Intraspecific variability of apple tree by indicators of vegetative and generative organs

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Abstract. The article describes the results of the analysis of morphometric parameters of a leaf plate (leaf plate area, the mass of one leaf in completely dry state, mass of 1 cm² of leaf in completely dry state) and the fruits of large-fruited apple cultivars in the V. Krutovskiy Botanical Garden. A significant positive correlation was found for winter apple cultivars between the number of leaves on the annual sprout and the mass of fruits. The obtained results can be used when conducting a preliminary determination of the expected yield of apple trees. It has been established that the varietal belonging of an apple tree influences the ecological efficiency and productivity of an apple orchard. The cultivars acknowledged prospective on the characteristics studied are recommended to use for creating apple orchards in the given and similar climatic conditions.

1. Introduction

One of the main tasks of botanical gardens is the creation of special collections of plants in order to preserve the diversity and enrichment of the plant world, as well as scientific, educational and outreach activities [1]. According to L I Atkina [2], despite the enormous importance of green spaces for the state of the atmosphere of large cities, the question of the structure and characteristics of the phytomass of woody plants in urban environments remains poorly understood.

Apple is one of the most common fruit crops in the European part of Russia [3]. The phytomass of apple trees was studied by L I Atkina et al. [2], V S Gegechkori et al. [4], M V Ignatova [5], V V Zamorsky [6], N P Bratilova et al. [7] and other scientists. A significant indicator of the photosynthetic activity of a cultivar is the state of the leaf apparatus, which is judged, in particular, by the number of leaves per unit of sprout. The number of leaves on the main axis correlates with the size of the photosynthesizing surface and determines the productivity of the crown volume of the tree and, in general, the yield of the cultivar. These characteristics of the apple tree differ considerably depending on the cultivar [8]. The indicator of the ratio of dry leaf mass to its area (LMA - leaf mass per area) and SLA (specific leaf area), which is the reciprocal of LMA [9-11], is widely used in environmental studies.

There is the V Krutovskiy Botanical Garden in Krasnoyarsk, where the collection of different cultivars of homemade apple trees (Malus domestica Borkh) [12] is concentrated, the beginning of the creation of which is laid by V M Krutovskiy in 1904. Apple cultivars differ in a number of ways. The cultivar characteristics of the apple tree include the size, shape of the fruit, its taste, the time of ripening and storage.
The territory of the Botanical Garden is located at the junction of the Kansko-Rybinsk basin and the forest-steppe zone of the West Siberian plain with the foothills of the Eastern Sayan, which causes sharply continental climatic conditions [13]. For cultivation of apple trees in the conditions of Siberia, the method proposed by V M Krutovskiy is used - in creeping form, called the Arctic or Krasnoyarsk stanian. Currently, the garden contains 39 large-fruited apple cultivars bred in the European part of Russia, in Siberia and abroad. The maximum age of the studied trees is 115 years [12].

2. Methods and Materials
5 model trees were chosen among the large-fruited apple cultivars. One annual sprout from the middle part of the crown of each of them was selected. All leaves from the model branches were collected and there have been determined: the area and mass of the leaf in a completely dry state.

The number of placed flowers and fruits was counted on a typical skeletal branch, with simultaneous determination of the number of flowering and fruiting branches in a clockwise direction for each model tree [14]. To determine the number of seeds in the fruit, 25 apples of each cultivar were collected, the seeds were taken out after maturity.

To process the experimental material there were used the mathematical statistics methods by Microsoft Excel. On the basis of the correlation analysis, the shape, direction, and tight connection between the studied characteristics were established. Regression analysis was performed using the Curve Expert program [15].

3. Results and Discussion
To determine intraspecific variability in indicators of growth and fruiting of apple trees in the V Krutovskiy Botanical Garden, a comparison of indicators for different cultivars of apple trees by morphometric characteristics, biomass and yield was done.

As a result of research, it was found that the area of leaf plate of different cultivars of apple ranged from 17 to 44 cm² (Figure 1).

![Figure 1. The area of the apple leaf plate cm².](image)

The largest leaf area was recorded for the Voronezh Vorgul cultivar, the smallest - for the cultivar № 22 (cultivar of V M Krutovskiy).

The leaf mass in completely dry state amounted to an average of 0.32 g. The largest mass of the leaf plate in completely dry state was observed in the Bismarck cultivar (0.47 g.). Also the cultivars Krasnoyarskoye, Krasnoyarskiy Sibiryak and Voronezh Vorgul are characterized by the high values of leaf mass. A smaller leaf mass is observed in the cultivars Pepin Kitayka, № 22 and Babushkino (Figure 2).
Figure 2. Mass of 1 leaf in completely dry state, g.

The indicator of the mass of 1 cm² of leaf in completely dry state was determined depending on the apple tree cultivar (Table 1).

| Cultivar                        | $\bar{x}$ | $\pm m$ | $\pm \sigma$ | $V$, % | $P$, % | $t_f$ with $t_{0.05}=1.70$ |
|---------------------------------|-----------|---------|--------------|--------|-------|-----------------------------|
| Papirovka                       | 0.011     | 0.0003  | 0.0006       | 5.7    | 2.6   | 3.31                        |
| Bely Naliv                      | 0.011     | 0.0004  | 0.0008       | 7.3    | 3.3   | 2.77                        |
| Peterburgskoye letnee           | 0.011     | 0.0006  | 0.0014       | 12.2   | 5.5   | 1.76                        |
| Medovka                         | 0.011     | 0.0004  | 0.0009       | 8.5    | 3.8   | 2.82                        |
| Antipskhalnoye                  | 0.009     | 0.0010  | 0.0023       | 25.1   | 11.2  | 2.76                        |
| Krasnoyarskoye                  | 0.012     | 0.0002  | 0.0003       | 2.9    | 1.3   | -                           |
| Anisik obynovennyi              | 0.011     | 0.0010  | 0.0021       | 20.1   | 9.0   | 1.54                        |
| Malinovka                       | 0.012     | 0.0004  | 0.0008       | 7.1    | 3.2   | 0.90                        |
| Bismarck                        | 0.012     | 0.0006  | 0.0014       | 11.9   | 5.3   | 1.03                        |
| Krasnoyarskiy Sibiryak          | 0.011     | 0.0003  | 0.0007       | 6.4    | 2.8   | 3.22                        |
| Chinese Pendant                 | 0.012     | 0.0002  | 0.0005       | 4.1    | 1.8   | 1.48                        |
| Voronezh Vorgul                 | 0.009     | 0.0004  | 0.0009       | 9.5    | 4.2   | 7.56                        |
| Winter Arcade                   | 0.009     | 0.0012  | 0.0028       | 30.3   | 13.6  | 2.36                        |
| Betler Chinese                  | 0.011     | 0.0005  | 0.0011       | 10.0   | 4.5   | 3.38                        |
| Shade                           | 0.008     | 0.0004  | 0.0009       | 10.9   | 4.9   | 8.97                        |
| Pepin Kitayka                   | 0.008     | 0.0005  | 0.0012       | 14.6   | 6.5   | 7.18                        |
| № 22                            | 0.007     | 0.0011  | 0.0024       | 33.6   | 15.0  | 4.45                        |
| Babushkino                      | 0.009     | 0.0006  | 0.0014       | 16.4   | 7.3   | 5.11                        |
| Average                         | 0.010     | 0.0002  | 0.0019       | 18.9   | 1.9   | 7.82                        |

The average mass of 1 cm² of leaf in completely dry state is 0.010 ± 0.0002 g. The largest mass of 1 cm² of leaf is observed in the cultivars Krasnoyarskoye, Malinovka, Bismarck and Chinese Pendant.
the fruits on the tree was 0.81, IOP Conf. Series: Earth and Environmental Science 316 (2019) 012012 doi:10.1088/1755-1315/316/1/012012

The ratio of dry leaf mass to its area (LMA) for the studied cultivars averaged 10.2 ± 0.35 mg/cm². Depending on the cultivar, the LMA varies from 7.4 to 11.7 mg/cm² (Table 2).

Table 2. Leaves indicators of different apple tree cultivars.

| Cultivar                  | The number of leaves on the annual sprout, pcs. | Leaf area, cm² | Mass of leaf in completely dry state, g | LMA, mg/cm² |
|---------------------------|-----------------------------------------------|----------------|----------------------------------------|-------------|
| Papirovka                 | 15                                            | 31.4           | 0.356                                  | 11.3        |
| Bely Naliv                | 14                                            | 29.4           | 0.326                                  | 11.1        |
| Peterburgskoye letnee     | 11                                            | 21.0           | 0.229                                  | 10.9        |
| Medovka                   | 14                                            | 27.4           | 0.298                                  | 10.9        |
| Krasnoyarskoye            | 10                                            | 35.3           | 0.402                                  | 11.4        |
| Malinovka                 | 12                                            | 32.4           | 0.379                                  | 11.7        |
| Bismarck                  | 16                                            | 39.1           | 0.411                                  | 10.5        |
| Krasnoyarskiy Sibiryak    | 14                                            | 39.4           | 0.429                                  | 10.9        |
| Chinese Pendant           | 16                                            | 31.4           | 0.360                                  | 11.5        |
| Voronezh Vorgul           | 14                                            | 44.2           | 0.420                                  | 9.5         |
| Winter Arcade             | 13                                            | 23.1           | 0.238                                  | 10.3        |
| Befler Chinese            | 12                                            | 31.1           | 0.332                                  | 10.7        |
| Shade                     | 15                                            | 35.9           | 0.294                                  | 8.2         |
| Pepin Kitayka             | 11                                            | 20.2           | 0.152                                  | 7.5         |
| № 22                     | 21                                            | 17.0           | 0.127                                  | 7.4         |
| Babushkino                | 15                                            | 21.7           | 0.205                                  | 9.4         |

When determining the flowering intensity and yield of apple trees, it was established that in 2018, on average, 4082 ± 404.7 pcs. of flowers were formed, 876.9 ± 76.05 pcs. of fruits per tree. The correlation coefficient between the number of flowers formed and the fruits on the tree was 0.81, which confirms the tight connection between these indicators. The number of flowers, depending on the cultivar, ranged from 698 to 8700 pcs., fruits - from 113 to 3040. The lowest yields were observed in the cultivar Bely Naliv, the highest – in the Malinovka (Table 3).

Table 3. Indicators of fruits and seeds

| Cultivar                  | Number of flowers, pcs. / tree | Number of apples, pcs. / tree | Number of seeds in the fruit, pcs. | Mass of seeds in the fruit, g | Mass of 1000 pieces of seed, g |
|---------------------------|--------------------------------|--------------------------------|-----------------------------------|-------------------------------|-------------------------------|
| Papirovka                 | 4270                           | 807                            | 6                                 | 0.154                         | 26.60                         |
| Bely Naliv                | 698                            | 113                            | 5                                 | 0.136                         | 29.35                         |
| Peterburgskoye letnee     | 1683                           | 814                            | 7                                 | 0.168                         | 25.27                         |
| Medovka                   | 6107                           | 894                            | 4                                 | 0.103                         | 26.90                         |
| Krasnoyarskoye            | 8352                           | 2275                           | 4                                 | 0.066                         | 16.38                         |
| Malinovka                 | 8700                           | 3040                           | 6                                 | 0.165                         | 26.52                         |
| Bismarck                  | 1576                           | 436                            | 6                                 | 0.231                         | 37.71                         |
| Krasnoyarskiy Sibiryak    | 3677                           | 1173                           | 5                                 | 0.146                         | 32.59                         |
| Chinese Pendant           | 4650                           | 1020                           | 8                                 | 0.254                         | 33.08                         |
| Voronezh Vorgul           | 3563                           | 506                            | 5                                 | 0.181                         | 38.90                         |
| Winter Arcade             | 3463                           | 1738                           | 9                                 | 0.328                         | 37.20                         |
| Befler Chinese            | 4340                           | 516                            | 8                                 | 0.256                         | 34.03                         |
The number of ripened seeds in the fruit ranged from 4 (Medovka, Krasnoyarskoye) to 9 pcs. (Winter Arcade), with an average value of 6.1 ± 0.15 pcs. for studied apple cultivars. The largest mass of seeds in one fruit characterizes the cultivar Arkad winter (0.33 g), the smallest - Krasnoyarskoye (0.07 g). The average seed mass in one apple is 0.19 ± 0.016 g. The indicator characterizing the sowing qualities of seeds - the mass of 1000 pieces of seeds - in the studied cultivars in 2018 was on average 31.1 ± 1.57 g, ranged depending on the cultivar, from 16.38 to 41.4 g. The largest mass of 1000 pieces of seeds was detected in cultivars Number 22, Voronezh Vorgul, Bismarck, Arkad winter. The coefficient of intraspecific variability of the mass index of 1000 pcs. of seeds is 20.2%, which corresponds to a significant level of variability.

It was established that the number of leaves formed on the annual sprout in the studied cultivars was from 10 pcs. (Krasnoyarskoye) up to 16 pcs. (Bismarck, Krutovskiy Green, Chinese Pendant). Correlation analysis showed the presence of a strong positive connection between the indicators of the number of leaves on annual sprouts and the mass of fruits for winter apple cultivars (r = 0.65). This dependence is approximated by the Logistic Model function (Figure 3):

$$y = 116.28/(1 + 14.86 \exp(-0.26x)); \quad R^2 = 0.44$$  \hspace{1cm} (1)

where, \(y\) – fruits weight, g; \(x\) – number of leaves on the annual sprout, pcs.

**Figure 3.** The dependence of the mass of fruits on the number of leaves on the annual sprout.

These results can be used when conducting a preliminary determination of the expected yield of apple trees.
4. Conclusion
Thus, as a result of the research, it was established that the apple tree has intraspecific variability by the area of the leaf plate, mass of 1 cm² of leaf, mass of 1000 pcs. of seeds. The cultivar belonging of an apple tree affects the ecological efficiency and productivity of an apple orchard. The selected cultivars are recommended for creating apple orchards in Siberia.

Acknowledgments
The study was carried out with the support of the Krasnoyarsk Regional Science Foundation during the participation in the event: "IV Scientific and Technical Conference" Forests of Russia: politics, industry, science, education".

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