatively impacted by the stress caused by water deficit in every stage of their development, but this negative (damaging) impact is more palpable when it hits the plants during more sensitive stages or traits like germination, flowering, root and shoot length, and flowering (Rauf, Munir et al. 2007, Gholamin and Khayatnezhad 2012, Khayatnezhad 2012, Mitra and Chowdhury 2019, Esmaeilzadeh, Fataei et al. 2020, Ghomi Avili and Makaremi 2020, Karasakal, Khayatnezhad et al. 2020). The stresses associated with water deficit impact both germination and the average time maize plant crops need to germinate (Willenborg, Gulden et al. 2004). These negative impacts are not limited to maize plants though, as stresses related to the shortage of water impact many crops (Mostafavi, Geive et al. 2011, Jia, Khayatnezhad et al. 2020, Si, Gao et al. 2020, Huang, Wang et al. 2021). Relevant studies concerning the relationship between germination and environmental stress attribute the hampering of germination caused by PEG to osmotic stress (Sidari, Mallamaci et al. 2008), however, it should be noted salinity and drought have similar impacts (Katerji, Van Hoorn et al. 2004), impairing plants' potential to conserve water and maintain its water balance (Legocka and Kluk 2005, Afa, Purwoko et al. 2018, Ahmad, Soetopo et al. 2018, Hegazi, Abd Allatif et al. 2018). The mechanism of the negative impact of water deficit stress is based on decreasing three factors: GP, GR, and seedling growth (Delachiave and Pinho 2003, Farhadi, Fataei et al. 2020, Gholamin and Khayatnezhad 2020, Gholamin and Khayatnezhad 2020, Khayatnezhad and Gholamin 2020). As confirmed by the results of a relevant study, salinity has crucially negative impacts on germination of seeds, which is one of the most important phases of plants' life, (Misra and Dwivedi 2004). The study used PEG compounds to devise an in vitro simulation of osmotic stress effects to ensure a stable water potential throughout during the experiment (Manoj and Uday 2007, Fataei, Varamesh et al. 2018, Jia, Khayatnezhad et al. 2020, Muhibbu-din 2020, Si, Gao et al. 2020, Valiallahi and Moradi 2020). This study compares the impacts of drought and salt-related stress on the germination of seeds stress in two cultivars of maize.

MATERIALS AND METHODS

Performed in 2018 under laboratory conditions, this study investigated two cultivars of corn: Golden West and Single Cross. The study designed a factorial experiment with an RCB layout with three replications. It included two separate experiments to investigate the impacts of DS caused by various levels of osmotic potential [0 (control), -2, -4, -6, -8, and -10 bar] by PEG-6000 treatments on the germination of corn.

Using sodium hypochlorite (1%) for sterilization, the study selected and rinsed (two times) twenty seeds of both cultivars for each experiment and each level of stress. The rinsed and sterilized seeds were put into an incubator set at 25°C on piles (two layers) of filter paper in Petri dishes for germination. The experiment counted those seeds that germinated in the incubator for ten days. In the meantime, if needed, PEG-6000 was added. Using the method designated by ISTA, the experiment recorded the amounts of GP, GR, RL, PL, and the DW of radical and plumule after ten days.

The formula below was used for GR calculation:

$$GR = \frac{\sum N}{\sum (n \times g)}$$

Here, GR is the germination rate; n is the number of germinated seeds on gth day and g is the number of germinated seeds in total. The experiment used the implemented method by a relevant study to measure PEG 6000's osmotic potentials (Michel and Kaufmann 1973). The study also used MSTAT-C to do data analysis and Duncan's MRT tests with a 5% probability level to measure the differences between means.

RESULTS

The results of variance analysis demonstrated that different drought stress levels caused significant differences for GP (0.05%); and RL, PL, and SL (0.01%); and insignificant difference for MGT and GR. The cultivars in the experiment represented significant amounts of GP, RL, and SL (0.01%) while PL was significant at a different percent (0.05%), and MGT was none-significant. Concerning the interactions between cultivars and stress levels, GP, RL, SL, and PL were significant while MGT and GR were insignificant. Moreover, based on the results, Golden West had the highest GP at 0 levels of PEG. In the introductory stress stages, the variable nature of germination is more prominent. Besides, results of mean comparison demonstrated that this cultivar also had the highest RL and PL and SL values at 0 and -2. The details are presented in Table 2.

Table 1: Results of analysis of variance

SV	Df	Germination (%)	Mean Germination time	Germination rate	Length of Radicale (cm)	length of Plumule (cm)	Length of Seeding (cm)
Drought Levels	5	79.24*	0.62^{ns}	0.002^{ns}	82.57**	27.24**	98.62**
Cultivars	1	542.35**	3.25^{ns}	0.057*	94.57**	0.057*	112.49**
D×C	5	74.58*	0.34^{ns}	0.002^{ns}	12.57**	2.01*	28.95*
Error	24	53.25	0.56	0.005	0.865	0.421	3.26

ns, * and **:non-significant, significant at 0.05 and 0.01 percentage probability levels, respectively.

Table 2: Means comparison simple effect of cultivar and stress levels on germination and seedling growth

Cultivars	Germination (%)	Mean Germination time	Germination rate	Length of Radicale (cm)	length of Plumule (cm)	Length of Seeding (cm)
Golden west	73.54	2.89	0.39	10.26	4.98	10.26
Single cross	65.26	3.24	0.32	7.65	3.41	7.35
Stress levels (bar)						
0	48.32	2.74	0.384	11.28	5.95	16.32
-2	46.21	2.65	0.359	8.62	4.01	10.26
-4	44.24	2.81	0.355	5.19	2.95	8.32
-6	40.37	3.12	0.341	4.32	2.44	5.62
-8	38.78	2.59	0.331	3.31	1.23	3.65
-10	35.97	3.29	0.298	3.12	0.51	2.98

Alebrahim et al. stated that a decline in osmotic potential in PEG and NaCl solutions led to increased MGT in lines of MO17 and B73 (Alebrahim, Janmohammadi et al. 2008). Similarly, in a relevant study concerning NaCl solution and sunflower genotypes, it was found that as osmotic potential declined, the MGT in genotypes increased in response (Khodadad 2011). As depicted in Table 2, PEG and a decrease of osmotic potential changed the GR significantly in the cultivars, which are confirmed by the results of relevant research experiments (Farsiani and Ghobadi 2009, Gholamin and Khayatnezhad 2010, Khodadad 2011). The observations indicated the highest levels of RL, PL, and SL at the control level in stress. Furthermore, it was found that stress greatly impacted all factors in a negative way. In fact, it caused the most negative impacts on all factors in the study (Table 2). These findings are in line with the results of several research studies (Almansouri, Kinet et al. 2001, Mohammadkhani and Heidari 2008, Farsiani and Ghobadi 2009, Jajarmi 2009, Kalefetoğlu, Turan et al. 2009, Khayatnezhad, Gholamin et al. 2010).

Theoretically, among the wide range of environmental factors that impede effective growth and development of plants, water stress caused by drought is the most significant (Khayatnezhad, Gholamin et al. 2010). Plants of different breeds react to DS with similar or even common physiological responses, as some of them metabolically behave in somehow similar ways under stress (Djibril, Mohamed et al. 2005). Water deficit negatively impacts the seeds' germination and seedlings growth (Van den Berg and Zeng 2006). Finally, the results indicated that Golden West had the highest level of resistance to harsh drought conditions, allowing it to have more yield potential than any other cultivar. In the end, given the obtained results, it was suggested that more research experiments needed to be conducted concerning similar cultivars, especially on Golden West as it has promising potentials.

CONCLUSION

Findings ranked Golden West as the top cultivar with the highest stress resistance as well as the highest levels of all traits.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Majid Khayatnezhad and Roza Gholamin conducted, planned, analyzed the data, wrote manuscript and interpreted the results and involved in manuscript preparation.

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