Intra-annual dynamics of cambial activity: comparison of three conifer species (Norway spruce, Scots pine & silver fir) in north-east France

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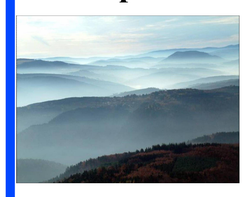
Introduction

Conifer tree-ring width mainly depends on the number of tracheids produced during the growing season by cell divisions in the cambial zone. Both cambial activity duration and rate determine the final number of produced tracheids. Studies on intra-annual dynamics of wood formation showed that climate has a strong influence on the timing of cambial activity[1], *e.g.* temperature at the beginning of the growing season. On the other hand, the rate of cell production is known to depend on the number of cambial cells before the growing season[2], which depend on tree species and vitality[3].

We would like to know if species has direct effects on the timing and rate of cambial activity. For that, we monitored during 2008 wood formation of 5 Norway spruces, 5 Scots pines and 5 silver firs grown together in a mixed stand in north-east France.

Materials & Methods

1. Experimental design



- North-east France (48°29'N, 7°9'E)
- North Vosges mountains
- 3 sites
- 15 trees/site:
  - 5 Norway spruces (*Picea abies* (L.) *Karst.*)
  - 5 Scots pines (*Pinus sylvestris* L.)
  - 5 silver firs (*Abies alba* Mill.)
- Weekly sampling
- 3 Years (2007, 2008, 2009)

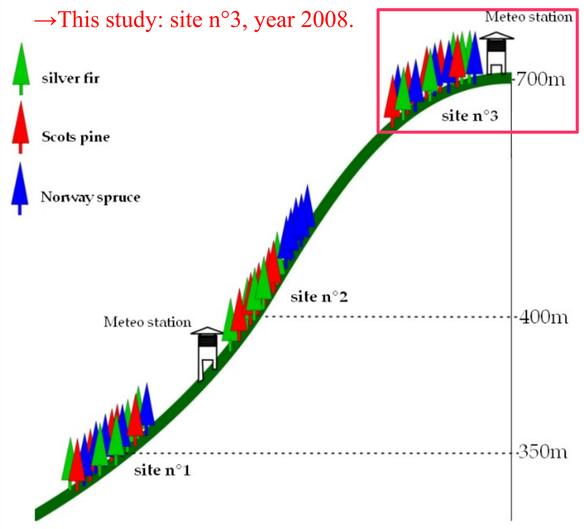


Fig. 1. Entire experimental design

2. Samples collection and preparation

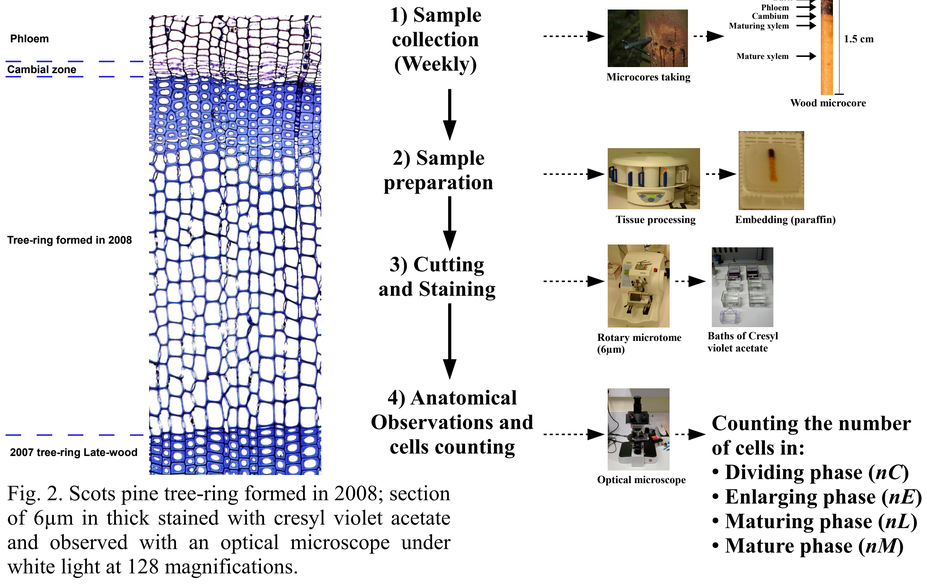


Fig. 2. Scots pine tree-ring formed in 2008; section of 6µm in thick stained with cresyl violet acetate and observed with an optical microscope under white light at 128 magnifications.

3. Wood formation phenology

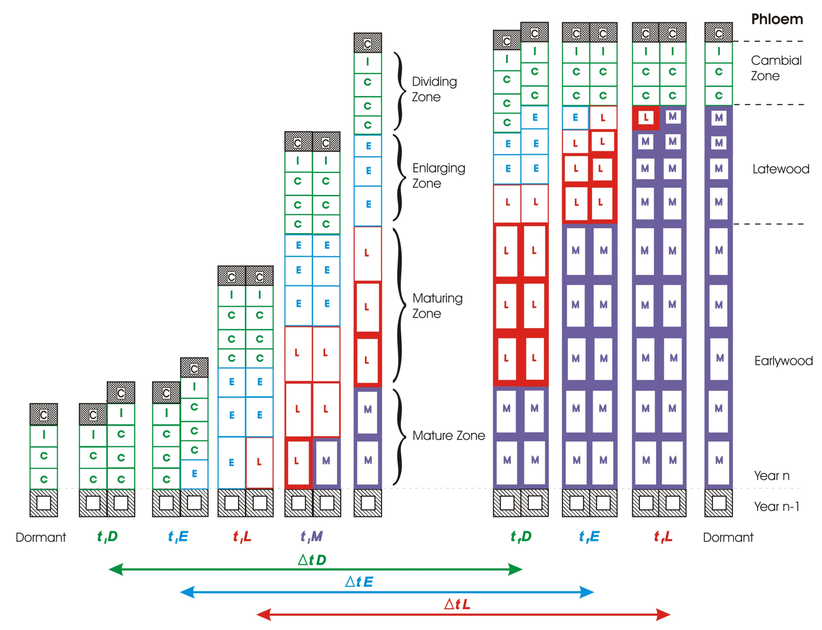


Fig. 3. Critical dates of cambial activity and wood formation definition. Xylem cells development throughout the growing season is represented along two schematic radial files; beginning of dividing (t_iD), enlarging (t_iE), maturing (t_iL) and mature phases (t_iM); end of dividing (t_fD), enlarging (t_fE) and maturing (t_fL) phases; durations of dividing, enlarging and maturing phases (ΔtD, ΔtE, ΔtL).

4. Critical dates and cell production rates computation

- Critical dates of cambial activity and wood formation were computed using logistic regressions.
- Cambial activity rates were computed from the Gompertz function fitted on the total number of produced tracheids through the growing season[5].
- Computation were made using functions of the R package CAVIAR[4].

Results

1. Dendrometric characteristics of the studied trees

Species	Age	Height (m)	Circumference (cm)	ICN	RCN
Norway spruce	73 ± 6	31 ± 2	180 ± 24	7,1 ± 1,2	83,3 ± 43,5
Scots pine	74 ± 8	32 ± 3	172 ± 29	5,8 ± 0,8	25,5 ± 13,9
silver fir	119 ± 6	27 ± 2	166 ± 15	5,9 ± 0,7	37,2 ± 23,0

Table 1. Dendrometric characteristics of the studied trees; for each species, values correspond to the mean for the 5 trees ± 1 standard deviation; initial number of dormant cambial cells (ICN); final ring cell number (RCN).

2. Wood formation calendar

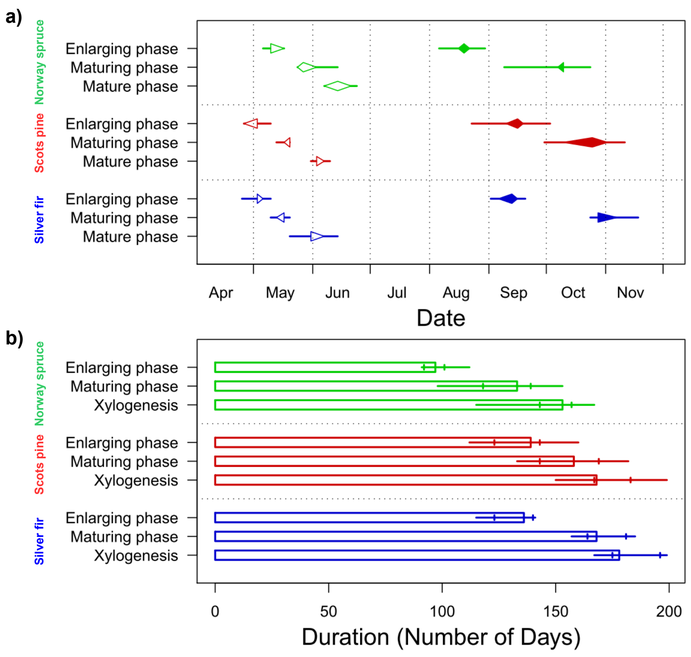


Fig. 4. Wood formation calendar for the 5 Norway spruces, 5 Scots pines and 5 silver firs in 2008; a) Critical dates of wood formation. b) Durations of wood formation.

3. Intra-annual dynamics of cambial activity

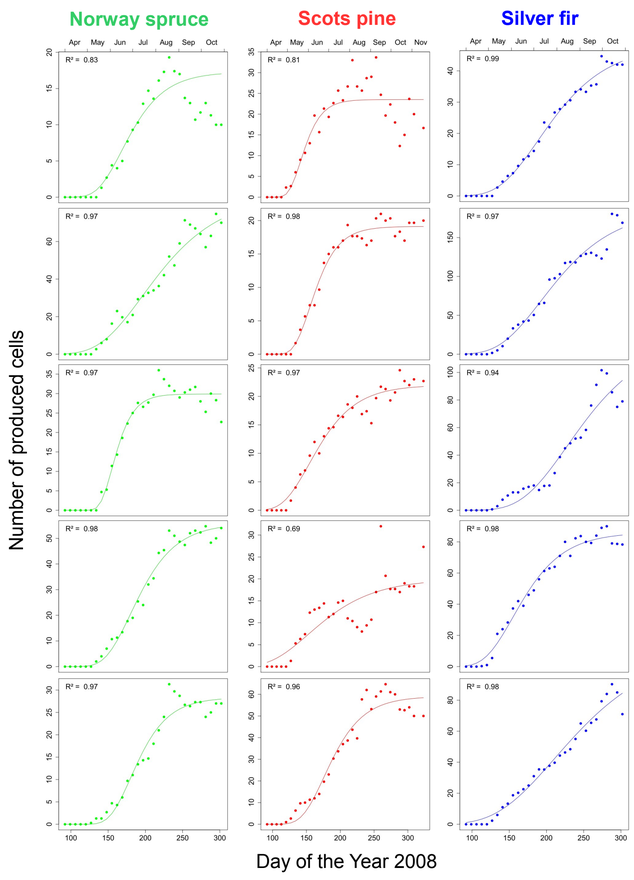


Fig. 5. Intra-annual dynamics of tracheids production. Points represent the observations ($nE + nL + nM$). Lines corresponds to the curve fitted with the Gompertz function from which are extracted the cambial activity rates.

4. Cambial activity rates

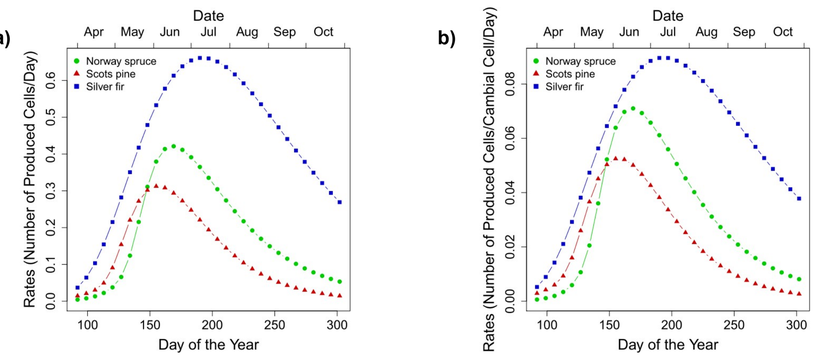


Fig. 6. Cells production rates estimated for the 3 species using the Gompertz function; For each species, rates correspond to the mean of the 5 studied trees; a) Rates computed for the entire cambial zone. b) Rates standardized by the number of cells in dormant cambium, *i.e.* before the beginning of the growing season.

5. Duration and rates of cambial activity and number of produced tracheids

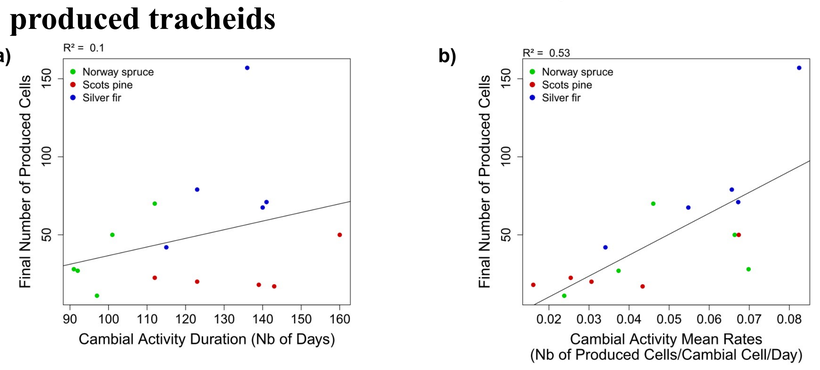


Fig. 7. Relationships between: a) cambial activity duration and the final number of produced cells; b) cambial activity rates and the final number of produced cells.

Discussion & Conclusion

- In our study, species did not have a strong effect on wood formation calendar and cambial activity duration. It is a bit surprising that Scots pine calendar did not differed from silver fir one's, because it is known that pine species have an earlier starts and a longer duration of cambial activity than other conifer species. But Scots pines were older and smaller in our study, and we know that cambial activity duration is shorter for old trees.
- Species has a direct effect on cambial activity rate.
- Regarding the relationships between cambial activity characteristics and the final number of produced tracheids, cambial activity rate is the most important factor explaining cell production variability.

Extension of these analyses for 3 years and 3 sites will allow a better assessment of each species behavior. Furthermore, it will allow a better understanding of the effects of ecological factors on the intra-annual dynamics of wood formation and the study of consequences on tree-ring structure.

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