Anatomical and morphological traits of the okra root system and the growing practice in plastic-covered greenhouses

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Abstract. The article presents studies of the anatomical and morphological traits of the okra root system and elements of the okra growing practice in plastic-covered greenhouses. The studies were carried out in 2018–2020 on the territory of the Educational and Scientific Production Center "Vegetable Experimental Station named after V. I. Edelstein", Federal State Budgetary Educational Institution of Higher Education Russian State Agrarian University – Moscow Timiryazev Agricultural Academy. The two ways of formation were studied (1 and 2 stems). As a result of the research, the anatomical and morphological traits of the okra root system were clarified, the highest yield of okra fruits of the Lady's Finger variety was established when plants were formed in two shoots. To obtain the highest yield of fruits, we recommend growing the Lady's Finger variety, forming plants in 2 shoots, while the yield is 1.6 kg/m$^2$, which is 0.2 kg/m$^2$ higher than the yield of this variety obtained when plants were formed in 1 shoot.

1. Introduction

Every year more and more people in the world and in our country prefer a healthy lifestyle and healthy food. People pay increased attention to their nutrition, monitor the balance of carbohydrates, proteins, fats, and include more vegetables in the diet, regardless of age [1,2,3].

In order to expand the range of food and prevent diseases such as peptic ulcer and gastritis, the population of many countries prefers okra fruits, as they are rich in mucilaginous substances [4,5].

Okra (Abelmoschus esculentus (L.) Moench) is a plant in the mallow family. Okra fruits are popular in tropical and subtropical regions of the world [6,7]. They contain vitamins A, K, ascorbic acid, carbohydrates and dietary fiber, lipids and amino acids [8,9,10]. The polysaccharides contained in okra fruits are biodegradable and biocompatible polymers, and therefore they are used in various pharmaceutical preparations [11, 12].

Young (3-4 day old) pods are eaten, overripe fruits are inedible. With the wrong storage temperature on store shelves, in local markets in producing countries, okra fruits quickly lose weight and marketability due to high respiratory metabolism, and quickly become stringy [13]. The taste of the fruits resembles eggplant and asparagus, which makes them widely used in cooking. Okra does not require long-term cooking: boiled or sauteed, it can serve as a side dish for meat or poultry, as well as a soup garnish. It goes well with tomatoes, garlic, onions, ginger, paprika, and other spices. Okra fruit is also pickled, frozen and dried, and its mature seeds are even used as a coffee substitute and cakes [14].
Over the last years, there has been an interest in okra fruits in Russia from consumers and from pharmaceutical companies, but there are no growing technologies. Meanwhile, the discussion on the choice of technology for the production of okra products in our country remains relevant, and, in our opinion, the answer to the question of which is more profitable - growing in open or protected ground, requires studying. In this article, we decided to share our experience in solving the problem. The studied varieties of the species *Abelmoschus esculentus* (L.) Moench are plants of southern latitudes, mesophytes, which are poorly adapted to drought conditions. In this vein, the study of the anatomical and morphological traits of the root system structure of the studied varieties will reveal their adaptive capacity. The study of the question of methods of plant formation on the growth processes and productivity of okra will determine the technology for the production of okra products.

The purpose of the work is to identify the best available technologies for growing okra in plastic-covered greenhouses in the summer-autumn turnover.

To achieve this goal we studied the anatomical and morphological traits of the root system structure of the studied varieties; revealed the influence of the methods of forming okra plants on the growth processes and productivity.

**2. Materials and methods**

Scientific research was carried out in 2018-2020 in a plastic-covered greenhouse on the basis of the Educational and Scientific Production Center "Vegetable Experimental Station named after V. I. Edelstein" Russian State Agrarian University – Moscow Timiryazev Agricultural Academy in the summer-autumn turnover.

Experiment I. We studied the root anatomy of varieties of the genus Hibiscus in young generative plants in a critical period with respect to water delivery - the phase of the beginning of budding. When carrying out ecological and anatomical studies of the root, permanent microtome preparations were made according to the method of Z.P. Pausheva [15].

Experiment II. Revealing the influence of the best possible ways of forming okra plants on growth, development and crop productivity. Two-factor experiment: factor A "cultivar genotype" - Lady's Finger, Red Velvet; factor B "methods of formation", option I – 1 shoot; option II – 2 shoots.

Experimental studies were carried out in a summer-autumn turnover in a plastic-covered greenhouse in accordance with common methods for vegetable crops in protected ground. Counting the yield was carried out in dynamics, weighing the fruits from the plot after each harvest [16].

Statistical processing of the data (the significance of differences was assessed by the Student's t-test and was considered statistically significant at \( p \leq 0.05 \)) was performed in Microsoft Excel 7.0 and STATISTICA 6.0.

Agricultural methods in the experiment: the beginning of the summer-autumn turnover on May 19-20, 2018-2020, liquidation on September 19-20, 2018-2020. Seedlings were grown in the seedling section of the Richel 9.6 SR series greenhouse. Seeds were sown in cell packs with a cell volume of 180 cm\(^3\), followed by transfer into pots with a volume of 0.8 l. The seedlings are 40 days old. Average daily temperatures were set depending on the phase of plant growth and development. Before planting seedlings, the soil in the greenhouse was mulched with black non-woven material. The density of the shoots in the I variant is 2.0 pcs/m\(^2\), in the II – 4.0 pcs/m\(^2\)

**3. Results and discussion**

Table 1 shows the laboratory findings of the anatomical and morphological traits of the root system of the studied varieties, as one of the indicators of their adaptive capacity and plasticity. The most attention was paid to the study of the conducting system (xylem and phloem), since the development of a more powerful conducting system ensures a faster flow of water into plant leaves and promotes more intense transpiration.

The root of the studied varieties is of the non-bunch type. The epidermis consists of one layer of tightly closed living cells, under the epidermis there is a two-layer angular collenchyma, then there is a three-layer cortical parenchyma, consisting of rounded cells. The greatest thickness of the xylem in
relation to the thickness of the root was noted in the variety Lady's Finger – 64%, which indicates the greatest drought hardness adaptation of the root system.

Table 1. Root anatomy of the studied okra varieties

| Varieties       | Epidermis, μm | Collenchyma, μm | Cortical parenchyma, μm | Phloem, μm | Cambium, μm | Xylem, μm | Root diameter, mm |
|-----------------|---------------|----------------|-------------------------|------------|-------------|-----------|-------------------|
| Lady’s Finger   | 24.55±2.4     | 134.28±2.8     | 38.8±3.8                | 598.6±7.0  | 46.8±4.2    | 3568.6±1  | 5.6±0.32          |
| Red Velvet      | 25.54±2.0     | 170.22±3.4     | 54.3±5.0                | 764.8±5.6  | 53.6±3.8    | 4210.2±1  | 7.2±0.12          |

Table 2. Influence of plant formation methods on the dynamics of growth processes (average for 2018-2020)

| Formation methods | Plant age (number of days from germination) | 45 | 75 | 105 | 135 |
|-------------------|--------------------------------------------|----|----|-----|-----|
|                   |                                            | 1  | 2  | 3   | 1   | 2  | 3   | 1   | 2  | 3   |
|                   |                                            |    |    |     |     |    |     |     |    |     |
| Lady’s Finger I   |                                            | 24±1.4 | 6.0±0.8 | 56±4.2 | 8±1 | 8.25±0.4 | 86.4±3.4 | 12±1 | 7.6±1 | 114.0 | 17±1 | 5.5 |
|                   |                                            | 2  | 8  | 4   | .0  | 3.0  |     |     |     |     |     |     |
| Lady’s Finger II  |                                            | 23±1.2 | 5.9±0.4 | 47.2±2.8 | 8±1 | 7.9±1.0 | 68.4±2.6 | 12±1 | 5.7±0 | 95.6±  | 15±1 | 5.2 |
|                   |                                            | 2.8 | 6  |     | .6  | 2.4  |     |     |     |     |     |     |
| Red Velvet I      |                                            | 22±1  | 5.5±0.6 | 54.4±2.6 | 8±1 | 8.1±1.0 | 74.0±3.4 | 11±1 | 6.5±0.8 | 97.5±   | 16±1 | 4.7 |
|                   |                                            | 2   | 0  |     | 2.5 | 2.5  |     |     |     |     |     |     |
| Red Velvet II     |                                            | 22±1  | 5.5±0.6 | 53.2±3.0 | 8±1 | 7.8±1.2 | 62.8±2.0 | 10±1 | 4.8±0.8 | 79.6±    | 14±1 | 4.2 |
|                   |                                            | 0   |     |     | 2.2 | 2.2  |     |     |     |     |     |     |

Note: methods of formation: I - one shoot, II - 2 shoots; 1- length of the main shoot, cm, 2 - number of leaves on the main shoot, pcs, 3 - internode length, cm.

The dynamics of the okra growth processes with different methods of plant formation is presented in table 2. No statistically significant influence of the "methods of formation" factor on growth processes was revealed. According to the results of biometric observations, the most intensive growth was observed before the beginning of fruit formation in the studied varieties in all formation variants, the average daily growth was 0.7 cm with the maximum value in the Lady's Finger variety. In the beginning of the fruiting period, a decrease in the intensity of growth processes was noted (by 105 days) and subsequently (by 135 days) this tendency remained. Additional shoot, fruit load, intense flowering and fruiting on the main shoot led to a decrease in internode length and, accordingly, to a decrease in average daily amount of growth in the studied varieties, which became most noticeable in the Red Velvet variety.

Based on the results of the two-factor experiment, evaluating the influence of factor A "methods of formation" and factor B "genotype of varieties", it should be noted that both factors statistically significantly influenced the average weight of okra fruits, productivity and crop yield (table 3). The length of the fruit was statistically significantly influenced by factor B "methods of formation",
however, none of the studied factors had a significant effect on the diameter of the fruit, the indicators are within the experimental error.

Comparing the yield of the studied okra varieties, it should be noted that the highest yield is in the Lady’s Finger variety in relation to the yield of the Red Velvet variety, in the option "formation in 1 shoot" by 0.2 kg/m², in the option "formation in 2 shoots" by 0.5 kg/m².

Table 3. Influence of plant formation methods on yield and its structure (average for 2018-2020)

| Varieties (A) | Productivity, pcs/plant | Fruit length, cm | Fruit diameter, cm | Average weight of one fruit, g | Crop yield kg/m² |
|---------------|-------------------------|------------------|-------------------|-------------------------------|-----------------|
|               | I I I I II II           | I I I I II II   | I I I I II II   | I I I I II II                 |
| Lady’s Finger | 17±2 22±2 9.2±2.2 9.0±1.5 1.9±0.2 1.6±0.4 | 18.5±3.4 16.6±0.6 | 1.4 1.6 | 1.2 1.1 |
| Red Velvet    | 16±2 20±3 6.5±2.0 6.3±2.2 2.0±0.4 1.6±0.2 | 16.4±2.8 12.2±0.4 | 1.2 1.1 | 1.2 1.1 |
| LSD₀.₀₅A=1.5  | LSD₀.₀₅B=0.6             | -                | LSD₀.₀₅A=0.85    | LSD₀.₀₅A=0.4 |
| LSD₀.₀₅B=1.8  |                        |                 | LSD₀.₀₅B=1.05    | LSD₀.₀₅B=0.1 |

Note: forming methods: I – one shoot, II – 2 shoots;

When considering the results of the yield of okra, it was found that the maximum number of fruits was formed in the variety Lady’s Finger in the second variant, which is 6 more fruits in relation to the first variant. The length and diameter of okra fruits in the Lady’s Finger variety differed insignificantly according to the variants. In the variety Lady’s Finger in the second variant of plant formation, a higher yield (1.6 kg/m²) was obtained, which is 0.2 kg/m² higher than the yield of this variety obtained during the formation of plants in 1 shoot. The Red Velvet variety in the variant "formation in 2 shoots" showed a decrease in the yield by 0.1 kg/m², despite the fact that in the variant "formation in 2 shoots" 4 more fruits were formed in comparison with the variant "formation in 2 shoots". However, the fruits had less fruit length by 0.2 cm, diameter by 0.4 cm and average weight of one fruit by 4.2 g, which led to a decrease in the yield from 1 m² (Table 3).

4. Conclusion

The conducted studies have revealed the prospects of growing the Lady’s Finger variety, which has the greatest drought hardness adaptation of the root system. To obtain the highest yield of fruits, we recommend growing the Lady’s Finger variety, forming plants in 2 shoots. The yield is 1.6 kg/m², which is 0.2 kg/m² higher than the yield of this variety obtained when plants were formed in 1 shoot.

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