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БИОЛОГИЯ И ЭКОЛОГИЯ *FORESTIERA NEO-MEXICANA* A. GRAY И ПЕРСПЕКТИВЫ ИСПОЛЬЗОВАНИЯ В НИЖНЕМ ПОВОЛЖЬЕ

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Изучены вопросы расширения ассортимента древесных и кустарниковых лесных насаждений в лесоразведении засушливых регионов. *Forestiera neo-mexicana* A. Gray является интродуцированным и маловстречаемым экзотическим тропическим растением в агролесомелиорации Волгоградской области. Место проведения исследования – коллекционные участки Волгоградского селекционно-семеноводческого комплекса в Кировском участковом лесничестве Волгограда, где произрастает *Forestiera neo-mexicana*. Проведена биоэкологическая оценка использования кустарника *Forestiera neo-mexicana* A. Gray в озеленении и защитном лесоразведении Нижнего Поволжья. С помощью методики фенологических наблюдений, разработанной сотрудниками Главного ботанического сада РАН (ГБС РАН), определены общая масса семян, морфометрические показатели плодов, динамика физиологического состояния кустарника. Биоэкологические свойства оценивали по пяти признакам: засухоустойчивость (шестибалльная шкала С.С. Пятницкого), зимостойкость (семибалльная шкала ГБС РАН), оценка интенсивности цветения и плодоношения методом В.Г. Каппера (пятибалльная шкала), жизненность (трехбалльная шкала). Согласно фенологическим наблюдениям, *Forestiera neo-mexicana* A. Gray в климатических условиях Волгоградской области проходит все фенологические фазы. При биоэкологическиой оценке свойств форестьеры по пяти признакам растение имеет высокий балл по интенсивности цветения и плодоношения (5 баллов), жизненности (5 баллов). Растение зимостойко (1 балл) и засухоустойчиво (1 балл). *Forestiera neo-mexicana* A. Gray может возделываться на участках, непригодных для общего землепользования, на пастбищных угодьях и использоваться в защитном лесоразведении.

Ключевые слова: *Forestiera neo-mexicana* A. Gray, интродукция, биоэкология, лесоразведение, ассортимент, перспективность

BIOLOGY AND ECOLOGY OF *FORESTIERA NEO-MEXICANA* A. GRAY AND PROSPECTS FOR USE IN THE LOWER VOLGA REGION

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The issues of expanding the assortment of tree and shrub forest plantations in afforestation of arid regions are studied. *Forestiera neo-mexicana* A. Gray is an introduced and under-recognized exotic tropical plant in the agroforestry of the Volgograd region. The study site was the collection plots of the Volgograd breeding and seed production complex in the Kirovsky district forestry of Volgograd where *Forestiera neo-mexicana* grows. Bioecological assessment of the use of *Forestiera neo-mexicana* A. Gray shrub in landscaping and protective afforestation of the Lower Volga region was carried

out. Using the methodology of phenological observations developed by the staff of the Main Botanical Garden of the Russian Academy of Sciences (MBG RAS), the total seed weight, morphometric indices of fruits and the dynamics of the physiological state of the shrub were determined. The bioecological properties were evaluated according to five traits: drought resistance (six-point scale of Pyatnitsky S.S.), winter hardiness (seven-point scale of the MBG RAS), evaluation of flowering and fruiting intensity by the method of V.G. Kapper (five-point scale), vitality (three-point scale). According to phenological observations, *Forestiera neo-mexicana* A. Gray passes all phenological phases in climatic conditions of the Volgograd region. In bioecological evaluation of the *Forrestiera* properties for five traits, the plant has a high score for flowering and fruiting intensity (5 points), vitality (5 points). The plant is winter hardy (1 point) and drought tolerant (1 point). *Forestiera neo-mexicana* A. Gray can be cultivated on the areas unsuitable for general land use, on pasture lands and can be used in protective forestry.

Keywords: *Forestiera neo-mexicana* A. Gray, introduction, bioecology, afforestation, assortment, prospects

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INTRODUCTION

Works on green construction and agroforestry reclamation in the Lower Volga region are inseparably linked with the use of a diverse assortment of woody plants [1–3]. Introducing new long-lived tree and shrub species into protective afforestation is a current task and requires a deep study of their biology, economic value, methods of reproduction, and implementation [4–6].

In the conditions of water resource scarcity in the dry steppe and semi-desert, the assortment of tree species for creating anti-erosion and pasture-protective strips can be expanded through the introduction of shrubs for greening and improving the ameliorative condition of urban landscapes [7–11].

Forestiera neo-mexicana A. Gray presents theoretical and practical interest regarding its resilience to the challenging forest-growing conditions of this region due to its morphophysiological features and economic-biological properties.

The genus *Forestiera Poir*. of the Oleaceae Lindl. family includes about 20 species, spread in the North and Central America. *Forestiera neo-mexicana* A. Gray is a multi-stemmed shrub reaching up to 3.5 m in height with an inverted-ovoid crown. The leaves are simple, elongated or inverted-ovoid, leathery, gray-green, up to 40 mm long and 8–18 mm wide. An interesting feature of forestiera is the orientation of its leaves relative to the sun: they turn following the sun so that the sun's rays glide along the surface

of the leaf laminas, preventing them from overheating[1, 2] [12].

The bioecology of *Forestiera neo-mexicana* A. Gray in the area of insufficient moisture is poorly studied. The shrub is quite rare in dendrological collections. In the North Caucasus, it is found only in Rostov-on-Don, in Sochi[3, 4], in the Lower Volga region – in the collections of the FSC Agroecology RAS, Volgograd[5]. It is occasionally cultivated as an ornamental shrub in household plots and gardens in the territory of the "Nizhnekhopyorsky" natural park [13].

The purpose of the study is to conduct a bioecological assessment of the shrub *Forestiera neo-mexicana* A. Gray to determine its potential for use in greening and improving the ameliorative condition of the urban landscapes in the Lower Volga region.

The research objectives are:

– to conduct a bioecological assessment of *Forestiera neo-mexicana* A. Gray based on five characteristics adopted in the study of the introduced species;

– to identify the dynamics of the physiological condition of the shrub during the vegetation period.

MATERIAL AND METHODS

The objects of the study were plants of *Forestiera neo-mexicana* A. Gray. Long-term introduction testing of this species was conducted in the collection plots of the Volgograd Selection and Seed Production Complex in the Kirov Forestry of Volgograd. The region is characterized by a sharply continental climate, distinguished by aridity, sharp fluctuations in air temperature (annual temperature amplitude – 32.0 °C, average annual – 7.6 °C), unstable moisture regime and its high variability (average annual precipitation – 350 mm). The summer period is characterized by low relative air humidity (down to 12–16%) with strong winds and dry winds (up to 55 days per year). The soils of the collection plots are light-chestnut medium-loamy with low humus content (0.54–0.94%). The combination of these factors hinders the introduction of many tree and shrub plants.

In 1998, 54 plants were planted, 53 survived, with a survival rate of 98.1%. The planting sites were spaced at 5 × 5 m. As of May 2023, over 78% have been preserved. The age of the plants is currently 24 years. The methodology of phenological observations of the Main Botanical Garden of the Russian Academy of Sciences (1975) was applied in the research. The average fruit weight was determined by weighing 100 fruits in triplicate on the VK-300 scales. Morphometric indicators of fruits – length and width – were determined with an accuracy of 0.01 mm (100 measurements for each type). According to GOST 13056.4–67 "Tree and shrub seeds. Methods for determining the weight of 1000 seeds" by weighing a sample of 250 seeds on the VK-300 electronic scales in two repetitions, the weight of 1000 seeds was determined.

The bioecological properties of the selected objects were visually assessed based on five characteristics traditionally used in the evaluation of the introduced species: drought resistance (S.S. Pyatnitsky six-point scale), winter hardiness (seven-point scale of the Main Botanical Garden of the Russian Academy of Sciences), assessment of the intensity of flowering and fruiting using the method of V.G. Kapper (five-point scale), vitality (three-point scale).

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The dynamics of the physiological state of the shrub during the vegetation period in terms of the pigment system of the green leaf (chlorophyll, flavonoids, anthocyanins) was determined using the DUALEX SCIENTIFIC device [14].

The obtained data from field and laboratory studies were statistically processed according to the methodology of G.N. Zaytsev and using the Microsoft Excel 2023 analysis package.

RESULTS AND DISCUSSION

The maximum temperature in 2023 was recorded in August (+38 °C), and the minimum in January (–20 °C). During the summer, air temperatures varied from +38 to +16 °C. In the winter months of 2023, the thermometer scale dropped to –20 °C and rose to +9 °C. The relative humidity in 2023 ranged from 38 to 87%. A drop to 38% was recorded in August, with the highest rate in January and February 2023 (87%). The total precipitation for the first half of 2023 amounted to 228 mm. The highest cumulative amount of precipitation fell in May (51.5 mm), with the least in June (27.5 mm). The average wind speed for the first half of the year was 4.9 m/s.

The data on the growth and condition of the plants testify to their high resistance to extreme environmental factors. The plants complete a full development cycle. The timing of the phenological phases is presented in Table 1.

The start of vegetation (mass swelling of buds) occurs in the first and second ten-day periods of April, early in spring, when there is no threat of early spring frosts. Leafing begins in the second ten-day period of April, simultaneously with shoot growth, which continues until the end of June. After the bush is covered with leaves, flowering is observed: male transparent-yellowish flowers bloom 2-3 days earlier than the female ones.

The flowering period varies from 15 to 20 days: it lengthens in cool weather and shortens in dry sunny conditions.

The plant is dioecious, with flower buds formed on shortened two-year shoots (see Fig. 1). Autumn leaf fall is recorded in mid-October. The introduced forestiera blooms and bears fruit abundantly, has good shoot-forming ability. Thus, the annual growth for 2023 averaged about 120 mm. Drought-resistant tree species never have large leaves and dense crowns.

Табл. 1. Данные сезонного развития *Forestiera neo-mexicana* A. Gray

Table 1. Data on the seasonal development of *Forestiera neo-mexicana* A. Gray

Phenological phase		Mean annual phenophase onset dates
Massive swelling of buds		05.04 ± 4,2
Bud bursting		11.04 ± 3,8
Full foliation		17.04 ± 4,0
End of shoot growth		25.06 ± 3,9
Full maturation of shoots		23.07 ± 4,1
Start of flowering	male	12.04 ± 3,6
	female	15.04 ± 4,0
End of flowering	male	26.04 ± 3,9
	female	30.04 ± 3,7
Mass ripening of fruits		27.07 ± 3,8
Massive foliage fall		11.10 ± 4,1
Duration of vegetation, days		189

Forestiera neo-mexicana is relatively consistent in diagnostic characteristics of the leaf structure and shape over most of its range in the southwestern United States, from California to New Mexico and in Western Texas (see footnote 2). In the conditions of the research region, the leaves are non-pubescent, round-oval to elongated, 10–40 mm in length and 5–18 mm in width (see Fig. 2).

Growth intensity is primarily related to soil and air humidity and the biological characteristics of the species. In 2023, the fruits of the studied shrub formed larger in size compared to the average multi-year data due to favorable conditions during the vegetation period. The mass of 1000 fruits was 55.6 g, which is 3.2 g higher than the average multi-year indicators (see Table 2).

Puc. 1. Генеративные органы
Fig. 1. Generative organs

Average leaf width – 11.6 mm

Puc. 2. Листовые пластины
Fig. 2. Laminas

The ecological and biological study of the introduced *Forestiera neo-mexicana* A. Gray indicates that this multi-purpose subtropical culture has successfully acclimatized due to its resilience to biotic and abiotic factors. Overall, the shrub is quite winter-hardy (1 point) and drought-resistant (1 point), which suggests the possibility of its use in protective afforestation and greening of the region (see Table 3). Thus, the degree of adaptation of this shrub to climatic conditions is high. The seeds do not require special pre-treatment for growing seedlings in autumn and can be sown in the ground in late autumn or early spring. It also propagates well vegetatively by summer cuttings and hardwood cuttings.

One of the valuable economic qualities of *Forestiera neo-mexicana* A. Gray is the absence of root suckers (see footnote 5).

When selecting an assortment of economically valuable multi-purpose woody plants for creating agroforestry complexes and multifunctional greening plantations in the dry steppe zone, special attention is given to decorative characteristics (see Table 4).

Decorative features of *Forestiera neo-mexicana* A. Gray begin to appear during the period of

Табл. 2. Характеристика плодов
Table 2. Characteristics of the fruits

Weight of 1000 grains, g				Fruit size, mm			
fruits		seeds					
Average	2023	Average	2023	Average		2023	
				length	width	length	width
52,4 ± 0,06	55,6 ± 0,04	8,8 ± 0,03	8,9 ± 0,02	5,8 ± 0,02	3,7 ± 0,03	6,1 ± 0,01	4,2 ± 0,02

Табл. 3. Эколого-биологическая характеристика *F. neo-mexicana*
Table 3. Ecological and biological characteristics of *F. neo-mexicana*

Height, m	Winter hardiness	Drought resistance	Flowering	Fruiting	Viability
2,5–3,0	Does not frost over (1 point)	Does not react to drought (1 point)	Abundant - 100% of flowers or inflorescences bloomed on the plant (5 points)	Full, abundant - after abundant flowering, almost all 100% of the flowers set fruit that matured (5 points)	Good, the plant is well developed, has a healthy appearance, well-developed shoots, buds and leaves, normalizes their coloration, abundant or good flowering and fruiting (5 points)

mass flowering of male inflorescences of bright yellow color. The greatest decorative effect is observed as numerous bluish spindle-shaped fruits mature. At the end of the vegetation period, before leaf fall, forestiera plantings acquire bright yellow shades.

The preservation of plant vitality under insufficient water supply is closely related to the functioning of pigment systems (see Fig. 3).

Plants with high drought resistance lose less water and have a more stable chlorophyll – a protein-lipoid complex of plastids.

Seasonal changes in the content of chlorophylls, carotenoids, and anthocyanins confirm the above. Towards the end of the vegetation period, there is a decrease in the content of the sum of chlorophylls a + b and the level of the nitrogen balance index (NBI). An increase in Flav values by 10.9% and Anth by 57.7% indicates a specific protective response to a complex of unfavorable growing conditions.

CONCLUSION

The results of the study and analysis of the long-term introduction of the introduced species *Forestiera neo-mexicana* A. Gray allow determining a high degree of decorativeness, noting the plant's resistance to drought, high and low temperatures. The dynamics of the physiological state of the shrub during the vegetation period in terms of the pigment system of the green leaf indicates pronounced protective reactions

Табл. 4. Оценка декоративности *Forestiera neo-mexicana* A. Gray
Table 4. Assessment of decorativeness of *Forestiera neo-mexicana* A. Gray

Flowers	Fruits	Leaves		Stem and branches	Crown
		Shape	Coloring		
Gathered in short clusters 4-5, female – inconspicuous greenish with reduced stamens, male – distinguished by long stamens with bright yellow anthers	Small grayish-blue spindle-shaped	Plain, not pubescent, leathery, roundish-oval to elongated, gray-green	Green in the summer, yellow in the autumn	Multi-stemmed shrub with obovate crown	Sprawling, rounded shape, medium dense

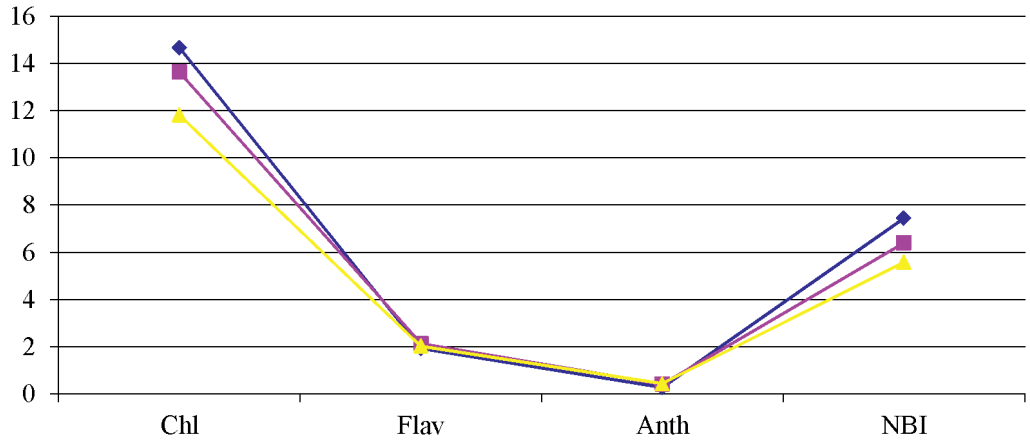

Рис. 3. Динамика физиологического состояния кустарника в течение вегетационного периода по показателям пигментной системы зеленого листа (Chl – хлорофилл, Flav – флавоноиды, Anth – антоцианы, NBI – индекс азотного баланса)

Fig. 3. Dynamics of the physiological state of the shrub during the growing season according to the indicators of the pigment system of the green leaf (Chl – chlorophyll, Flav – flavonoids, Anth – anthocyanins, NBI – nitrogen balance index)

of self-regulation due to features of water exchange – maintaining high absorptive capacity of root cells for water, economical use of moisture for transpiration, and rapid restoration of physiological functions under normalization of environmental conditions. All this has an adaptive value for increasing resistance to extreme environmental factors.

The analysis of the long-term introduction of the introduced species *Forestiera neo-mexicana* A. Gray allows recommending the shrub for use in green construction to strengthen the resilience of agroforestry landscapes with the aim of ecological optimization of protective afforestation in the Lower Volga region, as well as expanding the diversity of vegetation cover.

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