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Study of Growth, Yield, and Yield Quality Indicators of Tomato Hybrids in Hydroponic Systems under Greenhouse Conditions

A.M. Tadevosyan, N.A. Gasparyan, H.Z. Terteryan
Armenian National Agrarian University
alinatadevosyan1972@mail.ru, naira_job@yahoo.com, hasmik_terteryan1959@mail.ru

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ABSTRACT

The main goal of the research was to study greenhouse tomato hybrids under hydroponic greenhouse conditions and to enhance the agro-economic properties of tomato hybrids, offering farmers the hybrid that ensures high efficiency of tomato cultivation under hydroponic greenhouse conditions. During the vegetation period, phenological observations, biometric measurements, and crop counting were performed. Producing and selling vegetables in the local market is the primary activity of greenhouses and tomatoes occupy a significant place in vegetable production. In recent years, various varieties and hybrids have been imported into Armenia, most without testing. Tomato cultivation in greenhouses occupies a leading place in Armenia. The greenhouse tomato hybrids Merlis, Plumola, and Endeavor were researched.

Introduction

The common tomato, Lycopersicon esculentum Mill., is the most widespread species belonging to the genus Lycopersicon Tourn of the Solanaceae family (Edelshtein, 1962; Ananyan, et al., 1965; Zhukovsky, 1971; Zhuchenko, 1973; Matveev, Rubtsov, 1985; Akhatov, 2010, Chernysheva and Kolpakov, 2022). All tomato cultivars currently cultivated belong to Lycopersicon esculentum Mill, the biological species, which in turn is subdivided into three subspecies:

1. subsp. spontaneum Brezn – is a wild subspecies, which is divided into two other species: currant-like (var. pimpinellifolium) and raceme-like (var. racemigerum).

2. subsp. subspontaneum Brezn – is a semi-cultivated subspecies, which is divided into 5 other species: cherry-like (var. cerasiforme), pear-like (var. pyriforme), plum-like (var. pruniforme), elongated (var. elongatum), multi-stemmed (var. succenturiatum).

3. subsp. cultum Brezn – is a cultural subspecies, which is divided into the following varieties: common (var. vulgare), erect (var. vulgare), and large-leaved (var. grandifolium) (Zhuchenko, 1973; Akhatov, 2010).

Tomato subsp. cultum includes all cultivated varieties, which are divided into three groups according to the shape of the bush, the dynamics of the formation of leaves, flower clusters, and branches (Melikyan, 2005).

In greenhouses, when cultivated on vertical wires, the stem length of some varieties can reach up to 10 m or more. For example, in 2000 in Great Britain, vegetable growers grew tomato plants with a stem length of 19.8 m in greenhouses (Rubtsov, 2003; Melikyan, 2005; Akhatov, 2010). The high yield of tomato varieties and hybrids is not the only thing that matters, but the amount of biologically active substances contained in the fruits are also important. The quality and taste of the fruits are indicators of the fruits' nutritional value (Dilanyan, 2003; Kondratyev and Kandoba, 2007; Helmut, 2000). Tomatoes are rich in nutrients. Besides having high taste properties, fruits contain substances essential to human health. These substances include vitamins *A, B, C*, and PP, sugars, organic acids - citric acid, minerals - *Ca, Na, Mg, Fe,* etc. (Ayrapetova, 2000; Zurabyan, et al., 2003; Dilanyan, 2003; Kondrat'eva and Kondoba, 2007).

During 2018-2019, the Merlis hybrid was tested in a greenhouse environment of the Venlo type in the Lipetsk region of the Russian Federation (Bocharova, et al., 2020). A comparison was made between Maxesa and Merlis hybrids. Maxesa hybrid yield indicators were 68.3 kg m2 and Merlis hybrid yield indicators were 66.9 kg m^2. The Endeavor (Pic. 3) hybrid was also tested on various grafters in the Leningrad region of the Russian Federation in 2017-2018 (Puts and Snezhkov, 2021).

Materials and methods

The studies were carried out in 2021-2023, in the hydroponic greenhouse of Armenian National Agrarian University. The experiment includes two production phases. The object of the research was the tomato hybrids Merlis, Plumola, and Endeavor, which have not been compared under the given greenhouse conditions. Experiments were set up with 3 versions, and 4 replications. Several tomato hybrids were tested and the best were selected for recommendation to greenhouse farmers.

Planting density is determined by solar radiation, and the hybrid's growth (Asatryan, 2021). Planting density was 3.2 plants/m^2. During the growing season, the culture was carried out in a hydroponic greenhouse conditions according to the accepted culture protocol.

The following cultural activities were carried out: watering, nutrition, fixing stems to wires, pruning, removing leaves, lowering plants, pollination, and harvesting. Phenological observations, biometric measurements, and crop counting were conducted during the vegetation period. Following accepted agro-rules, climatic and nutritional regimes, as well as agro-technical measures, were provided for normal plant growth and development (Asatryan, 2021).

Results and discussions

The vegetation period is one of the most essential biological characteristics of the plants (Belik, 2000; Fatyanov, 2005; Torikov and Sychev, 2022). During the studies conducted in the vegetation period, phenological observations were made visually, and the beginning of regrowth, emergence of secondary and third stems, bud formation on the first and second flower clusters, the beginning of flowering, fruit formation, and fruit development stages were noted per the maturation times of the individual variants (Table 1).

Table 1. Vegetation period of tomato hybrids*

Tomato hybrids	Time to move to the greenhouse	Beginning of regrowth	Emergence of secondary stems	Emergence of third stems	The first inflorescence				The last inflorescence				Vegetation period (days)
					Bud formation	Beginning of flowering	Fruit formation	Fruit ripening	Bud formation	Beginning of flowering	Fruit formation	Fruit ripening	
Merlis	15.02	21.02	01.03	11.03	16.03	21.03	26.03	10.05	21.08	26.08	02.09	08.09	203
Endeavor	15.02	23.02	08.03	15.03	20.03	23.03	31.03	17.05	26.08	30.08	04.09	10.09	207
Prumola	15.02	22.02	04.03	13.03	18.03	22.03	29.03	14.05	23.08	28.08	03.09	09.09	206

*Composed by the authors.

Table 2. Weekly average growth of tomato hybrids*

Tomato hybrids	Weekly average growth (cm)	Average weekly growth			
		Number of leaves	Number of inflorescences	Number of flowers	Number of fruits per cluster
Merlis	17	3	1	7	5
Endeavor	16	3	1	6	4
Prumola	13	3	1	5	3

Table 3. Characteristics of the tested tomato hybrids*

Tomato hybrids	Fruit diameter (cm)	Average fruit mass (g)	Locule number
Merlis	21.4	130.2	3
Endeavor	19.9	127.8	3
Prumola	18.2	88.4	3

*Composed by the authors.

The studies have indicated that different hybrids of tomato plants have a slight difference in their growth and development stages with 3-4 days of variation. However, there was no significant difference between hybrids in terms of their growth, development, and vegetation period. The vegetation period was ranged from 203 to 207 days. In addition to phenological observations, biometric measurements were also conducted to study the morphological characteristics of the tomato plants (Table 2).

According to the data, the Merlis hybrid recorded the highest average weekly growth, 17 cm, whereas Plumola hybrids had the lowest height, 13 cm. Hybrids had the same number of leaves: 3 leaves appeared per week. The number of flowers in the investigated tomato hybrids varied from 5 to 7, the Merlis had the most.

Plant growth and quality indicators of yield should also be monitored during cultivation. There are clear requirements for export, which are internationally defined, according to which the quality indicators of the crop must meet the specified standards. According to the interstate standard 2018 on the requirements for the quality of tomatoes for fresh consumption, the quality of the tomato crop obtained as a result of the test was in compliance with the standard.

Merlis hybrids (Pic. 1) had the largest average fruit mass and fruit diameter, 130.2 g and 21.4 g, and Plumola (Pic. 2) was 88.4 g and 18.2 cm (Table 3).

Regarding fruit diameter and weight, Endeavor ranks between Merlis and Plumola hybrids. “Standard Dialog” LLC also conducted a chemical analysis of the harvested material (Table 4).

Picture 1. Cross section of Merlis hybrid.

Picture 2. Transverse section of Plumola hybrid.

Picture 3. Cross-section of Endeavor hybrid.

Table 4. Results of laboratory tests of fruits in experimented hybrids*

N	Index	Unit of measurement	Index value		Conclusion according to the results
			According to the normative documents	Results	
1.	Lead	Mg/kg	<0.5	<0.001	appropriate
	Arsenic	Mg/kg	<0.2	<0.001	
	Cadmium	Mg/kg	<0.03	<0.0001	
	Mercury	Mg/kg	<0.02	<0.0001	
2.	Lead	Mg/kg	<0.5	<0.001	appropriate
	Arsenic	Mg/kg	<0.2	<0.001	
	Cadmium	Mg/kg	<0.03	<0.0001	
	Mercury	Mg/kg	<0.02	<0.0001	
3.	Lead	Mg/kg	<0.5	<0.001	appropriate
	Arsenic	Mg/kg	<0.2	<0.001	
	Cadmium	Mg/kg	<0.03	<0.0001	
	Mercury	Mg/kg	<0.02	<0.0001	
4.	Nitrates	Mg/kg	<150	62.5	appropriate
	Patulin	Mg/kg	<0.05	<0.0001	
	Dry matter content in the liquid phase	%	-	4.0	
5.	Nitrates	Mg/kg	<150	58.61	appropriate
	Patulin	Mg/kg	<0.05	<0.0001	
	Dry matter content in the liquid phase	%	-	4.3	
6.	Nitrates	Mg/kg	<150	49.12	appropriate
	Patulin	Mg/kg	<0.05	<0.0001	
	Dry matter content in the liquid phase	%	-	5.0	

Table 5. The yield of tomato hybrids*

Hybrids	Yield		The difference according to the mean (6.9)	
	Kg/plant	Kg/m²	Kg/plant	%
Merlis	7.3	23.3	0.4	5.8
Endeavor	6.9	22	0.0	0.0
Prumola	6.4	20.4	-0.5	-7.2

*Composed by the authors.

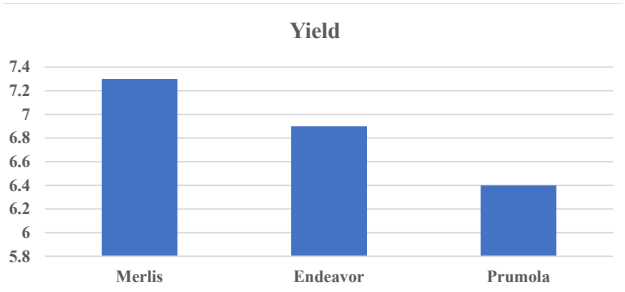

Figure. Yield of tomato hybrids, kg/plant *(composed by the authors)*.

Table data show that the obtained fruits are also ecologically safe. It is important to harvest tomatoes on time and sort the fruits as soon as possible after harvesting. Fruits are stored in small boxes with their stalks facing up. A high yield is the ultimate goal of developing any crop variety or hybrid.

The yield indicator was also determined by recording the yield per unit area (1 m^2) (Table 5, Figure).

As a result of our experiment, the Merlis hybrid has recorded the highest yield: 23.3 kg/m^2, Endeavor had 22 kg/m^2, and the Plumola hybrid had the lowest yield: 20.4 kg/m^2.

Regarding the mathematical analysis of the yield data, it is worth mentioning that the error of the experiment is within the permissible limits, and differences in yield of individual hybrids were compared with the average index of the three versions, 6.9 kg/plant, according to which there are no significant differences between them. However, the index of the first version increases, whereas the third version decreases.

It is also important to note that no crop diseases were observed during the vegetation period; greenhouse whitefly (Trialeurodes vaporariorum) and tomato moth (Tuta Absoluta) were observed as pests, which were controlled with appropriate plant protection products.

Conclusion

In contrast to the other tested varieties, the Merlis hybrid had a shorter vegetation period of 203 days, 3-4 days shorter than the other varieties. Another notable feature of the Merlis hybrid was the number of fruits formed on one bush, which amounted to 6, against those of other hybrids with 1-3 fruits. Merlis hybrid showed the highest weekly growth rate, 23.5 %.

Based on the yield data from the unit area (1 m^2), the Merlis hybrid has again obtained a yield of 23.3 kg/m^2, surpassing the yield of the other tested hybrids by 1.3-2.9 kg. According to the research findings, Merlis is preferred over other hybrids for cultivation in hydroponic conditions. Anyhow, hydroponic cultivation is also effective with Endeavor and Plumola hybrids.

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