# THE USE OF CUTTINGS OF NORWAY SPRUCE (*PICEA ABIES* (L.) KARSTEN) IN PHENOLOGICAL RESEARCH

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(Received for publication 13 September 1973)

ABSTRACT

This paper reviews the natural distribution and the genetic variability of Norway spruce. The variation is sufficient to allow the selection of physiologically distinctive clones which, after vegetative propagation, can be established on a number of divergent sites and used for phenological observations.

The climate of the European Alps is extremely variable and an understanding of it in connection with the physiological behaviour of provenances will prevent many reforestation problems.

## INTRODUCTION

The yearly alternation of growth and dormancy of trees is influenced primarily by daylength and temperature. For biological research weather stations are too few for characterizing the course of the weather during the year, and they are also insufficient for defining the different climate situations within a mountainous area. But nature gives us the possibility to obtain this information indirectly by observation of the phenology of plants on a range of sites (Schnelle, 1966). Thus we are able to describe the biological climate, which bears some relation to the meteorological climate (Tranquillini and Holzer, 1958). Great phenological differences exist in alpine country corresponding to the very variable climates there (Holzer, 1967a).

There exist a number of species with world-wide distribution which can be used for phenological studies (Schnelle and Volkert, 1957). These species are primarily agricultural but include some trees. Within the European Alps there is a considerable altitudinal and latitudinal range of forests. There is one tree species which (on the basis of its wide natural distribution) appears to be adapted to the entire range of temperature climate; that is Norway spruce (*Picea abies* (L.) Karsten).

## VARIABILITY IN NORWAY SPRUCE

Norway spruce occurs in three great areas: the northern-Baltic, the Hercynic-Karpathic, and the alpine southeast European (Rubner and Reinhold, 1960); in the Baltic area the species shows a transition to the east European species *Picea obovata* Ledeb. The results of several provenance tests illustrate both the variability of the species in a number of characters and its adaptability (Cieslar, 1895; Engler, 1905; Rubner, 1957; Schönbach, 1957). Despite this adaptability, however, many provenances do not survive and grow well in exotic situations. Within the species a number of clinal relationships exist (*see* Schmidt-Vogt, 1972, for summary). The most spectacular phenotypic change is seen in the change of branching type with altitudinal change (Holzer, 1964, 1970), and progeny tests show these differences to be genetic (Holzer, 1967b, 1969, 1972).

Because of these genetic and physiological differences it is necessary to understand the phenological behaviour at a number of sites within the Alps, to enable successful reforestation of these areas. Fig. 1 illustrates the range of climate in Europe. It shows that the growing season varies from more than 240 days in the low valleys down to zero in the highest Alps at 3000 m elevation. Roller (1965) reports that the number of days without frozen soil varies between valleys in the Austrian Alps from a maximum of 232 at 300 m elevation to a maximum of 170 at 1500 m.

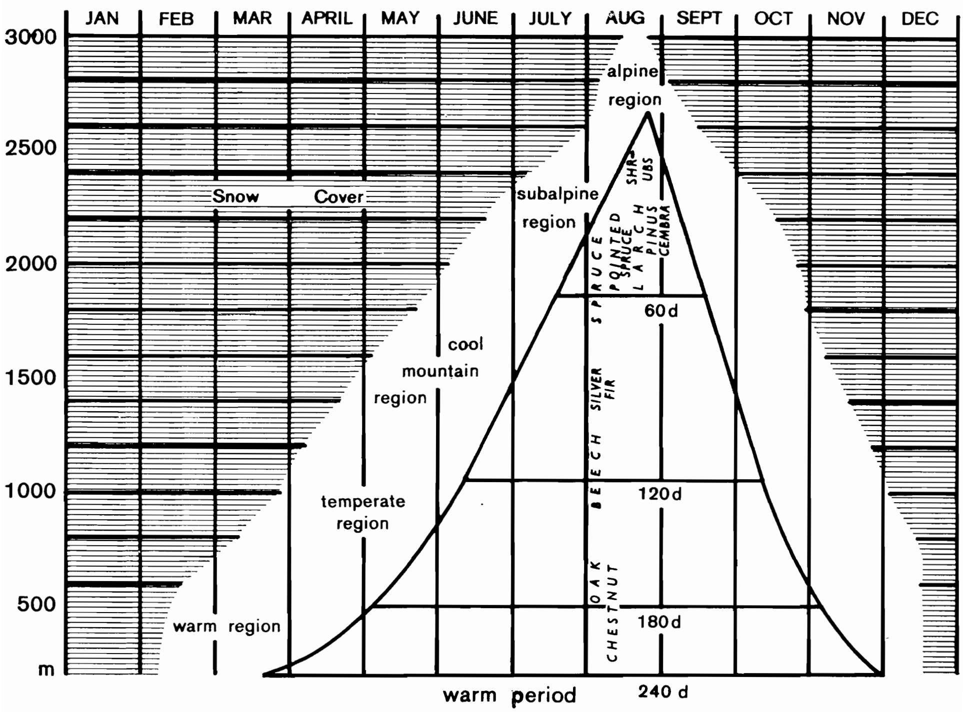


FIG. 1—Relationship between tree distribution, climate and altitude in central Europe

The minimum growing season required for tree growth is about 30 days, and with Norway spruce the growing season in the natural range varies from 30 to about 150 days. In plantation establishment, however, there is also a need to plant this species in areas with longer growing seasons. It is the job of tree improvement workers to find the best genotype for each of these conditions, but there is also a need on such sites to know how the climate varies during the growing season. The natural variability in Norway spruce makes it possible to assess the physiological importance of the differing climatic situations.

Within a small sample of plants there are great differences in phenological characters such as the date of bud-break in spring, start and duration of terminal growth, start and cessation of cambial growth, the set of lammas shoots and their intensity, the time of latewood production, and the onset of dormancy. And added to these characters we can find clonal variation in length and diameter of shoot and needles, stem diameter growth and branching type and angle (Ruden, 1965a, 1968).

## MATERIAL

Young plants of Norway spruce are easy to propagate by cuttings (Muhle Larsen, 1955; Ruden, 1965b; Kleinschmit, 1972; Lepistö, 1972; Holzer, 1972). There are differences in the rate of rooting, but the prospects exist of obtaining sufficient plants per clone to establish clonal trials for obtaining phenological data throughout the whole range of the Alps.

The variation in the performance of different provenances is of especial importance. Ruden (1968) listed some 16 properties of Norway spruce with significant heritability for observation. Phenological characters, such as bud-break or production of lammas shoots, can be so used (Langner and Stern, 1964; Stern, 1966). With the former character, the difference between earliest and latest flushing can be more than 27 days when trees are planted in the same locality and more than 53 days when observed within the altitudinal range in the Alps.

But the growth rate of progeny is also important and material is available in the species with a total height at age 12 years varying from 1 m to more than 4 m (Holzer, 1972 Table 2). This character may provide good information on the physiological adaptability of the different clones.

Table 1 is an example of a design for a trial which might yield good phenological data. With 15 clones — planted at 3 or 4 replicates — the most important possibilities seem to be covered in respect of height growth and time of bud burst. However, better differentiation would be given with 45 clones (i.e. three clones for every combination) so that other properties also could be varied.

TABLE 1—The variation of flushing time combined with height growth shows possibilities of variation for this trial

| Flushing | height growth | | | | |
|---|---|---|---|---|---|
| time | . . . | fast | . . . | slow | . . . |
| early | x | x | x | x | x |
| medium | x | x | x | x | x |
| late | x | x | x | x | x |

In a trial we have established we incorporated the presence or absence of lammas shoots into the system, along with altitude (Table 2). Seventeen clones were collected from a low altitude, 14 from a medium and 19 from a high altitude to give a total of 50 clones. With 4 replicates this makes a total of 200 plants at each site. The complete scheme (as in Table 1) could not be managed because of the difficulty of collection of sufficient clones. It was particularly difficult to find the slowest growing plants at low altitudes, and correspondingly there were no very rapidly growing plants at high altitudes (Holzer, 1972). The extent to which the matrix is complete is shown in Table 2.

TABLE 2 – An example of a phenological trial with cuttings of Norway spruce in the Austrian Alps. Four characters have been studied: flushing time (7 grades), height growth at 12 years (8 grades), altitude of provenance (low, medium, high), and formation of lammas shoots (upper lines with lammas, lower lines without lammas)

| Height at 12 years (m) | | Flushing time | | | | | | | | | | | | | | | | | | | | | Totals Altitude | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Early | | | | | | | | | | | | | | | | | | Late | | | Low (L) | Med. (M) | High (H) |
| | | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | L | M | H | | | |
| 4.0 - | + | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | - | - | - | - | - | 1 | - | - | 3 | - | - |
| | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - |
| 3.5 - 4.0 | + | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | - | - |
| | - | 2 | - | - | 1 | - | - | - | 1 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 3 | 2 | - |
| 3.0 - 3.5 | + | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | - | 1 |
| | - | 1 | - | - | 1 | 1 | - | - | 1 | - | - | - | - | - | - | 1 | - | - | - | - | - | - | 2 | 2 | 1 |
| 2.5 - 3.0 | + | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | - | - | 1 | - | - | - | - | - | 3 | - |
| | - | 2 | 2 | - | 1 | - | 1 | - | - | 1 | 1 | 2 | 1 | - | 1 | 1 | - | - | - | - | - | - | 4 | 5 | 4 |
| 2.0 - 2.5 | + | 1 | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | - | - | - | - | - | 2 | - | 1 |
| | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | 1 | - | - | - | - | - | 1 | 1 |
| 1.5 - 2.0 | + | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | 1 | - | - | 4 |
| | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 |
| 1.0 - 1.5 | + | - | - | - | - | - | - | - | - | 2 | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 3 |
| | - | - | - | - | - | - | - | - | 1 | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| <1.0 | + | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | 1 |
| | - | - | - | - | - | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 |
| Totals: | | | | | | | | | | | | | | | | | | | | | | | | | |
| With lammas | (+) | 1 | - | 1 | - | - | 1 | 1 | 1 | - | - | - | 2 | 3 | 1 | 2 | 1 | 1 | - | 1 | - | 1 | 7 | 3 | 10 |
| Without lammas | (-) | 5 | 2 | - | 3 | 1 | 1 | - | 3 | 1 | 2 | 3 | 4 | - | 1 | 2 | - | 1 | - | - | - | - | 10 | 11 | 9 |

## METHODS

For the purpose of this experiment we plan to establish a number of similar trials where these selected clones are to be planted in a randomised block (4 replicates per clone). These trials will be placed in several climatic and edaphic situations, particularly at different altitudes. The comparison of the results will give good information about the choice of provenance for different sites.

The relationship between flushing time and late frost injuries will provide data to aid in the selection of provenances for sites susceptible to late frosts (*see* e.g., Holzer, 1969a, b). The heritability of bud-burst data is very high so that its stability may be expected (Langner and Stern, 1964; Stern, 1966); but at this time we have no knowledge of the variation in flushing time of the same clones under different climatic conditions. Experience at low altitudes cannot be transferred to other sites and nor can results from one provenance be extrapolated to another. Information on this question seems to be important on account of the very different statements found in the literature (Münch, 1947; Rohmeder, 1948; Lacaze, 1969).

On the other hand there is also a need to relate flushing time to the total amount of height growth in spruce. The relationship is not consistent; sometimes late flushing provenances show better growth than earlier flushing ones—i.e. while the time of shoot elongation is shorter, the growth rate is faster (Rohmeder, 1952 Table 2).

Growth rate is somewhat dependent upon temperature conditions, and there are some clones that have a lower optimum temperature for maximum photosynthesis and respiration rates than others (Pisek and Winkler, 1959).

Similar observations are possible for the formation of lammas shoots. Different clones show different degrees of lammas shoot formation, and there are also different reactions to environment (Schmidt-Vogt, 1964; Hoffmann, 1965; Dietrichson, 1969; Holzer, 1967b, 1969b). Variation in lammas shoot production over the natural range of the species suggests that the formation of lammas shoots is restricted by higher altitude, shorter vegetation period, and lower temperature; but it is increased by higher humidity (as given at cooler conditions) and by more fertile soils. Observation at intermediate conditions shows that the formation of lammas shoots is replaced by prolepsis, that is a second shoot elongation without formation of a bud (Holzer, 1967b).

A very important character seems to be the initiation of dormancy of test plants. Especially at exposed sites and in areas with short growing seasons, it is important for planted spruce that this occurs sufficiently early. The occurrence of early frosts is especially dangerous for unadapted plants (Dietrichson, 1969; Nienstaedt and King, 1969; Robak and Magnesen, 1970; Holzer, 1969a).

Using an experimental system such as proposed here, it is possible to observe several morphological characters and to find the relationship between these and the planting site (Ruden 1968). It would also be possible to equate these trials with physiological research to determine the influence of environment on physiological characters (Pisek and Winkler, 1959; Tranquillini, 1959, 1964, 1966, 1969, 1971; Tranquillini and Turner, 1961).

## CONCLUSIONS

Norway spruce is a woody species with a wide natural distribution and with several types of trees, possibly genetic ecotypes (Schröter, 1898; Hoffmann, 1968; Holzer, 1970; Schmidt-Vogt, 1972). The selection of provenances and the knowledge of their physiological behaviour is very important for successful forestry—especially at different sites in the European Alps (Cieslar, 1895; Engler, 1913; Hoffmann, 1968; Langlet, 1964; Vincent, 1969). Few meteorological stations exist in the higher forested areas, and those data which are available do not provide a satisfactory comparison with tree growth (Tranquillini and Holzer, 1958). Test plantations with genetically diverse cuttings of Norway spruce may give useful information about growing conditions within the forests, and may aid choice of the best provenances for establishing new sites.

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