An assessment of clonal rootstocks of an apple tree in conditions of the steppe zone in the Trans-Volga-Ural region

E Z Savin\textsuperscript{ORCID 0000-0002-2974-5175}, T V Berezina\textsuperscript{ORCID 0000-0002-3528-0263}

Institute of Steppe of the Ural Branch of the Russian Academy of Sciences, Orenburg, Russia

E-mail: gaeyskayatatyana@mail.ru

Abstract. Small stature forms of clonal rootstock in combination with recognized and appreciable varieties promote to increase productivity in one and half - two times from a unit of the area. New clonal rootstocks are characterized by increased winter- and drought-resistance, enabling the growth of rootstocks' adaptiveness to the Trans-Volga-Ural region's extreme conditions. Conditions of the region are characterized by low temperatures in the winter to -40 – -42 °C. A deficit of precipitation and high temperatures to +40– +42°C is noticed in the summer. Our research aims to study the adaptive ability of groups of clonal rootstocks of an apple tree above 30 forms of selection in Central Russia, Povolozhie, and foreign countries. Laboratory-field methods "Program and methodology of selection of fruit…" (1999) were used to estimate the adaptiveness of rootstock forms, including drought-resistant kinds. Forms: 71-3-195, MM 106, Baba-arabskaya Adzhi, Ural 5, Ural 3, elite forms 6–9 H, 5-4-13 are characterized by high preservation (80-90%) among clonal rootstocks for the years of the study. Forms: Ural 5, 62-223, 54-118, Ural 2, elite forms 4-5, 4-19-3, 76-23-2, K-2, 71-7-22, Don 70-456 are characterized by drought-resistance. Rootstocks of semi dwarves: 64-134, Ural 6, Ural 2, elite forms 5-4-13, 4-19-3, 5-19-1, dwarfish forms are: 71-7-22, 58-238, 64-134, 62-14, K-2, Don 70-52, have received 4-5 points according to the plantation state. All kinds listed above showed high adaptive ability in extreme conditions of the Trans-Volga-Ural region and were initial material to establish intensive plantings.

1. Introduction

The fruit-growing tendency in the world directs to increase intensification of the sector. Needs in gardening products have risen every year; it connects with the growth of the population, change of diet preferences, and increased income level \cite{1, 2, 3, 4}. Under diversity of soil-climatic conditions in Russia, the most adaptive assortment of fruit cultures, including rootstocks, should be selected for each region \cite{5, 6, 7, 8, 9}.

Conditions of the Trans-Volga-Ural region are characterized by low temperatures in the winter - 40– -46 °C. Severe winters happen every 10-12 years \cite{10, 11}. The critical deficit of precipitation and high temperatures to +40 – +42 °C are noticed in the summer. There are low relative humidity and low-productive carbonate and salty soils.

In these conditions, fruit plantings should have enough high winter resistance of the aboveground and root system of a tree, an increased drought-resistance, and simplicity to soil differences. The wild apple \textit{(Malus sylvestris var praecox} (Pall.) Ponomar.), and Baba-arabskaya apple tree (Adzhi, Kizilja, Turshi, Yuvan, etc.) answer these purpose \cite{6, 12, 13}. Not all types of clonal rootstocks adapt to such conditions. Nevertheless, in favorable micro-conditions of the zone, we can grow successfully intensive apple trees' plantings, including on clonal rootstocks \cite{14}.
2. Material and Methods
An experiment was founded by provine of clonal rootstocks of an apple tree in the autumn of 1992 in the Sarakhskii fruit nursery located 100 km east of Orenburg in the upper terrace in 5-6 km of the left bank of the Sakmara river (figure 1).

![Figure 1. A scheme of the Sarakhskii fruit tree nursery.](image)

Soils are common chernozem, medium-power lightly loamy; a humus horizon is 45 cm. The humus content – 4.4%, pH – 7.6, \( \text{P}_2\text{O}_5 \) content of – 47 mg/kg, \( \text{K}_2\text{O} \) – 503 mg/kg of soil.

The object of the study is clonal rootstocks of apple trees selected by the Michurinskii SAU, the Saratov Experimental Station of Horticulture, the Crimea Experimental Station of Horticulture, and the Don Zonal Scientific Research Institute of Agriculture, East Malling stocks of MM series, the Polish rootstock P22, and the Samara NIIS&LR.

The average annual air temperature is 3.8°C. The average maximum temperature for the years of the study is 36.0°C. It increased to 38-39°C in different years (figure 2).

Relative air humidity is 64.6% on average in the summer, the sum of active temperatures varied from 1840 to 2938°C. The number of days with a relative humidity of 30% was 82 on average. It reached 120-130 days in separate arid years. Long-time average annual precipitation is 562 mm and varies from 283 to 763 mm. The minimal temperature was -42 – -43°C in the winter. The temperature has decreased lower -40°C six times during the study period. The depth of soil freezing reaches 108 cm, and on average, it is 48 cm (figure 3). A high snow cover promotes reducing soil freezing; it is 82 cm on average and reaches 1 m and even more elevated in different years [10].

Ten plants of each form were researched in the experiment. The scheme of plantings is 5 × 1.5–2 m. We monitored the safety of plantings, their state; the height of trees was measured [15]. Injury of plants by frost was not registered as there have not been critical temperatures for the last ten years.
3. Results and Discussion
We noticed high preservation (to 80-100%) among the following semi dwarves forms of rootstocks 71-3-195, MM 106, Baba-arabskaya the variety Adzhi, Ural 5, Ural 3, elite forms 6–9 H, 5-4-13. Low preservation (12–13%) was seen among rootstocks 65-151, 60-165, 3-6-47, 5-18-1.5-19-2 (Table 1). These forms were less adaptive to the conditions of growing. Rootstocks 64-134, 71-3-130, 1-48-47, Ural 6, Ural 2, 5-4-13, 4-19-3, and 5-19-1 are in good state to 4.0–5.0 points, and rootstocks 65-151, 5-18-1, 3-6-47 were in unsatisfactory state – 2.4–2.7 points. The height of the trees was 2.5–4.0 m. However, this group included trees 1.5 m – 71-3-130, Ural 6, 4-19-9, 4-19-3. It is necessary to conduct additional experiments in a garden in combination with cultural varieties to specify the size of rootstock forms described above. Forms 64-143, 62-223, 60-165, Ural 1, Ural 2, Ural 8, 4-5-1 had a harvest of 4-8 kg/tree for the last four years. Rootstocks of 64-134, 3-6-47, Baba-arabskaya apple tree Adzh, 54-118 had no harvest.
Forms 58-238, 62-14, P22, K-2, Don 70-52 was well preserved – 85–90% among dwarfish rootstocks. 62-396 and 19-7 (Ural 7) perished completely due to insufficient adaptiveness of plants to
extreme conditions of the region. Forms 60-187, 64-134, СПС-7 preserved themselves satisfactory (44–56%). Dwarfish kinds preserved themselves better at 1–1.5 points than semi dwarves due to the early finish of the growing processes and better preparation for the winter [5]. Forms P22, Б 10-19 are the exception. Dwarfish plantings often have a shrub-like shape with a height to 1 m (71-7-22, 58-238, СПС 7, К-2, Don 70-456, Don 70-52). Forms 71-7-22, 60-187, 62-14, Don 70-456 have given harvest of 0.5-2.5 kg/tree for 4 years.

_Malus silvestris_ var _praecox_ was in the best state (5 points) under 100% preservation among seedling rootstocks. By this moment (for four years of the monitoring), the harvest of it was the highest among seedling forms- 2.9 kg/tree. This form reached 4.5 m of height and showed the best adaptation to climatic and soil conditions of the Trans-Volga-Ural region.

**Table 1.** A state of plantings of rootstock forms of an apple tree in the Saraktashskiy fruit tree nursery (Establishment in the autumn of 1992. Data 2020).

| Rootstock          | Preservation, % | State, point | The total harvest for 2017-2020, kg/tree | Height, m |
|--------------------|-----------------|--------------|-----------------------------------------|-----------|
|                    | Semi dwarves    |              |                                         |           |
| 1. 64-143          | 51.3            | 3.2          | 8.6                                     | 2.3       |
| 2. 57-490          | 66.1            | 3.2          | 0.7                                     | 2.7       |
| 3. 65-151          | 13.5            | 2.5          | 0.9                                     | 2.4       |
| 4. 54-118          | 51.3            | 3.0          | 0.1                                     | 2.0       |
| 5. 71-3-195        | 87.5            | 3.2          | 1.4                                     | 1.5       |
| 6. 64-134          | 75.0            | 5.0          | 0.0                                     | 2.0       |
| 7. 62-223          | 29.8            | 3.0          | 8.1                                     | 2.1       |
| 8. 60-165          | 13.4            | 3.0          | 8.3                                     | 2.0       |
| 9. MM-106          | 92.8            | 3.0          | 0.2                                     | 1.2       |
| 10. I-48-47        | 100             | 4.0          | 0.2                                     | 1.8       |
| 11. Baba-arbskaya Uvan | 35.3          | 2.8          | 0.4                                     | 1.9       |
| 12. Baba-arbskaya Adzhı | 90.0          | 3.3          | 0.0                                     | 2.1       |
| 13. Ural 5         | 90.7            | 3.0          | 2.6                                     | 2.3       |
| 14. Ural 6         | 38.9            | 4.2          | 4.2                                     | 1.5       |
| 15. Ural 1         | 25.9            | 3.2          | 12.4                                    | 2.5       |
| 16. Ural 3         | 84.2            | 3.3          | 2.6                                     | 2.5       |
| 17. Ural2          | 38.9            | 3.8          | 6.6                                     | 3.2       |
| 18. Ural 8         | 46.2            | 2.9          | 4.2                                     | 2.7       |
| 19. 6-9H           | 89.6            | 3.8          | 2.2                                     | 2.3       |
| 20. 5-4-13         | 84.0            | 4.0          | 0.2                                     | 2.0       |
| 21. 4-19-3         | 50.0            | 4.3          | 0.5                                     | 1.7       |
| 22. 5-19-1         | 50.0            | 4.0          | 0.5                                     | 3.0       |
| 23. 4-5-1          | 55.6            | 3.6          | 6.8                                     | 2.8       |
|                    | Dwarves         |              |                                         |           |
| 24. 4-19-7         | 0.0             | 1.0          | 0.0                                     | -         |
| 25. 71-7-22        | 48.4            | 4.2          | 1.3                                     | 1.0       |
| 26. 60-187         | 47.3            | 3.1          | 2.5                                     | 1.0       |
| 27. 58-238         | 85.1            | 4.0          | 0.1                                     | 1.0       |
| 28. 64-134         | 55.9            | 4.0          | 0.2                                     | 1.0       |
| 29. SPS-7          | 44.4            | 3.9          | 0.0                                     | 1.0       |
| 30. 62-14          | 90.9            | 4.8          | 0.4                                     | 1.0       |
| 31. K-2            | 86.1            | 5.0          | 0.1                                     | 1.0       |
| 32. 71-3-137       | 81.2            | 2.8          | 0.1                                     | 1.0       |
| 33. Don 70-456     | 46.8            | 4.5          | 1.9                                     | 1.0       |
| 34. Don 70-52      | 90.5            | 5.0          | 0.0                                     | 1.0       |
|                    | Strong-growing (seedling) |          |                                          |           |
| 35. _Malus turkmenorum_ Juz. & Popov | 13.5         | 2.6          | 2.1                                     | 3.1       |
| 36. _M. prunifolia_ (Wild.) Borkh. | 41.2         | 3.4          | 2.1                                     | 2.6       |
| 37. _M. silvestris_ var _praecox_ | 100           | 5.0          | 2.9                                     | 4.5       |
| 38. Kepp            | 100             | 3.0          | 1.6                                     | 3.2       |
The research of drought-resistance of clonal rootstocks in laboratories made an opportunity to identify the most stable forms (table 2). According to the water deficit 2.5-3.9%, semi-dwarves rootstocks 62-223, Ural 5, Elita 4-5, Kinds 54-118, 65-151, Elita 19-7 are characterized by the least water loss for 6 hours – 17.9–19.8%. Rootstocks 65-151, 54-118, Ural 2, Elita 4-19-3, 19-7 are characterized by the water loss for 1 hour of withering – 2.99–3.52%.

Rootstocks 76-23-2 are the most stable for water deficit among dwarfish rootstocks – 4.3%. Forms 71-7-22, K-2, Don 70-456, 76-23-2 reach 18.68–20.9% of the water loss by leaves after withering for 6 hours. A water loss for 1 hour of withering is 3.11–3.3% among rootstocks: 71-7-22, K-2, Don 70-456.

In the laboratory research, Taiga zolotaya [gold] is distinguished among seedling rootstocks by all indicators (water deficit – 6.9%, water loss for 6 hours – 15.45%, a water loss for 1 hour of withering – 2.58%). The research of drought-resistance of clonal rootstocks in the laboratory made an opportunity to receive additional information to estimate the adaptiveness of rootstocks.

Table 2. Drought-resistance of clonal rootstock of an apple tree. Data for 2019.

| Rootstock                  | Water deficit, % | A loss of water by leaves after withering (6 hours), % | An average loss of water for 1 hour of withering, % |
|----------------------------|------------------|-------------------------------------------------------|----------------------------------------------------|
| Semidwarf rootstock        |                  |                                                       |                                                    |
| 64-143                     | 7.8              | 23.32                                                 | 3.89                                               |
| 57-490                     | 7.65             | 25.64                                                 | 4.2                                                |
| 65-151                     | 6.1              | 17.9                                                  | 2.99                                               |
| 54-118                     | 9.25             | 19.89                                                 | 3.32                                               |
| 62-223                     | 3.8              | 24.89                                                 | 4.15                                               |
| Baba-Arabskaya Adzhi       | 6.05             | 27.2                                                  | 4.53                                               |
| Ural 8                     | 5.85             | 26.35                                                 | 4.21                                               |
| Ural 5                     | 3.9              | 26.4                                                  | 4.4                                                |
| Ural 2                     | 12.05            | 21.11                                                 | 3.52                                               |
| Ural 6                     | 15.25            | 24.6                                                  | 4.1                                                |
| Ural 3                     | 11.1             | 24.35                                                 | 4.06                                               |
| 4-19-3                     | 7.97             | 20.2                                                  | 3.37                                               |
| 19-7                       | 5.45             | 18.55                                                 | 3.09                                               |
| 4-5                        | 2.5              | 21.8                                                  | 3.6                                                |
| Dwarfish rootstock         |                  |                                                       |                                                    |
| 71-7-22                    | 8.5              | 18.68                                                 | 3.11                                               |
| K-2                        | 6.8              | 19.63                                                 | 3.28                                               |
| SPS-7                      | 7.6              | 24.35                                                 | 4.06                                               |
| Ural 1                     | 7.55             | 24.75                                                 | 4.13                                               |
| 62-396                     | 9.3              | 21.87                                                 | 3.65                                               |
| Don 70-456                 | 14.6             | 19.8                                                  | 3.3                                                |
| 76-23-2                    | 4.3              | 20.77                                                 | 3.45                                               |
| Strong-growing (seedling) rootstock |            |                                                       |                                                    |
| *M. silvestris var praecox* | 9.3              | 17.25                                                 | 2.88                                               |
| *Taiga zolotaya*           | 6.9              | 15.45                                                 | 2.58                                               |
| *M. baccata* (L.) Borkh.   | 6.0              | 26.5                                                  | 4.42                                               |

4. Conclusion
The study of clonal rootstocks of an apple tree in the free-growing form under the Trans-Volga-Ural region condition gives additional information to estimate rootstock kinds of adaptation to growing conditions. Also, we received data on the power of the growing and crown habitus, preservation, state, and productivity of plantings. Severe winters under the temperature decrease lower -40°C (2002, 2006, 2009, and 2011) made a contribution into plantings subfreezing that led to plant destruction, first
of all, insufficiently adaptive rootstocks: 65-151, 60-165, 4-19-3 and other semidwarves rootstocks; and dwarfish forms 4-19-7, CTC-7. Among seedling rootstocks, the Turkmenkaya apple tree showed low preservation. It is necessary to mention the high preservation and state of semidwarves rootstocks: 71-3-195, Ural 5, Elita 6-9H; dwarfish: K-2, Don 70-52.

It should be noted that the early finish of growing processes positively influenced successful plant overwintering [5]. Plants with increased drought-resistance in extreme conditions (high temperature of the air and soil, low humidity in the sharp deficit of water) are less depressed. As a result, they can prepare better for the winter period.

5. Acknowledgments
This work was done as part of the Steppe Institute Theme (#GP AAAA-A21-121011190016-1).

References
[1] Gryazev V A and Sulamov E 1999 Cyclic recurrence of unfavorable winters and rootstock impact on winter-resistance of fruit trees A collection of reports Part I small stature forms of horticulture International scientific-applied conference on 23-24 July 1999 (Michurinsk: Michurinskiy SAU) pp 51-54
[2] Gryazev V A 2011 Fruit nursery study (Rostov-on-Don: Rostizdat) p 382
[3] Potapov V A, Ulianishchev A S and Krysanov Yu V 1991 A small stature intensive garden (Moscow: Rosagroproizvodstvo) p 231
[4] Solomatin N M 2018 A gene pool of clonal forms of an apple tree to improve the assortment of rootstocks, raw material and ornamental varieties in conditions of the Central chernozem region The auto-abstract on completion of the doctor of agricultural science degree (Moscow) 41 p
[5] Budagovskiy V I 1976 Culture of small stature forms of fruit trees (Moscow: Kolos) p 303
[6] Vitkovskiy V L 2008 Fruit plants of the world (Sankt-Petersburg: Lan) p 592
[7] Michurin I V 1948 Literary work 2 (Moscow: OGIZ) p 620
[8] Ponomarenko V V and Ponomarenko K V 2011 The history of the origin of the clonal rootstock of an apple tree Collection to 100th –the anniversary of V.I. Budagovsky (Michurinsk) pp 200-303
[9] Savin E Z, Berezina T V, Azarov O I and Demenina L G 2015 Results of the selection of clonal rootstocks of an apple tree in conditions of Middle Povolozhie Innovative tendencies and varieties for stable development of modern horticulture pp 196-230
[10] Agronomic resources of Orenburgskaya oblast 1971 (Leningrad) p 120
[11] Sedov E N and Ogoltsovoy T P 1999 The program and methodology of varieties study of fruit, berry and caryocarpous cultures (Orel: VNISPK) p 608
[12] Ponomarenko V V 1975 What is it Malus pumila Mill Botanical Jornal 60(11) pp 1574-1586
[13] Avdeev V I and Burnasheva N A 1992 An apple tree Catalog of the world collection of VIR 629 (Sankt-Petersburg: FSBSO "Federal Research Center N.I. Vavilov's All-Russian Institute of genetic resources") p 71
[14] Bererezina T V 2017 Impact of ecological conditions on development and preservation of fruit plantings in the Trans-Volag-Ural region (on the example of Orenburgskaya oblast) Auto-abstract in the competition of Ph.D. of biology degree (Togliatti) 20 p
[15] Kuznetsov P V 1941 A role of Pyrus salicifilia Pall in development of fruit-growing in arid regions Sovetskaya botanica 1-2 pp 103-108