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Influence of climate warming on the state of woody plants of the family *Oleaceae* Hoff. et Link. in the collections of the Botanical Garden of the Ural Branch of the Russian Academy of Sciences

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Abstract. The created collections of woody plants made it possible to evaluate the life cycle of forsythia *Forsythia ovata* Nakai, privet *Ligustrum vulgare* L., and high ash *Fraxinus excelsior* L. of the *Oleaceae* Hoff family. et Link. and their response to changing climatic conditions. Tall ash, common privet froze every year to the level of snow cover. The flower buds of the forsythia froze, and it did not bloom. Due to the increase in the average annual temperature from 1.7 °C to 2.69 °C since 1990, forsythia and privet began to bloom and bear fruit. Introductory populations were created and the most frost-resistant and abundantly flowering individuals were selected. But as a result of abnormal weather conditions and climate cyclicity, all young and old privet plants died in 1998. Common privet plants began to bloom profusely only in 2021 (sowing in 2018). High ash plants fully recovered and reached a height of 10-12 m.

1. Introduction

Climate warming is considered a fact recognized all over the world. Climate warming in Leningrad began in the early to mid-1970 N.E. Bulygin introduced the concept of bioclimatic cyclicity into scientific terminology. Subsequently, using the example of two 30 years, the cyclic climate variability due to the cyclic activity of the Sun and the effect of these changes on the frost resistance and reproductive capacity of introduced species were shown [1-3]. As a result of temperature rise, natural zoning changes, affecting ecosystems [4-5]. The phenological rhythms of the beginning of vegetation and flowering of species are changing [6-7], and the phenological adaptability of plants is also changing [8]. Botanical gardens have large collections of woody and herbaceous plants, and as a result of phenological observations, employees trace the role of temperature increase on plant growth and productivity [9-11].

The climate of the Ural region is continental, characterized by cold winters, cool summers and cloudiness, as well as spring frosts in the first ten days of June. Climate warming in Yekaterinburg began in the 1970 with a gradual increase in the average annual temperature from two degrees to + 3.5 with significant fluctuations in some years, the maximum average annual temperature was observed in



2003, 2005, 2012, +4 °C; in 2008 - +4.6 °C; in 2020 - +5.3 °C. The reaction of introduced plants to climate warming to a certain level in our conditions has a positive effect, since the plants fall, as it were, into the natural conditions for the existence of the species, i.e. the temperature range of the species is extended.

2. Materials and methods

On the example of forsythia species, ash and privet of the olive family *Oleaceae* Hoff. et Link. The reaction of plants to climate warming was traced. The condition of the plants was assessed from the beginning of cultivation in 1959-1960, the beginning of fruiting and the collection of seeds to create introduction populations of forsythia and privet in order to study intraspecific variability and identify more frost-resistant and ornamental individuals. Measurements of dead shoots were carried out in 1984 during the inventory.

3. Results

Forsythia ovoid *Forsythia ovata* Nakai was first grown in the Urals from seeds obtained from a catalog in 1962 from Leningrad (BIN). The average annual temperature in this decade was 1.7 °C and forsythia began to bloom from 1990, when the temperature increased (table 1). Forsythia begins to bloom in our conditions from late April - early May. The flowers are bright yellow, solitary, sometimes 2-3 pieces and bloom on the shoots of the last year's formation, the total duration of flowering is 8-12 days. The linear growth of the shoots begins 10-12 days after the start of flowering and the shoots develop from the apical bud located between the two flower buds. Forsythia is characterized by rapid growth in the first month of development, then there is a slight increase in shoot until September. The growth dynamics of the shoots is a unimodal curve. By the beginning of July, the shoots reach an average length of 12-20 cm and almost stop growing, laying flower and growth buds for the next year. Forsythia seeds ripen in mid-October. Laboratory germination of seeds from young individuals is 83.5-86.5%, and from older ones about 67%. In 1990, there was an abundant fruiting of forsythia and an introduction population was created from seeds by families. Subsequently, non-freezing specimens with abundant fruiting were selected.

Table 1. Average annual temperature and precipitation averages for 10 years in Yekaterinburg since 1970.

Years	Average annual climatic indicators	
	temperature, °C	precipitation, mm
1970-1979	2.21	464.3
1980-1989	2.69	510.9
1990-1999	2.91	560.1
2000-2009	3.43	556.3
2010-2020	3.46	509.6

At present, due to the increase in temperature factors, forsythia lays flower buds regardless of the snow cover (figure 1). Privet *Ligustrum vulgare* L. was grown from seeds obtained from Moscow and Odessa in 1958 and 1959. In 1995-1996 studies of frost resistance were carried out according to the nature of the induction curves of chlorophyll fluorescence [12]. In 1984, an inventory of plantings of the *Oleaceae* Hoff family was carried out. et Link. - privet *Ligustrum vulgare* L. and high ash *Fraxinus excelsior* L. All specimens of high ash froze up to 230-260 cm, privet shoots also froze very much up to 75-90 cm, almost to the base of the bush. As a result of the temperature increase in 1990, they grew back, began to bloom and bear fruit. An introduction population was created from privet seeds, but as a result of climate cyclicity and abnormal weather conditions, all privet plants died in 1998. She returned to the collection in 2018 and in 2021 the privet plants bloomed profusely. High ash

plants grew from dormant basal buds and reached a height of 10-12 m, damaged shoots died and the trunk began to look young.



Figure 1. *Forsythia ovata* Nakai.

4. Discussion

In the conditions of the Urals, an increase in temperature from +1 °C to +3.46 °C in 2020 has a positive effect. Currently, the temperature range for active growth and fruiting of previously freezing species has expanded. European plants, such as forsythia ovoid, common privet and high ash, which are widely used in landscaping in their homeland, have returned to collection funds.

However, due to the warming of the climate, abnormal climatic conditions began to appear more often. Therefore, for example, in 1998, all specimens of *Ligustrum vulgare* L. of different ages in the collection of the Botanical Garden died. The cause of death is damage to the cell membrane in plants, due to a two-hour low temperature of -1 °C.

5. Conclusion

Due to the warming of the climate, many introduced plants, previously considered to be of low resistance, have entered the phase of flowering and fruiting. Simultaneously with the increase in average annual temperatures, the number of years with abnormal weather conditions that worsen the condition of plants has increased, especially in the presence of frosts in late May-early June (2017). As a result of unusually high temperatures in spring, plants undergo a shift in all phenological phases (2012, 2021). With an increase in the sum of positive temperatures in the conditions of the Urals and abundant fruiting of coniferous and other deciduous plants, the range offered for landscaping urban areas increases.

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