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The results of the introduction of twisted pine (*Pinus contorta*) in Bolshoy Solovetsky Island

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Abstract

In the central part of the Bolshoy Solovetsky Island, in the same type of growing conditions, two plots were created in 1988: the first consisted of twisted pine (*Pinus contorta* Loud. var. *latifolia* S. Wats) crops and the second one was of Scots pine (*Pinus sylvestris* L.). The aim of the study was to establish the morphological parameters of the twisted pine and its growth in the conditions of the Bolshoy Solovetsky Island in comparison with the native species *P. sylvestris* L. Also, we aimed to identify the features of *P. contorta* var. *latifolia* and determine the possibility and necessity of further introduction of the species. The preservation of the twisted pine and scots pine cultures was determined. Accounting trees were selected (62 and 31 trees, respectively), in which morphometric indicators were measured. Wood samples (cores) were taken from them with an age drill to measure radial growth. The radial increment was measured using the MBS-9 microscope and the Lintab device. To measure the increase in height, six medium-sized model trees were cut down. According to the taxation indicators, the two types differed slightly and the differences were most often unreliable. The average height of the twisted pine trees was significantly higher compared to that of Scots pine. The thickness of the bark varied; on average, at the age of 18, it was 1.35 ± 0.038 mm for twisted pine and 1.86 ± 0.095 for Scots pine, that is, the native pine bark was 38% thicker. Typical for twisted pine were a significant number of pathologies noted in 22% of the studied trees.

Twisted pine was distinguished by a stronger development of the assimilation apparatus: the number of branches of the first order, the number of branches in the whorl, the life span of needles. An increase in radius (the width of the annual ring) was observed at 14–15 years, and then with age, the value decreased in twisted pine and remained at a consistently high level in Scots pine. The width of the late zone of the annual ring was 12% in Scots pine and 14% in twisted pine; but at a young age, the late wood in twisted pine was very small. The increase in height of the twisted pine was on average less than that of Scots pine. The dependence of the trunk volume on the diameter was almost identical in both species.

Key words

twisted pine, Scots pine, height, diameter, tree ring width, late wood, assimilation apparatus, pathologies

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Introduction

The introduction of new species into the flora of a particular area always pursues certain goals: obtaining new types of products, decorative qualities, increasing forest productivity and so on. It is obvious that the North American species of twisted pine (*Pinus contorta* var. *latifolia*) was used primarily to increase the productivity of existing forests. The positive experience of such introduction of a new breed is known in western European and Scandinavian countries (Backlund and Bergsten 2012; Elfving et al. 2001) and in our country (Fedorkov and Gutiy 2017; Zhigunov and Butenko 2019; Gutiy and Fedorkov 2016; Demidova et al. 2016; Rayevsky and Pekkoev 2013; Fedorkov and Turkin 2010).

Bolshoy Solovetsky Island is the largest in the White Sea and is widely known for its history, cultural monuments and natural attractions. Within the borders of the Solovetsky archipelago, there is currently the Solovetsky State Historical, Architectural and Natural Museum Reserve. This territory has a high attendance by pilgrims and tourists, and here the twisted pine could take its place both as a species that increases the productivity of the forests of the archipelago and as a decorative species – an additional object of attraction for tourists and nature lovers. In its natural range, the twisted pine spreads naturally on burning. Due to the high temperature, the closed cones open and the seeds, falling on mineralized soil, successfully germinate (Eisenreich 1959). On Bolshoy Solovetsky Island, twisted pine cultures were created by planting on a plot with favourable and suitable growing conditions.

The purpose of the study is to establish the morphological parameters of the twisted pine, its growth in the conditions of the Bolshoy Solovetsky Island in comparison with the native species – the Scots pine, and also to consider the possibility and necessity of further introduction of the species.

Material and methods

In the central part of the Bolshoi Solovetsky Island in 1988, crops of twisted pine (*P. contorta*) and many Scots pine trees (*Pinus sylvestris* L.) were created. Planting with seedlings (seeds – Yukon, Rusty Creek, 63°28' north latitude and 136°25' west longitude) was carried out under Kolesov's sword without soil preparation. Landing site passed by fire 8 years before landing. The distance between the rows was 2.5 m and the planting steps was 2.5 m. The area is hilly. The type of forest is bilberry pine forest. At present, the growing conditions favour the growth of bilberry and lingonberry in the ground cover. Dominant ground cover species (*Vaccinium myrtillus* L. and *Vaccinium vitis-idaea* L.) are present in approximately equal amounts. In addition, lichens from the genus *Kladonia* are also typical for the place. The soil under the crops is thin, sandy, fresh podzol.

The studies were carried out in the thicket phase with the approach to the perch (Merzlenko and Babich, 2021). The preservation of the cultures of twisted pine (*P. contorta* var. *latifolia*) and Scots pine (*P. sylvestris* L.) was determined. Trees were selected (62 and 31 trees, respectively), the diameters and heights of which were measured, the number of branches of the first order (extending from the trunk) was calculated and the maximum lifespan of the needles of the terminal shoots and lateral shoots was determined. Wood samples (cores) were taken from them with an age drill to measure radial growth. To measure the height gain, six medium model trees were felled.

In the laboratory conditions, the width of the annual rings was measured using the MBS-9 microscope with an accuracy of ±0.05 mm, as well as the width of the late wood.

Results

The taxation indicators of the two types differed slightly. The average diameter at chest height and trunk volume of the twisted pine were slightly higher compared to the Scots pine, but the differences in these parameters between the species are unreliable. The average height of twisted pine trees was significantly higher (by 85 cm; Tab. 1). The indicators of the assimilation apparatus of twisted pine surpassed those for Scots pine in the number of branches and in the life span of needles. The number of branches in the whorl prevailed in twisted pine. Up to the age of 6–8 years, the number of branches on the trees of twisted pine was less or the same as that of Scots pine (*P. sylvestris* L.), and in older age, the number was always greater in *P. contorta* var.

Table 1. Comparative assessment of morphometric indicators of species

Morphometric indicators of trees	Average value of indicators for the species with the error		Reliability of differences (Student's criterion)	
	Pinus contorta var. *latifolia*	*Pinus sylvestris* L.	calculated	tabular
Diameter at chest height, cm	6.77 ± 0.22	6.57 ± 0.3	0.5	2.6
Height, m	5.26 ± 0.13	4.41 ± 0.14	4.5	2.6
Trunk volume, m³	0.01138 ± 0.001	0.00914 ± 0.001	1.8	2.6
Number of branches on the tree, pcs	57.92 ± 1.39	46.02 ± 1.34	6.2	2.6
The life expectancy of the needles of the apical shoot, years	5.41 ± 0.09	3.74 ± 0.07	14.7	2.6
The life span of the needles of the lateral shoot, years	4.4 ± 0.06	3.42 ± 0.07	10.6	2.6

latifolia. The average number of branches was in the range of two to four in the whorl of Scots pine and two to eight pieces in twisted pine.

It is interesting to compare the bark of two types of pines. The average value of the bark thickness at the age of 18 was 1.35 ± 0.038 mm in twisted pine and 1.86 ± 0.095 in Scots pine, that is, in native pine, the bark was 38% thicker.

Attention is drawn to a significant number of pathologies in *P. contorta* and especially two vertexes in trees (13% of trees) (Fig. 1). There are other damages in equal quantities: cancer, dry top, trunk curvature. In general, 22% of the trees of the species are susceptible to pathologies. The reasons probably lie in the weak mechanical properties of the trunk on the one hand and the powerful snow cover in the region on the other hand.

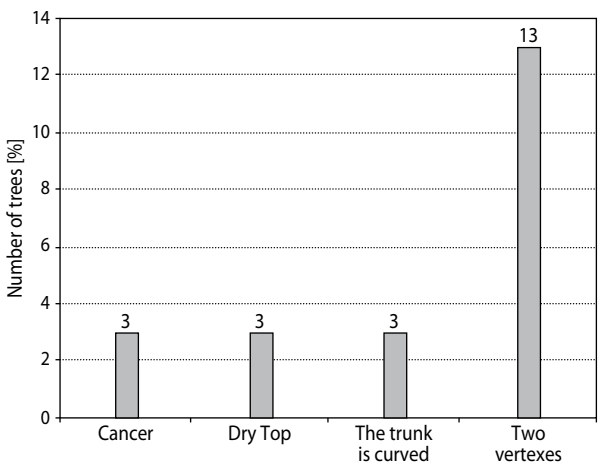

Figure 1. Pathology of twisted pine trunks

An assessment of the average size of the annual ring width in trees of different ages showed that in general, the radial growth of twisted pine and Scots pine was close in magnitude (Fig. 2). We can talk about significant differences in growth at the age of 9 and 15 years, and the strongest differences between the species are characteristic of 18 and 19 years of life. At this age (in these years), the growth of Scots pine was greater than that of twisted pine by 38% and 136%, respectively. Twisted pine demonstrated a distinct trend of increasing the width of the annual ring with age up to 13–14 years and then it declined. For the Scots pine also, increase in growth was observed at 14–15 years, following which the values of the width of the annual rings decreased slightly, remaining at a consistently high level. The average values of the annual ring width for the considered time interval were 3.02 mm for twisted pine and 3.30 mm for Scots pine.

It is interesting to trace the change in the width of the late zone of the annual ring in the twisted pine (*P. contorta* var. *latifolia*) in comparison with the Scots pine (*P. sylvestris* L.) On average, over the studied time interval, the width of the late zone in the Scots pine was 12% of the width of the annual ring and was 14% in the twisted pine. The change in the average values of the width of the late zone shows that the twisted pine is characterized by a pronounced trend of increasing this indicator with age, and in the Scots pine, on the contrary, it is weakly expressed and the size of the late wood is stable over time (Fig. 3). At a young age, the width of the late zone of wood in twisted pine is more than twice that of Scots pine. This explains the fact that at a young age, relatively many trees of the *P. contorta* var. *latifolia* species lie down, which was previously noted

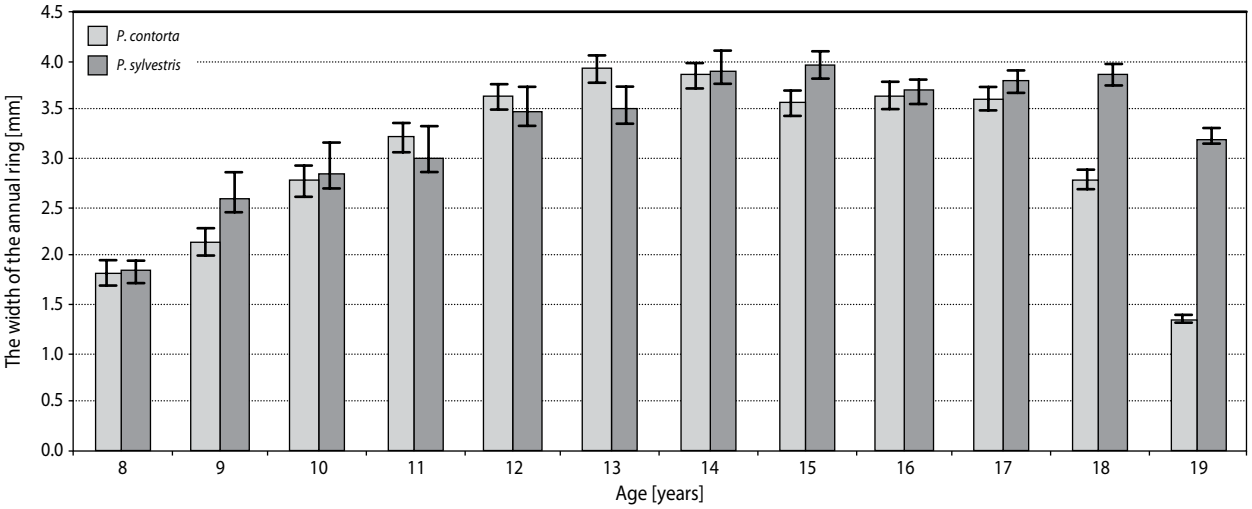

Figure 2. Changes in the width of the annual ring with age (average values with the error – vertical strokes above the columns)

in the literature (Feklistov et al. 2008). The data on the number of two-vertex pines and the curvature of the trunk of *P. contorta* var. *latifolia* are presented above. The manifestation of such changes is most likely due to the low mechanical properties of the trunks due to the small size of the late wood. At the age of 9–12 years, there is an increase in the accumulation of the late zone in the twisted pine relative to the Scots pine, and in the future, this increase persists. All the data presented are reliable for a significance level of 0.05.

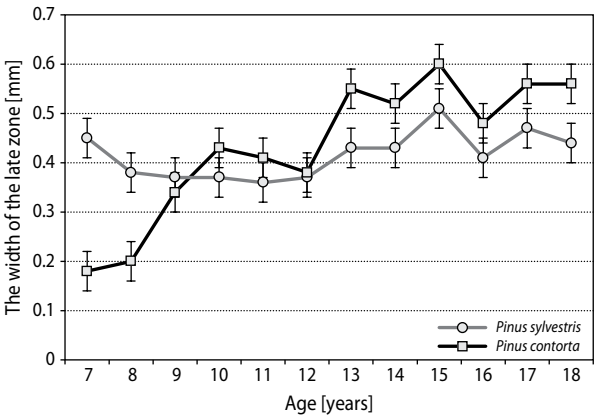

Figure 3. Change in the average value of the late zone of the annual ring with age (with an error – vertical strokes above the points of values)

The presence of well-defined whorls in model trees allowed us to obtain data on linear growth in height from the beginning of pine planting. In the first years after planting, the increase in height was small, differed little in species and was within 2–20 cm. Both breeds showed a very clear trend of height gain with age. In recent years, the increase in height of twisted pine (*P. contorta* var. *latifolia*) has become noticeably higher than the increase in height of Scots pine (*P. sylvestris* L.); in the last 2 years, the increase has been 50–60 cm in twisted pine and 40–50 cm in Scots pine. On average, over the entire period of growth, the height increase in twisted pine was less than that of Scots pine – 25.84 ± 0.92 and 28.05 ± 0.76 cm, respectively.

The dependence of the trunk volume on the diameter of the twisted pine (*P. contorta* var. *latifolia*) was actually the same as that of the Scots pine (*P. sylvestris* L.) (Fig. 4). The relationship was very clear and close. The presented approximation equations can be used to determine the volume of the trunk, both for one and for another breed. These dependencies once again confirm the previously considered conclusion about the unreliability of the difference in the average volume of the trunk of both species.

Discussion

We can sum up some results. If in the conditions of western Europe, twisted pine significantly exceeds Scots pine in productivity (Tigerstedt 1922; Metzger 1928), in the conditions of Sweden, productivity is al-

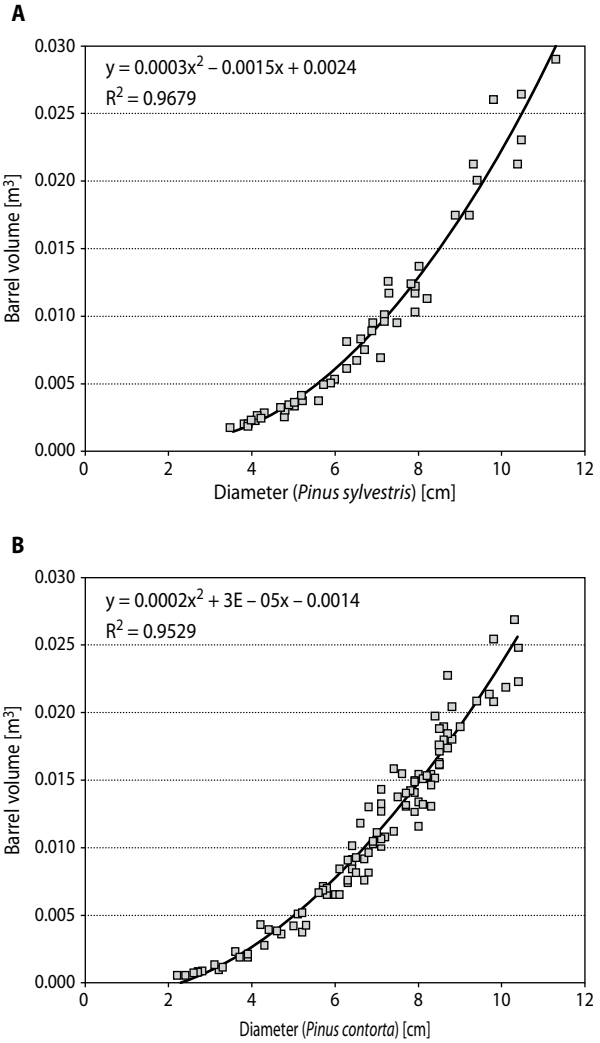

Figure 4. The dependence of the trunk volume on the diameter (A – Scots pine, B – twisted pine)

most 2 times higher (Swedish experiment 1972; Lindbeck 1977). Then, in the conditions of a more severe climate or, more precisely, the microclimate of the Bolshoy Solovetsky Island, this is not so obvious. In almost all growth indicators, both species had very similar characteristics. With the same initial density of crops (1600 pcs/ha), in the future, their safety differed: the planting of twisted pine was characterized by a fairly high safety (68%), which is slightly lower than the safety observed in Scots pine crops (76%). At the time of the study, the density was 1088 and 1216 units/ha for twisted pine and Scots pine, respectively. Taking into account the lower density of twisted pine and approximately equal volumes of trunks for medium diameters, wood reserves will be 10%–12% higher in Scots pine than in twisted pine. In addition, as shown above, 22% of *P. contorta* var. *latifolia* trees have pathologies. Therefore, it is hardly possible to increase the productivity of Solovetsky forests by introducing twisted pine.

Conclusion

- The safety of twisted pine (*P. contorta)* crops is quite high (68%).
- The taxing characteristics of twisted pine and Scots pine trees at the same age do not differ much. The average height of twisted pine is significantly higher.
- The assimilation apparatus of twisted pine is much better developed than that of Scots pine (the number of branches, the life span of needles, the number of whorls). In all respects,*P. contorta* Loud. var. *latifolia* S. Wats is superior to *P. sylvestris* L.
- In the conditions of Solovetsky archipelago, 22% of twisted pine trees ar characterized by pathological trunk changes. This is due to the weak development at a young age of the late zone of the annual ring of plants, which causes a weakening of the strength characteristics of its wood.
- The radial increment (the width of the annual ring) of the considered species in the studied time interval does not significantly differ, averaging 3.02 mm for twisted pine and 3.30 mm for Scots pine. It is noteworthy that in recent years, there has been a very significant lag in the growth of *P. contorta* var. *latifolia* from the native species.
- The width of the late zone of the annual ring in the twisted pine in the initial period of life is significantly less than that of Scots pine and only at the age of 9–12 years, it becomes larger, ahead of the Scots pine in this parameter.
- The average increase in height, in general, over an 18-year period in twisted pine is less than in Scots pine. However, the situation may change in the future, since in the last 2 years, the linear growth rates of *P. contorta* have been higher compared to *P. sylvestris*.
- The patterns of changes in the volume of the trunk from the values of the diameter at the height of the chest for both species do not actually differ.

Acknowledgement

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