The selecting suitable tomato (solanum lycopersicum) hybrids for growing by hydroponics in greenhouses

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Abstract. Among the tomato hybrids studied in the scientific article on hydroponic cultivation of tomatoes (Solanum lycopersicum) in the greenhouse, there are high-quality and high-yielding (yield 19.4-20.7 kg/m²) varieties resistant to fusarium wilt and cladosporiosis. It is stated that the share of the high yield is 93.6-93.9%, the weight of one fruit is 178-180 g) Daphnis F1, Torri F1 and Pink Paradas F1 hybrids were selected.

1 Introduction

Tomato (Solanum lycopersicum) is one of the main crops among vegetables, and it is important to increase its production and improve product quality. Currently, the area planted with tomatoes in the world is 3.0 million ha, its productivity is 70-100 t/ha in the open field, 180-200 t/ha in greenhouses, and 250-350 t/ha in hydroponic conditions [1-10]. Hydroponic farming reduces water wastage, prevents the spread of weeds, disease and nematodes, conserves water and fertilizers, and prevents environmental pollution. Currently, this method is developed in countries such as Holland, Turkey, South Korea, Israel, and China. Hydroponic greenhouses account for 80% of greenhouses in Scandinavian countries and more than 50% of greenhouses in the Netherlands [4].

In South Korea, experiments were conducted in hydroponic greenhouses aimed at reducing the diseases of vegetable products with environmentally friendly and beneficial fungi and growing high-yielding products. Many types of hydroponics are used: wick, drip, flow, water culture, nutrient film technology, aeroponics and chemoponics methods [7]. In Florida, USA, several tomato hybrids such as Jumbo, Laura, Caruso and Trend F1 are grown in greenhouses. According to the results, the Trust and Match hybrids had larger fruit, dark green, disease resistance and the highest yield [8].

It is important to select the optimal varieties and hybrids for the cultivation of high-yielding tomato hybrids among vegetable crops under hydroponic conditions in Uzbekistan, as well as to develop technologies for their cultivation.
2 Materials and methods

The purpose of the research is to distinguish tomato (Solanum lycopersicum) high-yielding, disease-resistant varieties and hybrids in hydroponic greenhouses. The tasks of the research are to distinguish promising hybrids in the cultivation of tomato (Solanum lycopersicum) seedlings in hydroponic greenhouses in terms of quick ripening, productivity, resistance to fusarium wilt and cladosporiosis, marketability, and fruit quality.

The research was conducted in 2015-2018 in a film hydroponic greenhouse built on the basis of South Korean technology at the “Center for Innovative Developments and Consultancy in Agriculture” at the Tashkent State Agrarian University. The experimental area is the Chirchik Highlands, characterized by high solar radiation, daily and seasonal temperatures, continental, dry and hot in summer, high humidity in spring, and cold hardiness in winter.

The hydroponic greenhouse is built on the basis of South Korean technology, the roof is arc-shaped, 7 sections, covered with polyethylene film, the area of the construction area is 5000 m². Each piece was 8 m to 94 m long. There are aluminum curtains, nets on the right, left, back and sides, and curtains on the right, left, back and top that protect the plant from the heat of the sun.

The greenhouse has an automated control system, consisting of fogging equipment that regulates air humidity, a ventilation system, sensors and sensors that measure air temperature, humidity and heat. In addition, it has a heating system (working with gas, oil products), a boiler room, a drip irrigation system, water and mineral fertilizer storage tanks, and a water and mineral fertilizer mixing system.

There are polyethylene cassettes, foam blocks, coconut husks and other substrates for conducting experiments, that is, for preparing seedlings. The experiment was conducted on F1 hybrids adapted to growing tomatoes in hydroponic conditions. In Uzbekistan, the Rofita F1 hybrid, adapted to growing in a modern hydroponic greenhouse, was planted as a standard. In the experiment, 6 hybrids from foreign seed companies such as De Ruiter Seeds, Enza Zaden, Syngenta, Zeraim Gedera, Seed Technologies, Tezier, Clause were compared to the standard Rofita F1 hybrid.

The experiment has 4 returns, the feeding area is 6.4 m². The planting pattern is 90+50/33 cm, the area is double, 4 m long, 1.6 m wide, and there are 24 plants. Experiments “Methodological recommendations for conducting experiments with vegetable crops in protected ground structures” [5], “Guidelines for breeding varieties and hybrids of tomato for open and protected ground” [1], “Methodological guidelines for growing heterotic tomato hybrids of breeding for protected soil” [6] and the statistical analysis of the results was calculated using the dispersion analysis method in the “Metodika polevogo opyta” [3] Statistica 7.0 for Windows computer program.

During greenhouse experiments, phenological observations included the time of sowing seeds, germination of 10% and 75% grasses, formation of 1st and 5th cotyledons, emergence of 1-2-3 pods, emergence of flowers in 1-2-3 pods, 1-2-3 shingles, the beginning and end of fruit formation was determined.

In biometric measurements, the length of the main stem, the number of leaves, the number of pods, and the number of fruits per pod were determined on the 97th, 170th, and 230th days after germination in 3 plants from each hybrid. The total harvest was collected in each area, each fraction was weighed separately on scales, and the marketable and non-marketable yield was calculated in kilograms per square meter. During the assessment of plants for disease resistance, it was found that they are infected with cladosporiosis. Observations were conducted in the second half of the plant’s growth period (March, April and May). Calculations were made based on the damage rate of plants in each site “Guidelines for breeding varieties and hybrids of tomato for open and protected ground” [1].
Experiments in preparation for sowing tomato seeds, one seed was sown in each nest of 264 foam block cassettes for sowing seeds, and after sowing, the seeds were mulched with a mixture of vermiculite and coconut husk to a thickness of 0.5-1 cm. Then, the seeds were soaked in water to moisten them, the cassettes were picked in one layer on a 40-cm-high straw, and the cassettes were covered with paper. The seeds were soaked until they germinated and the covering paper was removed as soon as the seeds germinated (Figure 1).

Fig. 1. Preparation of tomato seedlings in an experimental greenhouse and hydroponic cultivation

Phenological and biometric observations were made in the experiment. The dates of tomato seed germination, leaf emergence, budding, flowering, fruit set, and fruit ripening were determined.

3 The results and discussion

Tomato hybrids were sown in 240 cell cassettes made of special material (foam block) on August 4, 2016, August 18, 2017, and August 2, 2018. Preparation of tomato seedlings in the experiment was grown in a separate section of the greenhouse. According to the results of phenological observations, the seeds sown in foam blocks fully germinated in 5-7 days. Among the tested hybrids, Daphnis F1, Leslie F1 and Lamia F1, which germinated relatively early, germinated in 5 days. The latest germination was 7 days in Jalila F1 hybrid.

In the experiment, the appearance of the first and fifth leaves of the plants was observed. In this case, the first leaves appeared in 5-7 days between hybrids. The fifth leaves were observed on 22-25 days, i.e. on the earliest 22 days in Daphnis F1 and Pink Paradene F1 hybrids. In the remaining hybrid, it was observed between 23-25 days. On the day of the first seed emergence, the first seed emergence was observed at 38-39 days in Torry F1 and Daphnis F1 hybrids, and the third seed emergence was observed 50-52 days after seed germination in these hybrids. Among the remaining hybrids, Jalila F1 is a relatively late hybrid that ripens in 63 days.

Inter-hybrid when hybrids are observed to flower in the experiment. Torry F1 and Daphnis F1 were hybrids that bloomed relatively early, making 48-56 days. Leslie F1 and Jalila F1 hybrids flowered relatively late at 55-56 days. This, of course, depended on the adaptation of hybrids to hydroponic conditions and the biological characteristics of the variety.

In the conducted experiment, it was determined that the fruits of the tested hybrids ripened and ripened early. Torri F1, Daphnis F1 and Lamia F1 hybrids, which ripened the earliest, ripened 96-97 days after germination. Jalila F1 was the latest hybrid to harvest -108 days, and other hybrids were 100-106 days.
The studied hybrids can be divided into 3 groups depending on the period from the germination of the seeds to the ripening of the fruit:

1. Early hybrids (fruit ripening period 96 - 97 days: Daphnis F1, Torri F1, Lamia F1);
2. Medium hybrids (fruit ripening period 98 - 102 days: Rofita F1 (st), Pink Paradaes F1);
3. Late ripening hybrids (fruit ripening period 103 - 108 days: Leslie F1, Jalila F1).

According to the obtained data, the hybrid of standard Rofita F1 and Pink Paradaes F1 flowered and yielded equally. Torry F1, Daphnis F1, and Lamia F1 hybrids bloomed 2 - 3 days earlier than the standard, matured 5 - 6 days earlier than the standard, and other hybrids bloomed late and ripened later than the standard.

When determining the duration of the tomato yield period in hydroponic conditions, it was found that the hybrids yielded 201 - 232 days. Daphnis F1 and Lamia F1 hybrids yielded the longest 232 days (5 days longer than the standard). Hybrids with short duration of yielding were 201 - 211 days in Pink Paradaes F1 and Jalila F1, 26 - 16 days less than the standard.

Hybrids can be divided into the following groups according to the duration of production:

To the first group. Hybrids with a duration of 200 - 211 days (Pink Paradaes F1, Jalila F1);
To the second group. Hybrids (Leslie F1, Rofita F1 (st)) with a duration of 213 - 227 days;
To the third group. Hybrids with a duration of more than 230 days (Torri F1, Daphnis F1, Lamia F1).

In the experiment, biometric measurements were performed, in which the length of the main stem of the plant, the diameter of the main stem, and the number of leaves were determined based on the results of the measurements taken 97, 170, and 230 days after seed germination (Table 1). It was found that the length of the main stem of the tested hybrids increased from 88 to 196 cm after 97 days of seed germination, and from 198 to 355 cm after 170 days of observations. At the end of the plant growth period, i.e., according to the results of 230 days of observation, the distance between hybrids was 466 cm to 804 cm.

In the experiment, the length of the main stem in all three observations was the Torry F1 hybrid with the highest index (230 days - 804 cm) compared to the standard by 39 cm and the Jalila F1 hybrid with the lowest index (230 days - 466 cm) compared to the standard. 299 cm was found to be relatively short. In the remaining hybrids, it was found that it grew up to 508 - 782 cm at the last observation.

It should be noted that the length of the main stem also depends on the diameter of the stem. In the experiment, measurements of the diameter of the main stem were also determined in three observation periods. According to the results of the experiment, the largest or highest diameters at the last observation were hybrids Daphnis F1 and Torry F1, which were 2.1 - 2.2 cm, 0.1 - 0.2 cm higher than the standard, and hybrid Jalila F1 with a relatively thin stem (1.8 cm) was observed. Lamia F1 hybrid stand

<table>
<thead>
<tr>
<th>Hybrids</th>
<th>Number of branches, pcs</th>
<th>Number of fruits, pcs</th>
<th>Disease resistance, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Days</td>
<td>97</td>
<td>170</td>
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| Rofita F1 (st) | 57 | 170 | 230 | 97 | 170 | 230 | 0 | 0 | 0 |
| Daphnis F1 | 68 | 170 | 230 | 97 | 170 | 230 | 35 | 78 | 0 |
| Lamia F1 | 88 | 170 | 230 | 97 | 170 | 230 | 30 | 66 | 0 |
| Torry F1 | 97 | 170 | 230 | 97 | 170 | 230 | 30 | 66 | 0 |
| Pink Paradaes F1 | 107 | 170 | 230 | 97 | 170 | 230 | 30 | 66 | 0 |
| Jalila F1 | 117 | 170 | 230 | 97 | 170 | 230 | 30 | 66 | 0 |

Table 1.
On the 230th day of observation, we see that this indicator has increased. Because the increase in light and temperature caused shingles to appear quickly. There was one Daphnis F1 (16 pieces) hybrid, which produced more shingles compared to the standard, making 11–16 shingles in the hybrids. The Torry F1 hybrid (15 pieces) produced shingles in the same way as the standard Rofita F1 hybrid. The rest of the hybrids have fewer shingles than the standard (11–13 pieces).

In the experiment, we can see that the number of fruits is less in the previous observation, i.e. on the 97th day, and relatively increased in the observation on the 170th day. Among the hybrids, the standard Rofita F1 hybrid produced 30 fruits, and compared to it, 32–35 fruits were produced in the hybrids of Daphnis F1 and Torry F1. The Jalila F1 hybrid (24 pieces) gathered the least amount of fruit. On the 230th day of observation, the number of fruits of the control Rofita F1 hybrid was 66, while it was found that Daphnis F1, Torry F1 and Pink Paradaes F1 hybrids collected 2–12 more fruits. In the remaining hybrids, this indicator was 58–62 pieces.

Resistance to diseases and pests is also one of the main valuable economic traits when selecting promising hybrids. In particular, it is important to determine this indicator when growing tomato plants in film greenhouses, that is, in conditions with high relative humidity that allow the development of several pathogens.

Fusarium wilt and cladosporiosis or leaf spot diseases are more common when growing tomatoes in greenhouses, because these diseases spread quickly at high humidity (90%) and temperature (20–25°C). This leads to a decrease in the yield of tomatoes. Therefore, most greenhouse hybrids should be resistant to these diseases.

In the experiment, the diseases were detected by eye against a normal background and the observation results were presented. Among the hybrids, Leslie F1 and Jalila F1 were affected by fusarium wilt disease at a very low level (5%). The rest of the hybrids did not suffer from this disease.

Pink Paradaes F1 hybrid was affected by leaf spot disease (cladosporiosis) by 20% and 1.2 points. Jalila F1 hybrid was infected with this disease in 25% and 1.5 points. Other
hybrids tested did not suffer from this disease. In the experiment, all hybrids except Leslie F1, Pink Paradaes F1 and Jalila F1 hybrids were found to be resistant to diseases. The total yield of the tested hybrids was determined (Fig. 1). In this case, the standard Rofita F1 hybrid collected 38% of the total yield, i.e. 7.5 kg/m$^2$. Comparing the hybrids, Daphnis F1 and Torry F1 hybrids gave 20.6–22.6% higher yield and the share of the yield was 41–42%. We can observe that the Pink Paradaes F1 and Leslie F1 hybrids (98–109 %) collected a fabulous harvest, the same as the standard. The lowest was Jalila F1 hybrid, which was 7.0 kg/m$^2$, 93.3% of the standard.

In the experiment, it was found that Daphnis F1 and Torry F1 hybrids have a high percentage of early and late harvest for cultivation in hydroponic greenhouses.

Fig. 2. The Yield of tomatoes in a hydroponic greenhouse from F1 hybrids, kg, m$^2$ (until February 1, 2016–2018 on average)

Tomato hybrids can be divided into groups according to the percentage of tomorrow’s harvest (in %):

1. The share of tomorrow’s harvest is up to 40% (Lamiya F1, Rofita F1 (st), Jalila F1);
2. The share of tomorrow’s harvest is more than 40% (Leslie F1, Pink Paradaes F1, Torri F1, Daphnis F1).

Tomato F1 hybrids have one stem per plant and high remontant, i.e. uniform yielding (constant renewal of growth and flowering) and belong to the indeterminate type with strong vegetative growth. Most of the hybrids are grown in greenhouses [2].

In the research, the productivity indicators obtained from one square meter of various hybrids were determined in the conditions of small-scale hydroponics of tomatoes (Fig. 2). In this, the harvest was weighed in each harvest, according to each variant and repetition, and the marketable and non-marketable crops were separated. The total yield, marketable yield and the share of marketable yield, as well as non-profitable, i.e. deformed, crooked, double, heavily ribbed, rotten and damaged fruits were separated from the total harvest. Productivity can be divided into the following groups according to the classification "Wide unified classifier CEB of the genus Lycopersicon Turn" [9], which is generally accepted for the commercial productivity of tomatoes:

1. Hybrids with a very low yield of 15 kg/m$^2$, that is, below 70% (Jalila F1, Lamiya F1);
2. Hybrids with a low yield of 15.6–18.7 kg/m$^2$, i.e. 71–90% (Lesli F1, Rofita F1 (st));
3. Hybrids with an average yield of 19.4–20 kg/m$^2$, i.e. 91–105% (Pink Paradaes F1, Torri F1);
4. Hybrids with high productivity of 20 kg/m$^2$, i.e. more than 106% (Daphnis F1);
5. In our experience, we did not record hybrids with a very high product yield of 25.5–30.0 kg/m$^2$, that is, up to 130%.
In the experiment, the yield of tomato F1 hybrids in a hydroponic greenhouse (average 2016-2018) differed between hybrids. In this case, the highest marketable yield was obtained in Daphnis F1, Torri F1 and Pink Paradaes F1 hybrids, 19.4-20.7 kg per square meter, and the share of marketable yield was 93.6-93.9% (Fig. 3). It was noted that the marketable yield of the standard variant was 18.4 kg, 92.5%, and the remaining options were 14.4-15.6 kg, and the share of the marketable yield was 82-85.1%. This certainly means that in the selection of various hybrids of the tomato plant in small-scale hydroponic conditions, the samples with the highest yield were separated.

Compared to the standard Rofita F1 hybrid, it was found that Dafnis F1, Torri F1 and Pink Paradaes F1 hybrids gave 5-13% higher yield and better yield quality. The remaining options yielded 15-22% less than the standard.

In the experiment, the main reasons for obtaining a relatively high yield from the hybrids were their suitability for small-scale hydroponic conditions, the morphobiological characteristics of the hybrids and their suitability for hydroponic greenhouses.

The average weight of the fruit of the tested hybrids was determined in the conducted research. Daphnis F1, Torri F1 and Pink Paradaes F1 hybrids with the highest fruit weight among hybrids had an average fruit weight of 178-180 g, while the lowest value was 147 g in Lamia F1 hybrid. In other options, this indicator was 152-161 g (Fig. 4).

4 Conclusion
Daphnis F1, Torry F1 and Lamia F1 hybrids, which are early (5–6 days) and long (3–5 days), resistant to fusarium wilt and cladosporiosis diseases, as well as strong-growing hybrids Daphnis F1 (stem length 782 cm, number of leaves 48 pieces) and Torri F1 (stem length 804 cm, number of leaves 49 pieces) with high stem length, diameter and number of leaves were identified.

In hydroponic conditions, the best, high-quality and high-yielding tomato hybrids Daphnis F1, Torri F1 and Pink Paradaes F1 (19.4–20.7 kg/m²) were isolated, and the share of marketable yield was 93.6–93.9%, compared to the standard variety. was higher by 5–13%.

Daphnis F1, Torri F1 and Pink Paradaes F1 hybrids with the highest fruit weight (178–180 g) were identified.

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