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The Impact of Long-Term Fertilisation of Potato Starch Wastewater on the Growth of Scots Pines: A Retrospective Analysis

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IECF 2022

Mesic Scots pine Forest

Poor habitats with periodic water deficit

Fertilisation of Potato Starch Wastewater

*

28 years
1985-2012

Two stands of different ages

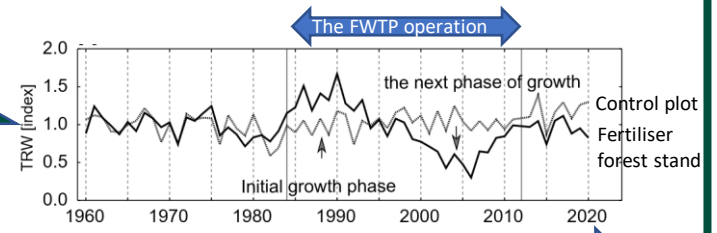
Sampling in 2020

2 control plots outside

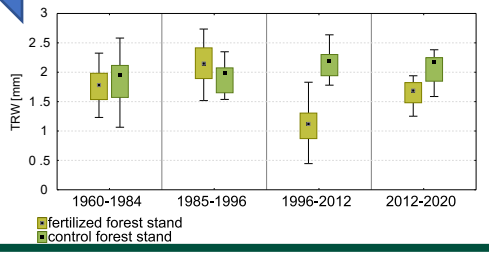
Dendro chrono logical analysis

Growth Reaction

Increase TRW



1985-1995 The FWTP operation 1996-2012



decrease TRW

Changes in Forest Ecosystem

Changes in wood anatomy

Share of earlywood in TRW ↑

↓ Quality of the wood

Sensitivity of trees to climatic conditions ↑

Suppression of tree growth

Strong reduction of stand density

Deformation of crowns and trunks

Changes in the species structure of the undergrowth

*Photo: Archives of the Forest Management and Geodesy Office–Department in Olsztyn, Poland

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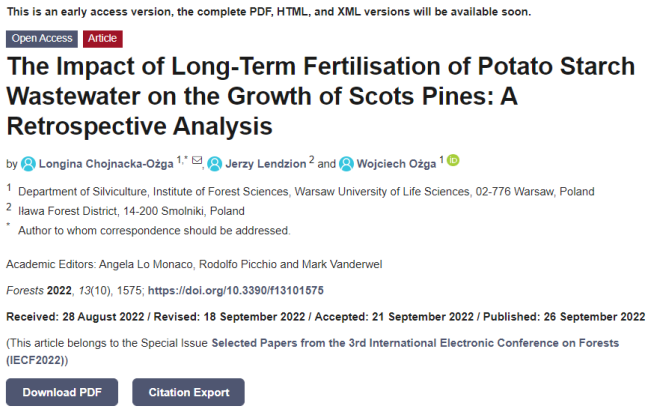
Abstract

The article discusses the impact of the application of potato starch wastewater as a fertiliser on the growth responses of Scots pines at the Forest Wastewater Treatment Plant (FWTP) in Iława. More specifically, our study sought to determine the direction, extent, and duration of changes in the trees' growth responses caused by the application of fertiliser and the influence of climatic conditions on secondary growth in the trees to which the fertiliser had been applied. As part of the study, the extent of and changes in the growth responses were determined with reference to annual ring widths and earlywood and latewood widths using dendrochronological methods. The research was carried out in four pine stands: two stands of different ages (80 and 110 years) located within the FWTP site and two control stands of corresponding ages located outside that area.

We found a two-way impact of potato starch wastewater on radial growth in the trees under study, with a stimulatory effect (27%–30%) in the first decade of fertiliser application followed in the subsequent years by a strong reduction in growth (30%–45%, depending on the age of the trees). The trends of these changes could be seen in both the overall annual ring widths and the widths of earlywood and latewood. The direction of the changes was the same for trees of different ages, although age was found to have affected the extent and duration of the stimulatory or inhibitory effect. Over the entire period during which the fertliser was applied, changes occurred in the structure of the wood as manifested in the increased share of earlywood. The sprinkler application of potato starch wastewater and the accompanying irrigation caused a shift in dendroclimatic relationships in comparison to the control plots. Surface irrigation and the resulting changes in water balance reduced the drought susceptibility of the pines under study. At the same time, however, trees weakened by the excessive concentration of toxic nitrates became more sensitive to temperature conditions in winter. The results confirm that the implementation of substances containing significant amounts of organic nitrogen and potassium into forest ecosystems may impair the vigour of trees, reduce stand productivity, cause an imbalance in the ecosystem and may consequently lead to forest degradation.

Keywords: tree ring widths; organic sewage; forest experiment; Pinus sylvestris; dendrochronology; Poland

See more in: Chojnacka-Ożga, L.; Lendzion, J.; Ożga, W. The Impact of Long-Term Fertilisation of Potato Starch Wastewater on the Growth of Scots Pines: A Retrospective Analysis. Forests 2022, 13, 1575. https://doi.org/10.3390/f13101575



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Introduction/Research problem

Biogenic disposal of wastewater sludge

↓

Conversion of sewage sludge to a soil amendment

Agriculture

↓

positive influence on plant production and improvement of soil properties

alternative source of nutrients for plant growth and an efficient soil conditioner enhancing certain physical properties of soil

in Europe > 50% of sewage sludge is used in agriculture

Environmental Threats

may lead to crop toxicity and environmental degradation

leaching of nutrients, pathogens, heavy metals and organic compounds to groundwater

pollutants from sewage can be absorbed by crops and pose health risks for consumers.

the long-term application of sewage potentially leads to Forest degradation

Forestry

↓

increasing forest productivity

improving forest soils of low fertility

the long-term application of sewage potentially leads to excessive nitrogen, potassium and metal accumulation

recycling of organic wastes in forests is very dependent upon correctly matching material to site type

Introduction/Research problem

EXPERIENCE in Poland

to evaluate the possibilities for productive utilisation of organic wastewater in tree plantations

Forest Wastewater Treatment Plant

the waste to be treated in the forest environment

potato starch wastewater from the nearby starch factory/ sprinkler application combined with additional irrigation in the growing season

initial assumptions

the disposal of this type of wastewater in a forest ecosystem growing on nutrient-poor sandy soils will contribute to an increase in tree biomass and improve the productivity of forest stands

potato starch wastewater is rich in nitrogen, potassium, and phosphorus

the possibility of using it to improve the nutritional status of stands

the impact of the long-term fertilisation

high concentrations of toxic compounds of nitrogen, potassium, phosphorus, calcium and magnesium in soils and groundwater

negative changes in the forest environment .

deformation of crowns and trunks

changes in the species structure of the undergrowth

strong reduction of stand density

reduction of root system

inhibition height growth

Forest degradation

Research goals

The aims of the study

(i) analyse the growth rhythm of trees from two stands of different ages subjected to sprinkler application of wastewater and trees from stands of corresponding ages which were not fertiliser;

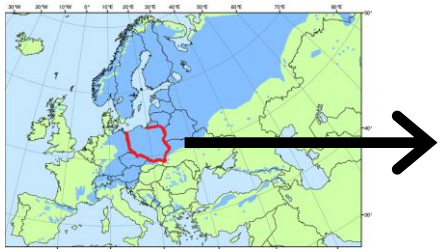
(ii) determine the direction, extent, and duration of changes in the trees' growth responses caused by the sprinkler application of potato starch wastewater;

(iii) determine the influence of climatic conditions on secondary growth in the trees to which potato starch wastewater had been applied.

The study focused on three characteristics of secondary xylem, namely (i) annual tree-ring width (TRW); (ii) earlywood (EW) and latewood (LW) width; and (iii) share of earlywood in the annual tree-ring width.

Study site

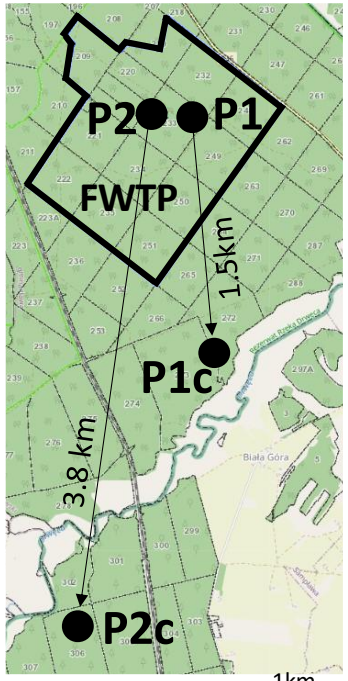
Poland → **Iława Forest District** → **Forest Wastewater Treatment Plant (FWTP)** → **Scot pine stands**



Blue colour- Scots pine range

Fertilisation of Potato Starch Wastewater

28 years
1985-2012

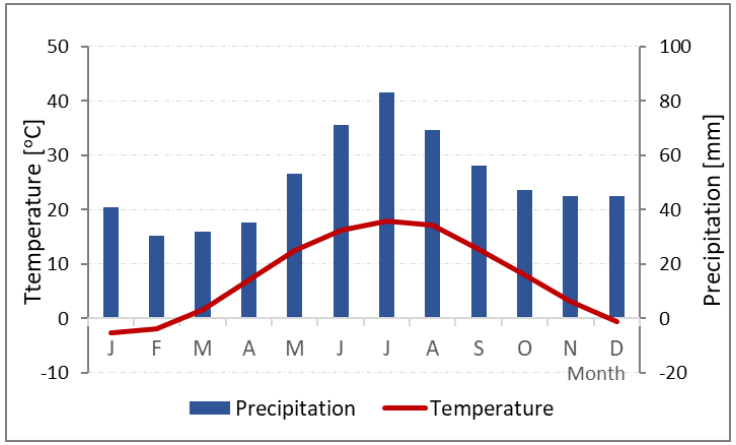


The study plots:

two stands of different ages (80 and 110 years; P1 &P2) located within the FWTP site

two control stands of corresponding ages located outside that area (P1c &P2c).

Climatic diagram for study site*



*for the years 1951–2020

Methods

Research → **Dendrochronological sampling in 2020** → **Cores from 12 trees on each study plot** → **Height of 1.3 m above the ground / Pressler increment borer.** → **Samples**: **drying**, **sanding**, **Scanning**

Standard dendrochronological techniques

1. **Measurements of tree-ring widths TRW and EW % LW (0,01mm)** → ***software: Coo-Recoder 9.3***
2. **Cross-dating tree-ring series: visual & statistical** → ***software: CDendro 9.3,*** **COFECHA**
3. **Chronology construction & basic statistic: TRW, EW & LW chronologies for each plot** → ***software: ARSTAN***
4. **Comparison of tree growth at the fertilized plots with the growth of trees at the control plots.** → ***software: non-parametric test, Kruskal–Wallis, to determine the significance of differences***

   Comparisons were carried out for:
   - ❑ the period prior to the launch of the FWTP (1960–1984),
   - ❑ the period of active operation of the FWTP (1985–2012),
     - two sub-periods: 1985-1995 & 1996-2012
   - ❑ the period following the decommissioning of the plant (2013–2020)

5. **Climate–growth relations: response function** → ***software: DendroClim2002***

   analyses for all plots separately for two periods:
   - ❑ the period preceding the fertiliser application (1951–1984)
   - ❑ the period following the commissioning of the treatment plant (1985–2020)

Results

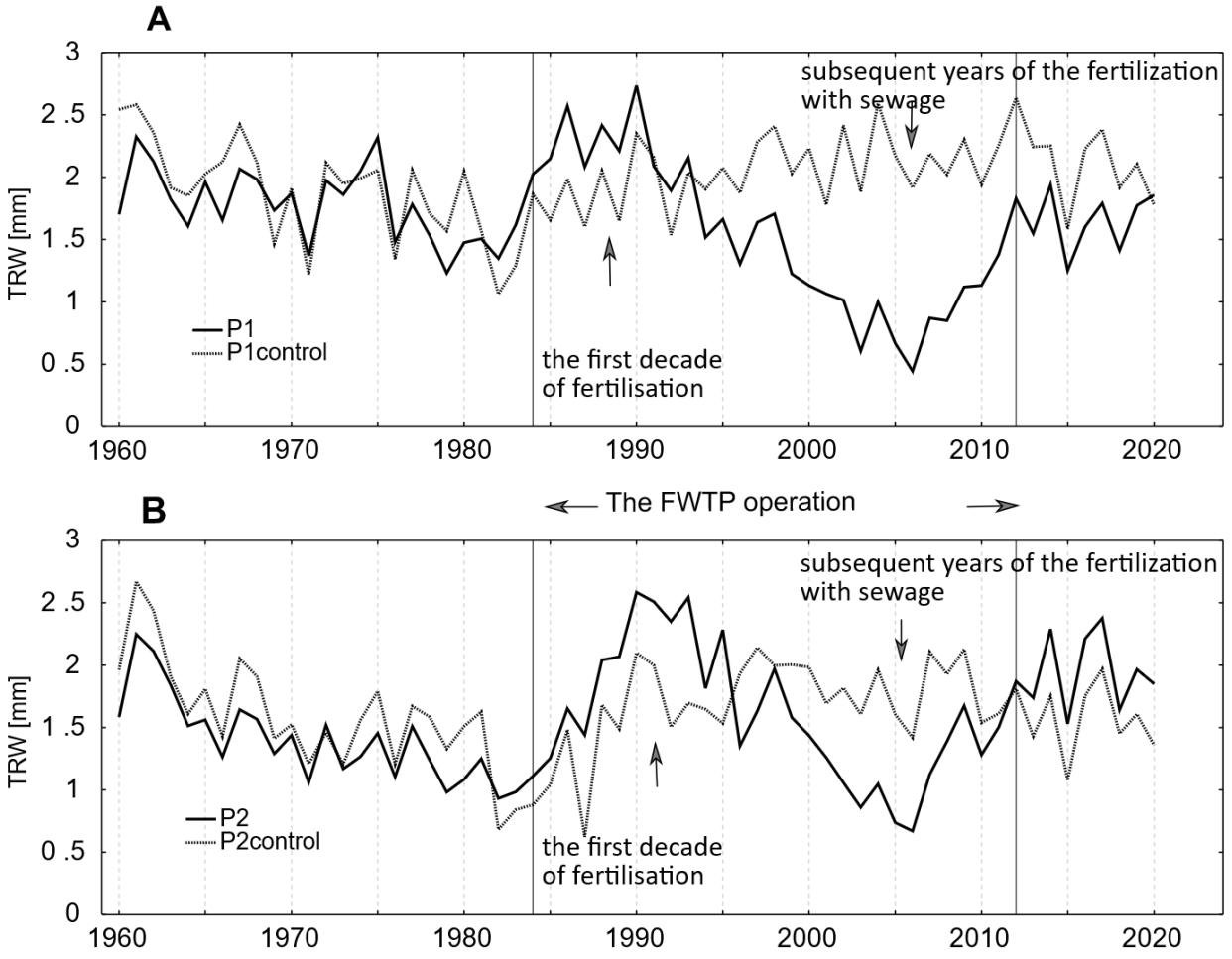
Results

Comparison of Scots pine growth at the fertilized plots with the growth of Scots pine trees at the control plots.

1. Comparison of TRW chronologies of Scots pine from study plots.

A–plots with younger trees
aged 40–45 when fertiliser application began (1984)

B–plots with older trees
aged 70–75 when fertiliser application began (1984)



The growth response of the pines under study to fertilisation was bidirectional, with an increase in growth during the initial period followed by a severe reduction

The reaction of both groups of trees was similar in terms of the direction of changes

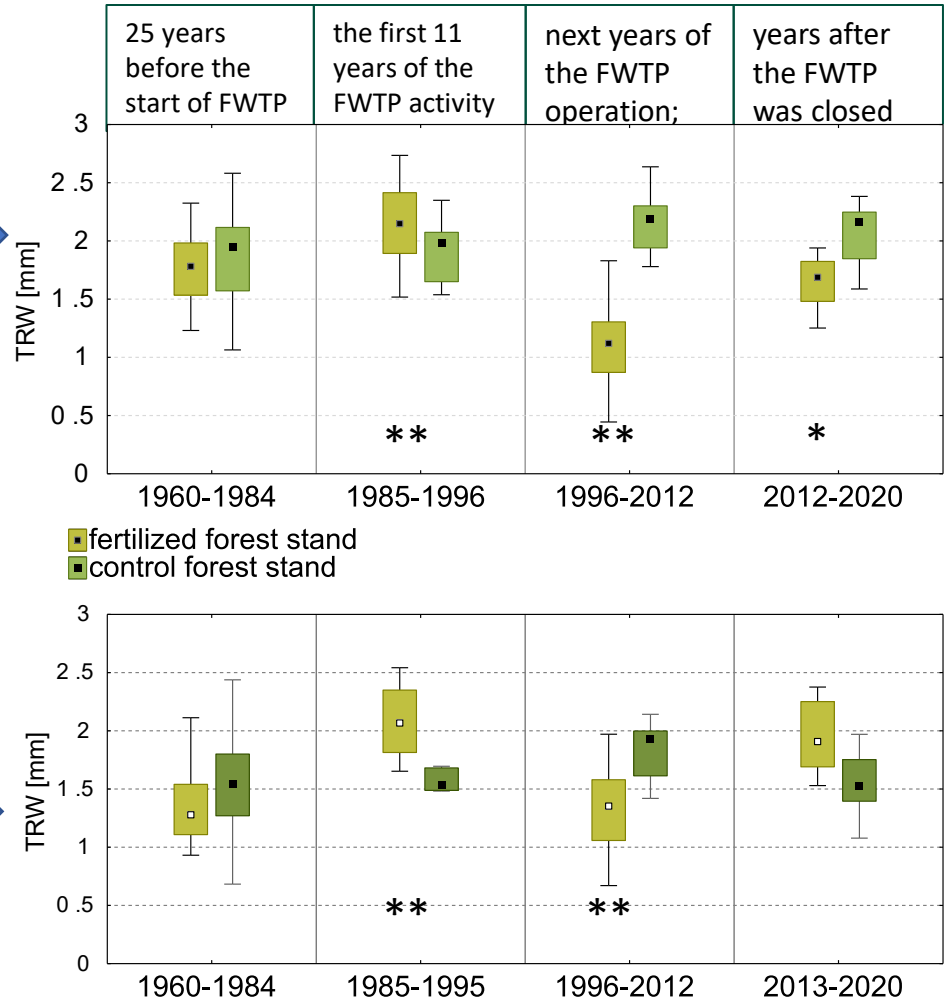
Results

Comparison of Scots pine growth at the fertilized plots with the growth of Scots pine trees at the control plots.

2. The differences in means TRW between the study stands in the different tree growth periods

A–plots with younger trees
aged 40–45 when fertiliser application began (1984)

B–plots with older trees
aged 70–75 when fertiliser application began (1984)



The first period of the fertilisation
1985-1995
a significant increase in the radial growth of trees growing in fertilizer plots: 25-30% higher than on the control plots and more than 30% higher than in the period preceding fertiliser

The next period of the fertilisation
1996-2012
period of period of significant growth reduction;

- younger trees - 45% lower than on the control plot
- older trees - 27% lower than on the control plot

Asterisks indicate a significant difference amongst mean tree-rings widths (median) of Scots pine on study plots; * represents that 0.01 < p-value < 0.05; ** represents that 0 < p-value < 0.01.

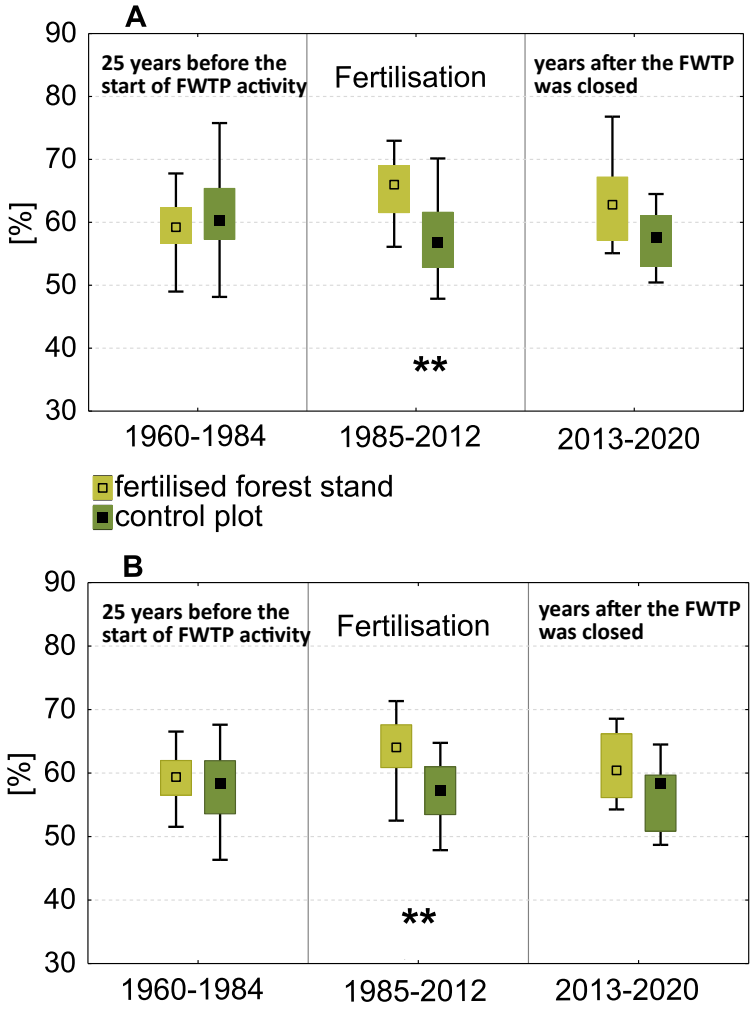
Results

Comparison of Scots pine growth at the fertilized plots with the growth of Scots pine trees at the control plots.

3. The share of earlywood to total annual ring width of Scots pine

A–plots with younger trees
aged 40–45 when fertiliser application began (1984)

B–plots with older trees
aged 70–75 when fertiliser application began (1984)



The changes in the structure of wood that occur as a result of sprinkler application of potato starch wastewater.

- fertiliser application caused the share of earlywood in the annual ring width to increase by an average of 6% in comparison with the control plots
- increased share of earlywood could be observed in periods of both increased and reduced growth and was more pronounced in the younger trees

Asterisks indicate a significant difference amongst mean tree-rings widths (median) of Scots pine on study plots; ** represents that 0 < p-value < 0.01.

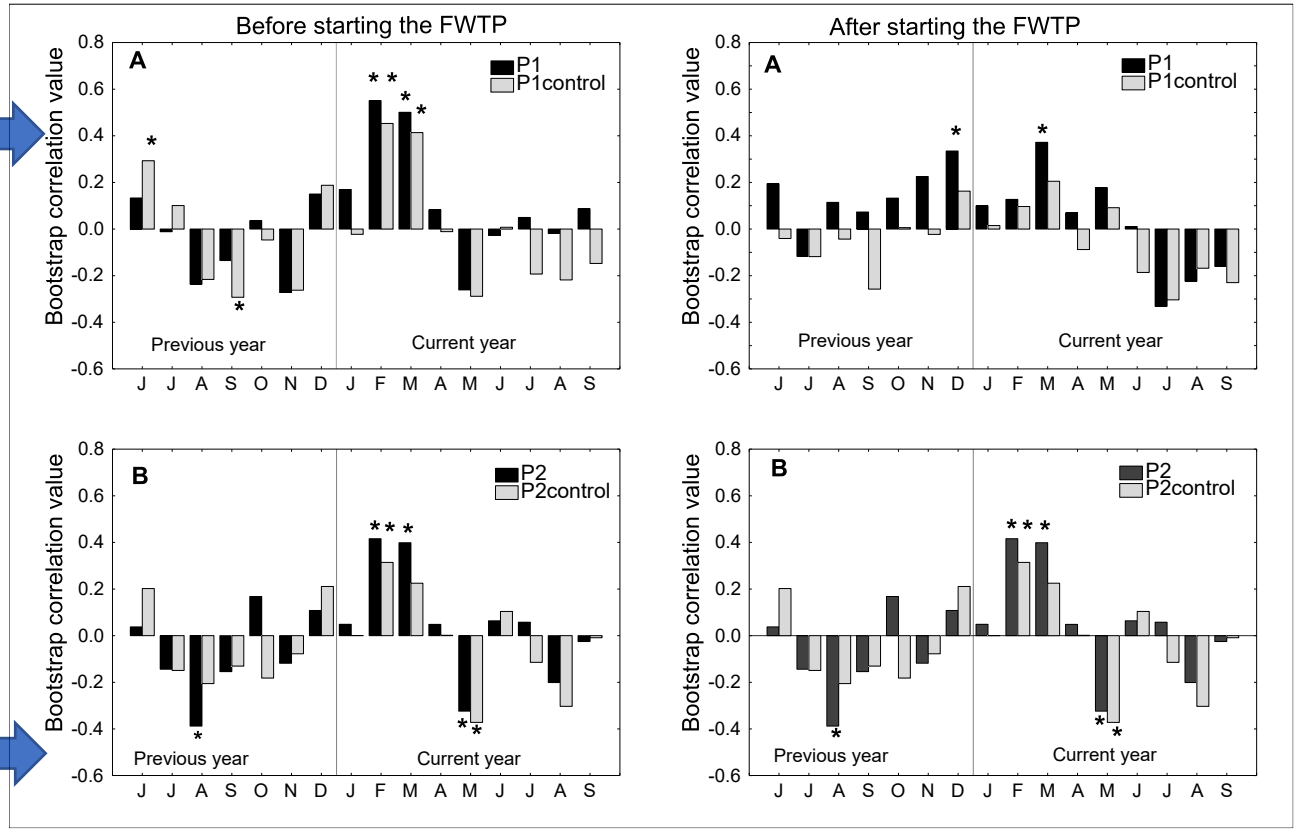
Results

Climate–growth relations.

1. Relationships between air temperature and radial growth of Scots pine growing on the study plots

A–plots with younger trees
aged 40–45 when fertiliser application began (1984)

B–plots with older trees
aged 70–75 when fertiliser application began (1984)



Asterisks (*) indicate significance at $p < 0.05$

The period before starting FWTP
1951-1984

the impact of air temperature on radial growth **was similar** in trend for all plots, the differences between the plot relating to the strength of linkages

The period after starting FWTP
1985-2020

different dendroclimatic response
the trees growing at fertiliser became more sensitive to temperature conditions in winter and spring in comparison to the control plots

Conclusion

1. The application of potato starch wastewater combined with additional irrigation in the growing season had a significant impact on radial growth in the Scots pines subjected to such treatment, with the changes in growth being bidirectional. The fact that nutrients were supplied with the wastewater caused an initial rapid increase in growth, which was then followed by a strong reduction in the next period. The direction of the changes was the same for trees of different ages, although age was found to have affected the extent and duration of the stimulatory or inhibitory effect.

2. Sprinkler application of potato starch wastewater caused changes in wood anatomy that manifested themselves in the increased share of earlywood in TRW.

3. The sprinkler application of potato starch wastewater and the accompanying irrigation caused a shift in dendroclimatic relationships in comparison to the control plots. Surface irrigation and the resulting changes in water balance reduced the drought susceptibility of the pines under study. At the same time, however, trees weakened by the excessive concentration of toxic nitrates became more sensitive to temperature conditions in winter.

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