Selection improvement of pear (*Pyrus communis* L.) in the Lower Volga region

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Abstract Over the past several decades, work has been carried out in the Lower Volga region to improve the assortment of pears using classical and analytical selection methods. Until 2016, the main breeding work was carried out in the Lower Volga Research Institute of Agriculture after the reorganization in the Federal Research Center for Agroecology of the Russian Academy of Sciences. The selection process was based on the methods of stepwise intervarietal hybridization. High-winter-hardy, but with low quality fruits, varieties of local selection and high-quality, but not sufficiently stable, varieties of western selection were used as parent forms. As a result, varieties and hybrids were obtained that have high fruit qualities and increased resistance to abiotic and biotic stress factors of various periods of consumption. Currently, three varieties are zoned in 8 regions, a number of varieties and hybrids are undergoing preliminary and state tests, and can be used both in production and further breeding as donors and sources of economically valuable traits.

1. Introduction
The southern regions of Russia, including the Lower Volga region, are favorable for the cultivation of most fruit plants, including pears, which are in great demand among the population. Due to the successful combination of soil and climatic conditions, this crop produces high yields of high-quality fruits suitable for fresh consumption and various types of processing [1].

At the same time, due to the specific conditions of the sharply continental climate of the Lower Volga region, for a long time the biodiversity of this culture remained very imperfect and meager, and consisted of old varieties that did not fully satisfy the needs of consumers. Winter-hardy local and old Russian varieties have mediocre taste and technological qualities of fruits, and the most winter-hardy southern varieties, with good quality indicators and cultivated in the Lower Volga region, suffer severely and sometimes freeze during severe winters (1954 - temperature -370°C, 1968 year - a snowless winter with a temperature of -28 ... -300C, 1978 - a temperature of -33 ... -350C, 2005 - a temperature of -28 ... -330C). The practical absence in the region of high-quality and adaptive varieties of late ripening period was also a constraining factor in the spread of this crop and sharply reduced the economic efficiency of its cultivation in industrial plantings. All these reasons created the preconditions for conducting selection work to create new varieties of pears of different ripening periods, which are resistant to unfavorable abiotic and biotic stress factors, high yield and quality of fruits, as well as early maturity and weakness [2].
Selection work was carried out in the following areas:

- study of the variety of the existing assortment of pear (Pyrus communis L) and the identification of valuable forms for use in breeding;
- choice of parental pairs for hybridization;
- hybridization of selected pairs, and also sowing seeds of the best varieties from free pollination, to obtain new genotypes of Pyrus communis L.

2. Materials and methods

The expansion of the biodiversity of fruit crops is possible both by attracting third-party forms of cultivated and wild plants, and by selective improvement of the existing assortment [3, 4, 5]. Work on the selective improvement of the domestic pear (Pyrus communis L) in the Lower Volga region was begun in the 50s of the last century by breeders Korneev V.A., R.V. and Zhukova L.K. At the first stage, a variety study of a number of different forms of pear was carried out and the identification of valuable varieties of local origin, foreign and Russian selection. From the beginning of the 80s of the last century to the present, the Federal Research Center for Agroecology of the Russian Academy of Sciences (until 2016 at the Lower Volga Scientific Research Institute of Agriculture) has been studying various genotypes of pear (Pyrus communis L) (more than 100 samples) and a hybrid fund (more than 1000 seedlings). The number of accounting trees of each variety ranged from 6 to 10 plants with 4-fold repetition [6, 7]. In the hybrid fund, each hybrid seedling was presented in a single copy [8].

The selection work to improve the assortment of pears in the Lower Volga region was based on the method of targeted inter-port hybridization and subsequent selection using local adaptive varieties [8, 9]. The hybridization technique included the following steps: isolation of the buds of the mother plants; castration of maternal flowers; pollen harvesting; verification of pollen viability before pollination; pollination. The isolation of the buds was carried out 5-6 days before flowering, using bags of gauze or parchment paper. For one family, 1000 flowers were isolated from a pear. Pollen was harvested from the paternal plant at the rate of one to two five days before pollination and stored in a desiccator filled with calcium chloride or sulfuric acid. Pollen viability was checked by germination for 4-5 hours in a 15% sucrose solution with the addition of 0.1 mg of boric acid per 100 ml of solution. After pollination, two revisions were performed. Hybrid seeds were sown in the nursery, where preliminary selection was carried out for 2 years. The separated seedlings were transplanted into a selection garden, where they were selected for economically valuable traits [8].

The degree of resistance of the initial forms and hybrids of domestic pear (Pyrus communis L) to adverse winter factors was evaluated against a natural background in open ground, in accordance with generally accepted methods [6, 7]. Economic signs of hybrids: productivity, early maturity, ripening period, quality of fruits; and biometric indicators of trees - the strength and nature of growth, the type of fruiting and other parameters were also evaluated according to generally accepted methods [6, 7].

Accelerated creation of new varieties of pears was based on the use of analytical selection method (genealogical method). Prebreeding was based on an understanding of the genetic determination of valuable traits needed for use in hybridization [10]. Due to the lack of effectiveness in applying the hybridological method to perennial fruit crops, in addition to it, genealogical analysis was used in genetic analysis. This method is appropriate from the point of view of both theory and practice of the breeding process and allows you to select genotypes that meet the requirements of donors, as well as to suggest the likelihood of the manifestation of valuable traits that are available to the ancestors. In the genealogical method, in addition to the appearance of signs of parental forms in the offspring, great importance was attached to the presence in hybrids of signs of progenitors that are absent from the parents [10].

3. Results and discussion

A number of valuable varieties and hybrids were created in the laboratory of selection and technology of fruit crops of the Federal Research Center for Agroecology of the Russian Academy of Sciences, as a result of work to improve the assortment of pears. At the same time, it was necessary to generalize the
accumulated experience in creating new varieties with the participation of local and best forms in the specific conditions of the Lower Volga. For this purpose, a genealogical analysis was used, successfully used to study most fruit crops [10].

As the source material in the selection of adaptive pear varieties, the most productive is the use of local as well as old adaptive varieties, the value of which was noted by many breeders (Michurin, Sedov, Savelyev, Falkenberg, Efimov, Mozhar, etc.) [2, 11, 12]. Varieties of late Mlievskaya, Mlievskaya dessert, Bergamot Mlievsky, as well as new Central Asian varieties - Bakhmal, Dilbar, Rano, Lastochka, and some West European varieties - Olivier de Serre and others took part in repeated crosses. All parent forms had certain positive qualities (table 1).

Table 1. Characterization of the original parental forms.

| Grade       | Winter hardiness | fruit ripening period | fruit weight, gram | fruit score | the chemical composition of the fruit appearance | taste | common sugars, % | acid, % | Sugar Acid Index |
|-------------|------------------|-----------------------|-------------------|------------|-----------------------------------------------|-------|-----------------|--------|-----------------|
| local varieties          |                  |                       |                  |            |                                               |       |                 |        |                 |
| Bergamot Volga           | high             | October-December     | 100-130           | 4.0        | 4.0                                           | 7.2   | 0.51            | 14.1   |
| Ilyinkia                | high             | July-August          | 80-120            | 4.0        | 4.2                                           | 8.9   | 0.18            | 52.4   |
| foreign varieties        |                  |                       |                  |            |                                               |       |                 |        |                 |
| Bere Winter Michurin     | high             | October - February   | 80-120            | 4.0        | 3.8                                           | 10.5  | 0.23            | 45.6   |
| Forest beauty            | average           | September             | 150-160           | 4.7        | 4.8                                           | 8.5   | 0.23            | 37     |
| Klapp’s favorite         | average           | August                | 170-210           | 4.7        | 4.6                                           | 8.3   | 0.4             | 21     |
| Williams                 | average           | August - September   | 170-180           | 4.8        | 4.8                                           | 8.3   | 0.42            | 19.8   |
| Kiffer’s seedling        | Above average    | October - September  | 150-180           | 4.4        | 4.2                                           | 8.1   | 0.3             | 27     |
| Olivier de Serre         | Average           | December - January   | 150-170           | 4.3        | 4.7                                           | 8.9   | 0.44            | 20.2   |
| Bahmal                   | Above average    | September - October  | 150-180           | 4.5        | 4.6                                           | 11.9  | 0.38            | 30.5   |

The most effective was the hybridization of the varieties of folk selection Merezhka, Bessemyanka, Belolistka, Bergamot Volga, Muscat Bergamot and Michurinsky variety Bere Winter Michurin with Western European and Southern varieties: Forest Beauty, Klapp's favorite, Kiffer's seedling, Williams and Dyush. As a result, winter-hardy varieties with high quality indicators of fruits were obtained: Early Dubovskaya, Winter Kubarevidnaya, Yubileynaya Korneeva, Seasonal (figure 1-3).

Figure 1. The selection model for optimization of the early Dubovskaya variety based on genealogical analysis.
Figure 2. The selection model for optimization the variety Winter Kubarevidnaya based on genealogical analysis.

\[\text{Winter Kubarevidnaya} \begin{cases} \text{♂ Bergamot Volga} \\
\text{♀ Williams + Clapp's Favorite} \end{cases} \]
\[\begin{cases} \text{♀ Forest Beauty} \\
\text{♂ Free pollination} \end{cases} \]

Figure 3. The selection model for optimization of the Yubileinaya Korneeva variety based on genealogical analysis.

\[\text{Yubileinaya Korneeva} \begin{cases} \text{♂ Bergamot Volga} \\
\text{♀ Duchess Angouleme + Kiffer's Seedling} \end{cases} \]
\[\begin{cases} \text{♀ Ussuri pear} \\
\text{♂ Williams?} \end{cases} \]

Variety Dubovskaya early, late summer ripening, has high winter hardiness transmitted from the Ussuri pear and high taste qualities of the fruits inherited from the varieties Forest Beauty and Bere Royal (table 2). Pear variety Winter kubarevidnaya winter ripening period of the fruit, inherits from the variety Bergamot Volga high winter hardiness, ripening period, but at the same time strong growth of the tree and later fruiting. From Western European varieties, the high quality of the fruits was transmitted to him. The Yubileinaya Korneeva variety has high winter hardiness and resistance to fungal diseases, which he inherited from the parental and ancestral forms of Volga Bergamot and wild Ussuri pear. At the same time, despite the presence of parental forms with high-quality fruits - Duchess Angouleme and Kiffer’s Seedling, it loses to many varieties in the quality of the fruits. Therefore, this variety was used in subsequent hybridization as a donor of high winter hardiness and disease resistance. As a result, we obtained such high-quality and adaptive varieties as Capella, Banquet, and others (figure 4).

Figure 4. The selection model for optimization of the variety Banquet based on genealogical analysis.

\[\text{Banquet} \begin{cases} \text{♀ Yubileinaya Korneeva} \\
\text{♂ Bergamot Volga} \\
\text{♀ Duchess Angouleme + Kiffer's Seedling} \end{cases} \]
\[\begin{cases} \text{♂ Olivier de Serre} \\
\text{♀ Ussuri pear} \\
\text{♂ Williams?} \end{cases} \]

The Banquet variety has inherited high adaptability from the parent and grandparent forms, from the parent form Olivier de Serre the high quality and shape of the fruit, and also early maturity and weakness of trees, which makes this variety one of the most promising for intensive gardening.

Good results when creating varieties and hybrids were achieved by sowing seeds of the best forms of various origin obtained from free pollination. The most productive variety, giving free pollination the largest number of promising elite seedlings, which later became varieties, was Bakhmal (figure 5).

In these combinations, the influence of environmental factors could contribute to the manifestation of positive transgressions and the emergence in F2 and subsequent generations of genotypes with
selection-valuable traits, the complex of which served as the basis for their allocation to the elite (table 2).

![Diagram](image)

**Figure 5.** The selection model for optimization of the Korneev Pamyat variety based on genealogical analysis.

The result of many years of selection work to improve the assortment using various methods, including interspecific hybridization and free pollination, became varieties, including zoned, and hybrids that are not inferior in winter hardiness to the local and most winter-hardy foreign varieties, but in quality indicators (size, taste of fruits) and yields exceeding them, and corresponding to the level of the best Western parental forms (table 2).

New pear varieties and hybrids can be considered as sources of selection-significant traits in pome breeding, not only in the Lower Volga region, but also in other regions of Russia, both in the southern and middle areas of fruit growing. Of particular value are genotypes that combine the adaptability trait with other valuable traits. These include sources:

- winter hardiness and high productivity: Yubileinaya Korneeva, Memory of Korneev, Banquet;
- early ripeness: Dubovskaya early, Hope;
- late ripening of fruits: Winter kubarevidnaya, Version;
- large-fruited: Banquet, Memory of Korneev, Chapel, Positive;
- high taste qualities of fruits: Banquet, Chapel, Nectar, Doctor;
- early maturity: Memory of Korneev, Banquet;
- weakness of trees: Banquet, Memory of Korneev.

Varieties of Yubileinaya Korneeva, Banquet, Memory of Korneev, Chapel can be considered complex donors and sources.

**Table 2.** Characterization of new pear varieties obtained in the laboratory of fruit crop selection of the Federal Research Center for Agroecology of the Russian Academy of Sciences.

| Grade                  | Origin                          | Ripening period | fruit weight, gram | Attractive appearance, rating | Taste, rating | Overall rating | common sugars, % | acid, % | Sugar Acid Index, % |
|------------------------|---------------------------------|-----------------|--------------------|------------------------------|---------------|----------------|------------------|---------|---------------------|
| Dubovskaya early       | Bere Winter Michurin x Forest beauty | August          | 125 - 130          | 4.5                          | 4.5           | 4.5            | 13.1             | 0.16    | 81.9                |
| Winter kubarevidnaya   | Bergamot Volga x Williams + Klapp's favorite | December-March | 150 - 170          | 4.5                          | 4.4           | 4.5            | 11.9             | 0.12    | 99.2                |
Yubileinaya Korneeva | Bergamot Volga x Duchess Angouleme + Klapp's favorite + Deccan Jules Guillot
---|---
Hope | No. 52 (Seedling №1 x Ilyinka) x Williams + Klapp's favorite + Deccan Jules Guillot
Chapel | Yubileinaya Korneeva x Olivier de Serre
Banquet | Yubileinaya Korneeva x Olivier de Serre
Zonal | No. 18 (Seedling No. 1 x Forest Beauty) free pollination bahmal
Memory of Korneev | Free pollination bahmal
Positive | Free pollination bahmal
Doctor | Free pollination bahmal
Version | Free pollination bahmal
Nectar | Free pollination bahmal
Seasonal | Bere Winter Michurin x Klapp's favorite + Olivier de Serre

### 4. Conclusion

The climatic conditions of the Lower Volga region contribute to the formation of signs of winter hardiness in hybrid seedlings of domestic pear (*Pyrus communis L*) in combination with large-fruited and good taste qualities of the fruits.

As a result of monitoring based on genealogical analysis and selection work on the pear using the forms of Seedless, Belolistka, Bergamot Volga, Bere Winter Michurin, Forest Beauty, Klapp's favorite, Kiffer's Seedling, Williams, Duchess Angouleme, Bakhmal and others, a selection model of genetic optimization was developed and highlighted new varieties and elites - Dubovskaya early, Winter Kubarevindnaya, Hope, Banquet, Memory of Korneev, Doktor, Chapel, Version, Nectar, Positive, Seasonal, that can improve the assortment of this crop in the Lower Volga Region, especially in terms of adaptive, high-yielding, high-quality varieties of different periods of fruit consumption. The fact that F2 hybrids obtained from the free pollination of F1 hybrids, which, in our case, are the polymorphic varieties Bakhmal, Yubileinaya Korneeva, etc. and don't manifest themselves so clearly, or don't combine and do not appear at all.

The regional assortment in the Lower Volga region was replenished with three varieties - Dubovskaya early, Winter Kubarevindnaya, Yubileinaya Korneeva, varieties - Banquet, Memory of Korneev, Positive, Version and others - are under variety testing. It is advisable to use the Yubileinaya Korneeva variety as a donor, other varieties and forms as sources of various breeding-significant characters in breeding programs for the further improvement of the domestic pear.

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