Climatic Adaptation of Seed Maturity in Scots Pine and Norway Spruce Populations

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Seed maturation of Scots pine and Norway spruce in a provenance experiment at Kortkeros (northern Russia) was examined by the X-ray method. Logarithmic relationships were found between seed anatomy development and long-term average thermal sum. Seed development in the northern populations of Scots pine and Norway spruce was a little faster than in the southern ones.

Keywords climatic adaptation, provenance experiment, seed maturation, X-ray method, Scots pine, Norway spruce
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1 Introduction

As for its reproductive function, seed maturation is one of the most important parts of the life cycle in forest trees. The main role of temperature in the maturation of Scots pine seeds has been reported in studies since the 1900s. The anatomical maturity of seeds depends clearly on the temperature regime during the summer of maturation (Heikinheimo 1921, Kujala 1927).

According to Sarvas (1972, 1974), the annual course of tree development is composed of numerous sequences of physiological events which commence in spring when the daily mean temperature exceeds +5 °C, and it forms a clear cycle. The development is controlled by the thermal factor and each stage of the closed cycle of a given tree species passed through in the main part of its range at a certain portion of annual temperature sums specific to the species and ecotypes.

According to this rule, trees transferred from colder regions with shorter growing seasons to a warmer region with a longer growing season are expected to develop seeds earlier that those transferred from warmer regions or the local trees. This tendency was, however, not apparent in the study by Henttonen et al. (1986).

The aim of this work was to study climatic adaptation of seed maturation in Scots pine and Norway spruce populations.

2 Material and Method

Provenance experiments for Scots pine and Norway spruce, established in 1977, were used. The experiments are located at Kortkeros, northern Russia (61°41´ N, 51°31´ E). They include 29 spruce and 24 pine origins from former Soviet Union in three blocks. Seven provenances were selected from the Norway spruce experiment and six provenances from the Scots pine experiment (Table 1). Open pollinated cones were repeatedly collected between August 5 and October 10, 1996 from 25–30 trees (2 cones per tree) for each origin (Table 2). After collection the cones were placed in cold storage (+5 °C) until the following day. The cones were dried for 24 h at +40…+50 °C. The seeds were extracted by hand, and subsequently subjected to X-ray (4 × 400 seeds per each origin). The results of the X-ray tests were classified according Simak (1957): 0 - neither embryo nor endosperm (empty seed); I - endosperm and embryo cavity developed but no embryo visible; II - one or more embryos, none longer than half of the length of the endosperm cavity; III - one or several embryos, the longest measures between half and three quarters of the length of the endosperm cavity; IV - one or more embryos, the longest one fills three quarters or more of the endosperm cavity.

From the radiographs the classes of anatomical development were determined and the anatomical potential of filled seeds (Ap) was calculated (Simak 1980). Ap is the calculated percentage of seeds that have the anatomical prerequisites (female gametophyte size and embryo length) for germination when physiological maturity is attained.

At Kortkeros, temperature data were obtained from the weather station located a few kilometers from the experiment. The temperature sums are expressed as effective temperature sums (+5 °C threshold) in degree-days (d.d.) calculated from January 1. The temperature sums were calculated from daily mean temperatures. The annual temperature sums over the period of 1961–1980 for the experimental site and provenances were obtained from the Russian Meteorological Service.

Regression analysis of Ap-values was used to determine whether provenances of Scots pine and Norway spruce showed any differences with respect to the levels of anatomical maturity. The regression curves for Scots pine and Norway spruce were drawn together on the graphs because the differences between the thermal sums in August 5 and 6 and August 26 and 27, 1996 are small and the thermal sums in October 9 and 10, 1996 are the same (Table 2).

Table 1. Location of provenances at Kortkeros experiment.

Origin	Latitude	Longitude	Altitude, m a.s.l.	Thermal sum
Norway spruce				
Sosnogorsk	63°27´	53°53´	70	863
Plesetsk	62°54´	40°24´	100	956
Kortkeros	61°41´	51°31´	60	1075
Pudoz	61°40´	36°40´	70	1140
Viljndi	58°24´	25°28´	90	1294
Nelidovo	56°24´	32°48	120	1330
Kaluga	54°27´	36°13´	110	1460
Scots pine				
Monchegorsk	67°51´	32°57´	180	665
Kandalaksha	67°00´	32°33´	90	742
Pinega	64°14´	43°14´	50	854
Syktyvkar	61°41´	51°00´	60	1070
Totjma	60°00´	43°00´	100	1160
Votkinsk	57°03´	54°00´	80	1400

Table 2. Dates of cone collections and thermal sums from January 1 in 1996 at Kortkeros provenance experiment

Norway spruce		Scots pine	
Date	Thermal sums	Date	Thermal sums
August, 5	818	August, 6	823
August, 26	960	August, 27	967
October, 9	1050	October, 10	1050

3 Results

There is a significant negative logarithmic relationship between the Ap-values of seed origin and the long-term average thermal sum. In the

Norway spruce experiment, the thermal sum explained 53 per cent of the seed maturity variation for the first cone collection (August 5, 1996), 87 per cent for the second cone collection (August 26, 1996) and 61 per cent for the third cone collection (October 9, 1996) (Figs. 1, 2 and 3).

Similar results were also found for Scots pine, although the relationship between the Ap-values and the thermal sums at the first cone collection (August 6, 1996) was not significant. In this case, thermal sum explained only 14 per cent of the variation of anatomical maturity.

The regression curves for pine and spruce cross each other to the point on the x-axis where thermal sums are about 1100 d.d. for the first cone collection (August 5 and 6, 1996), 1000 d.d. for

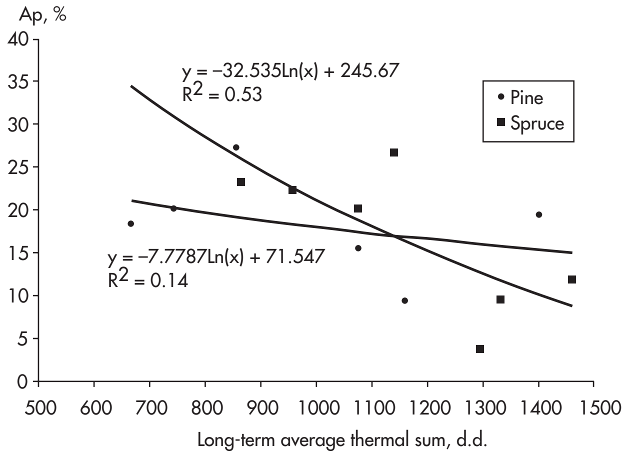

Fig. 1. The relationship between anatomical potential (Ap) and long-term average thermal sum for Scots pine (cone collection August 6, 1996) and for Norway spruce (cone collection August 5, 1996).

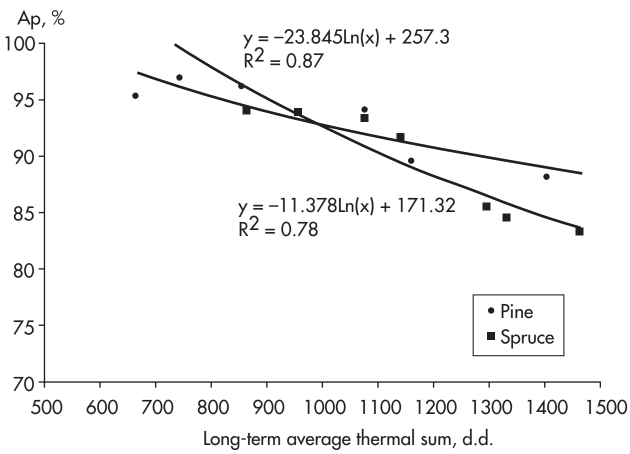

Fig. 2. The relationship between anatomical potential (Ap) and long-term average thermal sum for Scots pine (cone collection August 27, 1996) and for Norway spruce (cone collection August 26, 1996).

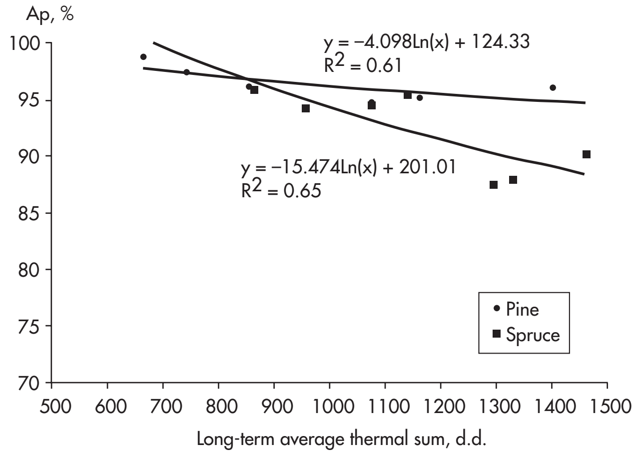

Fig. 3. The relationship between anatomical potential (Ap) and long-term average thermal sum for Scots pine (cone collection October 10, 1996) and for Norway spruce (cone collection October 9, 1996).

the second cone collection (August 26 and 27, 1996) and 850 d.d. for the third cone collection (October 9 and 10, 1996).

4 Discussion

According to Sarvas (1972, 1974), trees transferred from colder regions with shorter growing seasons to a warmer region with a longer growing season are expected to develop floral organs earlier than those transferred from warmer regions or the local trees. Our data are in agreement with Sarvas's model. It deals with maternal effects on the rate of seed development after background pollination. However, this tendency is not apparent in the work of Henttonen et al. (1986), but their study is based on Kujala's material collected in a geographically limited area (Finnish Lapland). Provenance experiments in Kortkeros include more widely distributed origins (Table 1).

The performance of the regression curves shows that the maturation of Norway spruce seeds is a little higher than for Scots pine in localities where long-term average thermal sums are less than 850–1100 d.d. (Figs. 1, 2 and 3). These differences are difficult to interpret because they are small, especially for the second cone collection (August 26 and 27, 1996) and the third cone collection (October 9 and 10, 1996). The reasons for these differences in seed maturation of Scots pine as compared with Norway spruce are unknown. One of them may be the small number of northernmost Norway spruce provenances in the experiment.

Our data suggested that the climatic adaptation of pine and spruce reproductive cycle is genetically controlled and it is not ubiquitous.

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