Features of Bioecology of Tree Species Intended for the Implementation of the National Project “Improvement of the Volga” in the Volgograd Region

A P Iozus ¹, S Yu Boyko, A A Zavyalov
Kamyshinsky Technological Institute (branch) of the State Educational Institution "Volgograd State Technical University"

Russian Federation, 403874, Kamyshin, Lenin street, 6A
E-mail: ¹ ttp@kti.ru

Abstract. Within the framework of the implementation of the national project “Improvement of the Volga”, it is planned to create a system of water protective forest belts along the banks of the Volga River. On the territory of the Volgograd region, forest strips will have to be created on unproductive, saline, gravelly and eroded soils. Therefore, to create plantings, we suggest using planting material selected as a result of many years of selection work, characterized by increased salt tolerance, frost resistance and durability. In extreme soil and climatic conditions of the region, when selecting an assortment of protective forest stands, the additive effect of salinization and drought on tree-shrub vegetation should be taken into account, especially on saline soils of low forest suitability. As a result of the research, it was possible to identify groups of tree species by the degree of increase in salt tolerance, which will allow introducing into the protective forest stands the sustainable and durable species and forms of woody plants created under the project.

1. Introduction

One of the most effective methods to deal with climate anomalies is to create a barrier in the form of green spaces that eliminate carbon dioxide from the atmosphere, mitigate global climate events. The previously created protective forest plantations without due care experience a process of considerable degradation and decay [1-5].

At the meeting on the implementation of the national project "Improvement of the Volga" under the leadership of Dmitry Medvedev, it was announced that experts consider the creation of a natural barrier - water protection forest strips along the banks-to be an effective method of protecting the river. The same method is considered by experts of the forest industry as a solution to the problems of reforestation in coastal areas [3-5].

According to preliminary estimates, to create protective forest belts along the entire length of the Volga River, 88 million seedlings must be planted on a total area of more than 35 thousand ha. In accordance with the requirements, plantings in the implementation of the national project should be created in a kilometer zone from the coastline. In the Volgograd region, the length of these lands is 570 km along the Volga River. From the border of the Saratov region to the city of Volgograd there are mainly chestnut, solonetzic and solonchak soils, and from the city of Volgograd to the border with the Astrakhan region there are solonetzes, brown solonetzic and solonchak soils. These lands are also unproductive, crushed stone, eroded, and frequent droughts and dry winds in this climatic zone make the situation particularly tense. Therefore, to create plantings, we propose to use breeding planting material, characterized by high salt tolerance, frost resistance and durability [4-8]. Protective plantings in these conditions should differ in biodiversity and include different types and forms of tree species, for which we previously carried out a set of breeding activities, which allowed us to select the most resistant to extreme factors and productive breeding material [3, 6, 8]. Planting material should be grown only in nurseries of the Volgograd region, and seeds should be obtained on previously created breeding
seed plantations. This article is a recommendation to the project under development on the establishment of water-protective forest belts, aimed at solving the problems of the national project "Improvement of the Volga".

2. Materials and research methods

The objects of research were various types of protective plantations created in the period 1948 to 1988 in the conditions of a dry steppe. Frost resistance of selected trees was determined by freezing of shoots and preservation after extremely harsh winters. In refrigeration units artificial freezing of 1-2 year old offspring with undisturbed root system was additionally carried out. Damaged plants were taken into account by staining tissues with tetrazolium salts after 1-2 days. The temperature at which 50% of the plants died was considered critical. Tissues of wood species have different physiological significance. This required the introduction of conditional coefficients and their general evaluation in conventional units. The coefficients are: for cambium - 10, for phloem - 4, for xylem - 4, and for core - 2. As a result, a general assessment was given in arbitrary units.

The study of the effect of easily soluble salts on the growth, development and condition of wood species was studied by the method of Migunova E.S.

3. Results and discussion

Low temperature is an abiotic factor that significantly reduces the durability of protective forest plantations in the arid zone. Freezing of root systems in low-snow winters often leads to the death of woody plants [3]. Proper selection and regionalization of tree species in this case is the main measure against freezing [2]. To preserve the assortment of tree species at low temperatures, it was proposed to isolate the temperature at which about 50% of plants die, and call them critical. Therefore, they decided to simulate extreme conditions by direct freezing in a climate chamber. It has been established that in Fraxinus lanceolata F and Halóxylon aphyllum M, low temperatures of -16 ... -18 °C during the period of winter dormancy do not cause decay. Partial damage was noted in Quercus robur L and Robinia pseudoacácia L at a temperature of -10 ... -12 °C; and at -13 ... -14 °C, more than 50% of plants die off, complete freezing out was observed at temperatures of -18 ... -19 °C. At temperatures of -20 ... -24 °C and lower, plants Fraxinus lanceolata F, Ácer negúndo L and Halóxylon aphyllum M die (Table 1).

Table 1. Additive influence of environmental factors on frost resistance of wood species under the city of Volgograd

| Kinds                          | Safety (%) after artificial freezing of plants previously grown in conditions Optimum -8°C -10°C -12°C -14°C -16°C -18°C -20°C -22°C -8°C -10°C -12°C -8°C -10°C |
|-------------------------------|-------------------------------------------------------------------------------------------------|
| (Quercus robur L)             | 100 96 50 50 30 6 0 0 64 40 18 0 0                                                                 |
| (Fraxinus lanceolata F)       | 100 100 100 100 100 100 84 100 100 100 67 9                                                   |
| (Ácer negúndo L)              | 100 100 100 100 100 96 89 80 100 90 80 0 0                                                  |
| (Robinia pseudoacácia L)      | 100 91 82 43 40 0 0 0 73 47 80 35 18                                                       |
| (Halóxylon aphyllum M)        | 100 100 100 100 100 87 - - 100 100 100 87 58                                               |

Frost resistance reaching a maximum in January and decreases by the end of winter in Fraxinus lanceolata F, Quercus robur L, Ácer negúndo L, Robinia pseudoacácia L, Halóxylon aphyllum M during the autumn-winter period is a variable value and directly depends on changes in air temperature and soil (Table 2).
Table 2. Dynamics of frost resistance of wood species in autumn-winter period

| Kinds                        | Temperatures (°C) at which 50 % of plants die by the terms of freezing |
|------------------------------|------------------------------------------------------------------------|
|                              | december     | january     | February-March |
| Fraxinus lanceolata F        | -18…-20     | -25 и ниже | -13…-14        |
| Quercus robur L              | -10…-11     | -14…-16    | -7…-8          |
| Ácer negundo L               | -18…-20     | -24 и ниже | -14…-15        |
| Robinia pseudoacácia L       | -13…-14     | -13…-14    | -7…-8          |
| Halóxylon aphyllum M         | -14…-14     | -22…-24    | -10…-11        |

Fraxinus lanceolata F showed higher frost resistance than Quercus robur L and Robinia pseudoacácia L.

Periodic droughts preceding severe winters also reduce the frost resistance of tree species. After a deep summer drought, further rather warm autumn weather and a favorable water regime of the soil contribute to the resumption of growth of shoots in Robinia pseudoacácia L, which significantly weakens the plant and reduces its frost resistance. When the temperature dropped to -8 °C, sprouts Robinia pseudoacácia L died. Fraxinus lanceolata F, Ácer negundo L, Quercus robur L and Haloxylon aphyllum M did not show similar processes. Other species have not shown such a direct dependence of frost resistance on drought.

The study of the influence of environmental factors allowed to comprehensively assess the adaptive capabilities of different species and recommend some of them for introduction into protective plantations, which should be placed on saline lands along the river Bank during the implementation of the national project "Improvement of the Volga".

Based on the literature data [4, 5, 7, 8] and after research, we suggest dividing trees and shrubs by salinity resistance into 5 groups according to the degree of increase of this trait (Table 3).

Table 3. Permissible, oppressive and toxic amounts of easily soluble salts for trees and shrubs

| Breed endurance category | Toxicity threshold; the amount of salts,% |
|--------------------------|-------------------------------------------|
|                          | 1  | 2  | 3  |
| Very weak salt tolerant  | >0.3 | Picea Excelsa L., Pinus silvestris L., Larix sibirica L. |
| Weakly salt tolerant     | >0.4 | Betula pendula Ehrh., Tilia cordata Mill, Ácer negundo L., Quercus robur L., Populus alba L., Populus nigra L., Gleditschia triacanthos L., U. laevis Pall. |
| Salt tolerant            | >0.5 | Elaeagnus angustifolia L., Armenica vulgaris Lam, Fraxinus lanceolata F, Robinia pseudoacácia L., Ulmus pumila L., Caragána arboréscens Lam, Ribes aureum L., Cotinus coggyría Scop., Lonicera L., Cerasus fructica G., Crategus L., Amelanchier Medic, Amygdalus nana L., Malus silvestris L. |
| The most salt-tolerant   | >0.7 | Támarix ramosissima, Surotia ceratodes |
| Salt-resistant           | >1.5 | Halóxylon aphyllum M, Salsola L. |

When creating protective plantings in the framework of the national project "Improvement of the Volga" in the Volgograd region, it is necessary to take into account our proposals for salt resistance of tree species.

From the very beginning of the organization of work on protective afforestation in the arid zone, mainly seeds harvested from fruiting crops of different regions, often significantly differing in soil and climatic conditions from local conditions for future growth, were mainly used.
Studies [3, 6, 9, 10, 11] showed that previously assumed durability of forest species was somewhat underestimated. IIm and shrub species in comparison with the forecast showed sufficient stability and durability. That, probably, can be connected with decrease in intensity of processes of degradation of plantings connected with that in the course of natural selection for 60-100 years the most unstable biotypes which remained represent the climax plantings which have entered a steady state were eliminated. As an example, we can cite the current state of state forest belts: Kamyshin-Volgograd, Elista-Cherkessk, Gromoslavskaya oak, protective forest plantations of the Bogdinsky NIAGLOS, protective forest plantations of the experimental farm VNIALMI, Volgograd, etc.

Professor N.I. Sauce, 1930 in the city of Kamyshin laid the first dendrological garden in the Volga region, where in the future a lot of work on the introduction and selection conducted AV Albensky.

About 400 species of trees and shrubs were tested, although in 1974 the number of species of the Kamyshinsky arboretum reached almost 700, only 100-120 species were recognized as promising, having passed the primary introduction. VNIALMI of the city of Kamyshin, using the arboretum and other plantings of the station as the parent, organized the wide reproduction of the selection material that had passed the primary introduction, followed by the transfer and introduction into the landscaping, protective and other plantings of the region.

In this case, it is advisable to differentiate the whole variety of soil conditions in the arid region according to the degree of forest suitability into three main categories according to the previously published “Manual on selective seed production of wood species for protective afforestation in arid conditions of the European territory of Russia”:

I-dark-colored, leached soils of depressions with additional moisture, which are the best: depressions with dark-colored intrazonal soils with root-accessible fresh groundwater or additional moisture due to redistribution of surface runoff (about 10-15 % of the area);

II-zonal soils leached to a depth of 2 m, considered average: soils on flat areas or gentle slopes with toxic salts deeper than 1.5 m (about 60-65 % of the area);

III-saline soils with shallow salt horizons, considered the worst: saline spots or areas with toxic salt horizons up to 1 m from the surface (about 20-30 % of the area).

Table 4. The longevity of the seed generation of trees and shrubs in the dry steppe zone of the southeastern region of the European territory of Russia

| Breed | I   | II    | III  | IV |
|-------|-----|-------|------|----|
| Trees |     |       |      |    |
| Quercus robur L | 40-50 | 25-30 | -    | -  |
| Ulmus pumila L | 25-30 | 20-25 | 10-15 | 5-7 |
| U. laevis Pall. | 25-40 | 20-30 | 20-25 | -  |
| U. foliacea Gilib. | 40-50 | 30-35 | 25-30 | 5-10 |
| Robinia pseudoacacia L | 40-50 | 30-35 | 10-15 | -  |
| Fraxinus lanceolata F | 40-50 | 25-30 | 15-20 | -  |
| Shrub |     |       |      |    |
| Cotinus coggyria Scop. | 40-50 | 30-40 | 20-25 | -  |
| Ácer tatáricum L | 30-50 | 25-40 | 15-20 | -  |
| Támarix L | 40-60 | 30-50 | 20-30 | 10-25 |
| Caragána arboréscens Lam | 50-70 | 40-50 | 30-40 | -  |
| Ribes aureum L | 20-25 | 20-25 | 10-15 | -  |

Table 4 presents the results of our studies on the longevity of seed progeny by groups of forest suitability in the dry-steppe zone of the South-East of the European territory of Russia.

The obtained data on the durability of tree and shrub species in the conditions of dry steppe (table 4) represent the results of hard primary natural selection in different types of plantings in the region. These results can be used in the future for the selection of breeding material to create biologically adapted and sustainable protective forest plantations in the implementation of the project "Improvement of the Volga".
4. Conclusion

1. In the extreme soil and climatic conditions of the region, when selecting the assortment of protective forest plantations created under the Volga Health project, the additive effect of salinization and drought on tree-shrub vegetation should be taken into account, especially on saline soils with low forest suitability. As a result of the research, it was possible to identify 5 groups of trees according to the degree of increasing salt tolerance, which will expand the range and optimize the breed composition for certain soil and climatic conditions of the Volgograd region during the implementation of the national project “Improvement of the Volga”.

2. By modeling extreme conditions by direct freezing in a climacamera, critical low temperatures were established for the main species of protective forest plantations.

3. 3 groups of conditions of places of growth are allocated and approximate durations of life of the main tree and shrub breeds in each of these categories are defined.

References

[1] Kulik, K.N, Salugin, A.N, Sidorova, E.A. Dynamic stability of arid ecosystems / Arid Ecosystems, 2012, № 2, T 2, p 86-90.

[2] Kulik, K.N, Pugacheva, A.M. The structure of plant communities of fallow land in the system of protective forest plantations in dry steppes / Arid Ecosystems, 2016, № 1, T 6, p 63-69.

[3] Kulik, K.N, Barabanov, A.T, Manaenkov, A.S, Kulik, A.K. Forecast assumption and analysis of the development of protective afforestation in the volgograd region / Studies on Russian Economic Development, 2017, № 6, T 28, p 641-647.

[4] Semenyutina, A.V, Podkopyrova, G, Khuzhakhmetova, A.Sh, Svintsov, I.P, Semenyutina, V.A, Podkopyrov, I.Yu. Engineering implementation of landscaping of low-forest regions / International Journal of Mechanical Engineering and Technology, 2018, № 10, T 9, p 1415-1442.

[5] Kabanov, S.V, Filatov, V.N, Eskov, D.V, Samsonov, E.V, Zaigralova, G.N. Resistance of pure and mixed coniferous forest stands in the conditions of the southern forest steppe / Journal of Pharmaceutical Sciences and Research, 2018, № 4, T 10, p 964-968.

[6] Iozus, A.P et al. Environmental and genetic assessment of different versions of crossing of maple and elm in the conditions of the southeast of European part Russian Federation / IOP Conf. Ser.: Earth Environ Sci. 316, 012010, 2019.

[7] Galdina T and Khazova E 2019 Adaptability of Pinus sylvestris L. to various environmental conditions IOP Conf. Ser.: Earth Environ Sci. 316 012002.

[8] Gibadullin, N.F et al The condition of landscape felling and its perspectives in protective forests / IOP Conf. Ser.: Earth Environ Sci. 316, 012006, 2019.

[9] Kostin, M.V, Manaenkov, A.S. Productivity and life length of oak (quercus robur l.) artificial crop in the northern Ergeny, Kalmykia / IOP Conf. Ser.: Earth Environ Sci. 316, 012057, 2019.

[10] Semenyutina, A.V, Podkopyrov, I.U, Semenyutina, V.A. Environmental efficiency of the cluster method of analysis of greener objects' decorative advantages / Life Science Journal, 2014, № 12, T 11, p 699-702.

[11] Kruzhilin, S.N, Taran, S.S, Semenyutina, A.V, Matvienko, E.Yu. Growth peculiarities and age dynamics of QUERCUS ROBUR L. formation in steppe region conditions / Kuwait Journal of Science, 2018, № 4, T 45, p 52-58.