Variability of summer apple tree varieties in 2019 by indicators of vegetative organs

N P Bratilova and O A Gerasimova

Faculty of Forestry, Reshetnev Siberian State University of Science and Technology,
31 Krasnoyarsky Rabochy Av., Krasnoyarsk, 660037, Russian Federation

E-mail: goa.1903@yandex.ru

Abstract. The article presents the results of a study of annual shoots of large-fruited apple varieties, characterized by early ripening and consumer maturity, in the Botanical Garden named after Vs. M. Krutovsky. The leaf area, weight of 1 cm² of leaf and 1 running centimeter of shoot in absolutely dry state are calculated. A significant positive correlation was revealed between the indicators of the area of the sheet and the mass of 1 cm² of sheet in absolutely dry state, and between the mass of 1 linear cm shoot and 1 cm² leaf. Using the regression method, it is possible to reduce labor costs for determining phytomass without resorting to additional measurements of the supply of dry foliage mass and to determine the increase in the mass of branches even in leafless periods. In Siberia, it is recommended to use the most promising varieties of apple trees in terms of photosynthetic activity and productivity for cultivation.

1. Introduction

Recently, the study of the characteristics of the leaf apparatus has attracted close attention, since leaves are the main photosynthetic organs of most plant species [1]. Measured traits and their interconnections are used to assess intraspecific and interspecific variability, which in turn can deeply affect plant growth, reproduction and ecosystem functioning [1, 2]. One of the frequently studied signs of ecological orientation is the ratio of dry leaf mass (LMA) per area [2–6].

Most often, the leaf area is determined using destructive methods and methods that are time-consuming. Currently, the work is underway to optimize the estimation of this parameter by means of the regression method using simple linear measurements in the field [7–9].

In Siberia, in the city of Krasnoyarsk there is a Botanical Garden named after Vs. M. Krutovsky [10]. This object is located at the junction of the Kansk-Rybinsk Basin and the forest-steppe zone of the West Siberian Plain with the foothills of the Eastern Sayan Mountains, which leads to the formation of sharply continental climatic conditions. It is a good choice of the place where the garden named after M. Krutovsky was laid at the mouth of the Laletina River on the I and II terraces of the right bank of the Yenisei River. It made possible to form a special, milder microclimate for the grown plants. The Botanical Garden is unique in the presence of a collection of home-grown apple trees (Malus domestica Borkh) of various varieties that differ in a number of ways: size, shape of the fruit, their taste, ripening and storage periods, etc. In a sharply continental climate M. Krutovsky proposed a method of forming apple trees. This method is called the Arctic or Krasnoyarsk stanza (creeping form). At the moment, 39 large-fruited varieties cultivated on the territory of the European part of Russia, in Siberia and abroad are been preserved in the garden, some trees have reached the 115th age [10].
2. Methods and materials
We have studied large-fruited varieties of apple trees, characterized by early ripening and consumer maturity. Among each variety, 5 model trees were selected, from which one model branch of the current year growth was selected from the middle part of the crown. In annual shoots, the phytomass was determined separately by fractions (leaves, branches) and leaf area. The mass of 1 cm² of sheet and 1 running centimeter of the shoot in absolutely dry state (a.d.s.) was calculated. Leaf area was determined using the Petiole.LeafArea program. The leaves and shoots were dried in a drying cabinet SHS-80-01 SPU at 105° C until absolutely dry.

Processing of the collected experimental material was carried out by the methods of mathematical statistics using the Microsoft Excel program. The level of variability of indicators was evaluated by a scale of S.A. Mamaev [11].

Between the studied signs on the basis of correlation analysis the form, orientation and tightness of communication were established. The detection of regression dependences was carried out using the cross-platform software Curve Expert [12].

3. Results and discussion
In a study of the growth and accumulation of phytomass of annual shoots, it was found that the average mass of the leaf plate of large-fruited apple varieties was 0.29±0.012 g, the indicator is characterized by a high level of variability (table 1).

| Indicator | \( \bar{x} \) | \( \pm m \) | \( \pm \sigma \) | V, % | P, % |
|-----------|-------------|-------------|-------------|------|------|
| Area of 1 leaf, cm² | 27.9 | 1.09 | 8.48 | 30.4 | 3.9 |
| Mass of 1 leaf in a.d.s., g | 0.29 | 0.012 | 0.090 | 31.3 | 4.0 |
| Mass of 1 running shoot cm in a.d.s., g | 0.071 | 0.0028 | 0.0218 | 30.6 | 3.9 |

The level of variability of the remaining studied indicators is increased.
When determining the intraspecific variability of summer varieties by morphometric characteristics and phytomass, it was revealed that the leaf plate area of summer apple varieties in 2019 varied from 14.3±1.93 (St. Petersburg summer) to 39.8±1.81 (Krasnoyarsk beauty) cm² (table 2).

| Variety | \( \bar{x} \) | \( \pm m \) | \( \pm \sigma \) | V, % | P, % | \( t_b \) at \( t_{05}=2.04 \) |
|---------|-------------|-------------|-------------|------|------|----------------|
| White filling | 26.9 | 2.07 | 4.64 | 17.3 | 7.7 | 4.69 |
| Nobilis | 30.1 | 3.89 | 8.70 | 28.9 | 12.9 | 2.26 |
| Papier | 22.9 | 3.16 | 7.08 | 30.8 | 13.8 | 4.64 |
| Grushovka Moscow | 33.6 | 1.85 | 4.14 | 12.3 | 5.5 | 2.40 |
| Arcade glass | 27.3 | 2.53 | 5.66 | 20.7 | 9.3 | 4.03 |
| Golden thorn | 35.1 | 2.79 | 6.24 | 17.8 | 8.0 | 1.43 |
| Petersburg summer | 14.3 | 1.93 | 4.33 | 30.3 | 13.5 | 9.64 |
| Astrakhan White | 25.3 | 0.70 | 1.56 | 6.2 | 2.8 | 7.48 |
| Medovka | 35.2 | 1.18 | 2.64 | 7.5 | 3.4 | 2.13 |
| Krasnoyarsk beauty | 39.8 | 1.81 | 4.04 | 10.2 | 4.5 | - |
| Aurora | 25.3 | 2.92 | 6.53 | 25.9 | 11.6 | 4.23 |
| Terentyevka | 19.6 | 1.88 | 4.21 | 21.5 | 9.6 | 7.73 |

The level of variation in leaf area varies from very low in varieties Astrakhan Beloe and Medovka to high in varieties Papirovka, Nobilis, St. Petersburg summer, Aurora and Terentyevka.
In 2019, the varieties Nobilis, Grushovka Moscow, Arcad cup, Golden thorn, Medovka and Krasnoyarsk beauty were distinguished by a large mass of leaf plates (table 3).

| Variety                | \( \bar{y} \) | \( \pm m \) | \( \pm \sigma \) | V, % | P, % | \( t_p \) at \( t_{0.05}=2.04 \) |
|------------------------|---------------|-------------|-----------------|------|-----|------------------------------|
| White filling          | 0.25          | 0.035       | 0.077           | 30.9 | 13.8| 3.05                         |
| Nobilis                | 0.34          | 0.040       | 0.090           | 26.2 | 11.7| 1.05                         |
| Papier                 | 0.23          | 0.036       | 0.081           | 35.2 | 15.8| 3.39                         |
| Grushovka Moscow       | 0.33          | 0.022       | 0.049           | 14.9 | 6.7 | 1.65                         |
| Arcade glass           | 0.35          | 0.021       | 0.048           | 13.8 | 6.2 | 1.33                         |
| Golden thorn           | 0.40          | 0.034       | 0.077           | 19.3 | 8.6 | -                            |
| Petersburg summer      | 0.16          | 0.015       | 0.033           | 21.2 | 9.5 | 6.49                         |
| Astrakhan White        | 0.29          | 0.011       | 0.025           | 8.8  | 3.9 | 3.19                         |
| Medovka                | 0.37          | 0.021       | 0.048           | 12.8 | 5.7 | 0.68                         |
| Krasnoyarsk beauty     | 0.33          | 0.018       | 0.040           | 12.1 | 5.4 | 1.82                         |
| Aurora                 | 0.21          | 0.023       | 0.051           | 24.3 | 10.9| 4.58                         |
| Terentyevka            | 0.21          | 0.020       | 0.045           | 21.3 | 9.5 | 4.77                         |

The level of variability of the mass of one leaf in an absolutely dry state varies from low in the Astrakhan white variety to high in the Papirovka variety.

Maximum mass of 1 running cm of shoot was noted in the variety Arkad glassy, also a large value of this indicator are characterized by varieties White filling, Nobilis, Grushovka Moscow, Golden thorn, Astrakhan white, Medovka, Aurora. Minimum mass of 1 running cm of shoot was detected in varieties Petersburg summer and Terentyevka (table 4).

| Variety                | \( \bar{y} \) | \( \pm m \) | \( \pm \sigma \) | V, % | P, % | \( t_p \) at \( t_{0.05}=1.70 \) |
|------------------------|---------------|-------------|-----------------|------|-----|------------------------------|
| White filling          | 0.076         | 0.0036      | 0.0081          | 10.7 | 4.8 | 1.18                         |
| Nobilis                | 0.086         | 0.0080      | 0.0180          | 20.9 | 9.4 | 0.39                         |
| Papier                 | 0.064         | 0.0046      | 0.0102          | 16.0 | 7.2 | 2.01                         |
| Grushovka Moscow       | 0.083         | 0.0041      | 0.0091          | 10.9 | 4.9 | 0.66                         |
| Arcade glass           | 0.092         | 0.0860      | 0.1924          | 30.3 | 13.6| -                            |
| Golden thorn           | 0.076         | 0.0101      | 0.0225          | 29.4 | 13.2| 0.98                         |
| Petersburg summer      | 0.038         | 0.0011      | 0.0025          | 6.5  | 2.9 | 4.14                         |
| Astrakhan White        | 0.084         | 0.0033      | 0.0074          | 8.8  | 3.9 | 0.60                         |
| Medovka                | 0.079         | 0.0076      | 0.0170          | 21.4 | 9.6 | 0.85                         |
| Krasnoyarsk beauty     | 0.063         | 0.0085      | 0.0191          | 30.4 | 13.6| 1.83                         |
| Aurora                 | 0.071         | 0.0074      | 0.0165          | 23.1 | 10.3| 1.42                         |
| Terentyevka            | 0.042         | 0.0070      | 0.0156          | 36.7 | 16.4| 3.39                         |

The reliability criteria for the differences \( t_p \) were calculated for the indices of annual shoots of summer apple varieties with average values for all studied plants (table 5).

| Variety                | Area of 1 leaf, cm² | Mass of 1 leaf in a.d.s., g | Mass of 1 shoot running cm in a.d.s., g |
|------------------------|----------------------|----------------------------|---------------------------------------|
| White filling          | 0.43                 | 1.08                       | -1.02                                 |

Table 5. Criteria for the reliability of differences \( t_p \) of indicators of different varieties of apple trees with an average value for the entire collection of summer varieties (at \( t_{0.05}=1.70, t_{0.05}=2.04 \)).
Nobilis  -0.54  -1.29  -1.77  
Papier      1.50    1.55   1.22  
Grushovka  -2.65  -1.68  -2.46  
Moscow      1.50      1.55    1.22  
Arcade glass  0.23 -2.32  -1.58  
Golden thorn -2.39 -3.02  -0.48  
Petersburg summer  6.14  6.87   11.10 
Astrakhan White   2.02  0.31  -3.17 
Medovka      -4.54 -3.39  -0.94  
Krasnoyarsk beauty -5.63 -1.80   0.85  
Aurora       0.85    3.05     0   
Terentyevka   3.81    3.39   3.85  
Averge meaning  27.9±1.09  0.29±0.012  0.071±0.0028

According to the data given in table 5, a number of conclusions can be made. So, for example, in the Arcade variety, the cup-shaped reliable differences with the average values for the entire collection of summer apple trees on the leaf area were not detected (t<sub>b</sub> is less than t<sub>0.05</sub>), however, the leaf mass indicator significantly exceeds the average value, which may indicate a large thickness of the leaf blade. Variety Astrakhan white also has a large thickness of the leaf blade. In the varieties Krasnoyarsk beauty, Grushovka Moscow, Aurora, the opposite direction is traced, they differ in the smaller thickness of the leaf blade in comparison with the average.

Correlation analysis showed the presence of a strong positive relationship between the area and mass of the leaf blade for summer apple varieties (r = 0.858). This dependence can be described by the Logistic Model equation (figure 1):

\[ y = \frac{4.07}{1 + 1.00 \times \exp(-1.19x)}; \quad R^2 = 0.76, \]  

(1)

where y – mass of 1 leaf in a.d.s., g; x – area of 1 leaf, cm\(^2\)

![Figure 1. Dependence of leaf mass in a.d.s. from the leaf area of summer apple varieties.](image-url)
The presence of a strong positive relationship between the leaf mass and 1 running centimeter of shoots in summer apple varieties was found ($r=0.723$). This dependence is approximated by the equation Exponential Association (Figure 2):

$$y=6.65 \cdot \exp^{(8.14x)}; \quad R^2=0.53,$$

(2)

where $y$ – mass of 1 leaf in a.d.s., g; $x$ – area of 1 shoot running cm, cm$^2$

**Figure 2.** The dependence of the mass of leaves on the mass of 1 shoot running cm of summer varieties of apple trees.

4. Conclusion

Thus, it was established that intraspecific variability is observed in the apple tree in terms of leaf area, leaf mass, and 1 running cm of shoot in absolutely dry state.

In Siberia, the most promising varieties of apple trees for cultivation, from the point of view of photosynthetic activity and productivity, are the varieties Grushovka Moscow, Golden thorn, Medovka, Krasnoyarsk beauty.

Using the regression method, which describes the relationship between leaf area and leaf mass in a completely dry state, it is possible to reduce labor costs for determining phytomass without resorting to additional measurements of the stock of dry foliage mass; and also determine the increase in the mass of branches even in a leafless period.

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