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VIABILITY OF OILSEED RAPE (*Brassica napus* L.) SEEDS UNDER SALT STRESS

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Although salt stress affects all plant growth stages, seed germination and seedling growth stages are the most sensitive. Therefore, the aim of this study was to examine the seed viability of selected oilseed rape cultivars in saline conditions and to determine the most tolerant cultivars to salinity stress at germination stage. The experiment included four released oilseed rape cultivars. The salinity stress was simulated in vitro conditions by adding different concentrations of NaCl solution to the growing media. Testing of the seed viability was performed by using the standard -laboratory method test and the accelerated aging test. In all four cultivars, with increasing concentrations of NaCl in the growing medium, significant changes were observed in determined characteristics. Results of accelerated aging test were lower than the standard laboratory test, which implies the importance of vigour tests as an additional indicator of physiological seed quality, especially under stress conditions. The most important source of variation is treatment, but the differences between the cultivars were also significant. Depending on traits, crossover and non-crossover cultivar × treatment interactions were observed.

Key words: accelerating aging test, germination, growth variables, salinity tolerance, standard laboratory method

INTRODUCTION

Oilseed rape (*Brassica napus* L.) is the most important protein and oil plant species in temperate climates. According to the land on which it is grown, it is in third place among oilseed crops in the world. It is grown on an area of 33.6 million hectares. Major producers are China, India and Canada, while in Serbia it is grown on an area of 12.000 hectares (FAO, 2010).

Oilseed rape is grown primarily for its seed that is high in oil (40-48%) (MARINKOVIĆ *et al*., 2009). After the oil extraction, a by-product meal containing 25-40% of protein (ENAMI, 2011) and 8% of oil remains and is a quality component of animal feed. This oil-plant has an

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important role in the production of biodiesel, which is an important source of biorenewable energy (JOVIČIĆ *et al*., 2011).

The success of the production is largely determined by climatic conditions during the growing season, so that even small deviations than optimal conditions can significantly threaten yield (MARJANOVIĆ-JEROMELA *et al*., 2011a). Due to climate changes and higher global average air temperatures, the areas under semi-arid and arid climates are constantly increasing. In these conditions, intensive farming without irrigation is not feasible. However, the use of inadequate irrigation water leads to an increase in salt content in soils as well as to salinity problems. A large amount of salt in soils is one of the most important factors limiting the successful production of crops thus greatly affecting the economic losses (JOSHI *et al*., 2009). Many authors believe that this plant species is moderately tolerant to salinity stres. This is the reason why oilseed rape is often called marginal land crop.

Germination is the basic indicator of seed quality and it highly depends on biotic and abiotic factors (VUJAKOVIĆ *et al*., 2011). It has long been known that plant tolerance to higher salt content is different in various stages of growth and development. Germination is certainly one of the most critical stages of plant development especially in saline conditions (CUARTERO *et al*., 2006). Disrupted germination in such circumstances is often the result of high concentrations of salt in the zones of sowing seeds due to capillary movement of soil solution, and later due to evaporation at the soil surface (ZAMANI *et al*., 2010). Considering that the germination process is not possible without water, the main negative effect of salt in soils is reflected in creating osmotic potentials that will prevent the seeds from absorbing a sufficient amount of water and sprouts. Also, in saline conditions seeds and seedlings absorb the Na^+ and Cl^- ions, which exert their toxic effects in plant cells (KHAJEH-HOSSEINI *et al*., 2003).

In stressful soil conditions with high salt content, the standard germination test, which is considered the best quality indicator, cannot provide enough reliable information on seed lots. Therefore, seed viability tests (vigour testing) should provide additional information on the physiological quality of seeds. The main task of vigour tests is to determine which seed lot could tolerate stress conditions in fields (ISTA, 2013). In order to compensate for the gap between the supply and demand for high-quality oil seed rape intended for human nutrition, animal feeds and bio-fuels, it is necessary to create genotypes adjusted to specific climatic conditions in the south-east region of Europe (MARJANOVIĆ-JEROMELA *et al*., 2011b).

Considering the growing demand for food production on the one hand and increasingly growing areas of saline soils on the other hand, studying the tolerance of seed and seedlings to increased salt content in soils is of great importance. The aim of this study was to examine the seed viability of oilseed rape cultivars in saline conditions, cultivar differences in response to salinity stress and to determine which cultivars are the most tolerant to the presence of salt in soils.

MATERIALS AND METHODS

The experiment

The experiment was carried out throughout 2010 in the Laboratory for Seed Testing at the Institute of Field and Vegetable Crops in Novi Sad. The research included four released cultivars of oil seed rape (Banacanka, Jasna, Kata and Zlatna) grown during the 2009-2010 growing seasons. Testing of the seed viability was performed by using the standard laboratory test (SL test) and the accelerated aging test (AA test). The substrates for germination in both tests were moistened with the NaCl solution of 0, 100, 150, 200 and 250 mM concentrations (Control, T100, T150, T200).

Standard germination test - Seed germination was determined by the SL test according to ISTA Rules (2010). Germination was performed in four replicates per hundred seeds on filter paper in Petri dishes. The incubation period has lasted for seven days at 20°C - 30°C. After 5 days, seedlings were transferred from petri dishes to filter paper, which was wrapped in order to ensure the free shoots and roots growth. Germination was determined after seven days.

Accelerated aging test - The AA test was performed according to the HAMPTON & TE KRONY (1995) method where the seeds were exposed to double stress conditions of high temperature and high humidity (100%). The seeds were kept in a water bath at 39°C for a period of 72h after which the process was repeated in the same manner as the SL test.

In both tests the germination and growth variables were determined, particularly the length and weight of fresh shoots and roots right after the testing was done. In addition to examine viability of oilseed rape seed under salinity stress, the germination and growth variables were determined, particularly the length and weight of fresh shoots and roots right after the testing were determined in both tests and analyzed in the study.

Data analysis

Statistical data analysis was conducted with Statistica v. 10 software (StatSoft Inc.). The data on each trait were submitted to two-way fixed analysis of variance (ANOVA) procedure. The differences in mean values among factor levels were compared by a Duncan`s multiple range test ($P < 0.05$). Prior to ANOVA procedure, dataset were explained by several linear model diagnostic tools in order to ensure the validity of model assumptions.

The sites regression model (CROSSA *et al*., 2002) and corresponding GGE (genotype plus genotype-by-environment) biplot was used to study response of the cultivars to the salinity stress treatments. The procedure for construction of GGE biplot is based on the following equation:

$$Y_{ij} - \mu - T_j = C_i + CT_{ij}$$

where Y_{ij} is the response variable (i.e. target trait) of *i*th cultivar at the *j*th treatment; μ is the overall mean; T is the main effect of the *j*th treatment; C is the main effect of the *i*th cultivar; and CT is the interaction among the *i*th cultivar and *j*th treatment.

The two-way table of each trait comprising cultivars in rows and treatments in columns was submitted to singular value decomposition (SVD) procedure to generate principal components (PCs) together with eigenvector values (or percentage of explained variance by each particular PC) of cultivars and treatments. Using singular values (SV) of PC and eigenvector values of cultivars and treatments, above equation is rearranged as follows:

$$Y_{ij} - \mu - \mathrm{T_j} = \lambda_1\xi_{i1}\eta_{1j} + \lambda_2\xi_{i2}\eta_{2j} + \xi_{ij}$$

where λ_1 and λ_2 are the SV of PC1 and PC2, respectively; ξ_{i1} and ξ_{i2} are the eigenvector values of *i*th cultivar for PC1 and PC2, respectively; η_1 and η_2 are the eigenvectors of *j*th treatment for PC1 and PC2, respectively; ξ_{ij} is the residual variation association with *i*th cultivar and *j*th treatment. To partition of SV into the corresponding cultivar and treatment eigenvectors can be generalized as follows:

$$c_{i1} = \lambda_1^{fl}\xi_{i1} \qquad t_{1j} = \lambda_1^{1-fl}\eta_{1j}$$

where l is number of PCs and f is partition factor for SV and ranged from 0 to 1.

Finally, GGE biplot used in this study is based on the following equation:

$$Y_{ij} - \mu - T_j = c_{i1}t_{1j} + c_{i2}t_{2j}$$

where Y_{ij} is the response variable for *i*th cultivar at *j*th treatment; μ is the overall mean; c_{i1} and c_{i2} are the PC scores of *i*th cultivar; t_{1j} and t_{2j} are PC scores of *i*th treatment.

All biplot in this study are interpreted by means of the "inter-product" principle (YAN & KANG, 2003) and coded within R computing environment (R DEVELOPMENT CORE TEAM, 2013).

RESULTS

Means and ANOVA

In order to examine the tolerance of different oilseed rape cultivars to salinity stress, the results of the SL test were compared to the results of the most important test for seed vigour examination – the AA test. The two way ANOVA for all traits indicated that all main effects were highly significant in the both test, where the most important source of variation is treatment and ranged 91.3% to 96.4% for SL test and 92.8 for 98.5% for AA test. Main effect of cultivar was also significant in all traits in both test, except for shoot length in the SL test and ranged from 0.6 to 8.51% in SL test and 0.3 to 6.0% in AA test (results not shown). In addition, the cultivar × treatment (C × T) interaction effect was significant only for root length in SL test and for germination and shoot length in AA test.

Table 1. Mean comparisons of measured traits in the SL test (Duncan test, P <0.05)

Cultivar	Treatment				
	Control	T100	T150	T200	T250
			Seed germination		
Banacanka	$97{,}50^{a\#}$	$95{,}25^{a}$	$89{,}75^{bcde}$	$83{,}25^{g}$	$72{,}50^{i}$
Jasna	$94{,}00^{ab}$	$93{,}25^{abcd}$	$89{,}50^{cde}$	$82{,}00^{gh}$	$70{,}50^{ij}$
Kata	$94{,}50^{a}$	$93{,}50^{abc}$	$87{,}75^{ef}$	$82{,}25^{gh}$	$67{,}25^{jk}$
Zlatna	$89{,}00^{def}$	$89{,}00^{def}$	$84{,}75^{fg}$	$78{,}25^{h}$	$63{,}75^{k}$
			Shoot lenght		
Banacanka	$66{,}75^{ab}$	$63{,}38^{abc}$	$33{,}10^{de}$	$21{,}63^{hi}$	$12{,}00^{j}$
Jasna	$68{,}63^{a}$	$66{,}63^{ab}$	$30{,}25^{def}$	$20{,}13^{i}$	$10{,}88^{j}$
Kata	$64{,}00^{abc}$	$63{,}38^{bc}$	$29{,}13^{efg}$	$23{,}88^{ghi}$	$9{,}38^{j}$
Zlatna	$63{,}63^{abc}$	$59{,}50^{c}$	$35{,}50^{d}$	$26{,}13^{fgh}$	$10{,}38^{j}$
			Roots lenght		
Banacanka	$104{,}63^{bc}$	$98{,}5^{cd}$	$53{,}17^{f}$	$45{,}88^{f}$	$21{,}88^{i}$
Jasna	$114{,}5^{a}$	$108{,}88^{ab}$	$50{,}63^{fg}$	$34{,}13^{h}$	$18{,}50^{i}$
Kata	$84{,}63^{e}$	$81{,}13^{e}$	$45{,}88^{g}$	$38{,}63^{h}$	$16{,}63^{i}$
Zlatna	$100{,}50^{cd}$	$97{,}38^{d}$	$51{,}63^{fg}$	$38{,}88^{h}$	$20{,}17^{i}$

[#] Means followed by the same letter are not significantly different. Means are comnpared by Duncan test.

The results of this study show that different NaCl treatments in germination substrates have a significant effect on the oil seed rape germination (Table 1). When it comes to the SL test, the highest percentage of germination was shown by the cultivar Banacanka at the control and treatment T100 (97.50%, 95.25%), followed by Kata and Jasna also at the control (94.50%, 94%). The cultivar Zlatna showed the lowest values of the tested variables at all salt levels in the germination substrate. A similar relationship between the studied cultivars but lower germination values was noted in the AA test (Table 2).

Table 2. Mean comparisons of measured traits in the AA test (Duncan test, P<0,05)

Cultivar	Treatments				
	Control	T100	T150	T200	T250
			Seed germination		
Banacanka	90,75$^{a\#}$	87,75^{ab}	82,00^{cdef}	75,50^{gh}	65,25^{i}
Jasna	86,75^{abc}	81,00^{def}	78,75^{fg}	74,00^{gh}	51,25^{j}
Kata	88,50^{ab}	86,75^{abc}	84,25^{bcde}	73,75^{gh}	50,25^{j}
Zlatna	86,00^{abcd}	81,00^{def}	79,00^{efg}	72,25^{gh}	48,25^{j}
			Shoots lenght		
Banacanka	63,63^{ab}	61,63^{bcd}	14,50^{f}	15,25^{f}	8,75^{h}
Jasna	66,38^{a}	63,13^{abc}	20,88^{e}	13,63^{fg}	9,75^{gh}
Kata	61,75^{bcd}	58,88^{cd}	21,00^{e}	16,63^{f}	8,5^{h}
Zlatna	62,38 ^{abc}	57,63^{d}	17,63^{ef}	13,14^{fg}	8,38^{h}
			Roots lenght		
Banacanka	98,50^{ab}	95,38^{ab}	38,25^{de}	28,63^{f}	15,63^{ij}
Jasna	100,5^{a}	96,63^{ab}	33,25^{ef}	19,00^{hi}	9,38^{k}
Kata	82,63^{c}	80,00^{c}	39,38^{d}	22,00^{gh}	10,63^{jk}
Zlatna	97,75 ^{ab}	93,38^{c}	27,25^{fg}	18,13^{hi}	10,88^{jk}

$^{\#}$Means followed by the same letter are not significantly different. Means are comnpared by Duncan test.

Salinity caused a significant (P<0.05) reduction on root length and shoot length at the higher NaCl treatments while analyzing the shoot and root length significant differences were noted between the cultivars and the applied treatments (Table 1). The highest shoot length had the cultivar Jasna at the lowest salt treatments T100 (68.63 mm), while the lowest was Kata at the T250 (9.38 mm). As for the root length, the cultivar Jasna also had the longest root at the control (114.50 mm), while Kata came out the shortest (16.63 mm). These results indicate that low concentrations of salt stimulate the shoots and roots growth, but a significant reduction occurred only at high NaCl treatment (T150) - by about 49% compared to the control.

When it comes to the AA test significant reductions in the shoots and roots length were present in higher NaCl treatments such as the case of the SL test (Table 1). However, in this test at the treatment T150 , there was a significantly larger decrease in seedling length compared to the control - about 29%. It should be emphasized that despite this major difference between these two tests at treatments T150 and T200, the values at the highest treatments were approximate. In this test the cultivar Jasna demonstrated the greatest values in the shoots length at all treatments between the cultivars, while cultivar Zlatna had the lowest. As for the root length, compared to the other cultivars, Jasna also showed the highest value in the control and the lowest value at the highest treatments.

Graphical analysis of cultivar response to salinity stress treatments

The biplot methodology is useful tool for analysis cultivar by treatment data since detects differences and similarities among the treatments in their cultivar discrimination as well as the differences and similarities among the cultivars in their response to the treatment changes. In other words, plotting the data in the space defined by the two PCAs provides a rapid means of visualizing similarities or differences in the data set, allowing for improved discrimination of cultivars (SUMNER *et al*., 2003).

Biplot for germination data for both tests explained almost all amount of total variance (over 99%) indicating the dominance of treatment main effect over the cultivar main effect and C×T interaction effects. Cultivars that are furthest from the biplot origin are connected with straight lines to form a polygon. Straight lines which originated from the center of the polygon divide it into several sectors. The pendicular lines, drawn to each side of the polygon starting from the biplot origin, are equality line which divides the biplot in the sectors which are defined by the most responsiveness cultivar.

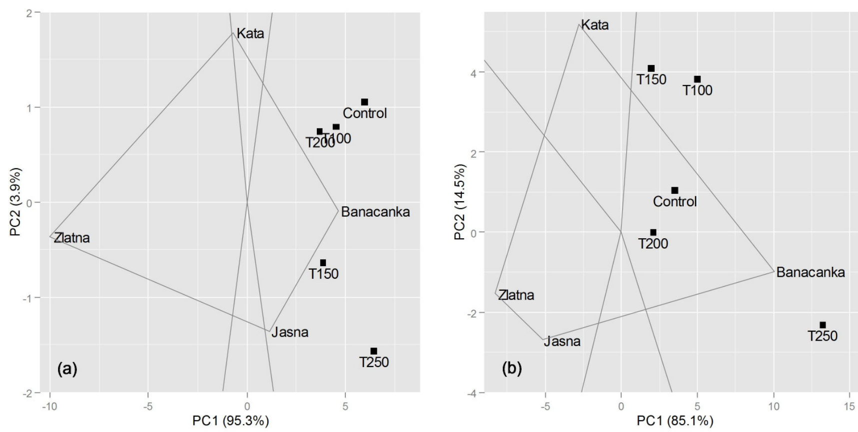

Figure 1. The "*which-won-where*" view of the GGE biplot for seed germination data a) SL test, b) AA test. Abbreviations are: Control – 0 mM NaCl, T100 – treatment 100 mM NaCl, T150 – treatment 150 mM NaCl, T200 – treatment 200 mM NaCl, T250 – treatment 250 mM NaCl

Four sectors were distinguished for each test. Considering that the treatments found within a sector are the treatments at which a given cultivar achieved the highest values of germination, the cultivar Banacanka, followed cultivar Jasna, were the best performers in all the salt treatments in the SL test (figure 1a). Biplot also distinguished two orthogonal subsets of treatments in their discrimination of cultivar reaction to salinity stress. The first subset of treatments includes control, T100 and T200 while second one includes two treatments (T150 and

T200), which are realted to cultivar Jasna. Biplot for AA test (figure 1b) revealed non-crossover C×T interaction since the cultivar Banacanka is the best performer of the all treatments. In comparison to figure 1a the grouping pattern of treatments is quite dissimilar.

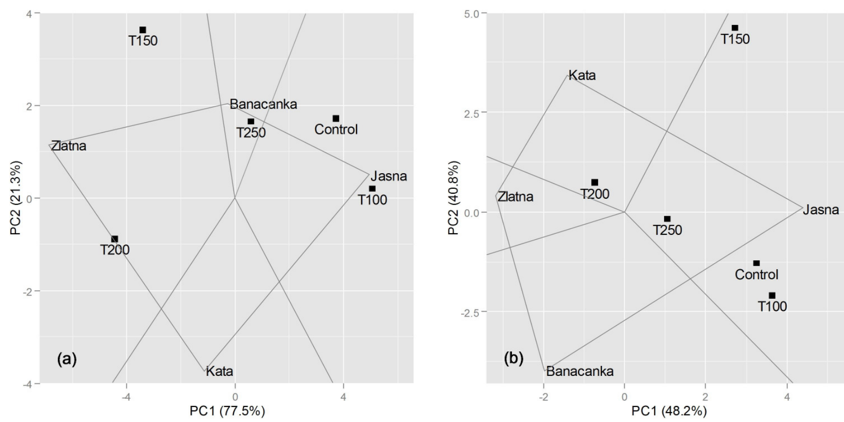

Figure 2. The “*which-won-where*” view of the GGE biplot for shoots lenght data a) SL test, b) AA test. Abbreviations are: Control – 0mm NaCl, T100 – treatment 100mM NaCl, T150 – treatment 150mM NaCl, T200 – treatment 200mM NaCl, T250 – treatment 250mM NaCl

As for the shoots length, the biplot explained 98.8% of the total variation at the SL test and 89.0% at the AA test (figure 2). With this trait biplot revealed strong crossover C×T interaction pattern since treatment PC scores had negative values. On the left polygon it can be seen that the Zlatna cultivar showed the highest values at T150 and T200, Banacanka was the best at the highest treatments and Kata was the poorest performer in all applied treatments. In contrast, the AA test, the cultivar Jasna was the best in the control, the lowest and the highest treatment of salt, while Kata was the best at medium treatments – T150 and T200. In AA test was confirmed crossover C×T interaction pattern.

As for the roots length, the biplot explained 99.6% of the total variation at the SL test and 96.9% at the AA test (figure 3). Crossover pattern also was confirmed in both tests, but the differences within the group were the least. In both tests, Banacanka is the best performer across the highest treatments, while Jasna is the best across control and the lowest salt treatment. Cultivar Zlatna is the poorest one. Also, biplot for both test are well separated in two groups. The NaCl treatments T200 and T250 are more suatable for cultivar Banacanka, while control and 10mM and 200 are more suitable for Jasna. These statements are generally in agreement with the results of Duncan’s test (Table 2).

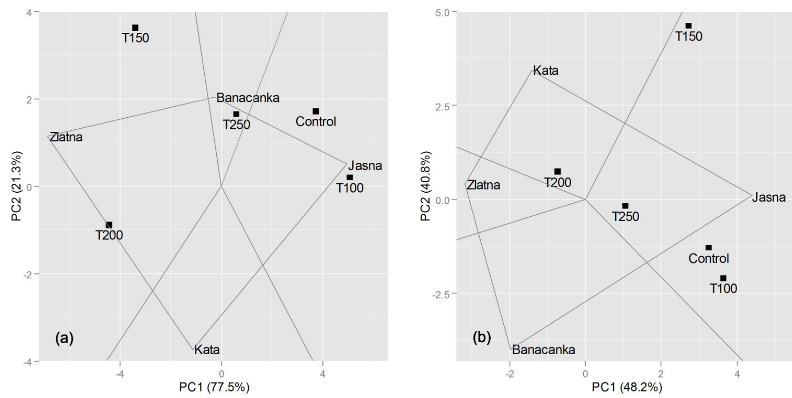

Figure 3. The "*which-won-where*" view of the GGE biplot for roots lenght data a) SL test, b) AA test. Abbreviations are: Control – 0mm NaCl, T100 – treatment 100mM NaCl, T150 – treatment 150mM NaCl, T200 – treatment 200mM NaCl, T250 – treatment 250mM NaCl

DISCUSSION

Due to the fact that the cultivar Banacanka showed higher germination at the lowest NaCl treatment in relation to germination of all other cultivars in the control, it can be noticed that there are significant differences among the tested cultivars. Significant differences in the percentage of germination were not observed between the control and the lowest treatment of NaCl, while significant reduction occurred starting at high salt treatments T150, T200 and T250. Biplot analysis also confirms these results. These results show that the cultivars included in the study have certain level of tolerance to low NaCl treatments. Similar results were reported by BYBORDI (2010) and JAMIL *et al*. (2005) who had examined various species of the *Brassica* genus. MOHAMMADI (2009) and RAUF (2007) found that the reduced germination at high NaCl treatments was caused mainly due to disturbances in osmotic regulation which lead to difficult water absorption in saline conditions, as well as to toxic effects of Na^+ and Cl^- ions. In contrast, FARHOUDI & SHARIFZADEH (2006) suggest that significant reductions in the percentage of germination occur with each increase in the NaCl treatment.

On the other hand, MAHMOODZADEH (2008) in his research reports that in the later stages of development, particularly in flowering and grain filling, oilseed rape is more sensitive to high salt content than in the stages of germination and seedling growth. He also suggests that a small amount of NaCl in the germination stage can have a positive effect on germination as optimal amounts of ions for metabolic processes in the cell are obtained.

A similar relationship between the studied cultivars but lower germination values was noted in the AA test. During this test seeds absorb moisture from the humid environment so that the moisture content in the seed increases and together with the high temperature leads to the accelerating and deterioration of seeds (ISTA, 2013). High temperatures and humidity, which are the main factors of seed aging along with higher treatments of salt in the germination medium, have influenced the obtained results. In the cultivar Jasna the average reduced germination at all used treatments, in between these tests, was the highest (11.5%), whereas the lowest was in cultivar Banacanka (7.4%). This cultivar also showed the highest values of germination at all treatments of salt compared to all the other cultivars, as well as the SL test.

Study of salinity stress involves several different aspects of plant metabolism, including lipid metabolism. The fact that germination of lipid rich seeds such as *Brassica* causes, among other processes, the rapid mobilization of storage reserves such as triacylglycerol in cotyledons of seedlings (KUMAR *et al*., 2004) may partly explain the different behavior of the cultivars depending on traits.

Plant response to excessive NaCl is complex and apart from the metabolic and physiological changes it also includes morphological ones (PARIDA & DAS, 2005). Shoot length and, primarily the roots are very important indicators when it comes to salinity stress because the roots are in direct contact with the ground/substrate and absorb water with the dissolved salts, while the shoot distributes it into other plant parts (JAMIL & RHA, 2004). Also, the negative effects of salt in the germination substrate reduce the speed of physiological and biochemical processes that influence the impeded development of the basic plant structure especially in the field conditions (MENESES *et al*., 2011). The accumulation of large amounts of ions such as Na^{-} can lead to salt toxicity and may result in cell dehydration and membrane dysfunction. These disturbances in ionic and osmotic balance could inhibit the crucial metabolic processes that affect the difficulties in plant growth (BYBORDI *et al*., 2010).

After examining cotton seeds, IQBAL *et al*. (2002) reached the conclusion that a possible reason for growth reduction under accelerated aging conditions could be a slowdown in biochemical activity in cells. During the aging process enzyme inhibition occurs that is required for converting food reserves in the embryo into a usable form, and then the formation of normal seedlings. By definition, highly vigorous seeds will be able to quickly and uniformly germinate in different, often unfavorable environments and based on this it can be concluded that with each increase of salt treatments only seeds with high vigour will provide strong and powerful seedlings and later on plants (ISTA, 2013).

Apart from the factors which directly affect the suppressed germination and seedling growth, the behavior of seeds in different environments is considered to be seed viability or vigour, and it depends on the influence of many factors during seed production, such as genetic potential, external factors, seed size and storage (HAMPTON, 2002).

In all tested cultivars in both tests, the average values of root length were higher compared to the average shoot length. This suggests that under various stress conditions during germination, the roots tend to be more elongated than the shoots. The same conclusion was drawn by MENESES *et al*. (2011) who had examined the impact of water stress on the cotton seed germination, considering that this is a general plant response to insufficient amounts of water, which is also one of the most significant adverse effects of salt stress. Also, this may in turn have the advantages increased ratio of water absorption to transpiration area a plant feature which is useful for dry land condition if last longer during other growth stages (MOUD & MAGHSOUDI, 2008).

ASHRAF *et al*. (2010) suggest that salt stress leads to a reduction in cell division cell elongation, primarily due to difficulties in nutrient absorbing, accumulation of large amounts of reactive oxygen species, inhibition of cellular enzymes, loss of turgor and hormonal imbalance, which certainly affect the plant growth suppression, and later on has a negative effect on the production of biomass and yield.

CONCLUSION

Based on the results of this study it can be concluded that there are significant differences between the examined cultivars. Although the gradual increase of the NaCl treatments was followed by a reduction in all the analyzed variables in selected cultivars, significant decrease occurred only at high salt treatments (T150). The relationships between the treatments at the AA test were the same compared to the SL test, but the values were lower.

Seed vigour testing through the modified AA test using substrates with different salt treatments certainly gives more information about seed quality and cultivar response to salt stress in comparison to the SL test and the original AA test.

In order to enhance plant tolerance to stressful environmental conditions, especially salinity, studying the response of different cultivars is of great importance in improving the efficiency of breeding and selection. Also, the knowledge of genetic variation in plant tolerance to salinity has a special role from the environmental and economic point of view in order to ensure the proper use of agricultural soils that are facing this problem.

In addition to standard and commonly used data analysis techniques, biplot offer additional possibilities, preferably in the part of visual displaying and understanding of important interactions which are omni-present in the datasets from seed science research.

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ŽIVOTNA SPOSOBNOST SEMENA ULJANE REPICE (*Brassica napus* L.) U USLOVIMA SONOG STRESA

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Izvod

Iako soni stres utiče na sve faze rasta i razvića biljaka, najosetljivije su faze klijanja semena i razvoja ponika. S toga je cilj ovog rada bio da se ispita životna sposobnost semena odabranih genotipova uljane repice u zaslanjenim uslovima i da se utvrdi koji od ispitivanih genotipova je najtolerantniji na ovakve stresne uslove u fazi klijanja semena i početnom porastu ponika. Eksperiment je obuhvatio četiri genotipa uljane repice. Uslovi zaslanjenosti su simulirani *in vitro* primenom različitih koncentracija rastvora NaCl u podlogama za naklijavanje. Ispitivanje životne sposobnosti semena sprovedeno je korišćenjem standardnog laboratorijskog metoda i testa ubrzanog starenja. Kod sva četiri genotipa, sa povećanjem koncentracije NaCl u podlogama za naklijavanje, uočene su značajne promene u ispitivanim parametrima (klijavost, dužina i masa ponika). Rezultati testa ubrzanog starenja semena su bili niže od rezultata standardnog laboratorijskog metoda, što ukazuje na važnost vigor testova kao dodatnih pokazatelja fiziološkog kvaliteta semena, prvenstveno u stresnim uslovima. Statistička obrada podataka je pokazala da je najvažniji izvor varijacije intenzitet sonog stresa, ali su razlike između genotipova takođe bile značajne.

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