

Project *brief*

Thünen Institute of Forest Genetics

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Provenance differentiation in growth and climate tolerance of Northern red oak (*Quercus rubra* L.)

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- The identification of suitable tree provenances with regard to growth and climate sensitivity serves to provide high-quality forest reproductive material for forestry practitioners.
- Northern red oak (*Quercus rubra* L.) showed a high plastic response in wood anatomical traits to environmental conditions while signals of local adaptation were weak.
- In terms of growth and reaction to extreme events, provenances from Germany are superior to those from the natural distribution area in North America and should therefore be implemented in provenance recommendations.

Background and objectives

Northern red oak (*Quercus rubra* L.) is currently the most common non-native deciduous tree species in Germany. It is characterised by positive traits such as high growth, versatile use of wood and high climatic tolerance. However, knowledge on growth differentiation and the response to short- or long-term climate influences is scarce, especially at provenance level to identify suitable forest reproductive material.

The joint project RubraSelect involved the selection and characterisation of high-quality and climate-adapted reproductive material of Northern red oak. The aim was to quantify the growth performance and drought stress tolerance of red oak in Germany in order to evaluate its adaptability to future extreme events. The focus was on the evaluation at provenance level. A comparison between provenances from the natural distribution area in North America (Fig. 1) and from German stands was intended to answer the question whether seed imports to increase tolerance to extreme weather events appear to make sense.

The identification of suitable provenances also served for 'plus tree' selection. The focus was on yield and dendroecological analyses of various Northern red oak provenances in a provenance trial in Germany. The individual trees identified as being of particularly high quality were propagated vegetatively. The grafts will be used to establish a seed orchard for the medium-term supply of high-quality forest reproductive material.

Approach

To quantify growth performance of Northern red oak provenances from German and North American stands, a provenance trial set up in 1991 was used. From this trial, three test sites were available in the north (Schleswig-Holstein), east (Brandenburg) and central part of Germany (Hesse) (Fig. 1).

The growth parameters were evaluated for each individual to assess the genetic or plastic proportion of the trait expression. Statistical methods such as simple variance analyses of the calculation of provenance-by-environment interactions were used for this purpose. To quantify drought stress tolerance, cores were taken from selected origins using tree ring analyses, prepared and then measured.

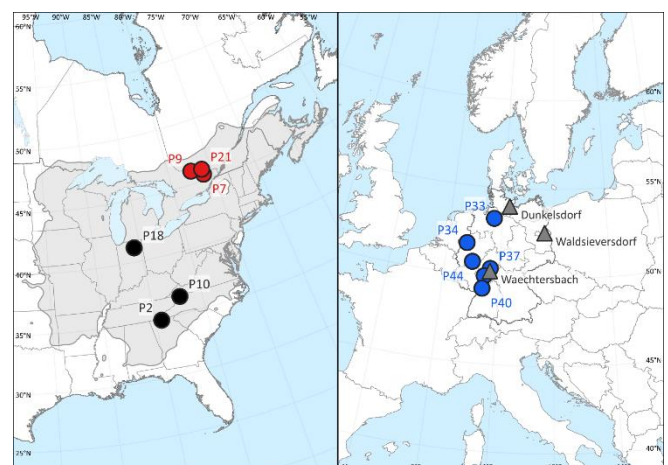


Figure 1: Location of Northern red oak provenances (circles; red = Canada, black = US, blue = Germany) and sites (triangles) for growth and dendroecological analyses. (Source: Thünen Institute modified according to KORMANN et al. 2024a)

Taking into account the environmental gradient along the experimental sites, the tree ring widths were correlated with climate variables and extreme years with drought and late frost were identified in order to quantify the response during and in the aftermath of an extreme year. The aim was to identify intraspecific differences in the response to short- and long-term climate fluctuations.

Based on the analyses, 50 plus trees with outstanding growth and form characteristics from above-average provenances were identified, twigs harvested and vegetatively propagated.

Results

Provenance-specific differences in terms of growth and climate sensitivity along the environmental gradient of the three trial sites made it possible to identify suitable provenances for the supply of high-quality forest reproductive material for forestry practice. The resulting significant provenance-by-environment interactions allow the identification of generalists and specialists, which can be used to improve provenance recommendations. Furthermore, summer drought as a growth-limiting factor and a dependence of growth on spring temperatures could be identified with the help of tree ring analysis. In addition, the response of wood anatomical traits showed a high plasticity depending on the site conditions and thus the broad site amplitude of this tree species. Signals of local adaptation, on the other hand, could not be observed. Overall, German provenances were characterised by a high growth performance and a high tolerance to late frost (Fig. 2).

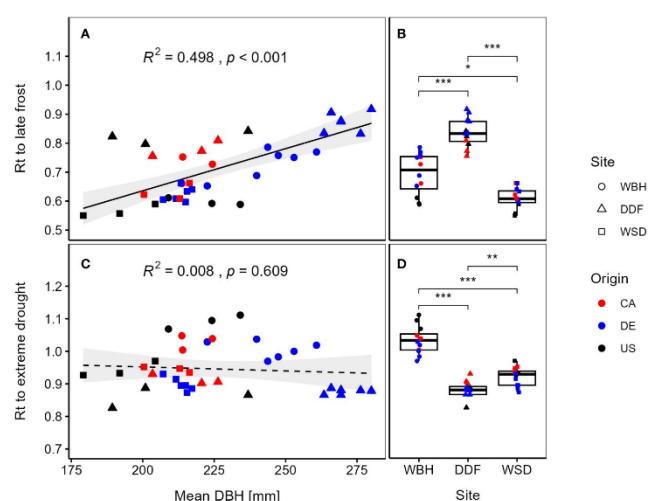


Figure 2: Correlation between resistance to late frost and drought, respectively, and absolute growth (dbh) for the selected 12 provenances at three sites of a provenance trial (WBH = Wächtersbach; DDF = Dunkelsdorf; WSD = Waldsiedersdorf). Significant differences between sites are indicated by the non-parametric Kruskal-Wallis test ($p < 0,05^*$; $p < 0,01^{**}$; $p < 0,001^{***}$) – (Quelle: Thünen Institute in KORMANN et al. 2024a).

The superior performance in adaptive traits of Northern red oaks on all three sites allow them to be classified as suitable generalists for implementation in provenance recommendations. In contrast, provenances from Canada proved to be specialists with a high tolerance to drought on all sites (Fig. 2). This characteristic could be used to increase adaptability to future drought events in Germany. Provenances from the southern part of the natural distribution area are not suitable for cultivation in Germany due to poorer trait expression. One reason for this may be the very different climatic conditions at the place of origin.

Conclusions

The provenance-specific reaction to late frost indicates different bud break timing. The intermediate timing of bud break of German provenances suggests selection processes that must have already had an effect on the parent generation during the relatively short cultivation phase of Northern red oak in Germany. However, signals of local adaptation could not be observed. Rather, Northern red oak is characterised by a high phenotypic plasticity in adaptation-relevant traits, which makes it suitable for a wide range of environments. At present, the use of provenances from the natural distribution area is not expected to increase performance. Considering rising temperatures and to increase genetic diversity, Canadian origins are a promising option that requires further validating studies. In this context, the evaluation of the adaptive potential of European (southern) provenances would also be a promising option for the future to assess their suitability for cultivation in Germany.

Further information

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Publications

[KORMANN JM, VAN DER MAATEN E, LIESEBACH M, LIEPE KJ, VAN DER MAATEN-THEUNISSEN M \(2024a\)](#). „High risk, high gain? Trade-offs between growth and resistance to extreme events differ in northern red oak (*Quercus rubra* L.)”. *Frontiers in Plant Science* 15:1374498.
[KORMANN JM, VAN DER MAATEN-THEUNISSEN M, UNTERHOLZNER L, LIESEBACH M, LIEPE KJ, VAN DER MAATEN E \(2024b\)](#). „Variation in vessel traits of northern red oak (*Quercus rubra* L.) provenances revealed high phenotypic plasticity to prevailing environmental conditions”. *Trees* 38 (5). 1283-1295.

[KORMANN JM, LIESEBACH M, LIEPE KJ](#)

(2023). „Provenances from introduced stands of Northern Red Oak (*Quercus rubra* L.) outperform those from the natural distribution”. *Forest Ecology and Management* 531, 120803.

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(2023). „Wachstum der Roteiche in (*Quercus rubra* L.) in zwei Herkunftsversuchsserien in Deutschland”. *Thünen Report* 105: 257-266.

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