Digitalization of the breeding process of clonal apple rootstocks

A V Verzilin, Yu A Fedulova, M Yu Pimkin
Michurinsk State Agrarian University, 101, International st., Michurinsk, 393760, Russia
E-mail: luckymiha@mail.ru

Abstract. The paper shows the results of many years of experience in breeding low-growing clonal apple rootstocks at Michurinsky State Agrarian University. The relevance of the introduction of digital technologies at all stages of the breeding process from the formation of a data bank for the selection of parental pairs to research in the garden of the competitive study of rootstock-varietal combinations is shown. The apparatus and software for specific research stages are proposed. It is found that the developed methodology and digital technologies make it possible to significantly reduce the time of the breeding process, achieve the intended results faster and more efficiently and most fully reveal the genetic potential of breeding achievements.

1. Introduction
In modern conditions further development of fruit growing and its intensification are impossible without the presence of adaptive low-growing clonal rootstocks, which provide a set of requirements for intensive-type orchards, namely: preservation of plantations, quick fruiting, high yields of high-quality fruits, dense placement of trees, the possibility of maintenance work etc. [1-3].

Today more than 20 clonal apple rootstocks of various growth rates have been obtained and included into the State Register of Breeding Achievements at Michurinsk State Agrarian University. This allows the cultivation of gardens of varying degrees of intensification. High plasticity and compatibility with varieties contributed to the accelerated development of industrial intensive horticulture not only in Russia, but also in most European countries, as well as in the USA [4].

It would seem that the selection of rootstocks could have been stopped, but, analyzing each rootstock separately, it is easy to notice both its advantages and disadvantages. Thus, the most popular rootstock 54-118 has a disadvantage for intensive gardening - the comparative vigorous growth of stock-varietal combinations and the Paradizka Budagovsky rootstock (PB) has a weak anchoring of the root system, which requires constant support in the garden [5-8].

The apple orchard requires a dwarf rootstock that is adaptable to growing conditions, but with good anchoring of the root system as the organization of the supports itself requires more than half of all the costs of orchard start-up. Thus, while there is a need, the search for such a rootstock should continue.

This is especially relevant in the modern conditions of constant sanctions from unfriendly countries, the need for import substitution and the creation of the possibility to export exclusive goods to other countries.

The effective selection of apple clonal rootstocks, begun by V.I. Budagovsky under the leadership of N.G. Zhuchkov in the 30s of the 20th century, has almost a century of history. During this period,
due to his competently structured work, the creative team of followers and support from the leadership, the university has a wide range of rootstocks of various growth rates, as well as a rich collection of hybrid rootstock, which allows continuing selection [11, 12].

The breeding process itself is long-term and very laborious. The inclusion of elements of digitalization at certain stages of breeding can make it easier. The digitalization of horticulture is a modern way to apply knowledge engineering in order to create an automated management system for applied developments for the production of fruit and berry products in agricultural enterprises [3]. The digitalization process in breeding is not only desirable at the present time, but also a challenge for modern scientific enterprises, limited in their capabilities, as well as the requirement to comply with certain conditions [11].

The purpose of the research is to analyze the directions and assess the scale of the use of digital technologies in the breeding of clonal apple rootstocks.

2. Materials and methods
The research was carried out on the basis of the long-term experience of the Problem Laboratory for the breeding of low-growing clonal rootstocks of apple trees and other crops of Michurin State Agrarian University, as well as the analysis and processing of information from the websites of electronic libraries and companies engaged in research in the field of breeding and seed production.

The research is carried out in connection with the program “Digital Economy of the Russian Federation” No. 1632-r adopted by the Government of the Russian Federation on the 28th of July, 2017.

3. Results
For a successful breeding process of clonal rootstocks, several components are required:
- Hybrid stock of clonal rootstocks and species composition of the apple tree;
- Mother plantation of primary study (seedlings);
- Laboratories for the primary breeding of promising seedlings;
- Laboratories for clonal micropropagation of promising seedlings;
- Mother plantation of the competitive study of the hybrid fund;
- Nursery of competitive study of rootstock-graft combinations;
- Orchard of competitive study of stock-graft combinations.

Long-term experience shows that successful hybridization is impossible without knowing the characteristics of the biological traits of the selected parents, as well as their ability to transmit hereditary traits to offspring [13].

A breeder should be well aware of the “abilities” of this or that parent. This is impossible without hybridological analysis. This is vast information that is formed into a databank based on many years of research. A wide range of the use of existing hybrids as one parent or another allows creating such a data bank. The history of each parental pair is recorded by a breeder in the journal from the moment of hybridization to receiving information from the orchard of the competitive study of rootstock - graft combinations.

The process of computerization of these data according to certain algorithms (percentage of yield of undergrowth seedlings, degree of rooting, frost resistance, salt tolerance, drought tolerance, cranking, productivity in mother plantation, compatibility, resistance to diseases and pests, as well as other indicators at all stages of breeding) most often makes it possible to select effectively parental couples. It is difficult to overestimate this information when changing a breeder.

In order to speed up the implementation of these observations and their analysis, the scientists of Siberian Federal Scientific Center of Agrobiotechnology of the Russian Academy of Science have developed software that can be used in the breeding process in order to obtain information and analytical data. Thus, for example, to save data on the assessment of the breeding value of experimental plants as a result of field observations on a basis of important characteristics for
breeding, the program “Field experiments. Registration and assessment of breeding material for agricultural crops” is used.

After hybridization and selection of the obtained seeds, they are marked and sown in the mother plantation of the competitive study. However, before sowing seeds, it is necessary to have information about the sowing site namely about the uniformity of the soil in terms of relief, acidity, the presence of nutrients, weed infestation and other indicators. Earlier the researchers carried out the assessment of breeding plots manually, which required a lot of time and effort, now All-Union Research Institute of Agricultural Mechanization has investigated the possibility of the use of unmanned aerial vehicles (UAVs) to monitor these areas [13].

After receiving one-year hybrid seedlings, the most promising ones are selected among initially a large number of them (5-15 thousand pieces) after their assessment by various express methods. The main indicators at this stage of selection are low growth rate, frost resistance and the degree of development of the root system.

The most time-consuming one is the assessment of weakness. This assessment is carried out not only and not so much by the height of the growth, but by the length of the root hairs. The shorter they are, the weaker the rootstock will be. If previously it was necessary to keep the separated strands of roots in alcohol or formalin for further study, then with the development of digital video recording, they can be easily recorded in a photo, analyzed and stored in a data bank.

It is necessary to note that after careful testing and strict selection by express methods, we get a plant in a single copy. If we use traditional breeding methods, then it takes 25-28 years to fully study this rootstock at all stages of selective breeding.

For accelerated reproduction of a promising rootstock, we have developed a method for clonal micropropagation with its subsequent placement at the next stages of the breeding process [11, 12]. After carrying out the thermotherapy, using meristematic tissues in the process of micropropagation, within 1-2 years we obtain the required amount (2-3 thousand pieces) of a clone of this rootstock in a healthy state. At the same time, the method of its micropropagation (nutrient medium, composition of macro, microelements, vitamins and other components of this medium at the stages of micropropagation) is performed and included into the data bank of this rootstock, taking into account its biological characteristics. This is especially important when it is necessary to further multiply it.

As it is mentioned above, long-term studies of a large series of clonal rootstocks show a direct correlation between the growth force of the rootstock and the development of the root system. Thus, the weaker the growth of the rootstock, the less developed its roots, which in the future causes the slopes of the trees and the need for permanent supports.

The solution may be the formation of a more developed root system in the symbiosis of this plant with the Ri-plasmid Agrobacterium rhizogenes of the A4 strain. Moreover, the morphophysiological parameters of the plants regenerated in vitro corresponded to the phenotypes of the original plant [12]. With a successful solution to this issue, there is no need to install supports, which will significantly reduce the cost of orchard start-up.

Due to the rapid reproduction of the desired plant, it becomes possible to study it simultaneously in the mother plantation of competitive study and in the nursery of competitive study of rootstock-graft combinations and after growing the seedlings in the nursery (after 2-3 years) we can study it in the orchard of the competitive study of rootstock-graft combinations.

Taking into account the rapid entry into the fruiting period on a weak rootstock (2-3 years after planting) and obtaining 3 harvests in a fruiting garden, it is possible to obtain (in 12-13 years after hybridization) sufficiently complete information to assess the rootstock and its transfer to a production test and experimental stations.

The territories of these plots are rather large and planting control requires more time and effort. However, even here, digital technologies become a remedy. Thus, the Wintersteiger Company, together with Delair, created the Delair UX 11 AG drone, using which it is possible to obtain plant data on the viability, plant height, flowering rate, plant occupation area, which is necessary in the study of the rootstock-varietal combinations in a nursery and orchard.
4. Conclusion
Modern development and the introduction of digital technologies can significantly increase the efficiency of the breeding process of low-growing clonal apple rootstocks.

The computer programs developed at Siberian Federal Scientific Center of Agrobiotechnology of the Russian Academy of Science make it possible to successfully carry out information and analytical support at various stages of breeding.

Unmanned aerial vehicles can significantly speed up and facilitate the collection of the necessary information for the analysis of selection results.

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