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Original scientific paper

VIGOUR OF MAIZE SEEDS PRODUCED AT THE MAIZE RESEARCH INSTITUTE "ZEMUN POLJE"

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Abstract: Maize is one of the economically most important crops. Its immense significance arises from its various uses, high yielding and the production scope. In order to establish a lucrative production, first-rate seeds are required. Therefore, the aim of this study was to test the vigour of maize seeds conventionally and organically produced. The seeds of the maize variety Rumenka were used and tested at the Maize Research Institute "Zemun Polje" in its Seed Testing Laboratory. According to the results, it can be concluded that although there was a minimal difference in the percentages of the first count of germinated seeds between the two types of seeds, the total germination was equal (98%). The results of the germination test performed after accelerated seed ageing indicate that total seed germination was higher in organic than in conventional seeds (39% vs. 33%). The electrical conductivity of the leachate per gram of weight of conventional maize seeds averaged 4.90 µS/cmg and 3.66 µS/cmg for organic maize seeds. According to stated values, it can be concluded that maize seeds of both production types are characterised by high viability and are suitable for earlier sowing under unfavourable environmental conditions. The results show that the radicle emergence was uniform amounting to 84% in conventional seeds and to 85% in organic seeds.

Key words: *Zea mays* L., germination, accelerated ageing, electrical conductivity.

Introduction

Maize (*Zea mays* L.), a field crop of universal significance, is primarily intended for human and animal nutrition, as well as a raw material for the processing industry (Pandurović, 2014). Furthermore, maize belongs to the family of grasses (*Poaceae*) and is an annual, monoecious, cross-pollinated crop that differs from other members of this family by its morphological traits. The maize

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kernel is actually a one-seeded fruit/grain and contains on average about 8–9% protein, 5% oil, 1.5% cellulose and 70% starch (Vančetović et al., 2012). In addition to its high energy value, the maize kernel has a relatively low nutritional value, because it is poor in digestible proteins and some other important nutritional substances. Breeders worldwide and in our country have been working very intensively to develop different forms of maize with specific production and quality grain traits in order to develop new genotypes such as red-seeded maize hybrids. The grains of the recently developed genotypes have a higher nutritional value for organisms of humans and domestic animals (Glamočlija et al., 2016). Maize is a very important part of every state economy, as it can be the basis for significant financial resources as an export item, which means that maize is of strategic importance for every state. The Republic of Serbia is an important producer of cereals at the regional level and in the European market. In recent years, maize has been grown on an area of around 1,200,000 ha (about 35% of arable land in Serbia), with an average yield of about 4.4 t/ha. Globally, the average maize yield increased by almost 70% during the period between 1980 and 2020. This increase was the result of a permanent progress in the breeding process and the development of increasingly high-yielding hybrids, as well as improvements in cultivation technology and the development of the new agricultural machines, mineral fertilisers and pesticides (Starčević and Latković, 2006). Organic farming positively affects natural biodiversity as it excludes the application of pesticides and GMOs. Contrary to conventional farming, organic farming favours preventive rather than corrective measures and integral plant protection technology (Bekavac, 2012). In addition, organic food production, especially in rural areas, utilises indigenous species and local varieties. Organic maize production in Serbia still takes place on small areas in comparison with conventional maize production. GMO seeds are not used in the organic maize production. Furthermore, the application of mineral fertilisers and the use of synthetic plant protection products are not allowed in this type of production. Therefore, the final product is a healthier food with a higher nutritional value compared to classical/conventional farming (Golijan and Marković, 2018).

The objective of the present study was to evaluate the vigour of conventional and organic maize seeds by comparing parameters of germination, accelerated ageing, electrical conductivity and the rate of radicle emergence and to determine possible differences between conventionally and organically produced seeds.

Material and Methods

The seeds of the red-seeded maize variety Rumenka, conventionally and organically produced in the 2014 production year, were tested. The field trial was set up in the location of Zemun Polje in 2014. Two plants were sown per hill and per row. The distance between the hills was 40 cm, while the inter-row distance was 75 cm. The sowing density was 66,700 plants ha-1. The elementary plot size amounted to 300 m^2 (0.03 ha) (6 m^2 x 50 rows). The harvest was performed in October and yielded 246 kg (fresh cobs). The following traits were tested and determined in the laboratory of the Maize Research Institute “Zemun Polje” during 2016: standard germination, electrical conductivity, rate of radicle emergence and the accelerated seed ageing test was performed.

1. The **seed germination test** was carried out in the standard germination chamber. The seed testing paper was used for the germination test. The test was done on four replicates of 100 maize seeds. Selected samples were grown on the moist paper. They were covered with filter paper, rolled up and placed into the chamber with the altering temperature of 20/30°C. The first count was made four days after the seeds had been placed into the chamber. The standard germination test for maize seeds lasted seven days (ISTA, 2016).

2. **The accelerated seed ageing test** was conducted in the accelerated ageing chamber. First, the working sample was drawn. Two hundred seeds of each genotype were placed in the accelerated ageing boxes. The seeds were placed on a mesh screen and suspended over 40 ml of distilled water. The seeds should not come into contact with water. Then, each box was covered with the lid and placed in the accelerated ageing chamber. The duration of the test period was 72 h from the moment when the maximum humidity was reached and when the temperature in the chamber reached 43°C (ISTA, 2016).

3. **The electrical conductivity test of seeds** was done using a conductivity meter that directly reads the values with the direct or the alternating current using a submersible cell. From the fraction of pure seeds with a moisture content ranging from 10% to 14%, two replicates of 50 maize seeds each were randomly counted and the weight was measured. Erlenmeyer flasks (eight for the seed samples and two as controls) were used for this test. They were first washed with distilled water, then filled with 250 ml of distilled water with a conductivity below 5 μS/cm and then covered. The prepared flasks were stored at a temperature of 20°C for 24 h. The reading had to be taken within 15 minutes of taking the flasks in order not to distort results. Prior to the use, the conductivity metre was calibrated using two standard solutions. When measuring the electrical conductivity, the electrical conductivity of the control Erlenmeyer flasks was read first and then that of the samples themselves. The Erlenmeyer flasks with the samples were slightly shaken and the cell was immersed. The reading was completed when stable conductivity values were obtained (ISTA, 2016).

The seed membrane integrity is indirectly determined by the electrical conductivity test. This test is used to assess the seed vigour, because it detects the deterioration process of the seed already in its early phase. The basic water conductivity was measured. Then, the conductivity per gram of the seed weight was calculated for each replicate. The average of two replicates was a test result for a certain seed lot. The conductivity of each replicate was estimated by the use of the following formula:

$$\text{conductivity} \left(\frac{\mu S}{cm \times g}\right) = \frac{\text{conductivity value} \left(\frac{\mu S}{cm}\right) - \text{basic value}}{\text{replication weight (g)}}$$

4. **Radicle test.** A working sample of 8 x 25 seeds was drawn and placed on the wet testing paper at 20°C. The number of seeds from which radicles developed was determined after 66 hours. Based on this number, their proportion was calculated (ISTA, 2016).

The obtained data were processed and graphically displayed by using the Microsoft Excel 2010 programme.

Results and Discussion

Seed germination

Figure 1 shows the first count of the tested maize seeds produced by conventional and organic methods, which was done four days after sowing for the standard germination tests. The results show that the first count of germinated maize seeds produced conventionally amounted to 88%, 93%, 90% and 82% over the replications, which means that the average first count was 88%. In the case of organically produced maize seeds, these percentages amounted to 90%, 91%, 91% and 91% over the replications, meaning an average of 91%. According to these data, higher percentages of the first count were read in organically produced maize seeds. Golijan (2020) read the first count of organically and conventionally produced seeds after sowing for the standard germination test and found that organically produced seeds had a higher first count than conventional seeds (70.75% vs. 34.25%).

The final result of seed germination of conventionally and organically produced maize is shown in Figure 2.

Figure 2 shows that the total germination of conventionally produced maize seeds amounted to 97%, 100%, 98% and 98% over the replications, or 98% on average. The corresponding values for organically produced maize seeds were 96, 96%, 100% and 100%, i.e., 98% on average. Ilbi et al. (2009) tested the germination of maize seeds using the standard germination test, but also observed plant emergence in the field under conditions that were certainly far from the ideal laboratory conditions. Eight samples containing 50 seeds each were tested under the laboratory conditions of the standard germination test. There were no statistically significant differences in seven of these eight samples. The germination of these samples was above 90%. Contrary to these results, plant emergence in the field was inferior. Four samples expressed a high percentage of plant emergence (90–96%), i.e., a high degree of viability, while the viability of the remaining samples was lower (emergence – 62–75%). Golijan Pantović et al. (2022) observed that the germination determined by the standard germination test was twice as high for organically produced maize seeds (88.25%) as for conventionally produced maize seeds (43.25%).

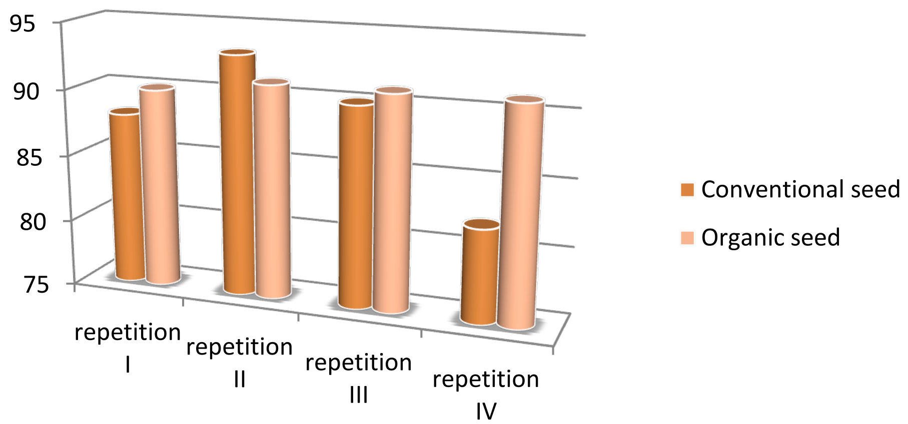

Figure 1. The first count of maize seeds produced conventionally and organically.

Standard germination tests are indicators of seed quality that can be used to predict plant emergence in the field when soil conditions are close to ideal (Durrant and Gummerson, 1990). However, the conditions under which seeds are tested are usually far removed from those prevailing in the field. The emergence of plants in the fields depends on the seed vigour (Milošević et al., 2010). In the majority of countries, maize is sown early in the spring when soil temperatures are low. At low temperatures, the seeds swell, but very often do not germinate and are invaded by pathogens (fungi). For these reasons, germination tests conducted according to the international rules under optimal conditions of temperature and humidity do not provide reliable predictions of plant emergence in the field. Under these circumstances, it is necessary to conduct tests under sub-optimal conditions and it is recommended to apply the cold germination test to estimate the maize seed vigour more accurately (Radić and Milošević, 2004).

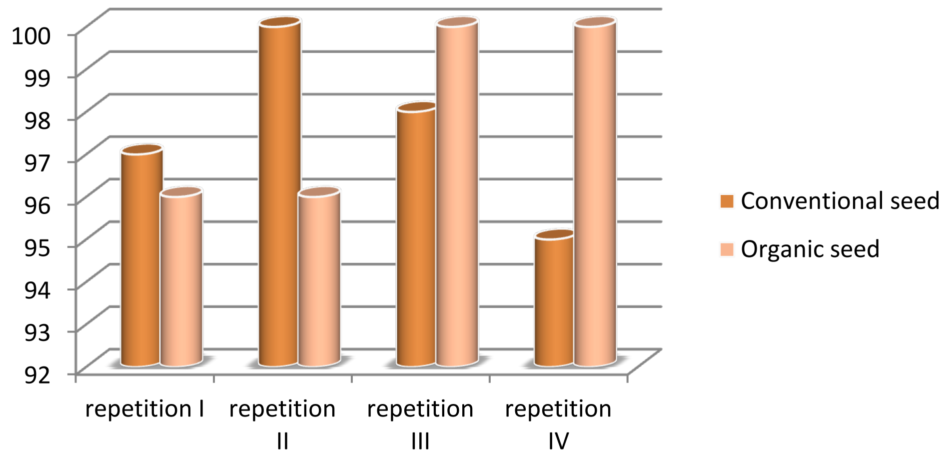

Figure 2. Germination of conventional and organic maize seeds.

Seed accelerated ageing

After accelerated ageing, the seeds were sown for germination under identical conditions as in the standard germination test. Figure 3 shows the first count of the observed maize seeds after accelerated ageing. Four days after sowing the seeds, the first count of the germination test was made.

Figure 3 shows that the first count of conventional maize seeds after accelerated ageing reached 14% and 16% (15% on average) over the replications. The corresponding values for the organic maize seeds amounted to 23% and 24% (24% on average). The results show that the first count of seeds after the accelerated ageing treatment was lower (below 25%) than for seeds not exposed to this treatment, and that organically produced seeds had a higher first count (24%) after the accelerated ageing treatment than the seeds of the conventionally produced crop (15%).

The total germination of maize seeds after the accelerated ageing treatment is shown in Figure 4.

Figure 4 shows that the total germination of conventional maize seeds after accelerated ageing amounted to 33% and 34% over replications (33% on average), while the values of organic maize seeds were somewhat higher and amounted to 38% and 40% (39% on average). The data collected show that the germination percentage after the accelerated ageing treatment was low (below 40%) for both conventionally and organically produced seeds, but that the organically produced maize seeds showed a slightly higher germination rate. The values of seed germination determined after accelerated ageing were significantly lower than the values determined in the standard germination test. Therefore, these values indicate the lower viability of the seeds and the fact that seeds sown in the field trials, where conditions are far from perfect laboratory conditions would almost certainly show low levels of germination. According to Golijan Pantović et al. (2022), who applied the accelerated ageing test to organic maize seed, there was an increase in the first count (78.5%) in comparison to the standard laboratory test (70.75%). High relative humidity and air temperature during the test reduced seed germination (from 88.25% to 84.25%), increased the percentage of non-germinated seeds and decreased the percentage of off-type seedlings. However, none of the stated differences were statistically significant. The seed germination (84.25%) of organic maize seeds obtained in the test conducted under stress conditions was lower than the percentage obtained in the standard laboratory test (88.25%). On the other hand, the germination of conventionally produced seeds was higher in the accelerated ageing test (46.25%). Nevertheless, the percentage of seed germination was below 80% in both cases, which was considered low vigourous seed lots. Milivojević (2016) tested seed quality of maize inbred lines of various maturity groups and genetic backgrounds and estimated that the average values of total seed germination amounted to 87.87% and 63.07% for seeds produced in 2014 and 2010, respectively, using an accelerated ageing test. Kavitha et al. (2017) found that accelerated seed ageing resulted in lower germination, shoot and root length, dry matter production and vigour index.

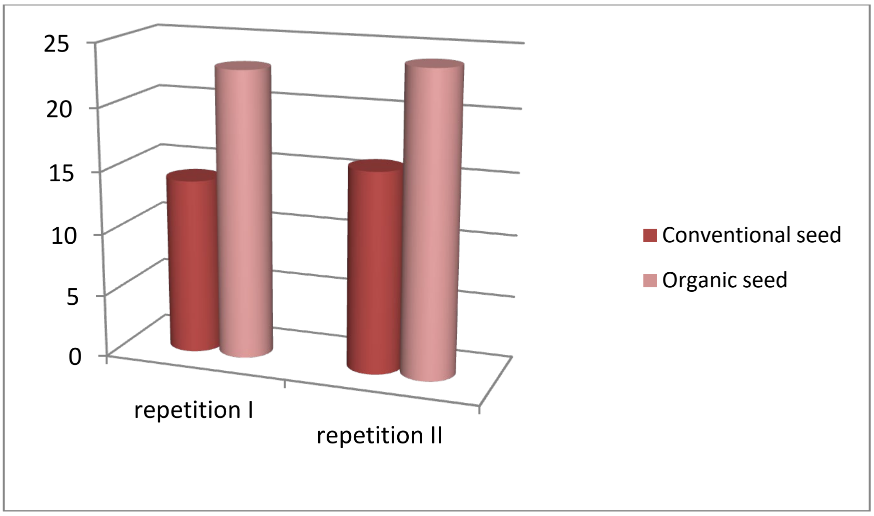

Figure 3. First count of conventional and organic maize seeds after accelerated ageing.

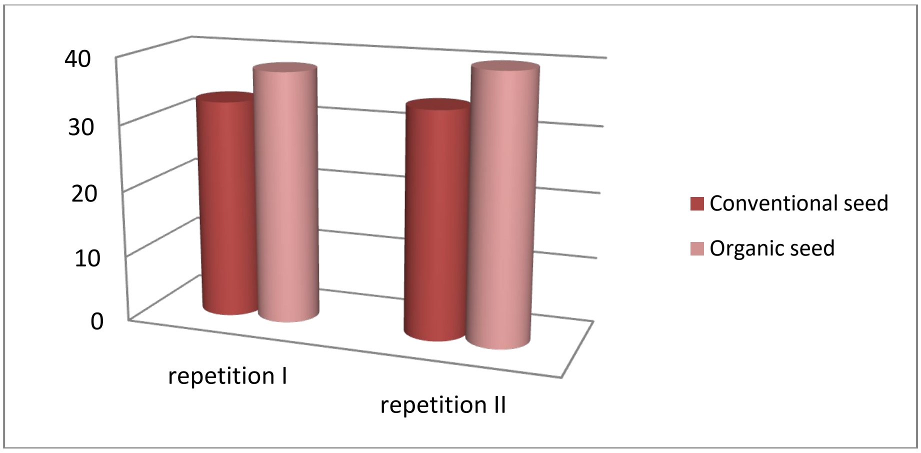

Figure 4. Seed germination of conventional and organic maize seeds after accelerated ageing.

Hussein et al. (2012) conducted the accelerated seed ageing test and found that the following properties of seedlings were reduced: dry and fresh weights, shoot and root lengths, vigour index, and germination speed index. The authors assumed that this was a consequence of the reduction in biochemical activities in seeds, because seed ageing adversely affected enzymes liable for converting reserve nutrients in the embryo into a form that could be taken up by the cell, thus impairing the formation of normal seedlings (Iqbal et al., 2002). According to Kapoor et al. (2010), the reduction in the length of shoots and roots as well as the seedling vigour index could be ascribed to breaking down DNA into smaller fragments during seed ageing, resulting in disrupted transcription that might cause the deficient or damaged synthesis of enzymes necessary for the initial stages of germination.

Woltz and TeKrony (2001) observed maize seed viability, i.e., maize seed germination after two different ageing treatments: at a temperature of 45°C for 72 h and at a temperature of 41°C for 96 h. The results indicated that maize seeds subjected to accelerated ageing at a temperature of 41°C for 96 h had a higher germination rate.

Electrical conductivity of seeds

Measuring the electrical conductivity of seed leachates provides an assessment of seed viability based on the release of electrolytes from plant tissues. If the electrolyte release is strong, that is, if the conductivity of the leachate is high, the seed is considered poorly viable, but if the electrolyte release is weak (low conductivity) seeds are considered more viable (ISTA, 1995).

The conductivity of the leachate per gram of seed weight was estimated based on the conductivity values obtained in this study, the initial seed weight and the baseline values using the formula given above and the results are shown in Figure 5.

Figure 5 shows that the leachate conductivity per gram of weight of conventional maize seeds averaged 4.90 μS/cmg. On the other hand, the conductivity of the leachate per gram of weight of organic maize seeds amounted on average to 3.66 μS/cmg. According to these values, it can be concluded that the seeds were highly viable. Sivritepe et al. (2015) obtained almost identical results: at temperatures of 20°C, 25°C and 30°C, electrical conductivity ranged from 1.7 to 5 μS cm^{-1} g^{-1}, 2.1 to 6 μS cm^{-1} g^{-1}, and from 2.2 to 7.3 μS cm^{-1} g^{-1}, respectively.

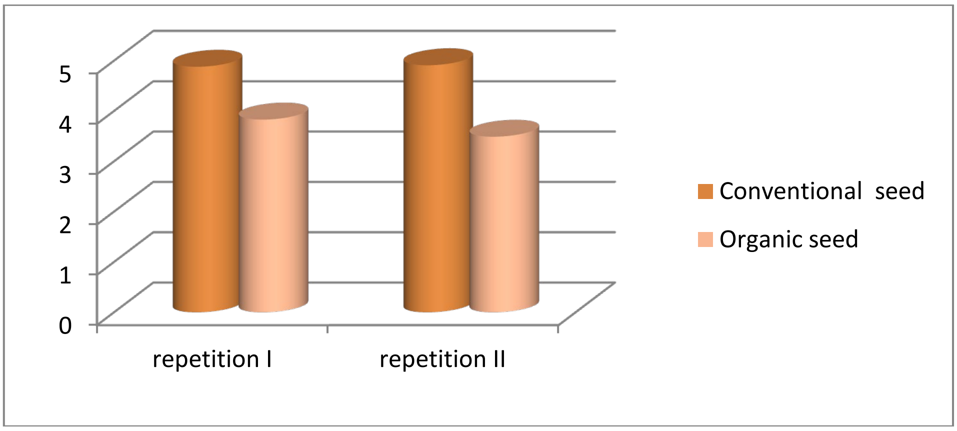

Figure 5. Conductivity of the leachate per gram of maize seed weight.

According to Hussein et al. (2012), seed germination decreases when the leakage of solutes is intensified. Lipid peroxidation is intensely related to the electrical conductivity of seeds. It could be said that the impacts of accelerated ageing and disruptions of the seed membrane affect the increase in peroxidation products and electrical conductivity (Al-Maskri et al., 2002). The loss of the quality of the complete membrane can result in reduced germination capacity, lower vigour and finally lower viability (Khan et al., 2003). Al-Maskri et al. (2002) showed in their study that the electrical conductivity of carrot seeds was higher with the enhanced ageing time. The electrical conductivity test of a seed lot shows the condition of the seed membrane. This test of single seeds indicated that the damage to the seed membrane was lower when the ageing time of the seeds was shorter. Khan et al. (2003) assumed that the delay in growth and germination in aged seeds probably depended on the membranes.

Radicle test

The radicle emergence tests were performed with conventional and organic maize seeds in eight replications with 25 seeds each. Figure 6 shows the results of radicle emergence of conventional and organic maize seeds. Based on the data in Figure 6, it can be observed that the radicle emergence of conventional maize seeds amounted to 19, 19, 22, 24, 23, 22, 21 and 18 out of 25 seeds in the replications, which corresponds to an average of 84% of germinated seeds. The corresponding values for organically produced maize seeds were 23, 21, 24, 22, 19, 21, 19 and 22 out of 25 seeds, corresponding to an average of 85% of germinated seeds. The results show that the percentage of radicle emergence of conventionally and organically produced seeds was quite uniform, that is, almost identical. Previous studies have not determined whether maize radicle emergence is reduced by soil moisture that is sufficient for seed imbibition, but not for radicle emergence. Slower germination, which is an indicator of early physiological ageing of seeds, is the main cause of reduced seed viability.

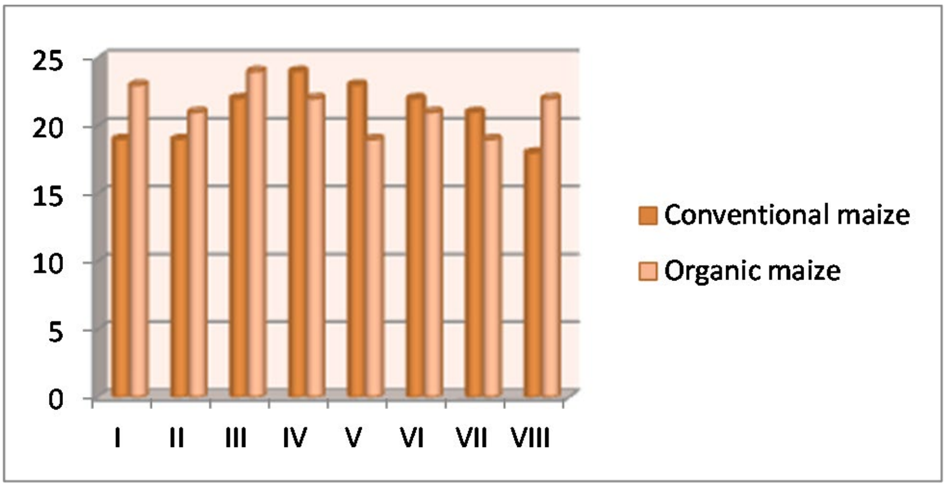

Figure 6. Radicle emergence in conventionally and organically produced maize.

Analysts from several laboratories have developed the radicle emergence test for maize seeds (Matthews et al., 2011a, b). The seed germination rate is accurately reflected in a single assessment of emerged radicles at the beginning of germination and this assessment is closely related to other parameters of the germination rate. The higher the number of radicles during the evaluation is, the higher the viability of the seeds, and vice versa, a lower number indicates a lower viability of the seed. A similar study was conducted by Helms et al. (1997). These authors showed that radicle emergence in maize was >85%, then the percentage of emerged radicles in sunflower increased from 59% under conditions of lower soil moisture to 90% under conditions of high initial soil moisture, while this percentage was very low in soya bean (22%).

Luo et al. (2015) conducted the study to evaluate the number of radicles at 20°C and 13°C for 84 hours and 150 hours, respectively. They then compared the results obtained with the results of the following tests conducted on seven sweet maize seed lots: complex stressing vigour test, cold test, germination energy, germination percentage, germination index, vigour index and mean germination time. The number of radicles at 20°C after 84 hours and at 13°C after 150 hours was significantly related to six estimations of vigour and germination percentages. The attained results imply that single numbers of radicles may be useful in seed vigour testing of sweet maize.

Conclusion

Based on the test results of standard germination, germination after accelerated ageing, the conductivity of the leachate per gram of weight of conventionally and organically produced maize seeds, as well as radicle emergence, the following can be concluded:

- The total germination of the tested seeds either conventionally or organically produced was equal (98%);
- After accelerated ageing, organically produced seeds had a higher first count (24%) than conventionally produced seeds (15%);
- The germination of organically produced seeds after accelerated ageing was higher (39%) than the germination of conventionally produced seeds (33%);
- The test results on the electrical conductivity of leachates show that seed viability was high for both conventionally and organically produced seeds; these seeds were equally resistant to unfavourable conditions at the time of sowing and emergence of the crop;
- The radicle test points out to the uniform germination rate for both conventionally and organically produced seeds;
- The results of the tests presented do not indicate significant differences between the seeds of conventionally and organically produced crops.

Acknowledgements

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ŽIVOTNA SPOSOBNOST SEMENA KUKURUZA PROIZVEDENOG U INSTITUTU ZA KUKURUZ „ZEMUN POLJE"

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R e z i m e

Po svom privrednom značaju kukuruz je jedna od najvažnijih ratarskih biljaka. Veliki značaj kukuruza proizilazi iz raznovrsne upotrebe, velike rodnosti i obima proizvodnje. Kako je za uspešnu proizvodnju neophodno kvalitetno seme, cilj ovog rada bio je da se ispita životna sposobnost semena kukuruza poreklom iz dva različita načina proizvodnje – organskog i konvencionalnog. Korišćeno je seme kukuruza sorte rumenka (konvencionalno i organski proizvedeno), a ispitano je u Laboratoriji za ispitivanje semena Instituta za kukuruz „Zemun polje". Prema dobijenim rezultatima može se zaključiti da je nakon minimalnih razlika u procentu energije klijanja konvencionalnog i organskog kukuruza, ukupna klijavost bila identična (98%). Rezultati ispitivanja klijavosti nakon ubrzanog starenja semena ukazuju da je ukupna klijavost kukuruza bila viša kod organskog semena (39%) u odnosu na konvencionalno seme (33%). Provodljivost ekstrakta po gramu mase semena konvencionalnog kukuruza u proseku daje 4,90 µS/cmg, dok kod semena organskog kukuruza provodljivost iznosi 3,66 µS/cmg. Iz navedenih vrednosti može se zaključiti da ispitivano seme konvencionalnog i organskog kukuruza poseduje visoku životnu sposobnost i pogodno je za raniju setvu pri nepovoljnim uslovima sredine. Prema dobijenim rezultatima, pojava primarnog korena je bila ujednačena i iznosi 84% kod konvencionalnog semena i 85% kod organskog semena.

Ključne reči: *Zea mays* L., klijanje, ubrzano starenje, električna provodljivost.

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