DETERMINATION OF MAIZE (*ZEA MAYS* L.) SEED VIGOR USING LABORATORY METHODS

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SUMMARY

Maize seed is during germination and cropping in the open under the influence of different agroecological factors, so high yields will be achieved mainly by sowing quality high vigor seeds. The aim of this research was to determine maize seed vigor by laboratory methods (mass of 1000 seeds, germination energy (GE), standard germination (SG), electrical conductivity (EC) and cold test (CT)) and at the same time examine the influence of genotype of three maize hybrides. The experiment was set up in four repetitions with 50 seeds for each method. A significant difference ($P \leq 0.01$) was found between the masses of 1000 seeds of the analyzed hybrids (314g, 307g, 252g). The energy of germination (66%, 63%, 61%), standard germination (94%, 95%, 91%) and cold test (87%, 97%, 83%) did not differ significantly. The determined values of electrical conductivity (7,96 $\mu Scm^{-1}g^{-1}$, 7,16 $\mu Scm^{-1}g^{-1}$, 5,23 $\mu Scm^{-1}g^{-1}$) were significantly ($P \leq 0.01$) influenced by hybrids. The analyzed seed was of satisfactory quality or vigor, and the influence of genotype was determined in seeds tested by electrical conductivity method.

Keywords: maize (*Zea mays* L.), quality, genotype

INTRODUCTION

The produced biomass of the plant depends on the quality of the seed used in sowing (Rapčan et al., 2006). Sowing seeds in the open field implies the fact that during germination and cropping the seed is exposed to various agroecological factors. Therefore, high maize yields can be primarily achieved by sowing quality high vigor seeds. Seed quality is a complex characteristic consisting of genetic, physiological, physical and health characteristics (Bukvić, (2015), quoting Marcos-Filho and McDonald (1998) as well as the finishing process (Gu et al., 2019), storage conditions (Šimić et al., 2011) and storage length (Timoteo and Marcos-Filho, 2013; Panayotov and Stoeva, 2017; Guberac, 2000). Vigor is the sum of the seeds physiological properties (Szemruch et al., 2019) and has an impact on the rate of germination and seedling growth under stressful conditions (Marcos-Filho, 2015). Thus, the value of vigor is estimated on the results of different research methods. Germination energy (GE) is a method which determines the speed of germination (Marcos-Filho, 2015), and standard germination (SG) is used for forecasting the germination in the open field if the conditions are almost optimal (Baldini, 2018). The cold test (CT) is the basic test for determining maize seed vigor (Marcos-Filho, 2015), because of its impact on the results of open field germination insofar as low temperatures and humid soil prevail (Lovato et al., 2005). The amount of electrolytes washed from the seeds during imbibition (Fessel et al., 2006) is measured by the test of electric conductivity (EC).

The quality of seed is first and foremost determined by its germination (Bukvić et al., 2007). Seed germination and the development of seedlings of field and vegetable crops are affected by genotype (Japundžić-Palenkić et al., 2017; Japundžić-Palenkić et al., 2015) as well as environmental conditions that prevail during the period of seed germination and seedling development. Therefore, the aim of this research was to determine the germination and vigor of maize by conventional laboratory methods.

MATERIAL AND METHODS

The research was conducted with the seeds of three maize hybrids and the following methods: mass of 1000 seeds, germination energy (GE), standard germination (SG), cold test (CT) and electrical conductivity (EC). The experiment was set up in four repetitions with 50 seeds for each method. The determination of germination energy (GE) and standard germination (SG) were performed by the rolled-towel method according to „The ordinance on methods of sampling and testing of seed quality“ Official Gazette 99/08. After pre-soaking in water in order to encourage germination, the seeds were lined up on filter paper that was soaked in distilled water and then, they were placed in plastic bags and put in an air conditioning unit chamber at the temperature of 20°C. The results of the germination energy were read after four days. The results of the standard germination were read after seven days. The cold test was performed by the modified „rolled-towel“ method. Pre-moistened filter paper and a mixture of sand and soil (in a ratio of 1: 2) (70% of water capacity) were stored for 24 hours at the temperature of 10°C. First, the samples were put in a plastic bag and were stored in climate chamber at 10°C for 7 days, then at 25°C for a period of 5 days (ISTA, 1999). In this research two temperatures of imbibition were used for determining electrical conductivity (EC) of maize seed (20°C and 27°C). Previously counted seeds were weighed and poured over with 250 ml of deionized water (Gu, 2019). Conductivity measurement was performed after soaking seeds for 24 hours at selected temperatures. Seed conductivity was obtained by dividing the value of the measured conductivity (μScm-1g-1) and the mass of the sample (g). After measuring the conductivity, the seed was dried and weighed. Based on the obtained results, the percentage of acquired water in relation to the initial mass of seeds was calculated and the correlation between the amount of water and EC was determined. The obtained data were statistically processed by ANOVA analysis of variance. The significance of the differences obtained was determined by the F-test, and the least significant differences were obtained by the LSD test.

RESULTS AND DISCUSSION

The analysed hybrids visibly differed in seed size. The smallest seeds belonged to hybrid H3. Its weight of 1000 seeds was significantly lower compared to the other two hybrids (Table 1).

Table 1 Significance of the influence of physical (mass of 1000 seeds) and physiological indicators (GE, SG and CT) of maize seed vigor

Tablica 1. Značajnost utjecaja fizikalnih (masa 1000 zrna) i fizioloških indikatora (EK, SK, i CT) vigora sjemena kukuruza

Hybrid / *Hibrid*	Mass of 1000 seeds / *Masa 1000 zrna* (g)	GE (%)	SG (%)	CT (%)
H 1	$307{,}50^{A}$	66	95	97
H 2	$314{,}10^{A}$	63	94	87
H 3	$252{,}35^{B}$	61	91	83
$LSD_{(0,01)}$	A,B	ns	ns	ns

GE-germination energy %; SG-standard germination %; CT-"cold test"; ANOVA-F test; ^{A,B} averages marked with different letters differ significantly by the LSD test at P=0.01; ns-not significant

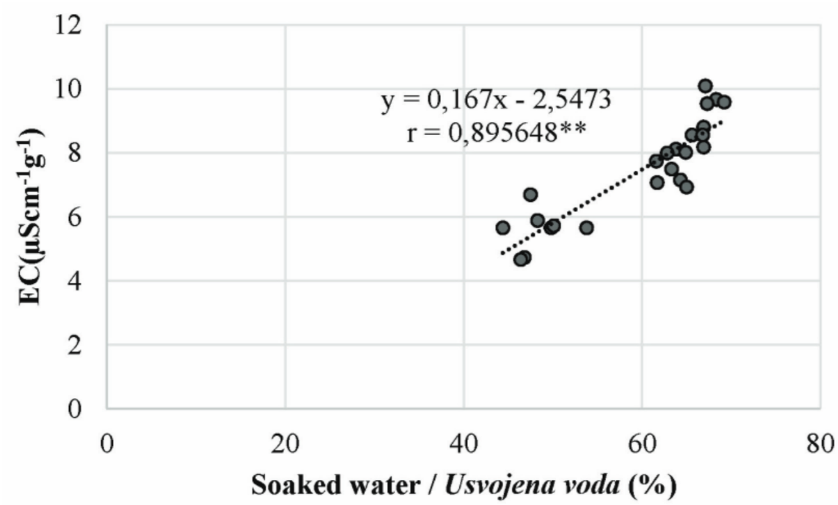
Poor and uneven germination is an undesirable seed property (Tkalec et al., 2016). Baldini et al., (2018) state that standard germination of maize seed, as has been obtained in this study (between 91% and 95%), significantly correlates with field germination at the usual sowing dates, which indicates high vigor seed. The analyzed hybrids had lower GE (61% and 66%) (Table 1) than expected, while standard germination was satisfactory and seeds were put up for sale as commercial seed. The original packaging (declarations) bore the repackaging mark, so there is a possibility that a large difference between GE and SG was found due to seed age and / or storage conditions (Timoteo and Marcos-Filho, 2013) as well as chemical treatment (Fessel et al., 2006) that significantly affects seed germination and are out of the scope of this research. The CT values of the analyzed hybrids were between 83% and 97% (Table 1), which, according to Fessel et al., (2006) and Vieira et al. (2017), implies that the seed of the hybrids analyzed in this study had a high vigor. It is interesting to note that hybrid H1 seed had a higher CT than SG which is not common since germination during CT took place in less favorable conditions of lower temperatures during the first 7 days. However, the optimal temperatures at SG resulted in a higher presence of pathogens which reduced seed germination compared to CT, where their number was less pronounced. The absence of the influence of genotype on maize seed germination in this research is in accordance with the results of the research of the influence of genotype on the germination of seeds of other field crops (Bukvić et al., 2008a), (Bukvić et al., 2008b). Tests used to determine vigor, such as EC, revealed differences in the physiological quality of seeds that had approximately the same germination (Vieira et al., 2017). According to Panobianco and Vieira (1996), genetic material plays a significant role in the results of EC maize seeds, and differences in EC values can be obtained between genotypes in which no difference was found between SG and other tests for the evaluation of vigor which was proved in this study (table 1 and 2). A significant difference in EC value was found between hybrid H3 and other hybrids at both imbibition temperatures (Table 2).

Tablica 2 Significance of the influence of EC (μ$Scm^{-1}g^{-1}$) and soaked water (%) on seed vigor
Tablica 2. Značajnost utjecaja EC (μ$Scm^{-1}g^{-1}$) i usvojene vode (%) vigora sjemena

Temperature / *Temperatura*	20°C		27°C	
Hybrid / *hibrid*	EC (μ$Scm^{-1}g^{-1}$)	Soaked water / *usvojena voda* (%)	EC (μ$Scm^{-1}g^{-1}$)	Soaked water / *usvojena voda* (%)
H 1	$7,16^{A}$	$63,58^{A}$	$8,52^{A}$	$66,55^{A}$
H 2	$7,96^{A}$	$63,28^{A}$	$9,68^{A}$	68^{A}
H 3	$5,23^{B}$	$46,48^{B}$	$5,93^{B}$	$50,3^{B}$
Average / *Prosjek*	$6,78^{B}$	$57,78^{B}$	$8,044^{A}$	$61,61^{A}$

EC-electrical conductivity (μ$Scm^{-1}g^{-1}$); Acquired water (%); ANOVA-F test; ^{A,B} averages marked with different letters differ significantly by the LSD test at P=0,01; ns-not significant

Also, in interaction with other conditions, seed size can have a significant impact on vigor indicators (Čičić et al., 2012), which can be related to this study since hybrid H3 seeds had a significantly lower weight or size (Table 1). Due to increasing climate change, a short-term deviation in soil temperature after sowing may arise, which opens up the possibility of researching EC of seeds at different imbibition temperatures. The determined value of the seed's EC at the imbibition temperature of 20°C was 6.78 μ$Scm^{-1}g^{-1}$ and differed significantly from the EC value obtained at 27°C (8.044 μ$Scm^{-1}g^{-1}$). An increase in the EC value, following the increase of the imbibition temperature, was also found in soybeans (Čičić et al., 2012), peas and sorghum Čičić et al. (2012) quoting Plenzer et al. (2003) and Kader et al., (2002). The obtained values of electrical conductivity, for all hybrids and both temperatures, in this study were in accordance with the results Fessel et al. (2006.) and indicated high vigor seed suitable for sowing in unfavorable weather conditions. Andrić et al. (2007) and Baldini et al. (2018) found that seeds with lower EC values and higher CT values had better field germination, especially in poorer field conditions. In this study, it was found that the imbibition temperature had a significant impact on the intensity of the acquisition of water (table 2). On average for all hybrids, a significantly higher water acquisition was found at 27°C (61.61%) compared to 20°C (57.78%) (Table 2) which is in accordance with the research done by Zaghdani (2002) which was performed on pea seeds. The amount of acquired water was significantly influenced by hybrids (Table 2). Hybrid H3 acquired significantly less water (46.48% and 50.3%, respectively) at both imbibition temperatures (Table 3). The established correlation between EC and the amount of water absorbed (r = 0.89565**) (Graph 1) indicates the possibility that the seed releases a larger amount of electrolytes into the environment due to stronger water acquisition during imbibition. Consequently, due to flooding and higher temperatures, there is a sudden uptake of water which leads to the imbibition damage of the seeds and thus to the release of electrolytes (Fessel et al. 2006) which favors the development of pathogenic microorganisms (Čičić et al. 2012).



Graph 1 Correlation between EC (µScm^{-1}g^{-1}) and soaked water (%) after 24 hours of imbibition
Graf 1. Korelacija između EC (µScm^{-1}g^{-1}) i usvojene vode (%) nakon 24 sata od zalijevanja

The determination of maize seed vigor by the previously mentioned methods was carried out in laboratory controlled conditions, where it was not possible to include all agroecological conditions to which the seed was exposed in the field. Therefore, based on the obtained results, there is a need for further laboratory and field research on seed vigor in order to obtain more reliable results which would enable forecasting with certainty the sprouting and development of seedlings, especially in unfavourable field conditions caused by increasingly pronounced climate changes.

CONCLUSION

The analysed hybrids showed good germination in laboratory conditions. The established values of standard germination indicate the reliability of germination and the development of seedlings in favourable field conditions. The cold test values of the analysed seed indicate the possibility of achieving a dense pattern of plants even in unfavourable, cold and wet sowing conditions. The hybrids had low values of electrical conductivity with a significant genetic influence on the measured feature. The amount of absorbed water and the electrical conductivity indicate the possibility of stronger stress impact on the seed if it is exposed to floods at higher temperatures.

ODREĐIVANJE VIGORA SJEMENA KUKURUZA (*ZEA MAYS* L.) LABORATORIJSKIM METODAMA

SAŽETAK

Sjeme kukuruza je tijekom klijanja i nicanja na otvorenom pod utjecajem različitih agroekoloških faktora pa se visoki prinosi mogu postići prije svega sjetvom kvalitetnog sjemena visokog vigora. Cilj ovoga istraživanja bio je odrediti vigor sjemena kukuruza laboratorijskim metodama (masa 1000 sjemenki, energija klijanja, standardna klijavost, električni konduktivitet i cold test) te ujedno ispitati utjecaj genotipa tri hibrida kukuruza. Pokus je postavljen u četiri repeticije s 50 sjemenki za svaku metodu. Utvrđena je značajna ($P \leq 0{,}01$) razlika između masa 1000 sjemenki analiziranih hibrida (314g, 307g, 252g). Energija klijanja (66%, 63%,61%), standardna klijavost (94%, 95%, 91%) i cold test (87%, 97%, 83%) nisu se značajno ($P \leq 0{,}01$) razlikovali. Utvrđene vrijednosti električnog konduktiviteta (7,96 $\mu Scm^{-1}g^{-1}$, 7,16 $\mu Scm^{-1}g^{-1}$, 5,23 $\mu Scm^{-1}g^{-1}$) bile su pod značajnim ($P \leq 0{,}01$) utjecajem hibrida. Analizirano sjeme imalo je zadovoljavajuću kvalitetu odnosno vigor, a utjecaj genotipa utvrđen je kod sjemena testiranog metodom električnog konduktiviteta.

Ključne riječi: kukuruz (*Zea mays L.*), kvaliteta, genotip

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