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ORIGINAL ARTICLE

The impact of the 2003 summer drought on the intra-annual growth pattern of beech (*Fagus sylvatica* L.) and oak (*Quercus robur* L.) on a dry site in the Netherlands

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Abstract

Climate change is expected to result in more extreme weather conditions over large parts of Europe, such as the prolonged drought of 2003. As water supply is critical for tree growth on many sites in North-Western Europe, such droughts will affect growth, species competition, and forest dynamics. To be able to assess the susceptibility of tree species to climate change, it is necessary to understand growth responses to climate, at a high temporal resolution. We therefore studied the intra-annual growth dynamics of three beech trees (*Fagus sylvatica* L.) and five oak trees (*Quercus robur* L.) growing on a sandy site in the east of the Netherlands for 2 years: 2003 (oak and beech) and 2004 (oak). Microcores were taken at 2-week intervals from the end of April until the end of October. Intra-annual tree-ring formation was compared with prior and contemporary records of precipitation and temperature from a nearby weather station.

The results indicate that oak and beech reacted differently to the summer drought in 2003. During the drought, wood formation in both species ceased, but in beech, it recovered after the drought. The causes of species-specific differences in intra-annual wood formation are discussed in the context of susceptibility to drought.

Keywords: Wood formation; Microsampling; Pinning

Introduction

It has been predicted that climate change will result in increased precipitation in North-Western Europe, notably during the winter (Metzger, 2005; Beersma and Buishand, 2004), and more pronounced droughts during summer (Zinyowera et al., 2001). The year 2003 was warm and sunny (mean annual temperature of 10.3 °C measured in De Bilt, the Netherlands), with precipitation during the summer months being the lowest in 100 years (Fig. 1).

Many of the forested areas in the Netherlands are located on sandy soils with limited water-holding capacity. These planted forests predominantly consist of Scots pine (*Pinus sylvestris* L.) and other coniferous species; they are gradually changing into more natural, mixed forests with beech and oak, with oak predominating on the drier sites (Den Ouden and Mohren, 2004). On these sandy soils, water availability is crucial in determining the competitive relations (mainly between oak and beech) in mixed stands.

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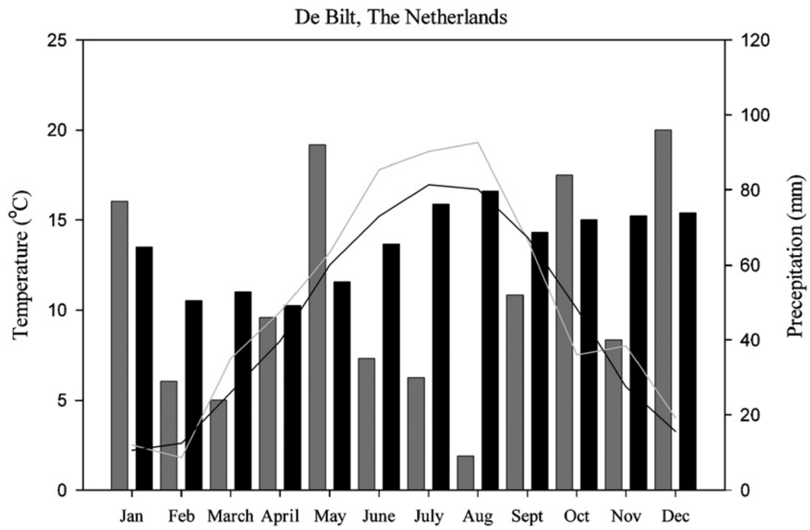

Fig. 1. Climate diagram, De Bilt weather station, the Netherlands: monthly mean temperature (lines) and monthly total precipitation (bars) in 2003 (gray) compared with the means from 1905–2005 (black).

Dendrochronological studies on oak and beech growing on dry sites in Central and Southern Europe have indicated that the tree-ring width (tree-RW) of both the species correlates positively with early summer precipitation and negatively with high summer temperature, which implies they will suffer if there is summer drought (e.g., Eckstein and Schmidt, 1974; Pilcher and Gray, 1982; Dittmar et al., 2003; Lebourgeois et al., 2005). However, under a temperate maritime climate, as occurs in the Netherlands, the RW of beech and especially of oak often fails to show a clear response to either temperature or precipitation in a particular month or season. The climate signal is too complex to be captured by tree-RW, which inherently integrates both favorable and unfavorable environmental signals over one or more years and lacks the resolution to capture and discriminate between different environmental signals. Intra-annual higher resolution variables such as earlywood width and latewood width (LW) (Nola, 1996; Garcia-González and Eckstein, 2003) and vessel-area variables (Sass and Eckstein, 1995; Fonti and Garcia-Gonzáles, 2004; Eilmann et al., 2006) may provide a solution to this problem, although additional information about intra-annual variation of wood formation is needed to produce more detailed physiological explanations.

Wood formation throughout the growing season can be studied either by the pinning method, i.e., introducing artificial markers into the wood by wounding the cambium (e.g., Wolter, 1968; Nobuchi et al., 1995; Schmitt et al., 2000), or by taking microcores (Deslauriers et al., 2003). In this preliminary study we tested both the methods. The objectives of this study were (1) assessing and comparing specific differences in intra-annual growth dynamics during 2003, the year with the driest summer since the start of instrumental recording in the Netherlands in 1899, and (2) using the pattern of intra-annual wood formation in oak and beech to better explain changes in the widths of earlywood, latewood and rings in a temperate climate.

Materials and methods

Study site

The study area was located in Oostereng (in the Veluwe area, centre of the Netherlands, 51°59′N, 5°43′E), in an approximately 80-year-old mixed forest of oak (*Quercus robur* L.) and Scots pine (*Pinus sylvestris* L.) with beech (*Fagus sylvatica* L.) growing on a poor sandy soil with the water table about 12 m below the surface. The climate is temperate maritime, with an average annual temperature of 9.5 °C and a mean annual precipitation of 760 mm in the period 1905–2005. The climate diagram from De Bilt weather station (Fig. 1) indicates only little variation in the mean total monthly precipitation and mean maximum monthly temperature during the summer months (June–August). In the summer of 2003, the temperature was 2 °C higher and the precipitation was only 59% compared with the averages for the period 1900–2000.

Study trees and periodic cambial sampling

In 2003, six dominant oaks (aged 50–80 years; diameter at breast height, DBH 14–37 cm) and three dominant beeches (age approximately. 80 years, DBH 37–54 cm) were selected for periodic cambial sampling. From April 29 to October 17, microcores were taken at intervals of 2 weeks. The small cores (1.5 mm in diameter, 10 mm long)