Tree-shrub species promising for protective afforestation and planting in the Volgograd region

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Abstract. For the successful development of agriculture and increase the productivity of the arid zone of the Volgograd region, preservation of the soil from water erosion and deflation, protective forest and greenery plantations that are resistant to harsh forest conditions are necessary. The objects of study are various species of poplar *P. nigra*, *P. bolleana*, *P. alba* etc., rose hips *R. rugosa*, *R. spinosissima*, *R. alba Maximus* etc., elm *U. campestris* × *U. pumila*, which were evaluated according to the following parameters: degree of damage to plants by drought, total amount of water, winter hardiness, as well as their growth and development. The study showed that species *P. nigra*, *R. rugosa*, *R. cinnamomea*, and *U. pumila* have the highest approximation coefficients. *U. laevis* and *P. deltoides* are moderately resistant to high temperatures, and the species *U. pumila*, *P. nigra*, *P. alba*, and *P. balsamifera* are thermo- and pathogenic resistant. A study of the morphological features of various poplar species revealed the tallest species *P. alba* and *P. nigra* (20–22 m). The tallest shrub species are *S. sorbiforia*, *R. alba*, and *R. canina*.

1. Introduction
In the arid conditions of the Volgograd region, protective afforestation and planting play a huge role in enriching flora and fauna, providing crop increases, preserving soil from water erosion, deflation, and increasing pasture productivity. According to the "Strategy for the development of protective afforestation in the Russian Federation for the period until 2025", another 645.9 thousand ha of forest shelterbelts should be created in the Volgograd Region, of which only 359.5 thousand ha are currently available [6]. An important role in enriching the assortment of plantations is played by species that are resistant to extremely harsh forest conditions: lack of moisture, droughts, dry winds and dust storms, salinity and saline soil, pests and diseases.

Tree species are of great interest: *Populus nigra* L., *P. bolleana* Louche, *Populus alba* L., *Populus balsamifera* L., *Ulmus pumila* Huds. and hybrids *U. campestris* × *U. pumila*, *U. pumila* × *U. campestris*, as well as, shrubs: *Spiraea vanhouttei* (Briot) Zabel, *Symphoricarpos albus* (L.) S.F.Blake, *Rosa rugosa* Thunb, *Rosa spinosissima* L., *Rosa alba* Maximus, *Rosa foetida* Herrn., *Rosa canina* L., *Rosa cinnamomea* L., *Sorbaria sorbifolia* (L.) A. Braun, *Spiraea japonica* L.f. and *Cotoneaster lucidus* Schltdl.

According to many scientists, the main task of expanding the use of local species in landscape design and plantings of various types is to create ornamental plants that are both environmentally and economically functional [12]. So, for example, rosehip species can be used in park gardening [14, 20, 11], perfumes [16], and the medical industry [18, 19, 21]. Some elm species and poplar species are
resistant to pests and diseases [7], are able to retain dust in plantations [22, 15], are resistant to flooding [13], and their microclonal propagation plays a significant role in adaptation to various stressful environmental conditions [17, 8–10].

2. Materials and methods
The objects of research were the following species of trees and shrubs: Ulmus glabra Huds., Ulmus minor Mill., Ulmus laevis Pall., Ulmus pumila L., U. campestris x U. pumila, U. pumila x U. campestris, Populus nigra L., P. alba L., P. balsamifera L. P deltoides Bartr. ex Marsh., Spiraea vanhouttei (Briot) Zabel, Symphoricarpos albus (L.) S.F.Blake, Rosa rugosa Thunb, Rosa spinosissima L., Rosa alba Maximus, Rosa foetida Herrm., Rosa canina L., Rosa cinnamomea L., Sorbaria sorbifolia (L.) A. Braun., Spiraea japonica L.f. and Cotoneaster lucidus Schltdl. The studies were conducted in 2017–2019. on the territory of dendrological collections of the Federal Research Center for Agroecology of the Russian Academy of Sciences (Volgograd, Kamyshin). When conducting geobotanical studies, the stationary method was used. In the vicinity of the selected site, a network of routes was laid evenly, capturing all available habitats of experimental plant samples [2]. The degree of damage to plants by drought was determined visually [3]. The five-point scale included the following damage points:

- 1 point – the crown is not damaged;
- 2 points – the crown is slightly damaged;
- 3 points – the crown is medium damaged;
- 4 points – the crown is badly damaged;
- 5 points – the crown is very badly damaged.

10 plants of each species were evaluated.

To determine the total amount of water in plants, 5–10 leaves were placed in metal boxes (2-fold repetition) and dried in a thermostat at 105 °C to constant weight.

The total amount of water (B) as a percentage of the wet weight of the sample was determined by the formula:

\[ B = (B - C) \times Sh (B - A) \]  

where \(A\) is the mass of the empty container (g), \(B\) is the container mass with wet sample (r), \(C\) is the container mass with dry sample (g).

Winter hardness was determined on a scale where highly winter-resistant are the varieties that are not damaged in ordinary winters (up to 1 point), having a degree of damage of up to 2 points in critical winters and not damaged in ordinary ones, not reducing yields after overwintering in critical conditions (3 points); weakly resistant are the varieties that are severely (up to 4 points) damaged in critical winters; non-resistant are the varieties that are moderately and severely damaged in ordinary winters, and in critical winters, as a rule, completely dying [4].

Plant growth and development was studied by annual measurements of the height, diameter and width of the crown [5]. Weather data were studied according to the website [23].

3. Results and discussion
Long-term experience of introduction shows that the growth indicators of plants in the arid zone can be limited by the weather conditions of the region of introduction. According to the results of the studies, it was found that the tallest species among the trees are P. alba L. and P. nigra L. (20–22 m), P. bolleana Louche (21 m), balsam poplar (18–21 m).

The equations of the growth pattern of some species enable the formation of the types of plantation spatial organization and planting density:

- \( R. \ canina \ y=0.7876 \ Ln \ (x)+6.2803 \ R^2 =0.8911 \)
- \( R. \ spinosissima \ y=1.5374 \ Ln \ (x)+6.4359 \ R^2 =0.9145 \)
- \( R. \ cinnamomea \ y=2.8851 \ Ln \ (x)+8.7636 \ R^2 =0.9295 \)
- \( R. \ rugosa \ y=2.4668 \ Ln \ (x)+7.9882 \ R^2 =0.9605 \)
- \( S. \ vanhouttei \ y=1.2119 \ Ln \ (x)+5.2397 \ R^2 =0.9051 \)
- \( P. \ nigra \ y=1.4671 \ Ln \ (x)+1.26655 \ R^2 =0.9871 \)
- \( U. \ pumila \ y=0.1023 \ Ln \ (x)+2.1237 \ R^2 =0.8466 \)
Among the shrubs, the tallest species are mountain ash, wild rose, white rose, wild rose and the Vanhoutte spiraea (Fig. 1).

Moisture content below 300 mm in combination with air drought and high temperatures causes varying degrees of metabolic disturbance, plant growth and productivity.

Field and laboratory studies have shown a slowdown in shoot growth, discoloration of leaves, their yellowing and drying in the species \textit{R. alba Maximus}, \textit{S. sorbifolia L.}, \textit{U. minor Mill.}, \textit{P. bolleana} Lounche. The water deficit in these species amounted to 15–20 \%, the remaining species lost water in the smallest quantities, were less demanding on water availability. The most adapted to dry conditions were rosehip species with an extensive range: \textit{R. spinosissima L.} and \textit{R. sanina L.}, their water deficit was 9–12 \%.

\textit{U. pumila L.} is more resistant to high temperatures than \textit{U. laevis Pall}. The average level of damage to the crown of \textit{U. laevis Pall.} in stands was 3.1 points, while that of \textit{U. pumila L.} was 2.8 points. The hybrid \textit{U. campestris} \textit{x} \textit{U. pumila} has a thermal damage level of 2.5 points and is superior in thermal tolerance to the hybrid \textit{U. pumila} \textit{x} \textit{U. campestris} with 3.4 points. \textit{U. campestris} is similar to the hybrid in thermal stability (3.4 points). With an increase in the number of trees damaged by high temperatures and drought, increases damage by necrosis, tracheomycosis and bacteriosis. An increase in thermal damage in the stands affects the distribution and development of pathogens of plant diseases, but the species composition of phytopathogens in all biotopes was similar. Of the shrubs in the greenery of Kamyschin city, the most drought resistant were \textit{Symphoricarpus albus} (L.) S.F. Blake, \textit{Spiraea japonica} L.f. and \textit{Cotoneaster lucidus} Schlidl. In urban conditions, thermal damage to plants provokes the development of diseases to a greater extent than in protective forest plantations. The weakening of trees by climatic and soil conditions is enhanced by anthropogenic and recreational pressure.

The degree of winter hardiness of species revealed the minimum winter temperatures. The lowest temperature in 2017 was observed on January 24 (–24.4 °C) and on February 8 (–25 °C). In 2018, low temperatures were observed on January 14 (–17.6 °C) and February 27 (–17.8 °C). Year 2019 was marked by mild weather conditions. The air temperature was only –13.7 °C on February 4.

All studied species were slightly frozen, but did not reduce productivity after overwintering; which indicates their high environmental flexibility and adaptation to new conditions in the region of introduction.

Monitoring of the pathological state of plants revealed a complex of diseases caused by pathogens in \textit{Rosales} species on stems and branches: \textit{Botrytis cinerea}, \textit{Coniothyrium wernsdorffiae} (cancer), as well as from the genera \textit{Cytospora}, \textit{Diaporthe}, \textit{Diplodia}, \textit{Fusarium}, \textit{Physalospora}. On leaves, the pathogens from the genera \textit{Sphaerotherca} causing powdery mildew and \textit{Peronospora} and \textit{Pseudoperonospora} causing downy mildew were identified. Also other pathogens were identified that cause various kinds of spotting (\textit{Cercospora}, \textit{Diplocarpon}, \textit{Phylllosticta}, \textit{Septoria}, \textit{Marssonina}), rust (\textit{Phragmidium mucronatum}) and drying (\textit{Verticillium dahliae}).
In the Volgograd region, the prevalence of elm pathologies and the degree of their development depends on age, mixing of breeds, planting density, row and growth conditions. Species of Ulmaceae are mainly 40 years or more and are infected with graphiosis, necrosis and bacterial dropsy (up to 65 %). In middle-aged plantings (15–25 years), plants are resistant to phytopathogens, while young trees (10–15 years) are almost completely healthy. The most resistant to diseases from elm family are U. pumila and hybrid U. pumila x U. campestris [1].

*Populus* species aged 40 years or more are slightly resistant to diseases. From 25 to 34 % of plantings under 30 years old are affected; trees under the age of 10 years are immune and less susceptible to bacterial dropsy (22.4 %), spotting (1.7 %), cytosporosis (19.0 %), black cancer (14.2 %).

The development of new nutrient resources by pathogens in introduced plants is primarily observed in species that have related species from native plants (for example, in species of P. Ulmus, Rosa, etc.). However, introducers that do not have a close phylogenetic relationship with the local flora are damaged by polyphage fungi, pathogens that enter the habitat along with introducers, as well as parasite species with a wide distribution range.

The causative agent, infecting the introducer, shows the characteristic symptoms of the disease. However, the plant uses its protective mechanisms, preventing the pathogen from forming a complete sporulation and continuing to colonize its species. This interaction between the pathogen and the host plant may continue for several years. This makes it difficult to detect a pathogen in a timely manner and diagnose a possible disease of an introduced plant. A resistant plant leads to a decrease in the number of pathogens, which can lead to the emergence of a highly specialized complex or a change in pathogens.

The shape of the crown allows dividing the types into application groups in stands of various types (Table 1).

![Table 1. Characteristics of species for planting in cities and towns](image)

| Species                  | Life form * | Crown shape | Application |
|--------------------------|-------------|-------------|-------------|
| Rosa. canina L.          | S           | g.          | g.          |
| R. cinnamomea L.         | S           | o.          | h., g., s., m |
| R. rugosa Thunb.         | S           | g.          | h., g., s., m |
| R. spinosissima L.       | S           | g.          | h., g. m.   |
| R. foetida Herrm.        | S           | g.          | h., g., s., m |
| R. alba Maximus          | S           | s.          | h., g., s., m |
| Spiraea vanhouttei Zabel.| S           | r.          | s., h       |
| Sorbaria sorbifolia L.   | S           | s.          | h., g., m.  |
| Ulmus pumila L.          | T           | w.          | s.g.        |
| U. pumila x U. campestris| T           | r.          | s.g.        |
| Populus nigra L.         | T           | r.          | s.g.        |
| P. bolleana Louche       | T           | o.          | s.g., h     |
| Populus alba L.          | T           | r.          | s.g.        |
| Populus balsamifera L.   | T           | b.          | s.g.        |

* Note. Life form: T means дерево, S means shrub; crown shape: r. means round, b. means broad, g. means globe, o. means ovoid, s. means spread; c. means creeping; w. means weeping; application: g. means groups, s. means single plantings (solitaire), m. means marge, h means hedge.

4. Conclusion
According to research, in the collections of the Federal Research Center for Agroecology of the Russian Academy of Sciences, species of trees and shrubs of various ages and geographical locations undergo a full cycle of seasonal development. Regression models of changes in the course of plant growth make it possible to justify planting density and form types of spatial structure. The highest approximation coefficients are: *P. nigra* (0.987), *R. rugosa* (0.960), *R. cinnamomea* (0.929), *U. pumila* (0.846). *U. laevis, P. deltoides* have an average degree of resistance to high temperatures (3.5–4.0 points). Heat and pathogen resistant are *U. pumila, P. nigra, P. alba* and *P. balsamifera*. The impact of industrial pollution increases the degree of thermal damage by 7–18 %. All studied species can be used in various types of
greenery plantings and agroforestry, as well as for the creation of multifunctional plantations: fruit, melliferous, medicinal, etc.

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