The productivity of the apple tree in the Vs. M. Krutovsky Botanical Garden

N P Bratilova, N V Moksina and O A Gerasimova*
Reshetnev Siberian State University of Science and Technology, 31 Krasnoyarskii rabochii prospekt, Krasnoyarsk 660037, Russia

*E-mail: goa.1903@yandex.ru

Abstract. The article presents the results of the research on the productivity of the apple tree of local selection varieties by I.V. Michurin, Clarkson, in the Vs. M. Krutovsky Botanical Garden from 2010 to 2019. The following indicators were analyzed: the number of fruits on a tree (pcs.), fruit weight (g), yield, (kg/tree), frequency of fruiting, specific load of crop fruiting (kg/1 m² and kg/1 m³ of crown). It was revealed that according to the complex of the studied indicators, such varieties as Bellefleur-kitayka and Bismarck can be considered promising for further selection work and practical gardening.

1. Introduction

Ensuring the stability of fruiting of perennial crops, taking into account the maximum realization of their hereditary qualities in different growing conditions is an important problem of modern gardening [1]. In regions with severe climatic conditions, in particular in Siberia, this task is especially urgent [2].

Productivity is an important economic characteristic of a variety that determines its biological characteristics and interaction with environmental conditions. This indicator consists of a number of components, among which in pome crops are such as early maturity, regularity and stability of fruiting, weight of fruits, density of distribution of fruit formations and fruit on shoots, and others [4].

The Vs. M. Krutovsky Botanical Garden, where the research was carried out, is a unique garden with apple trees of various geographical (European part of Russia, the Baltic states, Siberia, etc.) and genetic origin (varieties of local selection by I.V. Michurin, Vs. M. Krutovsky, Clarkson) [5, 6]. In total, there are 39 varieties of the apple tree in the collection, growing in a creeping form, the maximum age of which is 116 years.

The garden is located in the Sverdlovsk region of the city of Krasnoyarsk on the banks of the Yenisei River.

The purpose of these studies is as a result of studying apple varieties growing in the Vs. M. Krutovksy Botanical Garden to identify the best in terms of basic economic and biological indicators, adapted to local conditions.

It is known that varieties of local selection, as a rule, are characterized by separate valuable economic and biological traits that provide them with high ecological adaptability to environmental conditions [3]. Of the varieties of this genetic group, Antonovka ordinary, White filling, Moscow grushovka, General Orlov were studied.
Varieties of I.V. Michurin selection - Bellefleur kitayaka (Bellefleur American yellow x kitayaka, Pepin saffron (Rennet Orlean x hybrid (Pepin Lithuanian x kitayaka)).

Variety Bismarck (presumably a seedling of Aport) [7] was bred in New Zealand by Clarkson.

2. Methods and materials

To determine biometric indicators, the height of fruit trees (m), crown diameter (m) were taken into account. Next, we calculated the specific load of the crop per unit of crown volume (kg/1 m$^3$ of crown) and the projected area of the crown (kg/1 m$^2$ of crown). When calculating the yield load per unit of crown volume (V), the formula for the volume of the pyramid (correct or incorrect) was used:

$$V = \frac{1}{3} h S$$  \hspace{1cm} (1)

where h - tree height, S - crown projection area.

The projected area of the crown can be calculated as the area of a circle:

$$S = \pi r^2$$  \hspace{1cm} (2)

where r - is the radius of the crown, i.e. $\frac{1}{4}$ the sum of two indicators of the crown diameter (along and across the row).

The fructification frequency index [8, 9, 10] was determined by the formula:

$$F = \frac{(U_1-U_2)}{(U_1+U_2)} \times 100$$  \hspace{1cm} (3)

where F - is the index of the frequency of fructification, %; U1* - yield in a productive year, pcs/tree; U2* - yield in a less productive adjacent year, units/tree.

Fruiting frequency scale:
- 21 - 40% - with relatively regular fructification;
- 41 - 60% - with an medium frequency of fructifying;
- 61 - 80% - with a strong frequency;
- 81 - 100% - very high frequency.

U1*, U2* - the original method uses the c/ha indicator. We used the number of fruit per tree (pcs/tree) to determine the variation in the studied parameter within the variety.

3. Results and discussion

To determine biometric indicators, the height of fruit trees (m), crown diameter (m) were taken into account. Then the area of the crown projection (m$^2$) and the volume of the crown (m$^3$) were determined. It was found that the height varies from 1.0 ± 0.05 m for the Pepin saffron variety to 1.5 ± 0.08 m for Bismarck (table 1).

Table 1. Biometric indicators of the apple tree.

| Variety         | Height, m  | Crown diameter, m | Crown projection area, m$^2$ | Crown volume, m$^3$ |
|-----------------|------------|-------------------|------------------------------|---------------------|
| Antonovka ordinary | 1.3 ± 0.05 | 5.3 ± 0.29        | 22.4 ± 2.64                  | 9.8 ± 1.23          |
| White filling    | 1.3 ± 0.08 | 5.1 ± 0.23        | 21.3 ± 1.94                  | 9.2 ± 1.01          |
| Bellefleur-kitayka | 1.1 ± 0.09 | 4.6 ± 0.14        | 16.8 ± 1.00                  | 6.5 ± 0.77          |
| Bismarck         | 1.5 ± 0.08 | 4.4 ± 0.19        | 15.7 ± 1.35                  | 7.9 ± 0.97          |
| General Orlov    | 1.4 ± 0.09 | 6.2 ± 0.50        | 32.8 ± 5.53                  | 15.9 ± 3.07         |
| Moscow grushovka | 1.4 ± 0.07 | 5.1 ± 0.28        | 21.9 ± 2.64                  | 10.0 ± 1.22         |
| Pepin saffron    | 1.0 ± 0.05 | 4.7 ± 0.23        | 17.5 ± 1.75                  | 5.8 ± 0.56          |

The maximum indices of the projection area and crown volume were noted for the General Orlov variety (32.8 ± 5.53 m$^2$ and 15.9 ± 3.07 m$^3$, respectively).
By analyzing the data on the percentage of trees that entered fruiting (table 2), it was found that the maximum indicators for all studied varieties were observed in 2011 (100% fruiting in all varieties) and 2018 (from 96.4% to 100%). The least fruit yield of apple trees was in 2012 and 2017.

Table 2. Percentage of fruiting specimens of the total number of trees of a variety, %.

| Variety                  | Number of specimens, pcs. | Research year |
|--------------------------|---------------------------|---------------|
|                          |                           | 2010          | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| Antonovka ordinary       |                           | 9             | 100  | 100  | 66.7 | 100  | 100  | 88.9 | 66.7 | 100  | 100  |
| White filling            |                           | 20            | 95   | 100  | 65   | 100  | 95   | 100  | 85   | 100  | 100  |
| Bellefleur-Kitayka       |                           | 5             | 60   | 100  | 80   | 100  | 80   | 100  | 100  | 100  | 100  |
| Bismarck                 |                           | 28            | 100  | 100  | 78.6 | 96.4 | 100  | 100  | 82   | 96.4 | 96.4 |
| Moscow grushovka         |                           | 19            | 94.7 | 100  | 52.6 | 84.2 | 100  | 94.7 | 94.7 | 26.3 | 100  | 73.7 |
| General Orlov            |                           | 14            | 100  | 100  | 42.9 | 57.1 | 92.6 | 100  | 7.1  | 100  | 100  |
| Pepin saffron            |                           | 7             | 100  | 100  | 42.9 | 45.7 | 100  | 100  | 42.9 | 100  | 100  |

Over a 10-year period, most often 100% fruiting was observed in the varieties Antonovka ordinary, Bellefleur-Kitayka and Pepin saffron; less - in Moscow grushovka. This indicates the unstable fruiting of this variety, which is confirmed by determining the index of the frequency of fruiting (table 3).

The fruiting frequency index was determined by the generally accepted method [8, 9, 10]. In the studied varieties, this indicator varied from 13% in the Pepin saffron variety to 56.9% in the Moscow grushovka variety (table 3).

Table 3. Index of the frequency of fruiting.

| Variety                  | Average number of fruits, pcs/tree | Fruiting frequency index | Frequency rate |
|--------------------------|------------------------------------|--------------------------|----------------|
|                          | 2018 r.                             | 2019 r.                  |                |
| Antonovka ordinary       | 447.3                              | 146.4                    | 50.7           |
| White filling            | 552.5                              | 252.4                    | 37.2           |
| Bellefleur-Kitayka       | 819.6                              | 590.0                    | 16.3           |
| Bismarck                 | 602.6                              | 386.1                    | 27.0           |
| Moscow grushovka         | 492.0                              | 106.0                    | 56.9           |
| General Orlov            | 456.1                              | 293.7                    | 21.7           |
| Pepin saffron            | 512.1                              | 389.8                    | 13.0           |

Regular fruiting was observed in the varieties Bellefleur-Kitayka and Pepin Saffron. The varieties Bely naliv, Bismarck, General Orlov are characterized by relatively regular fruiting; Antonovka ordinary, Moscow grushovka are characterized by an medium frequency.

The weight and size of fruit in 2019 varied from 42.3 g in Moscow grushovka to 212.2 g in Antonovka ordinary, with average values for these varieties from 48.3 ± 1.50 g to 160.8 ± 10.02 g, respectively. Average values for fruit diameter ranged from 5.2 ± 0.13 cm (Pepin saffron) to 5.2 ± 0.13 cm (Antonovka ordinary), in height from 4.1 ± 0.07 cm (Moscow grushovka) to 6.19 ± 0.10 cm (Bismarck) (table 4).

Table 4. Fruit weight and fruit size.

| Variety       | Fruit weight, g | Fruit diameter, cm | Fruit height, cm |
|---------------|-----------------|--------------------|-----------------|
|               | Limits Xср ± m  | Limits Xср ± m     | Limits Xср ± m  |
| Antonovka     | 114.2 - 212.2   | 7.0 - 8.3          | 5.3 - 6.5       |
|               | 160.8 ± 10.02   | 7.5 ± 0.16         | 6.08 ± 0.12     |
In all the varieties presented, the diameter of the fruit is greater than the height, which indicates a deep-flat (turnip-shaped) shape of the fruit.

Intervarietal variability in the number of fruits on a tree is shown in figure 1. Analyzing the data, we can conclude that the number of fruit formed in all presented varieties was higher in 2018. The maximum value was observed in the Belfleur-kitayka variety.

![Figure 1. Number of fruit on a tree in 2018-2019, pcs.](image)

When determining the indicators of fruiting, it was found that the Antonovka ordinary variety (137.5 g) is the leader in terms of fruit weight over two years, Belfleur-kitayka and Bismarck (80.4 kg/v. And 66.4 kg/v., respectively) (table 5)

| Variety              | Average indicators for 2018-2019. | Specific crop load per unit |
|----------------------|----------------------------------|------------------------------|
|                      | number of fruits on a tree, pcs. | fruit weight, g              | crown projection area (kg/m²) | crown volume (kg/m³) |
| Antonovka ordinary   | 297                               | 137.5                        | 40.8                         | 1.8                  | 4.1                  |
| White filling        | 402                               | 95.9                         | 38.5                         | 1.8                  | 4.1                  |
| Belfleur-kitayka     | 705                               | 114.0                        | 80.4                         | 4.7                  | 12.4                 |
When comparing the specific load of the crop per unit area, it was found that the maximum indicators are observed in the varieties Belfleur-Chinese (4.7 kg/m²) and Bismarck (4.2 kg/m²). The same varieties (Bellefleur-kitayka and Bismarck) have high indicators of the specific load of the crop per unit of the crown volume - 12.4 and 8.4 kg/m³, respectively.

Individual variability in these indicators is observed. Thus, in the Bellefleur-kitayka variety, specimens with the maximum number of fruit on the tree were noted (table 6). For specimen No. 146 this value was 1274 pcs/tree for No. 173 - 1057 pcs/village, with an average value for the variety 705 pcs/tree.

Table 6. Average indicators of fruiting of the Bellefleur-kitayka variety for 2018-2019.

| №  | Tree number | Fruits on the tree, pcs. | Weight, g | Yield, kg/tree | Crown projection area, m² | Crown volume, m³ | Specific crop load per unit: |
|----|-------------|--------------------------|-----------|----------------|--------------------------|-----------------|--------------------------|
|    |             |                          |           |                |                          |                 | crown projection area (kg/m²) | crown volume (kg/m³) |
| 1  | 146         | 1274                     | 110.9     | 141            | 15.2                     | 4.0             | 9.3                      | 35.2                |
| 2  | 147         | 316                      | 124.0     | 39             | 15.2                     | 6.6             | 2.6                      | 5.9                 |
| 3  | 159         | 437                      | 108.2     | 47             | 15.2                     | 5.6             | 3.1                      | 8.4                 |
| 4  | 173         | 1057                     | 114.9     | 121            | 18.9                     | 7.5             | 6.4                      | 16.1                |
| 5  | 175         | 441                      | 112.7     | 50             | 19.6                     | 8.5             | 2.6                      | 5.9                 |

The specific load of the crop per unit of crown projection area for this variety varies from 2.6 to 9.3 kg/m², and per unit of crown volume from 35.2 to 16.1 kg/m³. This made it possible to identify the most promising specimens (No. 146 and No. 173) in the Bellefleur-kitayka variety according to the studied trait.

4. Conclusion
It was found that over a 10-year period, there were fruitful (2011 and 2018) and lean (2012 and 2017) years. The following varieties were highlighted: with regular fruiting - Bellefleur-kitayka and Pepin saffron, relatively regular - White filling, Bismarck, General Orlov, and medium frequency - Antonovka ordinary, Moscow grushovka. The varieties Antonovka ordinary, White filling, Bellefleur-kitayka, Bismarck are distinguished by large fruit. The analysis of intervarietal variability in the number of fruit on a tree showed that the Bellefleur-kitayka variety is the leader according to this indicator. When comparing the specific load of the crop per area unit, it was found that the maximum indicators are observed in the varieties Bellefleur-kitayka and Bismarck. Specimens with a high specific load of the crop per unit area and volume were highlighted in the Bellefleur-kitayka variety. According to the complex of the studied indicators, the varieties Bellefleur-kitayka and Bismarck can be considered promising for further selection work and practical gardening.

Acknowledgments
The reported study was funded by RFBR, project number 19-34-90089.

References
[1] Dragavtseva I A, Kuznetsova A P, Savin I Yu and Prudnikova E Yu 2019 Ways to ensure the stability of fruiting varieties of fruit crops based on assessing their adaptive potential in
changing environmental conditions *Gardening and viticulture* (Moscow: Federal Scientific Selection and Technology Center for Horticulture and Nursery) 3 34-42

[2] Usenko V I 2006 State and prospects for the development of Siberian horticulture Achievements of science and technology in the agro-industrial complex *Achievements of science and technology in the agro-industrial complex* 1 15-8

[3] Sedov E N, Krasova N G, Yanchuk T V, Korneeva S A and Galasheva A M 2020 Apple varieties of national selection and their role in improving the assortment *Gardening and viticulture* 2 14-20

[4] Krasova N G and Galasheva A M 2010 Productivity of apple varieties in an intensive garden *Modern gardening* 2 26-30

[5] Matveeva R N, Butorova O F and Moksina N V 1998 *Selection studies in the Botanical garden named after Vs. M. Krutovsky* (Krasnoyarsk: SibSTU) p 162

[6] Matveeva R N, Butorova O F, Moksina N V and Repyakh M V 2006 *Apple tree selection in the Botanical garden named after Vs. M. Krutovsky* p 357

[7] Bratilova N P, Matveeva R N, Butorova O F, Moksina N V and Repyakh M V 2019 The resource potential of different cultivars apple trees of Vs. M. Krutovsky collection *Journal of Native and Alien Plant Studies* 15 10-7

[8] Ogoltsova T P 1999 *Program and methodology for the study of varieties of fruit, berry and nut crops* (Orel: All-Russian Research Institute of Fruit Crops Breeding) p 608

[9] Karpenchuk G K and Melnik A V 1987 *Counting, observation, analysis, data processing in experiments with fruit and berry plants* (Uman) p 115

[10] Baytasov R R, Ananich I G and Bruylo A Since 2003 The problem of the frequency of fruiting and its quantitative expression *Agriculture - problems and prospects* 1(1) 55-8