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Drought effect on maize seedling development

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Summary: Drought stress is one of the most important abiotic stresses influencing performance of crops. Certain stress-related conditions can appear and slow down germination, seedling development and in some cases cause loss of life durability of seed. Assuming that drought in the substrate affects corn seed performance, such conditions were simulated in this study in order to examine their effects on seed germination and length in seven corn hybrids. Polyethylene glycol (PEG) 6000 has been used in laboratory studies for simulation of drought conditions. Different osmotic potentials of PEG solutions were used (control; -0.1, -0.3, -0.6 and -0.9 MPa). Germination percentage decreased as osmotic potential increased at PEG solution.

Key words: maize seed, drought stress, germination, seedling development

Introduction

During their growth, crops are usually exposed to different environmental stresses which may limit growth and productivity (Vujaković et al. 2011). It has long been known that seed exposed to unfavourable environmental conditions, like drought, germinate with difficulty (Petrović et al. 2016). At least 60-70% of the total cultivated land has been estimated to be affected by drought and indeed drought is one of the most important factor limiting crop yields (Bray et al. 2000).

Drought as a stress affect seed germination, resulting in poor crop emergence, reduction of plant stand below the optimum, increased presence of weeds and, ultimately, reduced yield and quality of commercial corn (Radić et al. 2007). Roots obviously play an important role in helping plants to find water and there is evidence accumulated over many years that a deep root system is helpful in helping plants to find more water and delay the effects of drought.

Seed germination is the first critical and the most sensitive stage in the life cycle of plants compromising the seedlings establishment (Kolb & Barsch 2010; Karagić et al. 2010). Drought tolerance testing in the initial stages of plant development is of a vital importance, because the seed with more rapid germination under water deficit conditions may be expected to achieve a rapid seedling establishment, resulting in higher yields (Petrović et al. 2016).

Polyethylene glycol (PEG 6000) is widely used to simulate drought conditions. It is a non-ionic water polymer, which is not expected to penetrate into plant tissue rapidly (Kawasaki et al. 1983). PEG is an inert osmotic agent whose molecules are too large to penetrate into seed, thus preventing any toxic effects. Because PEG does not enter the apoplast, water is withdrawn not only from the cell but also from the cell wall (Versulues et al. 2006; Petrović et al. 2016). Jafari et al. (2009) and Khayatnezhad et al. (2011) reported significant effect of a drought on the quality of maize seed, especially on seedling development.

The aim of this study was to determine whether maize seed germination and seedling growth were inhibited by the osmotic effect during the seedling development, and also identification of the hybrids sensitivity to osmotic stress.

Materials and Methods

Experiments were conducted in the Laboratory for Seed Testing of the Institute of Field and Vegetable Crops in Novi Sad, Serbia. They included 7 maize

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hybrids from different maturity groups (from FAO 300 to FAO 700).

The standard method of seed germination testing was used as control and the treatment of polyethylene glycol on seed germination as a test. The lengths of root and shoot were measured separately.

Polyethylene glycol application (osmotic stress) - Seeds were incubated on filter paper in Petri dishes, at 25°C. Filter paper was previously treated with distilled water containing different concentration of polyethylene glycol (PEG 600), with osmotic potentials of: -0.1 MPa, -0.3 MPa, -0.6 MPa and -0.9 MPa. Filter paper treated with distilled water was used as control. Germination percentage and seedling length were assessed 7 days after treatment. The tests were performed in 4 replications, 100 seeds per replication.

The obtained data were processed by the analysis of variance (ANOVA) procedure for the two-factorial design. Prior to ANOVA analysis assumptions were checked and if necessary data transformations were applied. Means were compared by Tukey HSD test. Data were analysed using Statistica v. 10.0 software (StatSoft Inc.).

Results

The highest average germination was determined in the control (92.71%), while the decrease was notable in all PEG solutions (Figure 1). The lowest germination was determined in the lowest negative osmotic potential (-0.9 MPa: 2.90%). Hybrid H3 had the highest average germination value over PEG treatments (53.10%), while hybrid NS 300 gave the lowest average germination (46.40%; Table 1).

The highest value of the root length was determined in control (10.14 cm), while the lowest value was determined at the last treatment with PEG (0.78 cm). The highest average value of root length over treatments was recorded in the hybrids H2 (5.53 cm) and H4 (5.52 cm), while the lowest was determined in the hybrid H1 (4.46 cm; Table 1).

With the decrease of osmotic potential PEG, a significant decrease in seed germination was found in all tested hybrids. Significant differences were determined by comparison of the observed osmotic potential of PEG solutions.

Table 1. The effect of PEG treatments on seed germination and seedling growth of seven maize hybrids

PEG treatment (MPa)	Seed germination (%)	Root length (cm)	Shoot length (cm)
control	92.7^{a,}	10.14^{a}	3.75^{a}
-0.1	78.7^{b}	7.73^{b}	2.04^{b}
-0.3	55.4^{c}	4.20^{c}	1.10^{c}
-0.6	23.8^{d}	2.43^{d}	0.00^{d}
-0.9	2.9^{e}	0.78^{e}	0.00^{d}
Hybrid			
H1	46.4^{b}	4.46^{c}	1.45^{a}
H2	51.6^{a}	5.53^{a}	1.42^{a}
H3	53.1^{a}	5.19^{a,b}	1.38^{a}
H4	52.4^{a}	5.51^{a}	1.37^{a}
H5	48.3^{b}	4.62^{c}	1.36^{a}
H6	50.5^{a}	4.82^{c,b}	1.34^{a}
H7	52.9^{a}	5.26^{a,b}	1.32^{a}

Means followed by the same letter are not significantly different at α = 5% according to the Tukey HSD test

Downward trend was also recorded for root length with the decrease of osmotic potential of PEG solutions (Figure 2).

The highest value of shoot length over hybrids was found in control (3.75 cm), while shoot development wasn't recorded in treatments with -0.6 MPa and -0.9 MPa (Table 1, Figure 3). This sensitivity is expressed at the highest values of negative osmotic potential of PEG. And there is a trend, similar to the previously observed parameters, a significant reduction in the length comes to the potential of -0.1 MPa. In contrast to the previously observed parameters for the shoot length characteristic that at higher potentials (-0.6 and -0.9 MPa) does not come to its formation (Figure 3).

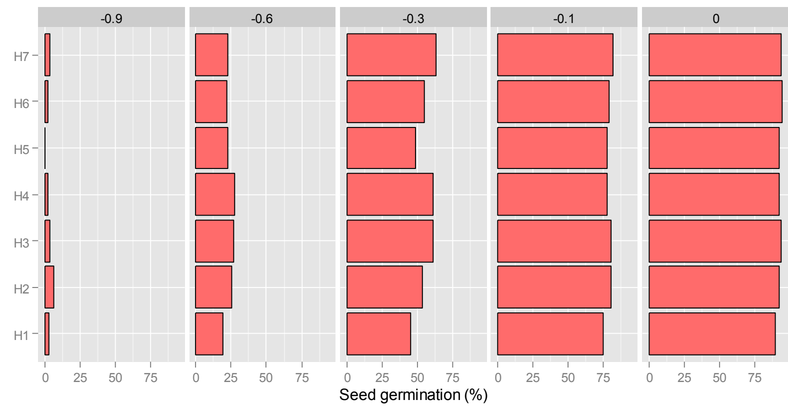

Figure 1. Effects of PEG treatments on seed germination on maize hybrids

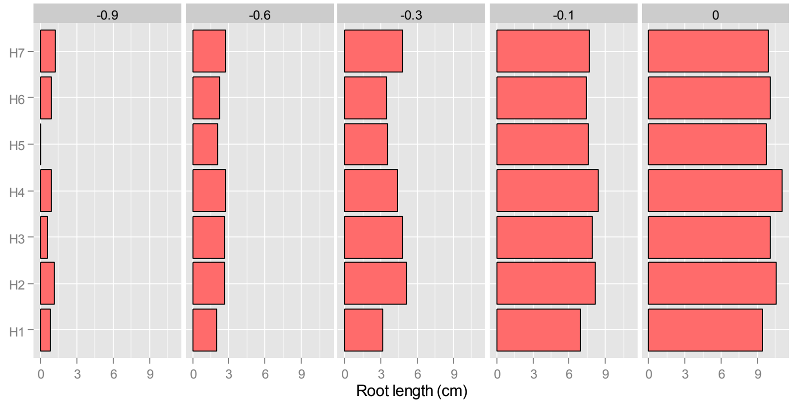

Figure 2. Effects of PEG treatments on root length of maize hybrids

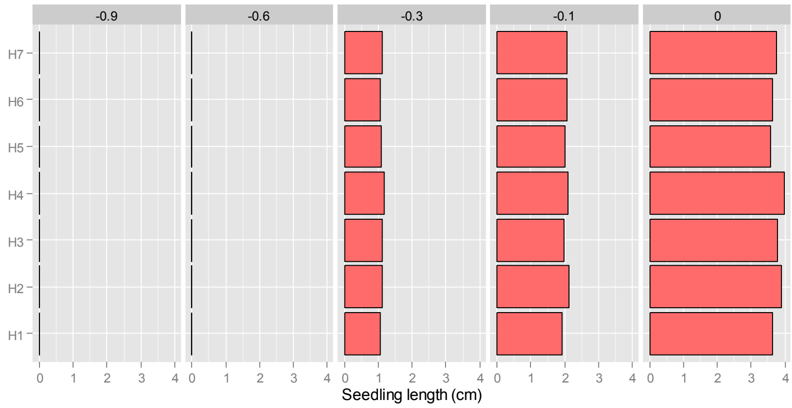

Figure 3. Effects of PEG treatments on shoot length of maize hybrids

Discussion and Conclusions

In this study, seven maize hybrids were compared with regard to their drought resistance to imposed stress in the controlled conditions during germination and early seedling growth stage. A similar approach was used to study the comparative effects of water and salt stress on seed germination in cowpea (Murillo-Amador et al. 2002), sunflower (Kaya et al. 2006), corn (Radić et al. 2007, 2008), sweet sorghum (Patane et al. 2013) and pea (Jovičić et al. 2013; Petrović et al. 2016).

The Tuckey HSD test showed significant differences between PEG solutions for germination values, and root and shoot length values. The results showed that seed germination decreased with increasing drought simulation. Rapid decrease of germination begins at -0.1 MPa. Murillo-Amador et al. (2002) reached the same conclusion and added that the decrease in germination rate was the same for all PEG treatments.

Differences between evaluated corn hybrids indicate to their differential sensitivity to drought stress. In this sense, genetic variability within a species offers a valuable tool for studying mechanisms of drought tolerance (Sayar et al. 2010a). The same authors concluded that final germination percentage decreased and delayed as osmotic potential decreased. Similar conclusion was made by Abogadallah & Quick (2009), who reported that drought stress (induced by PEG) may affect seed germination. El-Hendawy et al. (2005) pointed out that both osmotic and toxic effects have been implicated in inhibition of seed germination. Radić et al. (2008) reported that seed germination is more sensitive to drought stress than growth of established seedling.

This conclusion does not apply equally in root and shoot length. Common to both parameters, there is a statistically significant difference and it starts from the initial concentrations (control and -0.1 MPa). However, in this study the effect of osmotic stress on shoot length was more pronounced at higher concentrations of PEG, resulting in absence of the formation and development of seedlings. All hybrids were equally sensitive to decrease of osmotic potential. This indicates that shoot length is far more sensitive to the stress conditions than root length. The negative impact of drought conditions on the growth of the primary root and shoot was determined in sunflower (Kaya et al., 2006), in pigeon pea (Kumar et al., 2011), in wheat (Sayar et al. 2008, 2010a and 2010b) and pea (Petrović et al., 2016). They proved that lower osmotic potential can lead to a significant reduction in root and shoot length. Alian et al. (2000) concluded that these results basically give a true picture of water stress influence, although osmotic adjustment is not achieved in the same way under these stress. Kirigwi et al. (2004) concluded that low heritability for drought tolerance and lack of effective selection approaches limit development of resistant crop cultivars to environmental stress.

Drought stress is one of the most important abiotic stresses influencing performance of crops. This research is important for obtaining additional information to corn breeders in searching for characteristics responsible for the survival of plants under stress conditions.

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Uticaj suše na razvoj klijanaca kukuruza

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Sažetak: Suša je jedan od najvažnijih abiotskih stresova koji utiču na razvoj ratarskih kultura. Određeni uslovi koji su povezani s pojedinim stresovima mogu dovesti do usporavanja klijanja, razvoja ponika, a u nekim slučajevima i do gubitka životne sposobnosti semena. Pod pretpostavkom da nedostatak vode u supstratu utiče na karakteristike semena kukuruza, simulirani su uslovi suše u ovoj studiji sa ciljem da se ispita njihov uticaj na klijavost semena i razvoj ponika sedam hibrida kukuruza. Polietilen glikol (PEG) se koristi u laboratorijskim istraživanjima za simulaciju uslova suše. Koristili smo različite osmotske potencijale u rastvoru PEG-a (kontrola, -0,1, -0,3, -0,6 i -0,9 MPa). Procenat klijavosti je opadao sa smanjenjem osmotskog potencijala u rastvoru. Osetljivost korena i nadzemnog dela se povećava sa smanjenjem osmotskog potencijala. Na potencijalu od -0,6 i -0,9 MPa, nadzemni deo semena kukuruza nije se razvio.

Ključne reči: seme kukuruza, klijavost semena, uslovi suše

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