# Reproductive effort assessment for woody plants using Siberian spruce and Siberian fir

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**Abstract.** The correlation between the yield of Siberian spruce (*Picea obovata* Ledeb.) and Siberian fir (*Abies sibirica* Ledeb.) cones and radial wood increments was examined using long-term data (47 years) from direct observations. Broad-leaved coniferous woods of the Ufa Plateau (PreUral), which are located inside the Ufa River's water protection zone, make up the special polygon where the research was conducted. According to the experiments, there was no correlation with the yield of cones and the radial increment of wood, either positive or negative. Simultaneously, it was discovered that there is a rise in the radial increment of timber wood with an increase in the number of spruce and fir cones in the climatic circumstances of a particular year. The maximum growth of the plant's vegetative mass, in this case, the radial growth of the timber wood, is shown in the year with the highest cone output. Consequently, fir and spruce in this area have the effect of reversing reproductive effort.

## 1 Introduction

The phenology of woody plants is significantly shifting because of climate change [1, 2, 3]. Both the duration of the growth season and the time it takes for generative organs to mature are altered as a result of these changes. The quantity of matter and energy put in each stage of reproduction constitutes reproductive effort as a component of reproductive strategy [4]. Seed formation in perennial plants (which includes trees) occurs at the expense of both accumulated materials in generative organs and newly created materials in assimilation organs [5]. Animals have been researched extensively enough to understand how reproductive effort affects organism growth [6]. Because to the fact that plant mortality is frequently a side effect of sampling, evaluating the reproductive effort of perennial plants is challenging [7, 8].

It is vital to find different approaches to evaluate reproductive efforts using indirect methods. This allows for describing both the direct costs of the materials and energy used in reproduction and the cost of the risk involved with a specific level of the subsequent reproduction. A comparison of the yearly yield intensity of cones and seeds with the growth dynamics of trunk wood (radial increment) is one method for assessing reproductive effort in trees. Radial growth is a reflection of the general health of the individual tree and the

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impact that particular yearly external and internal factors have had on it (the wood). Therefore, radial growth can be a useful criterion for estimating the vegetative component of a certain tree.

In this study, we combined data on cone yield during a 47-year observation period with data on trunk wood radial growth to quantify the reproductive effort in two coniferous species.

## 2 Materials and methods

PreUral's broad-leaved coniferous woods were the site of the investigation. Geographically, the research area is restricted to the Pavlovka reservoir's water protection forests (Ufa River, Ufa Plateau). The selection of the study area is not accidental. Due to the long-term process of historical development (which dates back to the Holocene) and the range of relief forms, there are several different types of forest conditions that vary in the degree to which the main environmental components are manifested. Dark-conifer and broad-leaved tree species co-occurring at the edge of their ranges, the existence of altitudinal zonation and height differential in climatic distribution (temperature inversion), as well as the influence of human activity, have led to exceptionally mosaic plant cover [9].

Broad-leaved and dark-coniferous forests predominate in the study regions' primary forest formation, whereas birch and aspen forests make up the secondary forest types. All forest types are distinguished by complex polydominant composition, multilayer structure, range in age, and considerable floristic variety of grassland floors. All of the above make this area a unique testing ground for the study of the environmental features of various tree species.

Five distinct types of forests with varied species compositions of the dominant herbaceous vegetation in the grassland layer have trends in spruce and fir cone yields that have been documented. There were several different types of these forests, including fir-spruce forests with large ferns and goutweed in the grass layer (Site 1), fir-spruce-moss forests with different sedge species (Site 2), spruce-moss forests with small ferns (Site 3), fir forests with horsetail, wood sorrel, and goutweed (Site 4), and larch-moss forests with sphagnum (Site 5). Earlier, a more thorough explanation of forests was given [10, 11].

In these types of forests, permanent test plots were laid using conventional techniques [12] between 1975 and 1985. The yield of cones at each site was determined yearly (from 1975 to 2021) following O.G. Kapper's methodical suggestions [13]. A single tree's cone yield was calculated using a 6-point scale, with 0 representing no cones and 5 representing a very high production of cones (Table 1).

**Table 1.** The scale of cone productivity of Siberian spruce (Picea obovata Ledeb.) and Siberian fir (Abies sibirica Ledeb).

| **Cone abundance level** | | **Nature of cone placement within the tree crown.** |
|---|---|---|
| **In points** | **In gradations** | |
| 0 | absent | The tree is without cones. No cones can be found even with binoculars. |
| 1 | very small | Single cones on separate branches at the top and middle of the crown. Mostly on the crown's southern side. |
| 2 | small | Cones in small quantities on a few branches. Primarily at the top and middle parts of the crown, particularly on its south side. |
| 3 | middle | A considerable number of branches in the top and middle portions of the crown that have an average number of cones developing evenly or in groups. Especially on the crown's south side. |

| | | |
|---|---|---|
| 4 | large | Most branches in the upper and middle portions of the crown have many cones on them. They are occasionally arranged in clusters (5–10 pieces) on annual branches, particularly in the top part of the crown. |
| 5 | very large | All branches in the top and middle portions of the crown have an abundance of cones. Mostly in the top of the crown, where they are located in groups (10-15 pieces). |

Cone yield was calculated at each site using 10-26 trees of each species (spruce and fir). The most abundant seed-bearing trees were determined based on the study of long-term data, and cores from these trees were chosen in accordance with the conventional procedure to determine the radial growth of trunk wood.

All test-related data were statistically processed [14], and Statistica 8.0 was used to perform all analyses.

## 3 Results and discussion

The results of the correlation study revealed that there is generally no direct relationship between the yield of spruce and fir cones and the radial growth of trunk wood in any analysed type of forest (Tables 2 and 3). The correlation coefficients are only sometimes closer to one, suggesting that there is minimal association between the variables under comparison.

**Table 2.** Correlation coefficients of Siberian spruce (*Picea obovata* Ledeb.) cone yield with radial wood growth in various forest types.

| **Correlation** | **Site 1** | **Site 2** | **Site 3** | **Site 5** |
|---|---|---|---|---|
| min | -0.35 | -0.37 | -0.30 | -0.25 |
| max | 0.14 | 0.29 | 0.18 | 0.34 |

**Table 3.** Correlation coefficients of Siberian fir (*Abies sibirica* Ledeb.) cone yield with radial wood growth in various forest types.

| **Correlation** | **Site 1** | **Site 2** | **Site 4** |
|---|---|---|---|
| min | -0.17 | -0.25 | -0.25 |
| max | 0.44 | 0.25 | 0.34 |

The following feature was revealed after combining the data gathered throughout the course of the full observation period (47 years), which eliminated the impact of specific environmental conditions (Tables 4 and 5).

**Table 4.** The dependence of cone yields of Siberian spruce (*Picea obovata* Ledeb.) (in points) with radial wood growth (in mm.) in various forest types.

| **Cone yields, points** | **Radial wood growth, mm (*min-max*)** |
|---|---|
| 0 | 0.97±0.04 (0.08-4.00) |
| 1 | 1.06±0.05 (0.10-4.46) |

| | |
|---|---|
| 2 | 1.07±0.06<br>(0.10-4.72) |
| 3 | 0.99±0.06<br>(0.1-3.24) |
| 4 | 1.09±0.08<br>(0.10-4.00) |
| 5 | 1.27±0.12<br>(0.13-4.70) |

**Table 5.** The dependence of cone yields of Siberian fir (*Abies sibirica* Ledeb.) (in points) with radial wood growth (in mm.) in various forest types.

| **Cone yields, points** | **Radial wood growth, mm (*min-max*)** |
|---|---|
| 0 | 0.57±0.03<br>(0.01-6.00) |
| 1 | 0.62±0.05<br>(0.02-3.40) |
| 2 | 0.58±0.06<br>(0.04-3.26) |
| 3 | 0.64±0.07<br>(0.10-2.60) |
| 4 | 0.61±0.09<br>(0.10-2.00) |
| 5 | 0.80±0.18<br>(0.10-3.97) |

According to research, higher cone yields are correlated with more radial growth of trunk wood (i.e., the seed-bearing point index). The observed evidence differs slightly from conventional notions of reproductive effort since the radial growth of the trunk wood is a reflection of the total phytomass accumulated by the tree. It is accepted in forestry, as it is in biology generally, that trees "relax" from reproductive tasks and activate vegetative growth in years with weak seed production. The information we have provided indicates the contrary. The expansion of the tree's developing mass is likewise accelerated during the years with the highest cone production.

## 4 Conclusion

The analysis of the obtained results suggested that the activation of the reproductive process in spruce and fir in the conditions being studied does not negatively impact the accumulation of the tree's vegetative mass. Conversely, increasing cone and seed yields may stimulate vegetative growth. Because of this, the influence of reproductive effort on the general state of spruce and fir trees in the examined forest types is minimal.

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## References

1. I. J. Lorite, J. M. Cabezas-Luque, O. Arquero, et al., Agric. For. Meteorol. **294**, 108142 (2020)
2. Y. Fu, X. Li, X. Zhou, et al., Sci. China Earth Sci. **63**, 1237-1247 (2020)

3. I. Dox, B. Mariën, P. Zuccarini, et al., Agric. For. Meteorol. **327**, 109229 (2022)
4. E. R. Pianka, *Evolutionary ecology* (Harper and Row, New York, 1973)
5. M. V. Markov, E. N. Pleschinskaya, J. General Biol. **48**, 77-82 (1987) (in Russian)
6. J. A. Hutchings, *A Primer of Life Histories: Ecology, Evolution, and Application* (Oxford University press, Oxford, 2021)
7. K. Thompson, A. J. A. Stewart, Am. Nat. **117(2)**, 205-211 (1981)
8. F. A. Bazzaz, *Allocation of resources in plants: state of the science and critical questions*, in Plant Resource Allocation, Academic Press, London, 1-37 (1997)
9. N. A. Martyanov, A. A. Batalov, A. Y. Kulagin, *Broad-leaved forests of the Ufa plateau. Phytocenotic characteristic and renewal* (Gilem, Ufa, 2002) (in Russian)
10. G. A. Zaitsev, A. Y. Kulagin, A. N. Davydychev, Trees **32**, 511-518 (2018)
11. G. Zaitsev, A. Davydychev, A. Kulagin, et al, Forests. **12**, 851 (2021)
12. A. Kangas, M. Maltamo, *Forest inventory: methodology and applications* (Springer, Dordrecht, 2006)
13. O. G. Kapper, *On the organization of annual systematic observations on the seed production of tree species* in Works on forest experimental management, State Research Institute of Forestry, Moscow, 103-139 (1930) (in Russian)
14. S. M. Ross, *Introduction to Probability and Statistics for Engineers and Scientists* (Elsevier Academic Press, San Diego, 2009)