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EVALUATION OF COLD RESISTANCE AND EARLY RIPENING TRAITS IN STERILE FORMS OF TOMATOES

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ОЦЕНКА ПРИЗНАКОВ ХОЛОДОУСТОЙЧИВОСТИ И РАННЕГО СОЗРЕВАНИЯ СТЕРИЛЬНЫХ ФОРМ ТОМАТА

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The aim of the study was to identify a valuable source material among available tomato sterile forms for tomato breeding for cold resistance.

Materials and methods. The article presents the results of a study of 14 tomato sterile forms for adaptive ability based on a complex trait of cold resistance, the elements of which were determined in field and laboratory conditions. The material was assessed according to a set of features: the increase in plant height, the rate of growth recovery, the duration of the sowing-seedling and seedling-fruit ripening periods. Calculations of the parameters of general adaptive ability, homeostatic and variance of specific adaptive ability of sterile form genotypes by earliness and cold resistancehave been performed.

Results. The level of general and specific adaptive ability, as well as homeostatic of cold resistance, were determined. Valuable source material has been isolated according to the characteristics of cold resistancein the field and laboratory conditions.

The forms Mar ps 59, Mar ps 53 and Sat ps 52 were characterized by highest cold resistance in the laboratory conditions. These lines were characterized by seed germination in the range of 0,3–2,8 %, compared with other sterile forms with the germination 0,1–0,2 %. The increase in plant height under cool conditions in mentionedforms (Mar ps 59, Mar ps 53 and Sat ps 52) was higher (45–54 %) compared with other sterile forms.

In the field, the duration of the interphase period «sowing – seedlings» was the shortest in the forms Mar ps 59 and Sat ps 52 compared with other forms studied. Thus, the duration of the period «sowing–germination» in the mentioned forms was 19 and 18 days respectively, against the standard Flora 20 days. The increase in seedling height was 60–80 %, to the same extent with other forms and the standard 74 %.

Conclusions. The selected methods for assessing the traits of cold resistance and earliness and mathematical processing of the results allowed us to identify a valuable source material among sterile forms of tomatoes with a high level of adaptability of these traits.

Key words: *tomato, cold resistance, earliness, general and specific adaptive ability.*

Целью исследования было выявить ценный исходный материал среди доступных стерильных форм томатов для селекции томатов на холодоустойчивость.

Материалы и методы. В статье представлены результаты исследования 14 стерильных форм томатов на адаптивную способность по комплексному признаку холодоустойчивости, элементы которой определены в полевых и лабораторных условиях. Материал оценивали по набору признаков: увеличение высоты растений, скорость восстановления роста, продолжительность периодов созревания посевно-рассадного материала и проростков-плодов. Проведены расчеты параметров общей адаптационной способности, гомеостаза и дисперсии удельной адаптивной способности генотипов стерильных форм по раннеспелости и холодоустойчивости.

Полученные результаты. Определяли уровень общей и специфической адаптационной способности, а также гомеостатику холодоустойчивости. Ценный исходный материал выделен по характеристикам хладостойкости в полевых и лабораторных условиях.

Наивысшей хладостойкостью в лабораторных условиях характеризовались формы Мар пс 59, Мар пс 53 и Сат пс 52. Эти линии характеризовались всхожестью семян в пределах 0,3–2,8 % по сравнению с другими стерильными формами при всхожести 0,1–0,2 %. Прирост высоты растений в прохладных условиях у указанных форм (Мар пс 59, Мар пс 53 и Сат пс 52) был выше (45–54 %) по сравнению с другими стерильными формами.

В поле продолжительность межфазного периода «посев – рассада» была наименьшей у форм Мар пс 59 и Сат пс 52 по сравнению с другими изученными формами. Таким образом, продолжительность периода «посев – прорастание» у указанных форм составила 19 и 18 дней соответственно, против стандартных 20 дней Флоры. Прирост высоты всходов составил 60–80 %, на столько же у других форм и стандарта 74%.

Выводы. Выбранные методы оценки признаков холодоустойчивости и раннего созревания, а также математическая обработка результатов позволили выявить ценный исходный материал среди стерильных форм томатов с высоким уровнем адаптивности по этим признакам.

Ключевые слова*: томат, холодоустойчивость, раннеспелость, общая и специфическая адаптивная способность.*

Introduction

Most tomatoes are plants of the warm season and should be planted only after the danger of frost has passed. Tomato tolerance to low extreme temperatures is extremely important for the flowering phase and further fruit development. Flowering in the spring will occur if the daytime temperature is warm and the nighttime temperature does not drop below 13 °C. The temperature of growing tomato seedlings should be maintained at a constant level between 14–16 °C. Seedlings should not be transplanted until the last frosts [1].

Studies to increase the cold resistance of tomatoes using synthetic substances have shown that plant growth regulators reduce the negative effects of low temperatures by increasing the activity of cell membranes and reducing oxidative processes [2].

Complex crosses also contribute to the expansion of the genetic diversity of the original populations. At complex crosses selections on recessive signs can be already begun in the first hybrid generation. The use of complex crosses contributed to the origination of precocious, cold-resistant initial forms with valuable recessive traits, thus varieties Zoren, Flora, Boyan were created [3].

During normal growth and development, plants are exposed to various types of stress, such as drought, heat, ultraviolet light, air pollution and pathogen attack. Most plants receive physiological and biochemical damage due to exposure to temperatures above or below optimal for growth and development. As a result, these injuries are reflected in most metabolic processes, which reduces the ability to grow crops and, consequently, commercial yields [4].

Sterile forms of tomato are used to create heterosis hybrids of the first generation. At the current level of breeding due to the need to reduce the complexity of the hybridization process, the need for sterile forms of tomatoes is growing. The use of male sterility in tomato plants does not require emasculation of flowers and allows to improve and reduce the cost of hybrid seed production.

In tomato plants, several types of sterility are known due to the *ms*, *sl*, *ps* genes: longostilia, functional male sterility (FMS), pollen genetic sterility, stamen sterility, stamenlessnessof flowers [5]. The most promising and suitable for mass production of hybrid seeds is FMS caused by the *ps* gene [6].

In our studies we used the phenomenon of functional male sterility (FMS), which is due to morphological deviations from the normal structure of the flower (*ps* gene) [7–9]. To create F_1 hybrids we studied tomato samples with FMS which is characterized by the inability to crack anthers and is controlled by the *ps* gene.

Using the variety John Bear (donor of the *ps* gene) at the Kyiv research station, breeder V.A. Kravchenko created breeding sterile lines using sterility (*ps* gene): Tat *ps*, Kyiv *ps*, Mar *ps*, Sat *ps* and others. Plants of such lines formed 1–2 small fruits on a plant without seeds during the growing season. Compared to other types of sterility the reproduction of such sterile lines is simple.

Cold resistance of plants at the beginning of the growing season and during the functioning of the reproductive organs is important for breeding for heterosis. When creating cold-resistant and early ripening F_1 hybrids, the ability to grow rapidly at low temperatures in the cool early spring period is important. This study is devoted to the identification of valuable source material with good cold resistance traits among available sterile forms.

The research was carried out for 2016-2018 years on the experimental field of Bila Tserkva National Agrarian University in the collection nursery. We studied 14 sterile forms of tomato obtained from the Kyiv research station and created by Professor V.A. Kravchenko.

Establishment of experiments, study and evaluation of sterile forms were carried out in accordance with the [10]. The study was conducted in comparison with the standard Flora variety. Cold resistance was determined by the methods [11, 12].

Calculations of the parameters of general adaptive ability, homeostatic and variance of specific adaptive ability of sterile form genotypes by earliness and cold resistance were performed according to the method of [13, 14]. The obtained results were processed according to the [15].

Results

The complex trait of cold resistance of sterile forms was evaluated taking into account simple traits that are easy to assess: the number of germinating seeds, the increase in plant height under cold stress and the rate of resumption when returning to favourable conditions in laboratory and field experiments. The forms Mar *ps* 59, Mar *ps* 53 and Sat *ps* 52 were characterized by highest cold resistance in the laboratory conditions (Table 1). These lines were characterized by seed germination in the range of 0,3–2,8 %, compared with other sterile forms with the germination 0,1–0,2 %. The increase in plant height under cool conditions in mentioned forms (Mar *ps* 59, Mar *ps* 53 and Sat *ps* 52) was higher (45–54 %) compared with other sterile forms. The plants quickly recovered growth in the early ontogenesis stages after exposure to low temperatures (10–13 %) at the level of the standard variety Flora (10 %).

In the laboratory the sterile form Mar *ps* 59 was characterized by the highest homeostatic among sterile formson the trait «seed germination» 0,03, and on the trait «increase in plant height» 1,17, compared to the standard 0,06 and 0,54 respectively, and on the trait «growth resumption rate» 0,31 (0,11 in the standard).

The adaptive ability of hybrids is a valuable feature in selection for heterosis, so the creation of original sterile forms with high adaptive ability is important for breeding and seed production of tomato heterosis hybrids F_1. Under conditions of reduced variable temperatures in the laboratory on the basis of traits «seed germination» and «increase of plant height», we identified sterile forms of Mar *ps* 53 and Mar *ps* 59 with general adaptive ability (GAAi) in the range of 0,2–0,9and variance of specific adaptive ability (σSAAi) in the range of 0,7–4,0 (Table 1).

Table 1. **Evaluation of the traits forming the cold resistance of tomato sterile forms in the laboratory (average for 3 years)**

Variety, line	Trait											
	Seed germination				Increase of plant height				Growth resumption rate			
	%	Hom	GAAi	σSAAi	%	Hom	GAAi	σSAAi	%	Hom	GAAi	σSAAi
Flora – standard	6,0	0,06	0,0	1,7	50	0,54	0,1	4,0	10	0,11	0,0	16,1
Sat *ps* 51	0,5	0,01	-0,1	0,3	43	0,95	-0,1	2,7	9	0,15	2,3	7,0
Mar *ps* 53	2,0	0,03	0,2	0,7	54	0,66	0,6	4,0	10	0,11	-4,0	1,3
Mar *ps* 59	2,8	0,03	0,6	1,3	48	1,17	0,9	3,7	12	0,31	-3,4	0,7
Sat *ps* 52	0,3	0,01	-0,1	0,1	45	0,85	-0,1	2,7	13	0,46	0,2	0,5
LSD_{05}	2,1				14,4				4,5			

Note: GAAi – general adaptive ability; Hom – homeostatic; σSAAi – variance of specific adaptability; LSD_{05} – least significant difference at 0,05 significance level

The sterile form Mar *ps* 58 differed from other samples by the highest level of specific adaptive ability on the basis of the «growth resumption rate» of plants in the laboratory, which was 10,3.

The period from sowing to germination is important to determine early maturity and cold resistance. Tomato seeds of sterile forms showed different terms of germination under conditions of low temperatures. Under changing environmental conditions, resistance or instability to cold in the early stages of ontogenesis may not be maintained at the stage of functioning of the reproductive system. Therefore, the definition of cold resistance under the action of low temperatures on the growth and development of seeds and seedlings may not fully reveal the complex cold resistance [12, 16, 17].

To further test for cold tolerance we planted the seedlings to be exposed to periodic early spring cold snaps. When the temperature decreased to – 2 °C, sterile forms of Mar *ps* 59 and Sat *ps* 52 were characterized by high cold resistance (4,8 and 4,3 points respectivelyon a 5-point scalein accordance with [10] (Table 2).

Table 2. **Homeostatic and adaptive ability of cold resistance traits of tomato sterile forms in the field (average for 3 years)**

Variety, line	Sowing - seedlings period				Trait							
					Increase of plant height				Cold resistance of seedlings			
	Days	Hom	GAAi	σSAAi	%	Hom	GAAi	σSAAi	Point	Hom	GAAi	σSAAi
Flora – standard	20	0,67	5,4	0,7	74	1,84	5,0	0,5	2,5	0,09	0,8	0,2
Sat *ps* 51	21	0,67	0,6	5,3	80	2,84	-1,3	0,0	4,5	0,29	0,4	0,5
Mar *ps* 53	19	0,40	-0,1	6,0	55	2,14	0,7	1,0	4,0	0,49	-0,1	0,0
Mar *ps* 59	19	0,40	0,6	7,3	60	1,27	0,7	1,0	4,8	0,19	0,4	0,5
Sat *ps* 52	18	0,55	1,2	4,7	80	1,41	-1,3	0,0	4,3	0,17	0,2	0,2
LSD_{05}	1,8				8,6				1,1			

Note: GAAi – general adaptive ability; Hom – homeostatic; σSAAi – variance of specific adaptability; LSD_{05} – least significant difference at 0,05 significance level

In the field, the duration of the interphase period «sowing – seedlings» was the shortest in the forms Mar *ps* 59 and Sat *ps* 52 compared with other forms studied. Thus, the duration of the period «sowing – germination» in the mentioned forms was 19 and 18 days respectively, against the standard Flora, 20 days. The increase in seedling height was 60–80 %, to the same extent with other forms and the standard, 74 %.

In the field, sterile forms Mar *ps* 53, Sat *ps* 51 were isolated, which had a homeostatic index 0,40 and 0,67 respectivelyfor the period «sowing – seedlings», and 2,14 and 2,84 for the «increase of plant height» (1,84 in the standard Flora). These lines hadhigh homeostatic on the trait of «cold resistance of seedlings», 0,29 and 0,49 compared to the standard, 0,09, and other samples (Table 2). Different meanings in the laboratory and in the field, in our opinion, indicate the dependence of the trait expression on the variability of weather conditions over the years of cultivation.

In the field, the highest level of adaptability was observed in the sterile form Mar *ps* 59 for both general and specific adaptive ability. The value of GAAiwas 0,4–0,7 for all three traits, the value of σSAAi was 0,5–7,3 for all three traits.

Conclusions

Analysing the traits of cold resistance, we found that sterile forms Mar *ps* 59 and Sat *ps* 52 have the highest performance in laboratory and field conditions and are the best in terms of cold resistance among the studied lines. This character is valuable for use in breeding for precocious in tomatoes. To create early ripening, cold-resistant heterosis F_1 hybrids, we recommend using them as source forms.

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