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Selection Value Of Tomato Varieties And Lines According To The Set Of Cold Resistance And Adaptability Traits

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ABSTRACT

The paper reveals the results of research on the adaptive capacity of cold resistance traits in tomato varieties, which were studied in the field and laboratory conditions. The level of general and specific adaptive capacity and homeostatic cold resistance was determined. Valuable source material was selected on the basis of traits characterizing the cold resistance in the field and laboratory conditions. Valuable varieties with a high level of adaptability on the grounds of cold resistance - seed germination, plant height increase, growth rate, duration of the sowing-germination period were identified.

Key words: cold resistance, adaptability, homeostatic traits, plant height increase, growth resumption rate, tomato.

INTRODUCTION

Breeding the highly adaptable tomatoes varieties and hybrids with the seeds germinate quickly at low temperatures is of practical value. Tomato varieties and hybrids are rather heterogeneous in their ability to adapt to extreme environmental conditions. A.V. Alpatyev and co-workers managed to increase tomato cold resistance using hybrid material obtained from crossing geographically distant forms and intrahybrid crossing under further influence of low positive temperatures along with continuous selection. A number of selection lines can withstand short-term (1.5-2 hours) up to minus up -2^{0}C frosts and be highly productive and early-ripening at the same time (Alpatiev A.V., 1981).

Other researchers (Korchmar N.I., Luka E.A., 1991) determined the growth response of genotypes under conditions of reduced temperatures in early ontogenesis and found a significant difference in resistance between varieties and lines. Tomato growth, plant growth, number of leaves during stress and the recovery rate after stress are the best indicators of cold resistance of tomatoes. Under favorable conditions, after low temperatures treatment, the plants reccommenced the growth processes, which indicates the plant that adaptation to low-temperature stress (Trunova T.I., Astakhova N.V., 1995). Some changes took place in the leaf cells: a decrease in the area of the cytoplasm and almost complete disappearance of starch grains. There was a 3 times decrease in the area of cells and cytoplasm cut compared with the control.

Little attention was paid to breeding cold-resistant forms of tomatoes. In Ukraine, due to the lack of detailed research on cold resistance sources combined with other economically valuable traits, it was not possible to breed this kind of valuable varieties and hybrids. Our research aimed to analyze the components of cold resistance, identify the level of their manifestation and determine the adaptive capacity and homeostatic traits.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Being exposed to low antifreeze temperatures, plants in the moderate temperate zone are able to develop their frost resistance. Acquired resistance to freezing includes extensive reprogramming of gene expression and metabolism. Changes in the expression of hundreds of genes in response to cold temperatures are combined with increased levels of metabolites, some

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of which have a protective effect against the destructive effects of cold stress (Zhu et al 2007). Most varieties of tomatoes are sensitive to cool temperatures (from 0 to 15 0C) at all stages of plant development, including seed germination, vegetative growth and reproduction. When the germinate at low temperatures, many of the seeds do not germinate, the growth is delayed and the plants grow unevenly which result in delayed growth and development and causes variability in the crops ripening. Cold-resistant plants can grow faster in the early stages and thus they can grow faster than cold-sensitive plants. This can provide improved sowing times, adaptability and yield (Foolad *et al.* 2001).

Low-temperature stress for 3 days after sowing dramatically reduces germination potential, germination index and seed germination rate (Du *et al.* 2010). Researchers Khan *et al.* exposes to cooling twenty-days S-22 tomato seedlings (resistant to cooling) and RKM-1 (sensitive to cooling). The seeds were sown in clay pots and at the 40th day of growth stage the plants were exposed to various levels of low temperatures (10/3^{0}C, 12/7^{0}C, 20/14^{0}C, 25/18^{0}C) for 24 hours in a growth chamber. Low temperatures caused a significant decrease in growth, chlorophyll content and rate of photosynthesis in both varieties differently (Khan *et al.*, 2015).

The studies by Barrero-Gil *et al*. found that low temperatures are an environmental stress that threatens plants development, distribution and yield. Many tomato plants died in 5 days under constant exposure to 4 ^{0}C. Under the influence of variable temperatures of 4^{0}C and return to 25^{0}C, tomato plants increase their resistance to cooling. The cold acclimatization reaction in tomato plants causes the transcript reprogramming (Barrero-Gil *et al.* 2016).

The analysis of literature data testifies to expediency and prospects of researches on tomato cold resistance as a complex trait and establishing their adaptive ability.

RESEARCH CONDITIONS AND METHODS

We have studied for 4 years 228 varieties and lines of the collection of the National Center for Plant Genetic Resources of Ukraine, the varieties of the Institute of Vegetable and Melon crops and its research stations, as well as selection samples of the Kyiv Research Station bred by professor V.A. Kravchenko and kindly provided for research.

Planting and placement of breeding nurseries, the varieties and lines study and evaluation were carried out in accordance with the "Methods of experimental work in vegetable and melon crops growing" (1992). The study was conducted in comparison with the standard - Flora variety.

Cold resistance was determined by the methods of '*Plants stress resistance diagnostics*' (1988) and '*Diagnostics of tomato crops samples cold resistance*' (1990).

To assess the plants cold resistance, the seeds were exposed to low temperatures in natural (field) and artificial (laboratory) conditions. Wet seeds were placed in Petri dishes and kept in the refrigerator at variable temperatures until germination. The temperature mode: 12 hours at -1^{0}C and the following 12 hours - at +15-16^{0}C. The germinated seeds were counted at 7 days intervals within 20 days of germination. The similarity of each sample was determined by taking into account the percentage of hardy plants.

The increase in plant height was determined as a percentage 7 days after germination in the laboratory under the influence of variable low temperatures - 12 hours at -16^{0}C and 12 hours at -1^{0}C-0^{0}C. The rate of growth resumption was determined 3 days after the plants treatment with variable low temperatures. Researchers L.M.Polesskaya, A.G.Jacote, M.E.German, V.G.Harty point to the sign of "growth resumption rate", which better characterizes the tomatoes resistance to cold. We considered it appropriate to use this feature in our studies and

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showed it as a percentage increase in plant height 3 days after their exposure to low temperatures (Polesskaya L.M. *et al.,* 1991).

In the field, we performed the assessment of cold resistance considering the duration of the 'sowing–seedlings' period and determined the increase in plant height at low temperatures range of -1 - + 12^0C for 10 days.

The research was conducted in the fields of the Kyiv Research Station of the Institute of Vegetable and Melon crops of National Academy of Agrarian Sciences (NAAS), which is located in the Polissya area under a cooperation agreement with Bila Tserkva National Agrarian University (BTNAU). The climate of the district is temperate-continental, characterized by cold winters and moderately warm summers, with sufficient precipitation and snow cover. A sufficient amount of heat for growing heat-loving crops, sufficient moisture in the summer months and high humidity is a characteristic feature of the climate. The long frost-free period that lasts for 199-202 days on average is characterized by the sum of temperatures of 2650 – 2800^0C, which begins on April 10-15 and ends on October 23-26. The average annual rainfall (492 mm) is sufficient for growing tomatoes. Adverse weather conditions include the reduction of the frost-free period in some years to 154 days, rainy periods along with periods without precipitation, which last up to 23 consecutive days. The soils of the experimental plots are podzolic chernozems, low-humus, microporous and loamy. The horizon in the arable layer is semistructured (low lumpy-dusty), in the subsoil layer it is low-grained, low-compacted.

The technology of growing tomatoes in our research is generally accepted for the Polissya area. Field studies were conducted in the grain - vegetable crop rotation.

Weather conditions for the research years differed in agrometeorological indicators. The amount of precipitation during the study period ranged from 240 to 380 mm with the long-term average one of 346 mm.

The short-term decrease in temperature provided the conditions for assessing the resistance to short-term spring frosts and early maturity during the seedlings planting in open ground.

Statistical analysis was performed according to the "Methodological recommendations for statistical evaluation of selection material of vegetable and melon crops" (1993) and "Methods of field experience" (Dospekhov B.A., 1985).

To study the response of genotypes to changing environmental conditions, we evaluated the parameters of their adaptability. Assessment of general (GAC) and specific (SAC) adaptive capacity allows to select a number of quantitative signs for adaptive capacity. Calculations of the parameters of general and specific adaptive capacity of the varieties for cold resistance were performed according to the method of O.V. Kilchevsky, A.V.Khotyl'ova (1985). Homeostaticity on the main traits of cold resistance was determined according to V.F. Pivovarov (1985).

RESEARCH RESULTS

Direct methods of assessment - the accounting of plant endurance after their low temperatures treatment - are the most reliable among the known methods of diagnostics of heat-loving crops cold resistance. Our studies revealed a significant difference in the manifestation of the cold resistance trait in the varieties and lines. Seeds treatment with variable temperatures in the laboratory revealed the varieties resistance to low temperatures. Cold-resistant plants germinated faster, had a higher increase in plant height both at low temperatures and afterwards.

In the first phases of growth, the most cold-resistant varieties were Prelude, Nepryadvo, Picket, with 11.0-13.2 % average seed germination after 7 days of germination, 60 - 80% of plant

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height increase during growth and 13-24 %growth rate after 3 days after exposure to cold stress, which exceeded the same indicators in the standard variety of Flora (germination - 6.0 %, height increase – 50 %, growth resumption – 10 %) (Table 1).

Table 1. Adaptive capacity and homeostatisity of cold resistance traits in tomato varieties and lines in laboratory conditions (average for 4 years)

Sort, line	Trait											
	Seeds germination				Plant growth increase				Growth resumption rate			
	%	HOM	GAC	σAAC	%	HOM	GAC	σAAC	%	HOM	GAC	σAAC
Flora – standard	6.0	0.06	0.3	1.7	50	0.54	0.1	4.0	10	0.11	2.3	16.0
Prelyudia	11.0	0.12	1.4	3.3	60	0.80	1.1	5.0	24	0.46	9.9	11.0
Brylant	1.3	0.02	-1.0	0.7	40	0.50	-0.9	3.0	15	0.23	1.9	7.0
Line BB 597	4.0	0.05	-0.3	1.0	57	0.63	0.8	3.7	9	0.15	-2.1	7.0
Nepryadvo	12.8	0.22	0.6	0.3	63	0.93	1.4	5.3	24	0.33	9.9	24.0
Piket	13.2	0.14	2.0	2.7	80	0.93	3.1	8.0	13	0.19	1.7	8.2
Line KBD*	8.0	0.08	0.7	2.0	55	0.61	-0.6	-3.3	17	0.18	-0.1	23.0
Svitanok	8.0	0.50	1.0	0.7	70	1.48	1.8	4.7	9	0.13	-0.1	5.0
Strilka	4.0	0.06	0.3	1.0	57	0.70	0.3	4.2	14	0.20	2.2	8.5
Line K.s.	4.0	0.06	-0.1	0.3	60	0.70	-1.9	-0.7	13	0.20	-0.8	2.5
Kibis	5.2	0.06	0.6	0.7	75	0.89	1.6	6.0	9	0.12	-2.5	8.2
Amigo	2.0	0.03	0.3	1.0	60	1.70	0.9	3.3	8	0.13	-2.3	6.0
LSD_{05}	2.20				15.5				2.6			

Note: *KBD - [(Kazhelek Khodovsky x Breeding line) x *j-2*] x Jefferson

The selected varieties had a longer duration of the ‘sowing–germination’ period - 18-20 days in the field conditions (21 days for Flora standard) and an increase in plant height during growth at low positive temperatures (+6-12^{0}C) - 70-75% (in the standard - 74%) (Table 2).

Strilka, Line K.s., Svitanok, Kibis, Line BB 597, Line KBD varieties should be noted among other samples of the collection on the grounds of cold resistance. These samples differed in the average increase in plant height during growth - the plants effectively resumed growth 3 days after their treatment with low temperatures in the laboratory and in the field. Plants of these samples grew rapidly under cold stress - 55-75% in the laboratory and 68-85% in the field, with the standard level of 50 and 74%, respectively (table 1, 2).

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They quickly resumed growth 3 days after the stress - 9-17%, the increase in plant height compared to the standard variety Flora made 10%.

Thus, the assessment in different versions of the study made it possible to identify cold-resistant samples. We agree with researchers who believe that the difference in germination and growth of genotypes can be explained by the fact that the sign of the ability to germinate at low temperatures is polygenic and was caused by 3-5 or 11-20 genes (Fellner M., 2001, Zhuchenko A.A., 1988).

Table 2. Adaptive capacity and homeostatisity of cold resistance traits in tomato varieties and lines in field conditions (average for 4 years)

Variety, line	Origin	Growth period, sign							
		Sowing-germination				Growth resumption rate			
		days	HOM	GAC	σSAC	%	HOM	GAC	σSAC
Flora – standard	Ukraine	21	0.67	5.4	0.7	74	1.84	5.0	0.5
Prelyudia	Moldova	18	0.57	7.4	6.7	75	3.10	4.5	2.0
Brylant	Poland	20	0.50	5.4	2.7	76	0.86	5.0	1.5
Line BB 597	Ukraine	22	0.58	4.0	3.7	82	2.90	5.5	0.1
Nepryadvo	Ukraine	19	0.64	6.7	4.0	75	1.69	5.0	0.5
Piket	Ukraine	20	0.67	7.4	6.7	70	1.74	4.5	1.0
Line KBD*	Ukraine	18	0.47	5.4	0.7	85	2.00	6.0	0.5
Svitanok	Ukraine	18	0.47	6.0	2.7	68	1.50	5.5	1.1
Strilka	Russia	20	0.58	4.8	0.3	72	2.45	5.1	0.7
Line K.s.	Ukraine	19	0.64	6.4	1.3	76	0.90	5.6	0.2
Kibis	Russia	19	0.44	6.3	1.2	78	2.09	5.8	1.3
Amigo	Spain	19	0.64	7.8	6.7	76	0.90	5.6	0.2
LSD_{05}		1.3				6.4			

Note: *KBD - [(Kazhelek Khodovsky x Breeding line) x *j-2*] x Jefferson

Extreme environmental conditions disrupt the normal course of metabolic processes in the plant not only in the period of their direct action, but in the subsequent periods as well. Increased adaptive potential of genotypes is a vital precondition for maintaining the normal course of metabolic processes in the plant. The ability to optimize metabolic processes in certain environmental conditions is expressed through the index of homeostatic trait (Zhuchenko A.A., 1980). When assessing cold resistance, it is important to know the degree of homeostaticity of the trait among the samples that had the greatest resistance to low temperatures. In our opinion, the low homeostaticity of the traits of 'seed germination', 'plant height growth' and 'growth rate resumption' after stress in seedlings in the laboratory was explained by the action of a number of genes that allows successful selection for the trait. Experimental studies have shown that the greatest homeostaticity of the 'seed germination trait was typical for the following samples - Nepryadvo - HOM = 0.22 and Svitanok - HOM = 0.50 with homeostaticity of the trait in the Flora standard - 0.06. According to the homeostatic increase in height during stress, we identified the selected the varieties of Svitanok HOM = 1.48, Amigo - HOM = 1.70. Prelude and Nepryadvo samples had the highest homeostatic values - 0.46 and 0.33 compared to the standard Flora HOM = 0.11 on the basis of 'growth rate resumption'.

Thus, the Nepryadvo variety had the highest homeostatic indicators on the basis of cold resistance, which were studied in the laboratory. The level of homeostatic traits of cold resistance when tested in the field was similar to those obtained in the laboratory. In the Prelude, Line BB 597, Nepryadvo, Picket variety samples, the duration of the 'sowing –

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germination' period was characterized by greater homeostatics - 0.57-0.67. In these forms, the highest homeostatic feature of the 'plant height increase' trait was noted: HOM = 1.69-3.10, in the Flora standard - 1.84.

According to V.F. Pivovarov, it is higher stability, *i.e*. homeostatic genotype that indicates high resistance of the genotype to the variability of environmental conditions (Pivovarov V.F., 1985). Thus, forms that have the greatest cold resistance and show high stability are the best for each specific zone.

The original forms were grown in the years which were unstable in temperature and precipitation. To study the response of the genotypes to such changing environmental conditions, we evaluated the parameters of the adaptive capacity of genotypes. General adaptive capacity (GAC) is defined as the ability of crops to give a consistently high yield in variable growing conditions. Specific adaptive capacity (SAC) is the ability to respond and tolerate certain adverse environmental factors, including low temperatures (Kilchevsky *et al*., 1997). Assessment of GAC and SAC allows to select crops for their adaptive capacity against variable low temperatures and a number of quantitative features.

In the samples, we observed various levels of adaptability of cold resistance trait in the laboratory. The highest level of GAC and SAC was observed in the varieties of Prelude, Nepryadvo, Picket, Svitanok. Prelude and Picket varieties had higher adaptability - 1.4 and 2.0 compared to the standard - 0.3, according to the value of seed germination in laboratory conditions GAC. In terms of plant growth rate, the varieties of Prelude, Picket, Nepryadvo, Kibis and Svitanok had the highest indicators of GAC - 1.1-3.1 and high specific adaptive capacity - 4.7-8.0. The rate of growth resumption in variable environmental conditions was observed in the Prelude and Nepryadvo varieties - GAC - 9.9, which also showed a high effect of SAC - 11.0-24.0 (table 1).

When determining the cold resistance index, we also found the degree of manifestation of the traits related to cold resistance in the field. Studies have shown that most forms had high GAC and SAC in terms of cold resistance. The variety samples of Prelude, Brylant, Nepryadvo, Picket, Line [(Kazhelek Khodovsky x Breeding line) x *j*-2] x Jefferson, Kibis, Amigo and Svitanok had high level of adaptive ability. The 'sowing – germination' period had a higher general adaptive capacity - 5.4-7.8 (in the standard - 5.4) and SAC at the level of - 0.7-6.7 (standard - 0.7). On the basis of 'plant height increase' trait these samples had a high GAC - 4.5-6.0 and were equal to the standard - 5.0. They had a specific adaptive capacity at the level of the standard or higher - 0.5-2.0 (standard 0.5).

The Prelude, Nepryadvo, and Kibis specimens had a high adaptive capacity for traits that were studied both in the field and in the laboratory. Thus, the previously established data on the identity of the results conducted in different conditions - in the field and in the laboratory are confirmed. Evaluation of samples by different methods led to our selection of the same cold-resistant samples - Prelude, Nepryadvo, Picket with high performance on the grounds that characterize cold resistance.

CONCLUSIONS

Samples of Prelude, Nepryadvo, Kibis had high adaptive capacity on the features studied in both field and laboratory conditions. Thus, the previously established data on the identity of the results conducted in different conditions - in the field and in the laboratory are confirmed. Evaluation of samples by different methods resulted in selecting the same high performance cold resistant samples - Prelude, Nepryadvo, Picket on the grounds that characterize cold resistance.

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