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Original scientific paper

THE SEED VIGOUR OF SPELT PRODUCED AT THE MAIZE RESEARCH INSTITUTE "ZEMUN POLJE"

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Abstract: Spelt (*Triticum spelta* L.) has been increasingly attracting producers due to the biological properties and chemical composition of its seeds. As high-quality seeds are necessary for successful production, the vigour of organically and conventionally produced spelt seeds has been studied and results are presented in this paper. The seeds of the variety Nirvana produced by both methods at the Maize Research Institute "Zemun Polje" in 2015 were observed. According to the results, the germination energy of conventionally and organically produced seeds amounted to 30% and 69%, respectively. The total germination of conventionally and organically produced spelt seeds amounted to 99% and 93%, respectively. The percentage of abnormal seedlings of spelt produced by both methods amounted to 1% on average. The participation of diseased and dead seeds was higher in organically produced seeds (6%) than in conventionally produced seeds (0%). After the seed accelerated ageing test, a higher germination was observed in conventionally produced seeds (75%) than in organically produced seeds (68%). The electric conductivity of conventionally produced seeds amounted to 189.4 μS/cm and 195.2 μS/cm in the first and the second replication, respectively, while the values of organically produced seeds amounted to 95.5 μS/cm and 98.6 μS/cm, in the first and the second replication, respectively. The results obtained by the electrical conductivity test indicated that the conventionally produced spelt seeds (32.33 μS/cm g) were classified into the category of low vigour seeds in comparison to organically produced spelt seeds (27.65 μS/cm g).

Key words: *Triticum spelta* L., germination, accelerated ageing, electrical conductivity.

Introduction

According to data of the FiBL survey reported by Willer et al. (2022), more than 60 percent of the arable land was located in Europe. Cereals, including rice

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(5.1 million ha), green fodder (3.2 million ha) and oilseeds (1.8 million ha) were mostly grown on the arable cropland. In 2020, global organic production of cereals was performed on almost 5.1 million hectares (0.7%). Within the global organic production of cereals, wheat ranks first (30.88%), maize second (14.85%) and rice third (12.25%). On the other hand, in Serbia in 2020, organic crops were grown on the area of 20,970.75 ha in the following way: cereals on the area of 3,623.15 ha, while organic spelt was produced on only 256.14 ha (Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia, 2022).

The interest in growing spelt (species: *Triticum spelta* L., family: *Poaceae*) has been growing, as alternative crops have been gaining in their importance (Lacko-Bartošová et al., 2010). Spelt, due to its biological traits and chemical composition of its grain, belongs to resistant cereal species that do not require special growing conditions (Ugrenović, 2003). Its needs in terms of soil quality, climate conditions and cropping practices are modest, and it also does not require chemical treatments, which makes spelt suitable for the organic production (Golijan et al., 2019). Organic agriculture is defined as a system that manages agriculture and preserves biological diversity, and uses processes and technologies based on biological principles without the use of artificial inputs, i.e., genetically modified organisms (FAO/WHO Codex Alimentarius Commission, 1999). Based on its modest requirements for growing conditions and expressed qualitative properties that are in line with contemporary nutritional requirements, spelt ranks high within the organic system of cultivation (Nikolić et al., 2015). Vigour is the most important seed property, which, in the broadest sense, includes several interconnected traits due to which seeds germinate and develop under various (favourable and unfavourable) conditions (Lekić, 2009). The aim of seed vigour testing is to provide data on the sowing value for the wide range of environmental conditions and/or properties of seeds stored in warehouses. Since practice and literature data show the differences between seed germination in the laboratory and the field, it is assumed that the observed spelt varieties will also express differences between field and laboratory germination.

The objective of this study was to observe and compare the vigour of organically and conventionally produced spelt seeds, as well as to establish possible differences between them.

Material and Methods

Seeds of the conventionally and organically grown spelt variety Nirvana, used in this study, were produced in the experimental field of the Maize Research Institute "Zemun Polje" in 2015. The spelt variety Nirvana has been developed at the Department of the Organic Production and Biodiversity of the Institute of Field and Vegetable Crops in Novi Sad. It is a late variety, very resistant to low temperatures during winter. It forms covered kernels with a test weight of 75–78 kg, 1000-kernel weight of approximately 41 g and a protein content of about 15%. The variety contains all vitamins of the B group (except vitamin B12). Its content of Ca, Mg, P and Se is 7–8 times higher than the content in other cereals. It also contains a significant amount of Zn (nsseme.com).

The following tests were performed in the Seed Testing Laboratory of the Maize Research Institute "Zemun Polje" in May of 2016:

1) the standard seed germination test,
2) the seed accelerated ageing test, and
3) the electrical conductivity test.

1. The standard seed germination test. The standard seed germination test was performed in the standard germination cabinet. The filter paper was used as a germination medium. Maize and spelt seeds (4 x 100 seeds) were selected. Spelt seeds were cleaned of impurities. Counted samples were placed on the moist filter paper, covered with another filter paper, rolled and placed in the germination cabinet at the alternating temperature of $20 \Leftrightarrow 30^{o}C$ (ISTA, 2016). The energy of germination was read on the fourth day from the beginning of the germination test. The standard seed germination test for maize and spelt is carried out for seven and eight days, respectively.

2. The seed accelerated ageing test. The accelerated ageing test of seeds was performed in the accelerated ageing chamber (ISTA, 2016). Two hundred seeds were placed in each container. Once samples were drawn, the seed moisture content and the seed initial weight were determined. The tray mesh screen was placed into each container. Seeds were placed on the screen under which there were 40 ml of distilled water, taking care that the seeds did not come into contact with water. The containers were then covered with lids and placed into the accelerated ageing chamber. The test period lasted for 72 hours from the moment when the chamber temperature reached $43^{o}C$ and the maximum humidity was reached. After that, seeds were placed to germinate in the same way as when the standard seed germination test was performed.

Based on the initial moisture content, the initial seed weight and the final seed weight, the final seed moisture content was calculated using the following formula:

$$FM = 100 - IW \times \frac{100 - IM}{FW} \qquad (1)$$

where:

FM is final moisture, IW is initial weight, IM is initial moisture and FW is final weight.

3. The electrical conductivity test of seeds. An electrical conductivity metre was used to measure the electrical conductivity of seeds (ISTA, 2016). A total of 2 x 50 spelt seeds were randomly counted from the pure seed fraction with moisture

ranging between 10% and 14% and their weight was determined. Erlenmeyer flasks were used to perform electrical conductivity. Flaks were first washed with distilled water and then filled with 250 ml of distilled water with a conductivity below 5μS/cm and finally they were covered. Erlenmeyer flasks prepared in this way were stored at the temperature of 20°C for 24 h. After this time, each seed sample was placed in the prepared Erlenmeyer flasks, which were gently stirred to immerse all seeds. The remaining flasks were filled with distilled water to serve as a control. Flasks were then covered and returned to the temperature of 20°C for 24 h. Conductivity was read after 24 h.

Conductivity per gram of seed weight for each replicate was calculated after the reading of the basic water conductivity and the average of two replicates was a testing result of a certain seed lot. Conductivity for each replicate was calculated using the following formula:

$$\text{conductivity}\left(\frac{\mu S}{cm \times g}\right) = \frac{\text{conductivity value}\left(\frac{\mu \text{S}}{\text{cm}}\right) - basic \text{ value}}{\text{replication weight (g)}} \qquad (2)$$

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

Results and Discussion

Viability is the most important biological property of seeds. Seed viability not only shows the percentage of viable seeds in a particular sample, but also the ability of seeds to successfully develop normal seedlings under unfavourable field conditions (ISTA, 2014). This concept is reflected by the rate of germination, emergence and rooting in the field, as well as the general effect of storage substances in the endosperm in relation to the seedling growth (Lekić, 2009). Seed viability is most simply evaluated via seed germination (Lekić, 2003).

Standard germination tests are indicators of seed quality that can be used to predict the emergence of plants in the field if the soil conditions are almost ideal (Durrant and Gummerson, 1990). However, the conditions under which seeds are tested are often more favourable than those in the field. The plant emergence in the field actually depends on seed vigour (Milošević et al., 2010).

Figure 1 shows the germination energy of conventionally and organically produced seeds that was read on the fourth day of the standard germination test. The germination energy of conventionally and organically produced seeds amounted to 30% and 69%, respectively. The total germination of spelt seeds was read on the eighth day of the standard germination test. The final results of the germination of conventionally and organically produced seeds are presented in Figure 2.

The total germination of conventionally and organically produced spelt seeds averaged 99% and 93%, respectively, which indicates that, in addition to large differences in the percentage of seed germination of these two types of seed production, the differences in total germination were not large. As already stated, higher germination (99%) was expressed by conventionally produced spelt seeds. Morphological traits of spelt seeds (chaffiness) can, to the greatest extent, affect seed germination. In 2002 and 2003, Acko (2004) performed the two-year germination test under laboratory conditions using chaffy and hulless spelt. The obtained results differed from one another. The average germination of chaffy and hulless spelt seeds amounted to 96.4% and of 80.5%, respectively. According to these results, it can be concluded that the higher germination percentage was determined in chaffy seeds, and, therefore, these seeds are the best choice for the crop establishment.

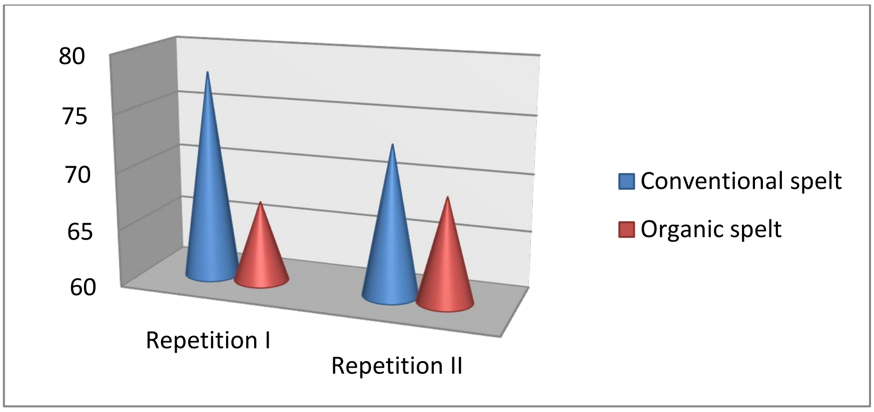

Figure 1. The germination energy of conventionally and organically produced spelt seeds.

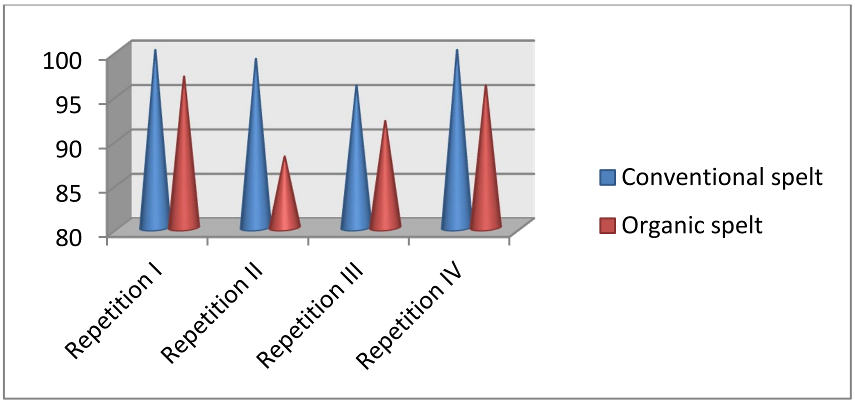

Figure 2. The seed germination of conventionally and organically grown spelt.

The accelerated ageing test is one of the most commonly used tests to determine seed vigour because it is closely related to the ability of seeds to germinate in the field (Lovato et al., 2001). In the course of the test, seeds absorb moisture from the humid environment, thus increasing their moisture content, which, together with the high temperature, results in accelerated seed ageing. High vigour seeds are more tolerant to stress conditions and will age slower than low vigour seeds. Results obtained on the effects of accelerated ageing on the germination of conventionally and organically produced spelt seeds are presented in this paper. Prior to the accelerated ageing test, the initial moisture content of seeds was measured. This content amounted to 10% and 8.3% in conventionally and organically produced spelt seeds, respectively. After this test, the seed weight was measured.

The final moisture content of conventionally produced spelt seeds amounted to 32% in the first replicate and to 33.9% in the second replicate, while the corresponding content of organically produced spelt seeds was slightly lower and equal in both replications and amounted to 31.3%. The final moisture content was compared to the values allowable by the ISTA. These values for spelt range from 28% to 30% (ISTA, 1995) and are somewhat lower than those obtained in the accelerated ageing test. This indicates that the spelt seeds that underwent accelerated ageing had poorer vigour than seeds that did not.

After accelerated ageing, seed germination was determined by the standard procedure. Seeds of conventionally and organically grown spelt were exposed to accelerated ageing and Figure 3 presents their germination energy (read on the fourth day from the day of placing seeds for germination testing).

The germination energy of conventionally and organically produced spelt seeds averaged 7% and 5%, respectively. The total germination energy of spelt seeds after accelerated ageing was read on the eighth day from the day of testing seeds and the final result is presented in Figure 4. After accelerated ageing, the seed germination of conventionally and organically grown spelt averaged 75% and 68%, respectively.

Obtained values of spelt seed germination after accelerated ageing were very low compared to the values gained by the standard germination test, and thus they are an indicator of lower seed vigour. These values also indicate the fact that the seeds, under environmental conditions, which are not ideal for germination, will probably express a low degree of germination. The percentage of abnormal seedlings of conventionally and organically grown spelt averaged 5% and 11%, respectively. The percentage of diseased and dead seeds in conventionally and organically grown spelt averaged 20% and 21%, respectively. A large number of papers describe various changes that occur in aged seeds, which are later manifested in seedlings, but some research has shown that there was no increase in the percentage of abnormal sunflower seedlings after accelerated ageing (Draganić, 2011). Many authors studied the effects of seed immersion (in aqueous or osmotic solutions) on different parameters of seed vigour. Thus, moistening of aged watermelon seeds (45°C, relative air humidity of 79% for 6 days) with vermiculate (25°C for 24h) resulted in the partial restoration of the initial germination of tested seeds (Chiu et al., 1995).

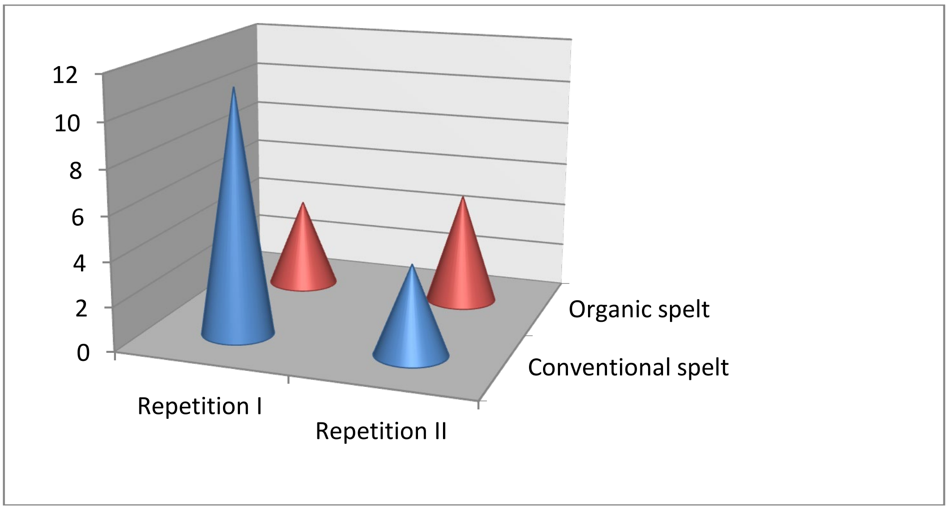

Figure 3. The germination energy of conventionally and organically produced spelt seeds after accelerated ageing.

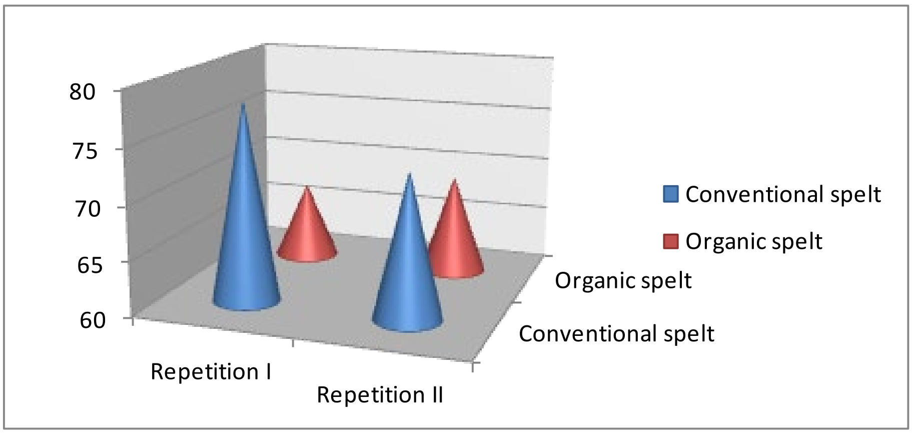

Figure 4. The germination of conventionally and organically produced spelt seeds after accelerated ageing.

The electrical conductivity measurement of seed extracts provides an assessment of the degree of loss by releasing electrolytes from plant tissues. Seed vigour can be established by the conductivity measurement of the immersion water in which seed samples were soaked. If the release of electrolytes is strong, i.e., if the extract conductivity is high, the seed is considered to be of poor vigour, but if the release of electrolytes is poor (low conductivity) then the seed is of high vigour (ISTA, 1995).

According to the conductivity formula, the basic value was obtained by measuring the conductivity of water (control), which, in the case of spelt seeds, amounted to 3.92 and 3.56 or 3.74 on average.

The spelt seed weight was determined prior to seed soaking and reading of the conductivity, and the obtained values are presented in Table 1, while the read values of seed conductivity are shown in Table 2. The electric conductivity of conventionally produced seeds amounted to 189.4 µS/cm and 195.2 µS/cm in the first and the second replication, respectively. The corresponding values of organically produced seeds amounted to 95.5 µS/cm and 98.6 µS/cm, in the first and the second replication, respectively. The obtained values (conductivity, initial seed weight and basic values) are inserted into the conductivity formula and the conductivity of the extract per gram of the seed weight was calculated and presented in Figure 5. The conductivity per gram of commercially and organically produced spelt seeds amounted to 32.33 µS/cmg and 27.65 µS/cmg, respectively (Figure 4). The obtained values were compared with the tabular values of conductivity, i.e., with allowable values (Milošević et al., 2010).

Table 1. The spelt seed weight before the reading of conductivity (g).

Spelt seed production	Weight of 50 seeds (g)	
	1st repetition	2nd repetition
Conventional spelt	5.73	5.93
Organic spelt	3.40	3.35

Table 2. The values of seed electrical conductivity (µS/cm).

Spelt seed production	Conductivity (µS/cm)	
	1st repetition	2nd repetition
Conventional spelt	189.4	195.2
Organic spelt	95.5	98.6

Allowable values of conductivity amount to:

1. 43 µS/cmg – the low vigour seed that is not suitable for sowing;
2. 25–29 µS/cmg – the seed can be used for early sowing under unfavourable environmental conditions, but at risk;
3. 30–43 µS/cmg – the seed is not suitable for early sowing, especially not under unfavourable environmental conditions, and
4. >43 µS/cmg – the low vigour seed that is not suitable for sowing.

According to the literature data accessible, rapid seed vigour tests that give reliable information about seed physiological potential indicating their association with enzymatic and respiratory activities as well as cell membrane integrity are the tests such as the tetrazolium test and the electrical conductivity test (Szemruch et al., 2015). The latter test is based on the strength of resistance to the flow of electric current imposed on the steep water of seeds. Resistance is a function of the amount of electrolytes in the solution. The electrical resistance of pure water is strong, but electrolytic substances, such as ionic substances, enable the flowing of electric currents. Numerous cells are composed of bases, acids or their salts, i.e., electrolytes. The efflux of electrolytes from seeds during their imbibition most probably demonstrates the condition of the seed cell membrane. The weaker seeds are the poorer the membrane cell is due to which the electrolyte loss and conductivity measurements are higher (Pandey, 1992).

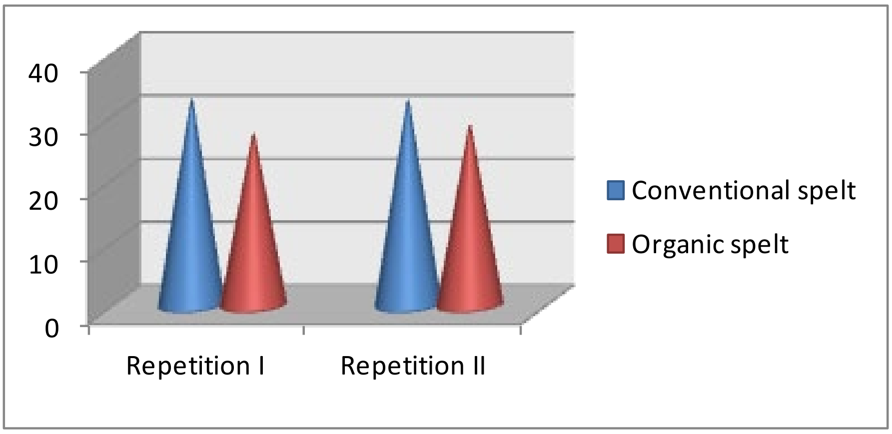

Figure 5. The conductivity of extract per gram of spelt seed weight.

Khan et al. (2010) performed a study related to seed quality tests and the field emergence of old and new wheat varieties during the 2003–2004 period. These authors used 32 samples of four wheat varieties and determined that the best estimation of seed vigour of the observed wheat varieties was achieved by the germination index, accelerated ageing and electrical conductivity, not only for ranking the quality of seed lots but also for predicting field emergence.

Results of the electrical conductivity test were feebly related to field emergence and the standard germination of seed lots of the four observed wheat varieties that varied in their vigour. Moreover, both tests, accelerated ageing and electrical conductivity, were very sensitive tests regarding seed lot quality ranking and showed a stronger correlation with field emergence than the standard germination test for all four varieties in two years of investigation. According to the electrolyte outflow determined by the conductivity test of wheat seed lots that differed in vigour, the cell membrane integrity was the primary result of vigour degradation. Kaya (2014) showed that the conductivity test could be used in the determination of safflower seed vigour due to its negative correlation with the germination and accelerated ageing tests, while the control deterioration test was ineffective in the seed vigour evaluation.

Conclusion

The standard seed germination test showed that commercially produced spelt seeds had higher germination (99%) than organically produced spelt seeds (93%). The seed accelerated ageing test showed that the germination of commercially and organically produced spelt seeds amounted to 75% and 68%, respectively. Test results show that there was a great difference in electrical conductivity between organically (95.5 and 98.6 µS/cm) and conventionally produced spelt seeds (189.4 and 195.2 µS/cm). The electrical conductivity testing of conventionally produced spelt seeds (32.33 µS/cmg) points out that these seeds are low vigour seeds. On the other hand, the corresponding value of organically produced spelt seeds was 27.65 µS/cmg, which means that these seeds have a greater potential for storage and higher resistance to stressful conditions during germination.

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ŽIVOTNA SPOSOBNOST SEMENA KRUPNIKA PROIZVEDENOG U INSTITUTU ZA KUKURUZ „ZEMUN POLJE”

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R e z i m e

Krupnik (*Triticum spelta* L.) privlači sve veću pažnju proizvođača zbog svojih bioloških osobina i hemijskog sastava semena. Kako je za uspešnu proizvodnju neophodno kvalitetno seme, u ovom radu je ispitivana životna sposobnost semena krupnika proizvedenog konvencionalnim i organskim načinom proizvodnje. Ispitivano je seme krupnika sorte Nirvana, konvencionalno i organski proizvedeno 2015. godine u Institutu za kukuruz „Zemun polje”. Prema dobijenim rezultatima, energija klijanja organskog i konvencionalno proizvedenog semena krupnika iznosila je 30% odnosno 69%. Ukupna klijavost konvencionalno proizvedenog semena krupnika iznosila je 99%, dok je klijavost organski proizvedenog semena bila niža i iznosila je 93%. Broj nenormalnih klijanaca konvencionalno proizvedenog krupnika u proseku je dao 1% nenormalnih klijanaca, a takođe i organski krupnik. Organski proizvedeno seme krupnika beleži veći udeo bolesnog i mrtvog semena u odnosu na seme iz konvencionalnog useva (0%), te u proseku daje 6% bolesnih i mrtvih semena. Nakon testa ubrzanog starenja semena, zabeležena je viša ukupna klijavost konvencionalnog semena krupnika (75%), u poređenju sa semenom organskog krupnika (68%). Električna provodljivost konvencionalno proizvedenog semena iznosila je 189,4 µS/cm i 195,2 µS/cm u prvom i drugom ponavljanju, dok su vrednosti organskog semena iznosile 95,5 µS/cm i 98,6 µS/cm, u prvom i drugom ponavljanju. Rezultati ispitivanja elektroprovodljivosti ukazuju na to da ispitivano seme konvencionalnog krupnika (32,33 µS/cmg) spada u kategoriju semena niže životne sposobnosti u odnosu na organsko seme krupnika (27,65 µS/cmg).

Ključne reči: *Triticum spelta* L., klijavost, ubrzano starenje, elektroprovodljivost.

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