ORIGINAL ARTICLE

Evaluation of solanaceous crops source material for resistance to abiotic factors

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Abstract

Aim: The results of the evaluation of the solanaceous crops source material for resistance to abiotic factors are presented. A number of studies are conducted on the development and improvement of rapid methods for assessing the source material: laboratory-based method for evaluation of solanaceous crops' cold resistance and salinity tolerance due to changes of the intensity of seeds germination under the effect of unfavorable factors (reduced positive temperatures and salinization) and for evaluation of drought resistance due to water-retaining capacity and water restoring ability of tomato leaves. **Materials and Methods:** The basis of the method for establishing salt tolerance is standard method for determining the germination, where along with the germination of seeds in the water, the option of cultivation of samples on selective backgrounds (with high levels of salinity) their parallel germination in saline solutions is introduced. To determine cold resistance was used high-quality collection of seeds of sweet pepper, bitter pepper, and eggplant with a high germination, same year, and place of reproduction. **Results and Discussion:** The results of determination of cold resistance of collection samples in the laboratory confirmed the existence of correlation dependence of "cold resistance" and "earliness" signs for sweet pepper and eggplant ($r = -0.58 \pm 0.15$ and $r = -0.62 \pm 0.14$, respectively) as well as signs of "cold resistance" and "the presence of anthocyanin coloration" for eggplant ($r = -0.65 \pm 0.15$). While creating a valuable breeding material of tomato to a certain extent, the research on water holding and water recovery capacity of leaves during their most sensitivity to lack of water in the flowering stage can be used. It is found that the majority of varieties have quite high (80.1-85.0%) level of water content in the leaves. The tendency of the maximum water content in the leaves of the well-leafy varieties, which were withdrawn in the Southern Regions, is noted. A significant difference in the parameters of drought resistance of tomato plants, the maximum expression of the indicator - 83.9 ± 1.7, the minimum - 56.1 ± 1.3 is found. Indicators of high drought tolerance were detected in breeding varieties of Moldova, Southern Russia, and Southern Ukraine.

Key words: Cold resistance, drought resistance, eggplant, express method, heat resistance, salt solutions, salt tolerance, source material, sweet peppers, tomatoes, water retention and water recovery capacity of leaves

INTRODUCTION

A variety of adverse weattxher and climatic factors make it necessary to include the selection process of the source material research and creation on its basis of resistant to abiotic factors of different varieties of vegetables. The presence of highly effective methods of evaluation and selection of breeding material, especially in the early stages of plant development, is very important.[1-3] We have conducted a number of studies on the development and improvement of express methods of the source material evaluation: Direct laboratory methods of evaluation of cold resistance and salt tolerance of solanaceous crops on the change of the intensity of germination of seeds under the influence of adverse factors (reduced positive temperatures and salinity) and evaluation of drought resistance on water retention and water recovery ability of tomato leaves.

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MATERIAL AND METHODS

Express-method of Salt Tolerance Evaluation

Existing methods for evaluating cold resistance and salt tolerance of plants are divided into the direct field (accounting changes in biometric data) and indirect physiological and biochemical and biophysical (taking into account the changes in the individual processes and links of metabolism and correlate with indicators of evaluation with direct methods). The disadvantage of direct field evaluation methods is duration and laboriousness, indirect methods - complex technically. More suitable for the primary mass evaluation of a large number of samples are direct laboratory express methods.[4,5]

The basis of the method for establishing salt tolerance is standard method for determining the germination, where along with the germination of seeds in the water, the option of their parallel germination in saline solutions is introduced. Laboratory method of diagnosis of beet crop salt tolerance was proposed by Vir in 1986.[6,7] The aim of our work was the experimental selection of the conditions for evaluation of salt tolerance (brine concentration, temperature, and duration of the germination of seeds) for solanaceous crops, which allow differentiating collection samples by resistance groups.[8,9]

To Determine the Salt Tolerance of Solanaceous Crops

Tomato, sweet pepper and eggplant, we have improved the laboratory method. For the study, the selections of 20 collection samples of tomato, sweet pepper, and eggplant were formed and were determined their salt tolerance by the laboratory method and in the cultivation of these samples on selective backgrounds (with high levels of salinity).

RESULTS

According to the research results, the distribution of collection samples of tomato, sweet pepper, and eggplant by salt tolerance, determined in laboratory conditions and cultivation on the selective background was carried out [Table 1].

Table 1: Salt tolerance of collection samples of solanaceous crops in the control selection

Gradation	Salt tolerance (%)	% of matches when determining both methods
Tomato		
High salt tolerance	>51	100
Medium salt tolerance	31-50	100
Low salt tolerance	11-30	99.8
Not salt tolerant	<10	99.5
Sweet pepper		
High salt tolerance	>51	100
Medium salt tolerance	31-50	99.8
Low salt tolerance	11-30	99.8
Not salt tolerant	<10	98.0
Eggplant		
High salt tolerance	>51	100
Medium salt tolerance	31-50	100
Low salt tolerance	11-30	100
Not salt tolerant	<10	99.8

The results of determining the salt tolerance of collection samples in laboratory conditions are practically identical to those obtained during the growth of these samples on selective backgrounds (with high levels of salinity) in lysimeters, which indicates a high precision of laboratory method evaluation.[10]

Express-method of Cold Resistance Evaluation

Among the known methods of diagnostics of cold resistance of heat-loving vegetables, the most widely used are direct evaluation methods - taking into account the plants that survived exposure to low positive temperatures. In addition, there is a method that is based on the dependence of cold resistant plants on the seed's ability to germinate at low temperatures. The possibility of this diagnostics is confirmed by research on corn, soybeans, millet, rice, pumpkin, cucumber, zucchini, squash, and tomato.[11-14] This method was modified by us for crops of sweet pepper, bitter pepper, and eggplant. Taking into account the biology of each crop, it has been experimentally determined the temperature and the duration of its influence, as well as the terms of accounting indicators to identify a clear differentiation of the varieties by the level of cold resistance.[15,16]

Using the method the evaluation of cold resistance of collection of sweet pepper, bitter pepper, and eggplant was conducted. To determine the cold resistance, the high-quality seeds with a high level of germination were used, of the same year, and place of reproduction.

The results of the determination of cold resistance of collection samples in the laboratory conditions confirmed the existence of correlation dependence of "cold resistance" and "earliness" signs for sweet pepper and eggplant ($r = -0.58 \pm 0.15$ and $r = -0.62 \pm 0.14$, respectively) as well as signs of "cold resistance" and "the presence of anthocyanin coloration" for eggplant ($r = -0.65 \pm 0.15$).

Determination of Drought Tolerance of Tomato

Maximum tomato productivity can only be achieved with optimal provision with necessary factors of plant growth and development, including the important role played by water. However, in recent years, the climatic conditions in our area were characterized by a more intense and prolonged dry periods. The drought is the biggest harm during active growth and the formation of generative organs of plants. For most farm crops, it is found that vegetation under water deficit requires a higher water holding capacity of tissues and the resistance of photosynthesis to the drought. For varieties which have a low water holding capacity of tissues, often observed depression of photosynthesis.

Therefore, the creation of varieties that could better tolerate the dry season, that is, to a lesser extent stress from losing moisture and more quickly recover vital processes is an important task of breeders.

While creating a valuable breeding material of tomato to a certain extent, the research on water holding and water recovery capacity of leaves during their most sensitivity to lack of water in the flowering stage can be used. The above studies can be used to evaluate the genetic sources in their selection for hybridization and prediction of the effectiveness of targeted selection for improved drought tolerance.

To better study the reaction of varieties for the long drought, we have evaluated collection samples of tomato. Diagnostics was conducted by a laboratory method. To estimate the water content in tissues, we have used the method of Litvinova,[13] "methods of diagnostics of plant resistance (drought, heat, salt, and Frost)," which was modified for the crop of tomato. The water content in leaves was determined by the difference between wet and dry weight of leaves (in the percentage of their wet weight).

According to Litvinova,[13] the water content in the tissue of more drought-resistant plants should be greater than in less drought resistant. Gradation of the water content from the wet weight in percentage for tomato is as follows: <70.0% - very low; 70.1-75.0% - low; 75.1-80.0 - average; 80.1-85.0% - high; > 85.0% - very high water content.

Leaves (middle part) were collected from the upper tier half an hour before sunrise. Samples were immediately placed into cups with ground stoppers to prevent loss of water during transportation. In the laboratory, samples were weighed together with the cups and then dried without removing them from the cups at a temperature of 105°C. As cups previously were weighed it's easy to determine the dry and wet weight of samples. The total amount of water (x) in % of the wet weight was determined by the formula:

$$x=100\ (b-c)/b-a,$$

Where, a - weighing bottle weight, b - mass of weighing bottle with wet weight, c - mass of weighing bottle with dry weight, g.

As a result, the study found that the majority of varieties have quite high (80.1-85.0%) water content in the leaves. The tendency of the maximum water content in the leaves of the well-leafy varieties, which were withdrawn in the Southern Regions, is noted.

It is known that heat and drought tolerance are genetically determined traits, but mostly they are determined by the degree of plant reactions to drought and overheating. Therefore, the ability of plants to withstand adverse external environmental factors is mainly determined by the physiological and biochemical mechanisms of protective adaptive reactions.[17]

In conditions of the strong influence of the stressor physiological and biochemical processes are directed primarily at preserving moisture in the plant cell and viability recovery. In this aspect, we have studied the water holding and water recovery capacity of tomato leaves.

Middle leaf samples of plants were collected at 8 a.m. (4^{th} tier from the top) into plastic bags, weighed, placed on racks, and kept for 24 H at room temperature. After withering, leaves were weighed and placed into a container of water to restore turgor. One day later, the leaves were re-weighed and the coefficients were calculated.

To determine the water retention, water recovery and drought coefficient for tomato crop the methodology developed for potatoes was taken as a basis.

Was determined:

- Water retention coefficient

$$K = \text{Water retention } (M_{dur}/M_{fresh}) \times 100\%$$

Where, M_{dur} - leaves weight after drying up, M_{fresh} - mass of fresh leaves;

- Water recovery coefficient

$$K_{wr} = (M_{sat}/M_{fresh}) \times 100\%$$

Where, M_{sat} - leaves weight after water saturation, M_{fresh} - fresh leaves weight, and based on this

- Drought resistance coefficient

$$K_{ps} = (K_{water\ retention} \times K_{ov})/100\%.$$

The research was focused on the determination of the coefficient of drought resistance. A significant difference in the parameters of drought resistance of tomato plants was

Table 2: The variability of drought tolerance indicators of tomato

Indicator	Minimum and maximum values	
	V_{min}±Sv	V_{max}±Sv
Water retention capacity (%)	72.4±1.5	81.8±1.8
Water recovery capacity (%)	89.1±1.7	103.6±2.0
Drought resistance coefficient (%)	56.1±1.3	83.9±1.7

found, the maximum expression of the indicator - 83.9 ± 1.7, the minimum - 56.1 ± 1.3 [Table 2]. Indicators of high drought tolerance were detected in breeding varieties of Moldova, Southern Russia and Southern Ukraine. This is completely consistent with the results of the visual assessment of collection samples plants in the field conditions without irrigation.

In all the studied varieties water retention coefficient was less than water recovery one. It was found that the varieties with a low water retention capacity of tissues are more often observed with depression of photosynthesis which in turn, affects the productivity index. The water retention capacity of the tomato leaves is also connected with resistance to drought.

The ability of plants to endure drought is caused by different characteristics of morphological, anatomical structure, and changes in physiological processes.[18] If drought resistance is associated with changes in anatomical and morphological structure, it is correlated with lower productivity. It is determined that more promising should be considered field of research for improving drought resistance through changes in physiological processes.[19-21]

CONCLUSIONS

Offered and improved by us laboratory methods for determining salt tolerance of solanaceous crops - tomato, sweet pepper, and eggplant by the germination of seeds in salt solutions and determination of cold resistance by the germination of seeds in cold weather conditions appeared to be sufficiently reliable and uncomplicated, have high accuracy, they are convenient and effective for primary assessment as express methods. While creating a valuable breeding material of tomato during heat and drought resistance selection, it is effective to use assessment for the water retention and water recovery capacity of leaves during their most sensitivity to lack of water in the phase of flowering and drought resistance coefficient.

REFERENCES

1. Merezhko AF. Principles of search, creation and use of valuable features donors. The identified gene pool of plants and breeding. In: Theoretical Aspects of Plant Breeding. St. Peterburg: VIR; 2005. p. 179-89.
2. Medvedev SS. Plant Physiology. St. Petersburg: Publishing House of the St. Petersburg University Press; 2004.
3. Udovenko GV. Resistance of plants to abiotic stressors. In: Physiological Basis of Plant Breeding. St. Petersburg: VIR; 1995. p. 293-352.
4. Leonova TG, Chikida NN. Evaluation of salt tolerance of *Aegilops* L. In: VIR Collection. Genetic Resources of Cultivated Plants in the XXI Century: II International Vavilov Conference. St. Petersburg; 2007. p. 96-97.
5. Kuznetsov VV, Khidirov BR, Borisova NN. Common systems of cotton resistance to salinity and high temperature: Facts and hypotheses. Plant Physiol 1990;37:987-96.
6. Sinelnikova VN. Determination of salt tolerance of vegetable crops upon seed germination in saline solutions. Beet. St. Petersburg: VIR; 1986.
7. VIR. Evaluation of Cold Resistance of Pumpkin Crops on the Early Stages of Development. St. Petersburg: VIR; 1983.
8. Shabetia OM. Express methods of evaluation of salt tolerance of solanaceous crops. Vegetable and Melon Growing 2001;46:16-20.
9. Shabetya ON, Shabetya VV, Andryushchenko VB. Determination of eggplant resistant to adverse environmental conditions. Vegetable and Melon Growing 2002;47:13-7.
10. Shabetia OM and Linskyi VP. Result of evaluation of eggplant collection for cold resistance. Vegetable and Melon Growing 2005;50:31-4.
11. Shabetia OM, Shabetia VV. Patent for Useful Model No. 30268. Ukraine: Laboratory way of Determining Cold Resistance of Bitter Pepper. Bulletin “Industrial Property”; 2008. p. 4.
12. Shabetia OM, Shabetia VV. Patent for Useful Model No. 30269. Ukraine: Laboratory Way of Determining Salt Tolerance of Bitter. Bulletin “Industrial Property”; 2008. p. 4.
13. Litvinova L. Methods of Diagnosis of Plant Resistance (Drought, Heat, Salinity and Frost). St. Petersburg: VIR; 1970.
14. Kushnirenko MD, Kurchatova GP, Shtefyrtsa AA, Pecherskaya SN, Klevtsova EV, Bashtovaya SI. Express Methods of Diagnostic of Heat-Drought Resistance and Periods of Plants Watering. Chisinau: Shtiintsa; 1986.
15. Tkachuk ES. Changes of photosynthetic activity in plant adaptation to water scarcity. In: Physiological, Biochemical and Ecological Aspects of Plant Sustainability. Irkutsk: Siberian Institute of Physiology and Biochemistry of Plants; 1977. p. 146-51.
16. Genkel PA. Physiology of Plants Heat-and Drought Resistance. Moscow: Science; 1988.
17. Altergot VF, Mordkovich SS, Ignatiev LA. Principles of plants drought and heat resistance evaluation. In: Methods of Evaluation of Plants Resistance to Adverse

Environmental Conditions. Leningrad: Kolos; 1976. p. 6-17.
18. Andryuschenko VK. Methods of Optimization of the Biochemical Selection of Vegetables. Chisinau: Schtinica; 1981.
19. Genkel PA. Current state of plants drought resistance problem and further ways of its study. In: Physiology of Plant Resistance (Frost, Drought and Salinity). Moscow: Publishing AS USSR; 1960. p. 385-401.
20. Genkel PA, Badanova KA, Levina VV. About new laboratory method of diagnosis of heat-and drought resistance for selection. Plant Physiol 1970;17:431-5.
21. Udovenko GV. Methods of Diagnosis of Plant Resistance (Drought-, Heat-, Salt-, Frost). Leningrad: VASHNYL; 1970.

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