Spring barley varieties and perspective ranges laboratory screening against artificially created salinity stress backgrounds

L M Eroshenko¹ and O V Levakova²

¹ Federal Research Center Nemchinovka, 6 Agrochemists Street, village Novoivanovskoe, Odintsovo district, Moscow region, 143026, Russia
² Research Institute of Seed Production and Agricultural Technologies - the branch of the Federal Science Agricultural Engineering Center VIM (All-Russian Research Institute of Agricultural Mechanization), 1 Parkovaya Street, Podvyaz’e, Ryazan district, Ryazan region, 390502, Russia

E-mail: levakova.olga@bk.ru

Abstract. The results of salinity resistance assessment of 5 spring barley ranges (Hordeum vulgare L.) Grass family (Poaceae) - Yaromir, Nadezhny, Znatny, Zlatoyar, and 9 types of own plant-breeding lines which are supposed to be perspective for the future use are given in this article. NaCl impact in the concentration of 0.7 and 0.9 mPa (0.98 and 1.26% NaCl) on seed germination and morphological indicators such as length and quantity of roots, length of seedlings were studied. The salinity stress resulted in the inhibitions of the roots length and seedlings in the provocative background if to compare with the control group background samples. At the concentration of 0.7 mPa salinity resistance value varied from 62.4 to 96.6% which corresponds to 1-2 salinity resistance groups. At the concentration of 0.9 mPa salinity resistance varied from 27.9 to 80.8% which corresponds to 1-3 salinity resistance groups. The yield capacity and adaptive qualities were examined on the initial data basis. Thus, there was a correlation dependence at both of sodium chloride concentrations revealed between the yield capacity of the field experience samples and the laboratory test samples.

1. Introduction

Barley is the second most frequent type of grain crop in Russia following wheat and is one of the most important crops of the world agriculture. About 8.0 million of hectares are annually occupied by it in the Russian Federation. Years of agricultural practice proved that barley is one of the most drought-resistant, hardy and early-ripening grains. Due to these specifics, barley can be grown within all grain-seeding regions of Russia. The further successful cultivation of this grain crop is inextricably linked to the barley new varieties implementation [1].

Slightly and medium salted soils represent large areas which are potentially applicable for agricultural activities all over the world. Along with that increasing frequency of extreme environmental events caused by the global warming fosters the process of further salinization of areas and leads to the decrease in the productivity of agro- and biocenoses, reduction of biodiversity and, as the result, significant economic losses [2, 3, 4].
Therefore, it’s getting more and more frequent for the international meetings, workshops and congresses of the soil scientists holding in different cities and countries to be devoted to the salinized soils monitoring based on the contemporary survey methods, to the map compilation methods, to the assessments, recording and forecasts for the soil salinization process and to the genesis issues. All the issues mentioned above are relevant for Russia, especially for its South regions, where the major agricultural lands are situated and salinized soils are very common [5, 6]. The reduction of the grain crops yield capacity in Russia due to the soil salinization process may reach 85%. The quality of grains deteriorates significantly too. In order to reduce losses and ensure the growth of grain production under unfavorable conditions, the creation of salinity resistant varieties is of crucial importance. A prerequisite for the successful solution of this problem is the hereditary nature of the stability trait and the presence of barley samples with high resistance to salinity stress in the world collections, which allow successful selection for salt resistant varieties [7, 8, 9].

Many scientists’ studies were devoted to identifying the features of grain varieties aimed at creating highly productive salt-resistant genotypes. In most studies, significant differences between the responses of varieties to salinity stress were demonstrated, and various mechanisms of juvenile resistance were analyzed [10, 11, 12]. During the study of the salinization’s impact on the plants many scientists concluded that reduction of the salinity-resistant plants growth processes the within the salinity stress background caused by NaCl salts occurs in a slower manner than for non-salinity-resistant plants [13, 14, 15, 16, 17]. This regularity is relevant for barley as well. Despite the development of new morphological, physiological and biochemical methods of surveys certain achievements on plant-breeding samples selection for resistance to salinity stress, from one hand, and salinity process increasing due to negative environmental factors demonstration increasing – from the other hand, the need and relevance of the research conducted with regard to barley in this direction were defined [18, 19, 20].

The salinity resistance issues studying within the field conditions is complicated by instability of the abiotic factors impact, different level of their intensity and activating of the compensatory reactions mechanisms that lead to misrepresentation of the indicator value.

Therefore, the need for varieties’ stress resistance laboratory express-diagnose is increasing, which at the early stages of ontogenesis is also justified by the fact that plants in the sprouts phase are sensitive to stresses and the differences between varieties showing during this period are usually kept as a genetic trait for the adult plants as well.

Salinity resistance is a complicated physiological stress that determines the need for adaptation of three independent factors: increasing of the osmotic pressure, toxic effects of ions and oxide stress. Under the stressor’s influence the growth and development of plants, their metabolism activity is suppressed, cells conditions are deteriorated [21, 22]. Due to this fact, the resistance of the plants to the complex of abiotic factors, which is the main reason of the yield capacity reduction, is of the most interest [23, 24].

The estimation of the varieties resistance to the environmental stress factors and their sustainable ability to produce yield or ecological-genetic approach to the plant-breeding process allows to develop ways and methods of existing varieties rational usage, as well as to obtain new genotypes which are resistant to the limiting factors of the environment. Therefore, the adaptability and resistance to the edaphic stresses of the contemporary varieties matter became extremely relevant. To fulfill this task, the plants adaptability potential as a complex need to be researched and available techniques as well as the assessment criteria should be developed.

The goal of the research is to assess suitability of the salinity resistance level laboratory valuation for the forecast of the perspective spring barley lines and varieties agronomic sustainability to soil salinization and the level of their adaptive potential.

2. Materials and methods
Plant-breeding work aimed at the creation of the spring barley environmentally flexible varieties is conducted jointly with the Federal Research Center “Nemchinovka” upon the creative cooperation
agreement. Simultaneous study of lines within different points of the zone allows to evaluate the genotypes’ reaction to the external environment conditions and define the ones with wide adaptability qualities. During the series of the laboratory experiments held at the department of plant-breeding of the Research Institute of Seed Production and Agricultural Technologies - the branch of the Federal Science Agricultural Engineering Center VIM (All-Russian Research Institute of Agricultural Mechanization) in 2017-2019 the research material was presented by 5 varieties of spring barley – Yaromir, Nadezhny, Znatny, Zlatoyar, Raphael and 9 own plant-breeding lines which are supposed to be perspective for the further use.

Sodium chloride (NaCl) was used as a stressor toxicant. The determination of the salinity resistance was conducted with the use of the roll estimation method, based on recording of the root growth inhibition process within the salinity stress conditions comparing to the control group. Two salinity backgrounds were used- fluids with osmotic pressure of 0.7 and 0.9 mPa (0.98 and 1.26% (NaCl), respectively). Vessels with rolls were placed in the thermostat with the temperature of 22 °C. On the fifth day, the rolls were unwrapped and the length of the longest root of each plant was measured. The level of root growth inhibition was judged by the ratio of the average root length in the salt liquid comparing to the control group. The analyzed samples were divided into three groups: 1 – stable; 2 – medium-stable; 3 - sensitive. The barley yield within the field conditions on allotment sowings on 12 m² of acreage, with a fourfold repeatability was taken into the consideration in our research. The seedling rate was 5.0 million germinating seeds per hectare.

Statistical processing of the obtained data was performed by using Microsoft Office Excel 2010. The following parameters were calculated: arithmetic mean values (M), standard error (± SEM), and significance level (p; differences were considered as statistically significant at p < 0.05).

3. Results and discussion
The conducted laboratory analysis of the sprouted seeds derived during the plants reproduction within the Ryazan region condition in 2017-2019 revealed a significant reduction in the length of roots and sprouts on provocative backgrounds comparing to the control group background. Thus, at NaCl concentration of 0.7 mPa, the average root length decreased by 20.0%, sprouts - by 31.0%, and at NaCl concentration of 0.9 mPa by 52.7 and 50.0%, respectively. The average value of the salinity resistance criterion, calculated by the level of the roots length reduction under various conditions of salinity stress, comparing to the control group was 80.9 and 47.8%. The number of germ roots decreased on average by 0.7-1.8 pcs comparing to the control group.

As follows from the Table 1 the varieties data salinity resistance differed from each other both in weak and stronger level of salinity. The studied genotypes salinity resistance trait variation coefficient, estimated on a slight solution background with a standard deviation of 12.8, was 15.9%. More significant differentiation between the varieties was observed if the increased salinity stress was applied. Along with the standard deviation of 17.4 the variation coefficient was 36.3%. During the seedlings testing at the NaCl concentration of 0.9 mPa, significant roots and sprouts depression of varieties, which are salinity resistant at the concentration of 0.7 mPa such as Znatny, Zlatoyar and plant-breeding lines 30/3-12h 983, 27/3-12h 977, was revealed. These samples groups salinity resistance went down by 52.6-63.6% within the stronger salinity stress background, and the roots and sprouts average length was 83.6 mm and 67.1 mm less relatively comparing to the control group. Extra salinity resistance to salinity stress of the perspective lines 141/1-09h 746, 181/3-12h 897, 31/4-12h 90 was revealed within the different levels of salinity stress background. Salinity resistance of these samples defined at different levels of NaCl solution concentrations complied with the 1-st group of resistance. The plant-breeding line 20/4-11 h 723 was defined to have weak salinity resistance with low values of salinity resistance criterion (69.9-27.8%) among others.

Detection of the kinds with high capacity potential and resistance to the environmental stress factors is the core principle of the new barley ranges creation process. Numerous data indicates the dependence between root system of a variety and its capacity and resistance to extreme environmental factors.
Differences in growth depression of the varieties’ seedling and early roots, which are genetically determined by the different salinity stress resistance, are a priori linked to yield capacity and adaptability.

Soil and climate conditions during the years of the ecological survey caused significant impact on the barley yield capacity formation. Whilst dark gray forest heavy loam soils of the Ryazan region provided sustainable yields of spring barley, there were significant fluctuations in the yields of this grain crop on comparatively poor sod-podzolic soils defined over the years (Table 2).

### Table 1. Spring barley varieties and ranges salinity resistance to laboratory-simulated Sodium Chloride salinity, 2017-2019.

| Variety, plant-breeding line Name | Control group | 0.7 mPa (0.98%) | 0.9 mPa (1.26%) | Salinity resistance, % ce group (0.7 mPa/0.9 mPa) |
|-----------------------------------|---------------|----------------|----------------|-----------------------------------------------|
| Roots length, mm ±SEM             | Seedling, mm  | Quantiy of roots, M mm ±SEM | Seedling, mm  | Quantiy of roots, M mm ±SEM | Seedling, mm  | Quantiy of roots, M mm ±SEM | Seedling, mm  | Quantiy of roots, M mm ±SEM | Seedling, mm  | Quantiy of roots, M mm ±SEM |
| Yaromir                           | 118.1 ± 133.5 | 7.1 ± 82.8 | 72.0 ± 6.3 | 58.0 ± 60.3 | 6.1 ± 10.9 | 0.4 | 70.1/49.1 | 1/2 |
| Nadezhny                         | 108.0 ± 83.2  | 6.7 ± 95.5 | 55.8 ± 5.9 | 46.2 ± 45.6 | 5.1 ± 11.9 | 0.7 | 88.4/42.8 | 1/2 |
| Znatny (State variety testing)    | 118.7 ± 105.8 | 7.1 ± 97.3 | 85.1 ± 6.8 | 33.5 ± 63.2 | 6.0 ± 11.9 | 0.7 | 82.0/28.2 | 1/3 |
| Zlatoyar (State variety testing)  | 120.3 ± 102.6 | 7.6 ± 104.3 | 75.9 ± 5.9 | 37.8 ± 37.5 | 4.1 ± 12.4 | 0.8 | 94.7/31.4 | 1/3 |

| 20/4-11h 723                      | 121.1 ± 116.1 | 7.4 ± 77.4 | 69.4 ± 6.7 | 33.7 ± 31.4 | 3.5 ± 11.4 | 0.7 | 65.8/51.0 | 2/2 |
| 60/2-09h 714                      | 126.4 ± 104.7 | 7.3 ± 92.6 | 66.4 ± 6.8 | 68.5 ± 62.2 | 5.9 ± 10.8 | 0.8 | 73.3/54.2 | 1/2 |
| 30/3-12h 983                      | 108.3 ± 102.4 | 6.8 ± 90.6 | 77.9 ± 6.4 | 34.4 ± 32.3 | 5.3 ± 13.8 | 0.9 | 83.7/31.8 | 1/3 |
| 141/1-09h 746                     | 112.0 ± 98.0  | 6.9 ± 103.9 | 67.8 ± 6.0 | 71.3 ± 63.8 | 6.0 ± 19.6 | 0.3 | 92.8/63.7 | 1/1 |
| 48/3-12h 1016                     | 129.5 ± 122.9 | 7.2 ± 91.5 | 62.9 ± 5.8 | 70.8 ± 61.4 | 5.0 ± 11.8 | 0.7 | 70.7/54.7 | 1/2 |
| 27/3-12h 977                      | 128.8 ± 117.7 | 6.9 ± 117.8 | 95.4 ± 6.4 | 35.9 ± 27.1 | 3.4 ± 11.2 | 0.7 | 62.4/51.2 | 2/2 |
| 181/3-12h 897                     | 109.1 ± 109.6 | 6.8 ± 105.4 | 82.9 ± 6.3 | 88.2 ± 78.8 | 6.1 ± 14.1 | 0.3 | 96.6/80.8 | 1/1 |
| Average                           | 116.8 ± 106.3 | 7.0 ± 93.5 | 73.4 ± 6.3 | 55.3 ± 53.3 | 5.2 ± 17.4 | 0.9 | 80.9/47.8 | 1/1 |

| CV, %                            | 6.6 ± 12.8    | 4.3 ± 14.4 | 16.6 ± 7.9 | 33.8 ± 32.7 | 17.3 ± 15.8 | 0.7 | 15.8/33.8 | 1/1 |

| σ                               | 7.7 ± 12.6    | 0.3 ± 13.5 | 12.2 ± 0.5 | 18.7 ± 17.4 | 0.9 | 12.8/17.4 |
Vegetation period of 2017 was comparatively favorable for barley evolving process and growth in both geographical locations. Comfortable air temperature and extra rainfall facilitated the yield capacity detection which was at the level of 8.0 t/ha and varied significantly from 6.9 to 8.8 t/ha within the Moscow region conditions. Vegetation conditions during 2018 and 2019 were characterized by higher temperatures and higher water-deficient regime within the Moscow region and allowed to estimate fully the plant-breeding material adaptability and resistance to abiotic factors. Significant impact on the correlation coefficients value and salinity resistance values of agroecological factors and salt solution concentration was revealed during the testing years.

The testing results with regard to the studied characteristics presented in the Table 3 below demonstrate that during the high-yield year of 2017 in the Moscow region a weak negative dependency (r = -0.120) at the concentration of 0.7 mPa and an unreliable positive dependence (r = 0.313) at the concentration of 0.9 mPa were observed.

| Table 2. Spring barley varieties and plant-breeding lines yields capacity during the ecological testing, t/ha. |
|-----------------------------------|----------------|-------|-------|-------|-------|-------|-------|
| Variety, plant-breeding line      | Moscow region  |       |       |       |       |       |
|                                  | 2017 | 2018 | 2019 | average | 2017 | 2018 | 2019 | average |
| Yaromir                          | 7.33 | 3.80 | 4.79 | 5.31 | 6.22 | 6.03 | 6.19 | 6.15 |
| Nadezhny                         | 8.42 | 4.78 | 5.19 | 6.13 | 6.44 | 5.89 | 6.26 | 6.20 |
| Znatny                          | 7.63 | 4.10 | 4.80 | 5.51 | 6.19 | 6.82 | 6.56 | 6.52 |
| Zlatoyar                         | 8.60 | 4.43 | 4.84 | 5.96 | 5.76 | 6.06 | 6.10 | 5.97 |
| Raphael                          | 8.47 | 5.04 | 5.06 | 6.19 | 6.57 | 6.14 | 6.70 | 6.47 |
| 20/4-11h 723                    | 7.25 | 3.55 | 4.06 | 4.95 | 6.53 | 6.48 | 6.46 | 6.49 |
| 60/2-09h714                     | 8.08 | 5.20 | 5.07 | 6.12 | 5.95 | 5.86 | 7.01 | 6.27 |
| 30/3-12h 983                    | 7.39 | 4.08 | 4.54 | 5.34 | 5.66 | 5.83 | 6.07 | 5.85 |
| 141/1-09746                     | 8.29 | 4.76 | 5.17 | 6.07 | 6.03 | 5.58 | 6.58 | 6.06 |
| 48/3-12h 1016                   | 8.34 | 4.65 | 5.28 | 6.09 | 6.17 | 6.91 | 6.83 | 6.64 |
| 4/3-12h 933                     | 8.83 | 4.56 | 4.84 | 6.08 | 5.54 | 5.19 | 6.27 | 5.67 |
| 27/3-12h 977                    | 6.91 | 5.09 | 5.07 | 5.69 | 5.51 | 6.16 | 6.76 | 6.14 |
| 181/3-12h 897                   | 8.14 | 5.31 | 5.14 | 6.20 | 6.36 | 6.46 | 6.86 | 6.56 |
| 31/4-12h 90                     | 7.44 | 5.29 | 5.13 | 5.95 | 6.06 | 6.55 | 6.36 | 6.32 |
| Average                         | 7.94 | 4.62 | 4.93 | 5.83 | 6.07 | 6.14 | 6.50 | 6.24 |
| σ                               | 0.60 | 0.56 | 0.32 | 0.39 | 0.35 | 0.47 | 0.30 | 0.28 |

Under the Ryazan region conditions when increased yield capacity was observing during the testing years any plausible dependency between salinity resistance value and capacity level (r = -0.202-0.344) was not determined. The lack of reliable correlations between these values may indicate comparative independence of salinity resistance trait from yield capacity potential and the use of this trait with regard to barley is supposed to be needless. Stronger positive dependencies (r = 0.402-0.632) between salinity

| Table 3. Coefficients of correlation between yield capacity and salinity resistance values during the ecological varieties testing (2017-2019). |
|-----------------------------------|----------------|-------|-------|-------|-------|-------|
| Saline solution concentration     | Moscow region  |       |       |       |       |       |
|                                  | 2017 | 2018 | 2019 | 2017 | 2018 | 2019 |
| 0.7 mPa                          | -0.120 | 0.443 | 0.402 | -0.202 | 0.116 | -0.065 |
| 0.9 mPa                          | 0.313 | 0.632* | 0.591* | 0.227 | 0.001 | 0.344 |

*P < 0.05.
resistance and yield capacity formed within the rainless Moscow region are the subject of practical interest. The availability of the reliable statistics data especially those with salinity resistance values defined within the more concentrated saline solution background are more likely to allow forecasts for varieties reactions to unfavorable environmental factors at the early evolving stages of the plants.

Hereby the laboratory assessment of the varieties salinization may be used not only as a test of plants salinity resistance responding to a stressor’s influence but also as a biological marker of the genotypes with high flexibility.

4. Conclusion
Barley reaction to salinization, which is known as an important food crop with high yield capacity and stress resistance characteristics, remains an insufficiently studied issue, which is also actual one for plants physiology, ecology, and agriculture practices. The studies showed remarkable varietal specific of the reaction to salinization of barley’s seedlings at different levels of osmotic pressure of saline solution. The analysis of the seedlings length, roots quantity and the length of the sprouts of 14 varieties samples revealed the kinds which less or more sensitive to salinity stress. The assessment of the selection numbers at a higher salinity stress allows not only to test plant-breeding kinds in a better way but also can be used as the criterion for their adaptability evaluation. The results obtained reflect a promising outlook of usage of salinity resistant plant-breeding lines 141/1-09h 746, 181/3-12h 897, 31/4-12h 90 for further improvements of the kinds which are being created.

References
[1] Levakova O V 2018 Study of the spring barley source material in order to use it in the selection process for the Central region of the Russian Federation Legumes and Cereals 2 61-65
[2] Dorofeev N V, Boyarkina E V and Peshkova A A 2006 Nitroreductase activity in plant organs of various species under the influence of salinization Agricultural Biology 5 11-15
[3] Kuznetsov V V and Shevyakova N I 2010 Polyamines and plant adaptation to saline environments Desert Plants 28 261-298
[4] Pleskachev Yu N and Borisenko I B 2012 The use of "Ranch" in the use of barley Scientific-Agronomic J. 2 30
[5] Garg N and Manchanda G 2008 Salinity and its effects on the functional biology of legumes Acta Physiol Plant 30 595-618
[6] Bourgon L, Amoros B, Naranjo M A and Vicente O 2007 Drought and salt tolerance conference by overexpression of splicing factors in transgenic plants Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca: Horticulture 64 326-331
[7] Chao D Y, Hai L Y, Min S, Da L and Xian L H 2005 Salt-responsive genes in rice revealed by DNA microarray analysis Cell Res 10 796-810
[8] Chen Z, Zhou M, Newman I, Mendham N, Zhang G and Shabala S 2007 Potassium and sodium relations in salinized barley tissues as the basis of differential salt tolerance Funct Plant Biol. 34 150-162
[9] Cuartero J, Bolarin M C, Asins M J and Moreno V 2006 Increasing salt tolerance in the tomatoes Journal of Experimental Botany 57 1045-1058
[10] Yusufov A G 2018 Evolutionary and ecological aspects of plant resistance to stress South of Russia: Ecology, Development 1(13) 199-205
[11] Bataeva D S, Usenbekov B N, Rysbekova A B, Mukhina Zh M, Kazkeev D T, Zhanbyrbayev E A and Sarbaeva I A 2017 Evaluation and selection of source material for the selection of salt-resistant varieties in the Republic of Kazakhstan Agricultural Biology 3 544-552
[12] Munns R and Tester M 2008 Mechanisms of salinity tolerance Annual Review of Plant Biology 59 651-681
[13] Danilova E D, Medvedeva Yu V and Efimova M V 2018 Influence of chloride salinization on growth and physiological processes of medium-ripened varieties Solanum tuberosum L. plants Vestn. Tomsk. State University. Biology 44 158-171
[14] Batasheva B A and Eldarov A A 2005 Barley plant resistance to salt stress *Agricultural Biology* 5 56-60
[15] Sharipova G V and Veselov D S 2008 Effect of NaCl-salinization on the reactions of barley varieties differing in drought resistance *Agrochemistry* 10 18-26
[16] Zaitseva R I, Komarov N M and Sokolenko N I 2017 Salt resistance of spring barley varieties grown in the Stavropol territory *Bulletin of the Stavropol Research Institute of Agriculture* 9 148-155
[17] Bohme N A 2014 Intraspesific diversity of cultivated barley (Hordeum vulgare L.) on resistance to chloride salinization *Agrobiology* 2 16-23
[18] Abdullaev R A, Kosareva I A and Radchenko E E 2015 Laboratory screening of barley samples from Dagestan for resistance to chloride salinization *Achievements of Science and Technology of the Agro-Industrial Complex* 7 24-26
[19] Omarova Z A and Absaludinova M R 2016 Laboratory diagnostics of the barley varieties resistance to chloride salinization *Proc. of the Samara Scientific Center of the Russian Academy of Sciences* 2(2) 605-608
[20] Veselov D S, Sharipova G V, Chernov V E, Pendinen G I and Kudoyarova G R 2017 The effect of salinization on the growth and indicators of water exchange in barley different varieties *Proc.s of the Ufa Scientific Center of the Russian Academy of Sciences* 3(1) 141-147
[21] Tiwari S, Krishnamurthy S L, Kumar V, Singh B, Rao A R, Mithra A, Rai V, Singh A K and Singh N K 2016 Mapping QTLs for salt tolerance in rice (Oryza sativa L.) by bulked segregant analysis of recombinant inbred lines using 50K SNP chip *PLoS ONE* 11(4) e0153610
[22] Hien Thi Thu Vu, Duc Duy Le, Ismail A M, Ham L H 2012 Marker-assisted backcrossing (MABC) for improved salinity tolerance in rice (Oryza sativa L.) to cope with climate change in Vietnam *Australian J. of Crop Science* 6(12) 1649-1654
[23] Hosseini S J, Tahmasebi S Z, Pirdashti H 2012 Screening of rice (Oryza sativa L.) genotypes for NaCl tolerance at early seedling stage *Int. J. of Agronomy and Plant Production* 3(8) 274-283
[24] Huyen L T N, Cuc L M, Ismail A M, Ham L H 2012 Introgression the salinity tolerance QTLs Saltol into AS996, the elite rice variety of Vietnam *American J. of Plant Sciences* 3(8) 981-987