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SCREENING BREEDING LINES OF SWEET PEPPER AS PROMISING GENOTYPES FOR ESTABLISHING NEW VARIETIES

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Abstract. The article presents research results of sweet pepper breed lines selected as a promising material to solve the problem of creating new varieties of sweet pepper under the conditions of the Lower Volga region. It is necessary to study the various sweet pepper genotypes, select those that stand out for several valuable traits, and study their offspring for use as donors when creating new varieties. During 2020–2022, 54 collection samples were tested, and 29 breeding lines proved to be the best in several ways. This study investigated the maturity duration, fruit weight, pericarp thickness, and fruit color of the selected genotypes. The selected sweet pepper lines are of interest for further breeding work and can be used as genetic sources of valuable traits when creating new varieties under the conditions of the Lower Volga region of Russia.

Keywords: Vegetables, sweet pepper, breeding lines, phenology, fruit weight, pericarp thickness, fruit color.

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СКРИНИНГ СЕЛЕКЦИОННЫХ ЛИНИЙ ПЕРЦА КАК ПЕРСПЕКТИВНЫХ ГЕНОТИПОВ ДЛЯ СОЗДАНИЯ НОВЫХ СОРТОВ

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Аннотация. Приведены результаты исследований по выделению селекционных линий перца сладкого как перспективного материала при создании новых сортов. Для решения задачи по созданию новых сортов перца сладкого для условий Нижнего Поволжья необходимо изучение коллекционных образцов перца сладкого, отбор выделившихся по ряду ценных признаков, изучение их потомств для использования в качестве доноров при создании новых сортов. В течение 2020–2022 гг. были испытаны 54 коллекционных образца. Лучшими по ряду признаков показали себя 29 селекционных линий. Особое внимание уделяли изучению продолжительности периода «всходы — техническая спелость плодов», массе плода, толщине перикарпия, окраске плода. Выделившиеся линии перца сладкого представляют интерес для дальнейшей селекционной работы и могут использоваться в качестве генетических источников ценных признаков при создании новых сортов в условиях Нижневолжского региона России.

Ключевые слова: овощеводство, перец сладкий, селекционные линии, фенология, масса плода, толщина перикарпия, окраска плода

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***Introduction*.** Screening line breeding and genotypes are still an active method to increase genetic improvement before releasing plant breeding programs based on the obtained observations [8]. Agriculture is considered a principal pillar of the country's economy [9] and growing vegetables is one of the industries that play an essential role in supplying the population with foodstuffs of high biological value. Increasing the country's food independence is impossible without increasing the production of vegetables, which are indispensable food products for the population, ensuring human health to a certain extent. However, the consumption of vegetables per capita due to insufficient production is 105.7 kg, which does not correspond to the scientifically based norm of 140 kg [7]. In second place among nightshade crops in southern Russia is sweet pepper. Sweet pepper (*Capsicum annum* L.), belonging to the family Solanaceae, is one of the world's most varied and widely consumed vegetables. It originated in the Mexico and Central America regions [10; 16]. Sweet pepper Fruits have a high taste and nutritional and medicinal properties. You can use them fresh for canning, marinating, freezing, and

home cooking. They differ in shape, color, and size of fruits. Eating 1–2 of its fruits can provide the daily requirement of an adult for biologically active substances [2].

Table 1

Chemical composition and nutritional value of sweet pepper

Contents, %				Energy value		Vitamin contents, mg/100g		Acidity, %
Water	Protein	Fats	Carb	kcal/100g	kJ/100g	Vitamin C	Carotenoid	
92	1.3	–	4.7	23	96	150	1	–

Sweet pepper is a valuable vegetable crop used in various industries: food, pharmaceutical, and traditional medicine because of the richest biochemical composition of the fruit [6]. Pepper contains vitamin C, carotene, sugars, PP, B6, B12, and other biologically active substances [3]. Analyzing the figure, we can conclude that the vitamin C content in sweet pepper is much higher than in other vegetable crops (Figure 1).

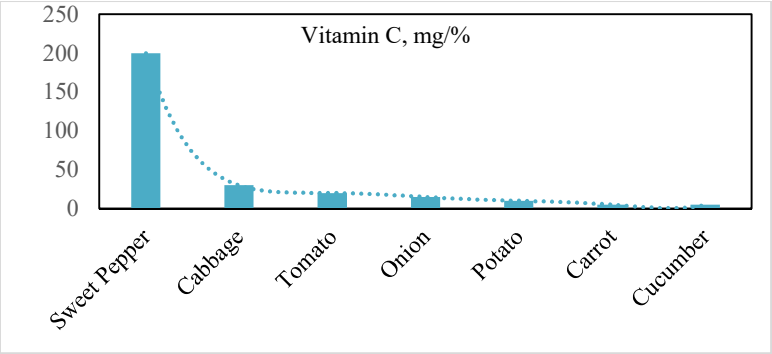

Figure 1 — Comparative characteristics of the content of vitamin C in vegetables, mg/%

The continuous demand and growing consumption of pepper require an increase in yield and varietal diversity, considering the various uses of the fruit. In Russia, a situation has developed in which imported seeds have largely replaced domestic ones. However, many of them, especially foreign selections, do not meet the requirements of the local market and are not adapted to local climatic conditions. The fundamental factor for increasing the yield of sweet pepper is introducing new, more productive varieties and hybrids with high-quality fruits that are resistant to diseases and pests, requiring minimal cultivation costs [3]. In recent years, primarily foreign hybrids have been grown in the fields, which are not always adapted to the region's climatic conditions. Therefore, grow in different regions of Russia for different categories of producers and to use products with high-quality fruits. The creation of domestic competitive high-yielding varieties of pepper with improved economically valuable traits, high technological qualities, with increased resistance to biotic and abiotic environmental factors in the regions of their cultivation, considering the requirements of producers, sellers, and consumers, is an urgent task. In this regard, we conducted a preliminary test of

collecting samples to identify the most promising under the conditions of Lower Volga region of Russia.

Materials and methods. The preliminary test included 54 collection samples of sweet pepper lines obtained as a result of selection (Table 2).

Table 2

List of the studied genotypes 1

Item No.	Genotype No.	source	Item No.	Genotype No.	Source
1	1SP2020	Georgia	28	1SP2022	Netherlands
2	20SP2020	Netherlands	29	2SP2022	Hungary
3	8SP2020	Netherlands	30	3SP2022	Hungary
4	4SP2020	France	31	4SP2022	Hungary
5	6SP2020	France	32	5SP2022	Hungary
6	5SP2020	France	33	6SP2022	Netherlands
7	7SP2020	France	34	7SP2022	Netherlands
8	3SP2020	Italy	35	8SP2022	Netherlands
9	19SP2020	Netherlands	36	9SP2022	Hungary
10	18SP2020	Netherlands	37	10SP2022	Hungary
11	17SP2020	Netherlands	38	11SP2022	Russia
12	16SP2020	EU	39	12SP2022	Russia
13	15SP2020	Netherlands	40	13SP2022	Russia
14	14SP2020	Netherlands	41	14SP2022	Russia
15	13SP2020	Turkey	42	15SP2022	Russia
16	12SP2020	France	43	16SP2022	Russia
17	11SP2020	Netherlands	44	17SP2022	Russia
18	10SP2020	Turkey	45	18SP2022	Russia
19	9SP2020	France	46	19SP2022	Russia
20	2SP2020	France	47	20SP2022	Russia
21	1SP2021	Russia	48	21SP2022	Russia
22	2SP2021	Russia	49	22SP2022	Russia
23	3SP2021	Russia	50	23SP2022	Russia
24	8SP2021	Russia	51	24SP2022	Russia
25	9SP2021	Russia	52	25SP2022	Russia
26	10SP2021	Russia	53	26SP2022	Netherlands
27	11SP2021	Russia	54	27SP2022	Netherlands

The experiments were conducted on the experimental station at Astrakhan State University, Southern Russia. Planting scheme 70 x 25 cm. Agrotechnical measures were carried out according to well-known methods [6, 1]. Irrigation method — drip, 4–5 times a week, depending on weather conditions and the condition of the plants. Sweet pepper was grown through seedlings. Sowing was carried out with dry seeds in the first decade of April in cassettes in the greenhouse complex. Care consisted of timely watering, loosening, weeding, and fertilizing with mineral fertilizers (Table 3).

Table 3

Agrotechnical management for the cultivation of sweet pepper

The work	The description
Predecessor	Winter wheat
Basic tillage	Autumn disks to a depth of 8–10 cm, plowing to a depth of 27 cm
Spring soil preparation	Harrowing in February, cultivation to a depth of 8–10 cm in March. In April, repeated harrowing + cultivation to a depth of 8–10 cm
Sowing seeds	In the 1st decade of April
seedling care	Watering: treatment against root rot, black leg; watering with Previkur Energy (30 ml/10 liters of water or Maxim 025. Thrips treatment: Confider (15 ml/10 l of water) Foliar feeding of seedlings: Novalon Foliar 20–20–20 (25 gr/10 l of water) + Hydrohumin (25 ml/10 l of water)
Transplanting	In the 1st decade of May
Watering (drip irrigation)	The first three weeks after planting the seedlings, watering with an interval of 1–3 days with an irrigation rate of 30-50 m3 / ha, then after 3–4 days (depending on the prevailing weather conditions)
Foliar top dressing Beginning of vegetation of plants: Flowering start: Fruit formation:	Novolon Foliar 10–45–15 (1 kg/ha) Novalon Foliar 20–20–20 (1 kg/ka) Hydrohumin — 1 l/ha Speedfol Bor — 1 l/ha Speedfol Calcium 0.5 l/ha Novolon Foliar 9–12–40 (1 kg/ha)
Integrated protection Pest protection:	 Confidor 20 % w.w.c. — 0.25 l/ha, Karate Zeon 5 % mk.s — 0.1 l/ha
sweet Pepper disease protection	Quadris 25 % s.s. — 0.6 l/ha Nativo — 0.2l/ha Strobi — 0.3 l/ha
Weed control:	Hand weeding 4–5 times per growing season
Fruit harvesting	In technical and biological ripeness

During the growing season, phenological observations were carried out according to the phases of development according to the "Guidelines for the selection of varieties and hybrids of pepper, eggplant for open and protected ground," 1997 [1]. The main morphological features were assessed using the UPOV method [21]. Breeding samples were evaluated by the growing season's duration, the fruit's average weight, and the thickness of the pericarp. According to the guidelines for the approbation of vegetable crops, 1982, varieties with less than 100 days from mass shoots to technical ripeness of fruits belong to the group of very early, 101–120 days — early, 121–135 — medium early, 136–150 — late, more 150 days is very late [4]. The selected samples, according to the sum of economically valuable traits, were used in further work as donors for various breeding directions.

Results and discussions. Due to variation of consumers demands in countries and to the various cultivation methods applied, many pepper genotypes

numbers are grown [13]. According to Mihálka et al., 2000, Mihálka et al., 2003 there are observed differences in regeneration capacity among the cultivated pepper genotypes [17; 18]. In order to solve the problem of creating new varieties of sweet pepper for the conditions of the Lower Volga region, we set a goal — the study of collecting samples of sweet pepper, the selection of those distinguished by several valuable traits, the study of their offspring for use as donors in the creation of new varieties. During 2020–2022 54 collection samples were tested. Twenty-nine breeding lines proved to be the best in many ways. At the same time, special attention was paid to the study of the duration of the period and "seedlings — technical ripeness of fruits" since breeding for early ripeness remains one of the priority areas and does not lose its relevance for the vast majority of crops, turning out to be a decisive condition for a sustainable increase in the size and quality of the crop [5]. The conducted studies show that between the collected samples of sweet pepper under the conditions of the Lower Volga region, there are significant differences in the duration of the period from germination to technical ripeness (Table 4).

Table 4

Distribution of studied genotypes according to maturity speed

Very early (≤ 100 days)	Early (101–120 days)	Mid-early (121–135 days)	Late (136–150 days)	Very late (≥150 days)
20SP2020	4SP2020	8SP2020	14SP2020	–
18SP2020	6SP2020	9SP2020		
17SP2020	5SP2020	6SP2022		
13SP2020	1SP2020			
1SP2022	7SP2020			
8SP2022	19SP2020			
	16SP2020			
	15SP2020			
	12SP2020			
	11SP2020			
	10SP2020			
	3SP2020			
	2SP2022			
	3SP2022			
	4SP2022			
	5SP2022			
	7SP2022			
	9SP2022			
	10SP2022			

It can be seen from the figure that 66 % is the number of samples belonging to the group of early (101–120 days), 10 % are medium-early (121–135 days) samples, and late ones make up only 3 %. Phenological observations made it possible to identify the earliest samples with a period of "shoots — technical ripeness" of less than 100 days, and they account for 21 %: 20SP2020, 18SP2020, 17SP2020, 13SP2020, 1SP2022, 8P2022, which can be used as sources of early ripeness. The shortest duration of this period for the sample 17SP2020 is 60–

65 days (Table 4). Also, a critical, economically valuable feature is the weight of the fruit. The average fruit weight for the studied samples varied between 50–350 g. Samples with a fruit weight of more than 140 g can be recommended as sources of large-fruited varieties.

The following samples should be used in breeding work to create large-fruited varieties: 8SP2020 (160–200 g), 4SP2020 (190–230 g), 5SP2020 (180–220 g), 6SP2020 (190–230 g), 7SP2020 (150–190 g), 14SP2020 (190–210 g), 18SP2020 (300 g), 17SP2020 (170–200 g), 9SP2020 (300–350 g), 1SP2022 (200–250 g), 2SP2022 (150–170 g), 4SP2022 (150–180 g), 9SP2022 (140–160 g), 10SP2022 (170–200 g), 16SP2022 (160 g), 3SP2022 (150 g). The maximum fruit weight (300 g) was obtained from 9SP2020 (Table 5). Different studies indicated that low fruit weight of bell pepper under different humidity regimes was observed [15] and during summer season pepper fruit weight ranged from 27.9 g to 90.5 g in India [11]. Whereas, in other investigation pepper fruit weight was higher than100 g [19] and fruit weight of sweet pepper ranging from 120 g to 132 g under different moisture treatments [12].

Table 5

Distribution of sweet pepper genotypes by fruit weight, g

Fruits ≥ 140 g		Fruit ≤140 g	
8SP2020	160–200 g	12SP2020	50–55 g
4SP2020	190–230 g	5SP2022	110–130 g
6SP2020	190–230 g	20SP2020	130 g
5SP2020	180–220 g	1SP2020	120 g
7SP2020	150–190 g	19SP2020	135 g
17SP2020	170–200 g	15SP2020	120 g
14SP2020	190–210 g	13SP2020	110 g
9SP2020	300–350 g	11SP2020	110 g
1SP2022	200–250 g	10SP2020	120 g
2SP2022	150–170 g	3SP2020	115 g
4SP2022	150–180 g	7SP2022	125 g
9SP2022	140–160 g	11SP2020	110 g
10SP2022	170–200 g	6SP2022	130 g
18SP2020	300 g		
16SP2020	160 g		
3SP2022	150 g		
8SP2022	140 g		

A crucial trait in pepper breeding is the thickness of the pericarp. Modern commercial cultivars, especially paprika hybrids, must have a wall thickness of at least 7 mm (Table 6). Of the studied samples, the sources of the thick pericarp (from 7 mm) can be:

Table 6

Distribution of the studied genotypes according to the thickness of the pericarp

Genotype	The thickness of the pericarp (≥7 mm)	Genotype	The thickness of the pericarp (≤ 7 mm)
6SP2020	7–8 mm	20SP2020	5–6 mm
5SP2020	6–8 mm	8SP2020	5–6 mm
1SP2020	6–7 mm	4SP2020	6–7 mm
16SP2020	До 9 mm	7SP2020	5–7 mm
1SP2022	7 mm	19SP2020	5–6 mm
3SP2022	7–8 mm	18SP2020	6–7 mm
4SP2022	6–8 mm	17SP2020	5–6 mm
6SP2022	8 mm	15SP2020	5–6 mm
9SP2022	7–8 mm	14SP2020	5–6 mm
10SP2022	7–8 mm	13SP2020	6 mm
1SP2022	7 mm	12SP2020	6–7 mm
		11SP2020	5 mm
		10SP2020	6 mm
		9SP2020	6 mm
		3SP2020	6–7 mm
		2SP2022	5 mm
		5SP2022	5 mm
		7SP2022	6 mm
		8SP2022	6 mm

As a result of the morphological evaluation of the studied samples, it was noted that almost all varieties and lines had compact, densely leafy plants, the necessary shape of the fruit (cone-shaped, cuboid, trapezoid, etc.), which meets the requirements of breeding programs. The color of fruits in biological ripeness for all samples was attractive: red, yellow, and orange. However, agricultural producers of sweet pepper and processing enterprises also use fruits in technical ripeness, so the color of fruits in technical ripeness should be from white to light shades of green, as it is more attractive to the consumer and for all types of processing (Table 7).

The work continued on the identification and use of breeding new genetic sources of economically valuable traits. In the direction of sweet pepper breeding, the best samples with cream and yellowish color in technical ripeness were selected for processing: 4SP2020, 5SP2020, 7SP2020, 16SP2020, 20SP2020, 3SP2022, 8SP2022, 9SP2022, 10SP2022. Seeds of individual selections were obtained, characterized by the following features: a beautiful shape and color of the fruit, the most enormous mass of the fruit, a wall thickness of more than 7 mm, and early ripeness. These genotypes are promising for a new breeding programs whereas offspring phenotypic variation follows its parental variation more closely, and the breeder is in positive case for making a better presumption about the phenotypic variation of the progeny, following the parental variation [14]. Our findings are similar with research study to evaluate twenty one genotypes of sweet pepper representing different sources whereas

a wide variations were observed in the morphological characteristics such as fruit set; fruit length; fruit length; fruits per plant; fruit yield of the studied genotypes [20].

Table 7

Morphological characteristics of the studied genotypes of sweet pepper

Genotype	Plant	Fruit		
		Form	Color	
			Physiological maturity	Biological maturity
20SP2020	Semi-spreading, well leafy	cuboid shape	Cream color	Glossy red
8SP2020	Semi-spreading, strong growth force, good foliage	Conical	light green	Orange
4SP2020	With a powerful root system, balanced, open, good foliage	Cone shaped with a blunt tip	Cream color	Glossy red
6SP2020	Compact, open, well-balanced, medium vigor.	Cone shaped with a blunt tip	Glossy light green	red
5SP2020	Powerful, balanced. With good sheet apparatus	Cone-shaped with a sharp tip	yellow green	red
1SP2020	compact	Conical	dark green	Intense red color
7SP2020	Powerful, compact	Cone shaped with a blunt tip	creamy	red
19SP2020	Vigorous growth force and powerful root system	Trapezoidal	dark green	bright red
18SP2020	Compact, vigorous growth force	cuboid shape	dark green	Glossy red
17SP2020	Semi-spreading, with good foliage	Elongated trapezoidal shape	yellow-green	red
16SP2020	Semi-spreading	cone shape	creamy	red
15SP2020	Compact with a well-developed root system and high foliage	cuboid shape	light green	Intense yellow color
14SP2020	compact	cuboid shape	bright green	Glossy yellow
13SP2020	compact	cone shape	dark green	Dark red
12SP2020	Compact, strong, with a strong root system, good foliage	Elongated cone shape	dark green	Glossy red
11SP2020	Compact, well leafy	cone shape	light green	bright red
10SP2020	With a good root system. compact	cone shape	dark green	red
9SP2020	Compact, with strong growth force and excellent foliage	cuboid shape	Greens	Red
3SP2020	compact	Elongated, cone-shaped	Glossy light green	red
1SP2022	Close, with good vigor	cuboid shape	Green	Red
2SP2022	Compact. Powerful, with a well-developed root system	cone shape	light green	red
3SP2022	Compact, strong root system	Block type, oblong	Cream color	Red
4SP2022	Compact, powerful growth force, well-developed root system	cone shape	dark green	Dark red
5SP2022	Compact with a powerful root system	oblong-flattened shape	dark green	dark red
6SP2022	semi spreading,	cone shape	Light green	Yellow color
7SP2022	compact	conical shape	green color	bright red
8SP2022	Semi-spreading	cuboid shape	yellow-green	Of red color
9SP2022	Strong with a powerful root system	cone shape	Cream color	Red
10SP2022	Semi-spreading, with a strong root system	cone shape	Cream color	Glossy red

Conclusion. This study was carried out to isolate the source material suitable for inclusion in the breeding program of creating varieties for the southern regions of Russia. The promising source material has been identified for inclusion in the breeding process: for precocity (vegetation period to technical ripeness is no more than 110 days); large-fruited (weight more than 140 g): thickness pericarp (7–10 mm). Also, in the direction of sweet pepper selection for processing, the best samples with cream and yellowish color in technical ripeness were selected. Thus, it can be said that the isolated sweet pepper lines are of interest for further breeding work and can be used as genetic sources of valuable traits when creating new varieties under the conditions of the Lower Volga region of Russia.

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