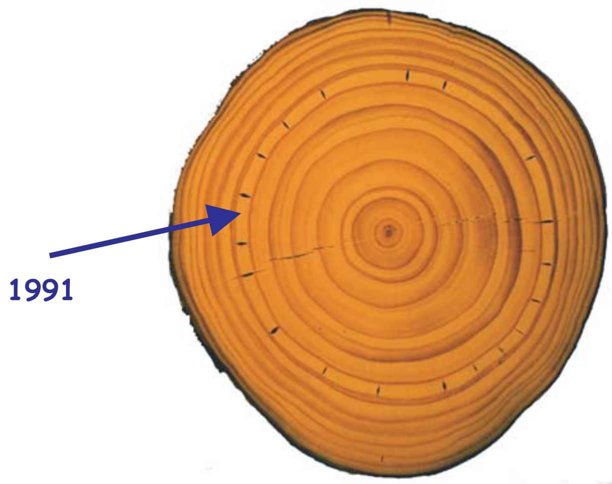
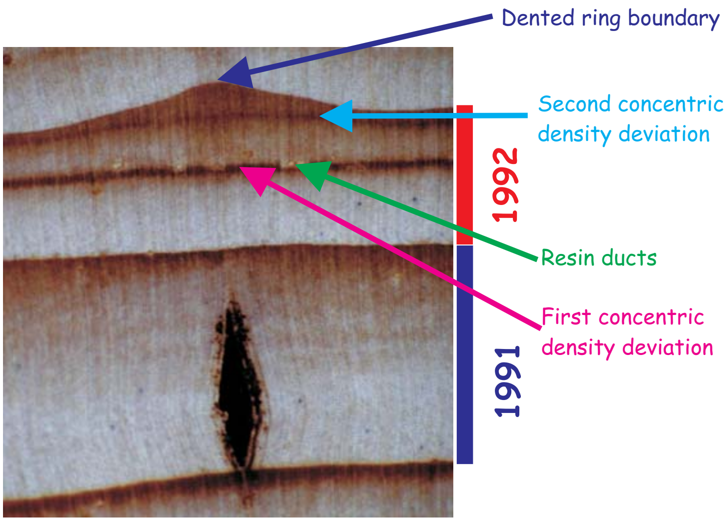
Mechanism leading to intra-ring radial cracks in young spruce trees

Michael Grabner, Burgi Gierlinger and Rupert Wimmer



Material and methods

Two 19-year old clonal Norway spruce (Picea abies (L.) Karst.) trials located in southern Sweden, were sampled. 288 disks were sanded, crossdated and for each year the number of trees showing radial cracks was determined.



Results

Radial cracks were most frequently found in the 1991 ring, on both sites. The tracheids surrounding the radial cracks were filled with resin, indicating living ray parenchyma present at the time of crack initiation. No traumatic tissues were found in the 1991 rings suggesting that crack initiation did not occur in the crack year. In the 1992 ring, two concentric intra-annual density bands were seen, followed by a dented tree-ring boundary with the tip of the bump in one radial line with the crack. The first density band was accompanied by abundant resin ducts. The year after the "crack-year" (1992) was extremely dry in May-June, August and October, intermitted by rainfall events.

Interpretation

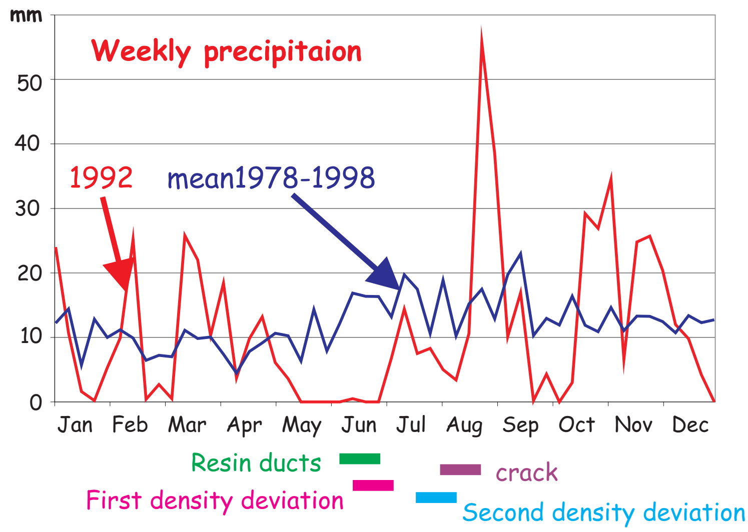
•The cracks seen in 1991 have been most likely initiated after completion of the second concentric intra-annual density band in the 1992 ring.

•A strong drought period in early summer 1992 (mid May end of June) has slowed down cambium activity resulting in the first visible density band accompanied by resin ducts.

•Rainfall in July led to a water recharge of the cambium region and a resumption of radial growth.

•Another drought event followed and the cambium responded with a slowdown, visible as the second density band. This resulted in high tangential contraction of the outermost lignified ring (1991), with the tensile strain finally reaching the fracture limit → internal mechanical failure occurred.

•The developing radial crack has concentrated mechanical stresses and forced the cambium to respond with locally accelerated cell division rates, visible as a dented ring boundary.



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Introduction

Intra-ring radial cracks in the wood of living trees have been linked to strong tangential shrinkage initiated by frost, severe drought, wind or lightning (Knuchel 1947). Nördlinger (1878) was first in suggesting drought as the major cause and Cherubini (1997) has suggested water imbalances in early spring as a likely cause of intra-ring radial cracks observed in old-grown spruce. This study suggests a mechanism leading to radial cracks by comparing tree-ring anatomy and weekly precipitation data.

Material and Methods

Two 19-year-old clonal spruce (*Picea abies* (L.) Karst.) trials from Hermanstorp (56°45', 15°02'; 180 m a.s.l.) and Knutstorp (55°58', 13°18'; 75 m a.s.l.), located in southern Sweden, were sampled for this study. Both trials were located on high-productive sites formerly used as agricultural land. From 288 spruce trees 3cm thick disks were taken from the first internode, approximately 80 cm above ground. Disks were sanded, crossdated, and the number of trees showing radial cracks determined for each year. The anatomy of the crack-rings were observed microscopically and relevant climate data analysed

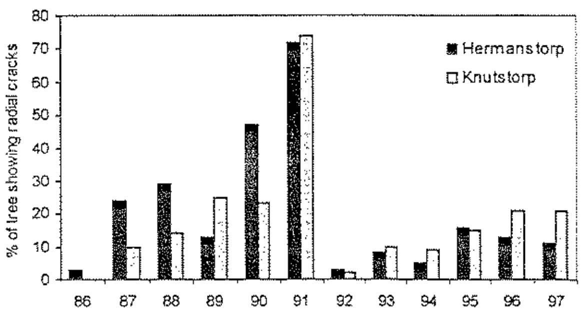

Fig. 1: Percentage of trees showing radial cracks on the two sites; 1986–1997; number of trees: Hermanstorp = 116, Knutstorp = 172.

Results

Radial cracks were most frequently found in the 1991 ring, on both sites (72%, resp. 74% of all trees, Figure 1). The subsequent year 1992 was characterized by almost zero cracks. The fact that both sites behaved similarly suggests that environmental factors must have played a significant role.

The longitudinal tracheids surrounding the radial cracks were filled with resin, which indicates that living ray parenchyma tissue was present at the time of crack initiation. No traumatic tissues were found in the 1991 rings, which suggests that crack initiation did not occur in the same year. In the subsequent 1992 ring, two concentric intra-annual density bands were seen, followed by a dented tree-ring boundary with the tip of the bump in one radial line with the crack (Figure 2, 3). The first density band was accompanied by abundant resin duct formations. A climate data analysis revealed that the year after the "crack-year" was extremely dry in May–June, August and October, intermitted by rainfall events (Figure 4).

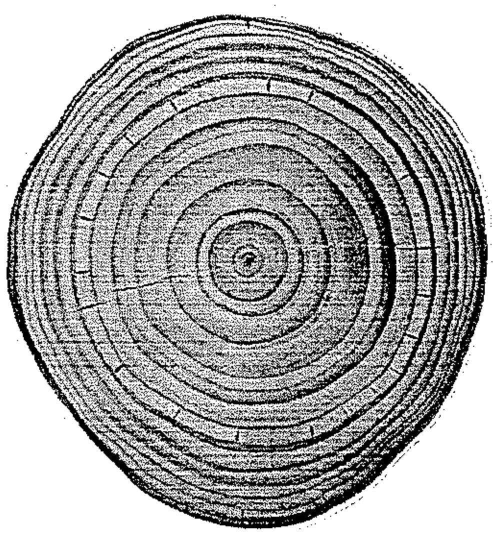

Fig. 2: Radial cracks in a 19-year-old spruce tree. Disk showing the frequent radial cracks in the 1991 tree ring.

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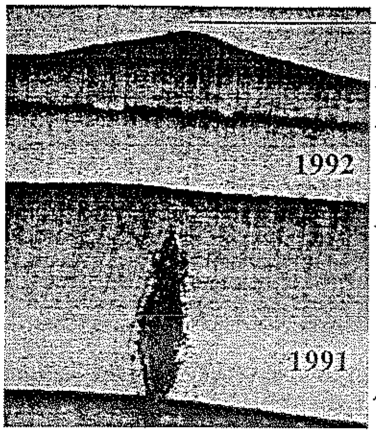

Fig. 3: Radial cracks in a 19-year-old spruce tree. Close-up of a radial crack in the 1991 ring and the subsequent 1992 ring showing two density bands, and a convexity of the ring boundary.

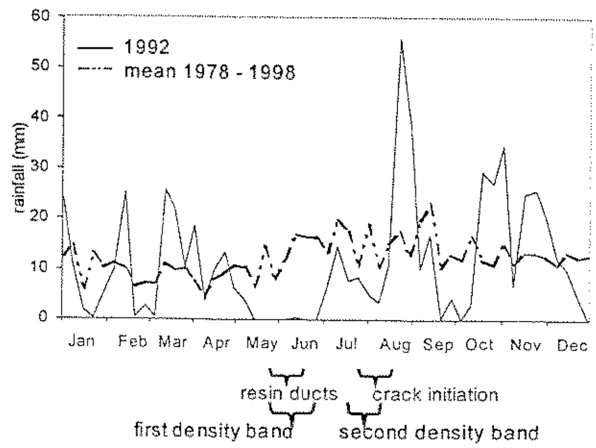

Fig. 4: Weekly precipitation of the year 1992 compared with the long-term average. Drought periods are seen in May–June, August and September–October. These periods can be linked to the formation of density bands, resin ducts and intra-ring radial cracks.

Discussion

The cracks in 1991 have been most likely initiated after completion of the second concentric intra-annual density band in 1992. Based on conclusions from observed tree-ring anatomy and weekly weather data the following scenario of crack initiation is proposed: The severe drought period in early summer 1992 (mid May – end of June) slowed down cambium activity resulting in the first visible density band. This density band was also accompanied by resin ducts as a typical stress response (Wimmer and Grabner 1997). Rainfall in July led to a re-hydration of the cambium and a resumption of radial growth. The wet period was soon followed by another drought event and the cambium responded with a slowdown, visible as the second density band. This second dehydration resulted in high tangential shrinkage of the outermost lignified ring (1991) with the tensile strain finally reaching the fracture limit. As a consequence, internal mechanical failure occurred. The developing radial crack has then concentrated mechanical stresses and forced the cambium to respond with locally accelerated cell division rates, visible as a dented ring boundary.

In summary, we have strong evidence that extreme weather fluctuation, i.e. dry–wet cycles, may have resulted in high internal mechanical tension strains due to tangential shrinkage that have exceeded fracture limits of wood. During the 1992 growth period the 1991 ring was the one most recently completed. Because of present growth stresses (Kübler 1959) the 1991 ring also carried the highest load of tangential and vertical tension forces during the 1992 growing season. It is therefore plausible that additional shrinkage due to dehydration led to internal material failure, observed as intra-annual radial cracks.

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