RADIAL GROWTH RESPONSE OF JAPANESE WALNUT (*JUGLANS AILANTIFOLIA)* TO METEOROLOGICAL CONDITIONS IN LATVIA

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Abstract

The introduction of non-native tree species has been used as a climate change mitigation tool. To ensure the anticipated benefits, the analysis of species radial growth reactions to meteorological factors should be carried out. Initially, tree species were introduced to non-native regions as food resources, yet the focus has now shifted towards favourable wood properties and growth rates. This study used tree ring width measurements of Japanese walnut *Juglans ailantifolia* and climate data to examine the relationships between these variables. A total of 30 trees were sampled from a stand located in the southern part of Latvia. Tree ring width (TRW) was measured, and residual chronology was derived. Pearson correlation analysis was used to detect the correlating meteorological factors, and a linear mixed-effects model was used to detect the key factors. The correlation analysis indicated generally low correlation coefficients between TRW and meteorological factors, primarily correlating with summer precipitation, both the current and preceding summer, highlighting carry-over effects. Furthermore, signature years underscored the negative effect of low temperatures and summer droughts on the radial growth of Japanese walnuts. However, the observed variation in TRW between years, not fully explained by meteorological factors, suggests a dynamic rather than stable relationship.

Key words: climate, introduced trees, Japanese walnut, radial growth.

Introduction

The geographical distribution of plant species is affected by climate change, which is characterized by temperature increases and reduced precipitation amounts (Scheffers *et al*., 2016). On the one hand, climate change can bring benefits. Due to phenological shifts causing earlier budburst and delayed leaf aging in autumn, the growing season has been prolonged for about 11 days since the 1960s (Menzel & Fabian, 1999), resulting in a primary production increase. However, the anticipated positive effects can weaken as a result of elevated evapotranspiration (Lindner *et al*., 2014). To reduce the potential negative impact of climate change, non-native species introduction has been identified as a strategic tool. While species introduction brings a lot of gains, it also carries potential risks (Hasenauer, 2020), such as species becoming invasive, with common walnut (*Juglans regia*) serving as an example. Though it is widely distributed across Europe, this species demonstrates invasiveness in its secondary range (Lenda *et al*., 2018). Despite the potential risks, tree species that were known as food resources including almond (*Prunus dulcis*), apricot (*Prunus armeniaca*), peach (*Prunus persica*), sweet chestnut (*Castanea sativa*), and common walnut, have been introduced since ancient Greek times (Pötzelsberger *et al*., 2020). An important aspect of walnut cultivation in ancient times was the broad range of conditions in which they could grow (Gupta, Behl, & Panichayupakaranan, 2019). Nowadays, walnuts do not hold a significant value from an ecological perspective, yet they are economically important because of their high-quality timber, often sold at high prices. The wood of walnut has an aesthetic appeal and is easy to process; therefore, it is preferred for luxury furniture and veneer applications (Paź-Dyderska, Jagodziński, & Dyderski 2021). In some countries, Japanese walnut is cultivated for nut production, such as Belarus, Lithuania, and Ukraine (Marazzi *et al*., 2022). Findings reveal that the nuts from species indigenous to Japan (*J. ailantifolia, J. subcordiformis*) exhibit significantly higher protein and mineral content and reduced fat levels compared to conventional cultivars (Fukasawa *et al*., 2023). Within its native range, Japanese walnut grows in diverse mixed-riparian forests (Tamura & Hayashi, 2008). Yet even in its distribution area, the climate affects the phenological response of this species, such as flower abortion due to early spring frosts (Marazzi *et al*., 2022). Japanese walnut has compound leaves that can reach 90 cm in length with 11–19 hair leaflets and upright red female inflorescences that can produce up to 20 fruits (Marazzi *et al*., 2022). Visually distinguishing *Juglans* species is challenging; similar species, tigernut (*Juglans mandshurica*) and Japanese walnut (Roloff & Bärtels, 2018), are separate species, but molecular phylogenetic studies propose that these taxa should be regarded as a single species (Mu *et al*., 2017). The identification of Japanese walnut is further complicated by its potential hybridization with butternut (*Juglans cinerea*) (Boraks & Broders, 2014; Brennan *et al*., 2020). Research, primarily focused on the chemical composition of the seeds, suggests that cultivars exhibit reduced resistance to environmental factors (Fukasawa *et al*., 2023). Meteorological factors control the radial growth of trees, demonstrating the complex interaction between biological inheritance and environmental signals in shaping growth patterns (Matisons *et al*., 2019). Hence, the objective of this study was to evaluate the impact of meteorological factors on the tree ring width of Japanese walnuts in Latvia.

Materials and Methods

An experimental plantation of Japanese walnuts growing in Latvia, Code 'Figure 1', was chosen for radial increment analysis. The plantation with a size of 0.58 ha was established in the 1960s and has reached around 60 years of age (Laiviņš, 2020). Over time, a natural mixture of common ash *Fraxinus excelsior* and bird cherry *Padus avium* has occurred within the plantation. No forest management has occurred in this territory. The average temperature varied from -2.9±3.3 °C in February to +18.5±1.6 °C in July. The annual mean temperature, calculated from 1992 to 2021, was +7.3±0.7 °C, while the mean temperature for the summer months (June–August) was 17.4±1.0 °C. Annual precipitation averaged 641±70 mm, with the summer months having the highest monthly precipitation of 72.8±29 mm. The meteorological data were sourced from CRU for grid points (Harris *et al*., 2020).

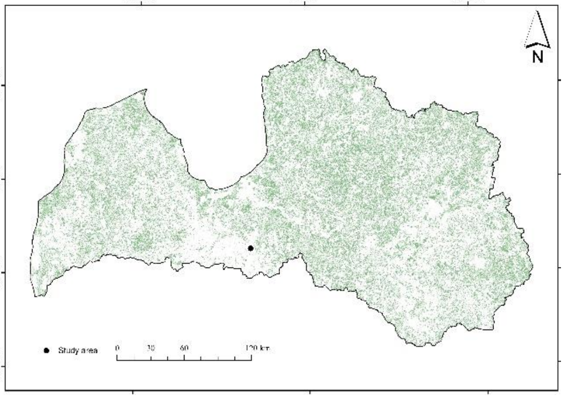

Figure 1. Location of the study area of Japanese walnut in Latvia. The green colour indicates territories with forest cover.

In 2020, an inventory and sample collection occurred. Tree diameter and height were measured, and Pressler's increment corer was used to extract two cores from opposing directions from each of the 30 dominant healthy trees. Following drying, the cores were mounted on wooden mounts and sanded. A LINTAB6 measuring table was used to measure tree-ring widths (RinnTech, Heidelberg, Germany). TRW was cross-dated using COFECHA (Grissino-Mayer, 2001). Variability in the TRW series was characterized using r-bar, expressed population signal, mean sensitivity, first-order autocorrelation, and signal-to-noise ratio (Wigley *et al*., 1984). Principal component analysis (PCA) was used to determine radial growth patterns between selected trees. Data series were prewhitened, and residual chronology was used to determine bootstrapped Pearson correlation coefficients (Zang Biondi, 2013) with meteorological data. A linear mixed-effects model was used to detect the key meteorological factors.

Results and Discussion

Out of the 30 studied trees, successful cross-dating was done for 29 trees for the period from 1964 to 2020. The mean diameter was 36.9 ±5.5 cm, ranging from 26 to 52 cm, see 'Figure 2'. This is similar to the diameters of black walnut (*Juglans nigra*) growing in Romania, Croatia, and Germany (Nicolescu *et al*., 2020). This suggests comparable levels of productivity. The mean height of the sampled trees was 24.9±1.9 m, ranging from 21 to 30 m, see 'Figure 3'. This is lower than for black walnut at a similar age in Italy, Croatia, and Romania (Nicolescu *et al*., 2020) where mean height was between 24 and 30 m.

Figure 2. Measurement of the Japanese walnut with the biggest diameter.

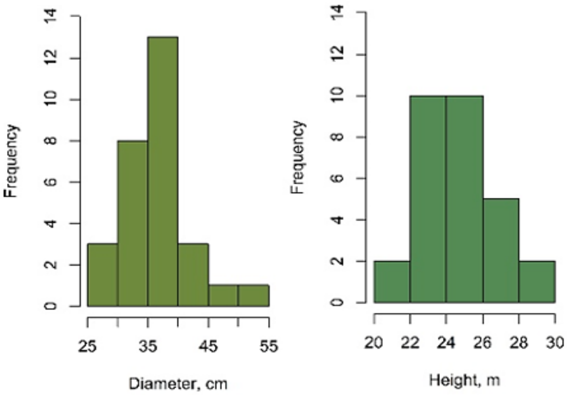

Figure 3. Frequency of diameter (cm) and height (m) classes for the studied Japanese walnut trees.

The expressed population signal (EPS) of the sampled trees surpassed 0.85 (Wigley *et al*., 1984) with a value of 0.96. An intermediate (Speer, 2011) signal-to-noise ratio (SNR) and mean sensitivity (SENS) values were detected at 31.55 and 0.24, respectively. First-order autocorrelation, which describes the connection between previous and current growth was intermediate (0.36). Two principal components for tree-ring width were identified, which explained 61.4% of the total variance between trees. A homogenic response was observed, and no divergence of the growth between trees was detected; therefore, all tree-ring width (TRW) measurements were analyzed as a single group. Several signature years were detected in TRW throughout the analyzed period, see 'Figure 4A'. The highest growth rates were observed at the beginning of the development from 1964 to 1973, with an overall declining tendency indicating an age trend. The apparent decline and divergence in growth observed around 10 years of age (1973–1977) might be linked to the onset of nut production, which happens around this age (Webber *et al*., 2022).

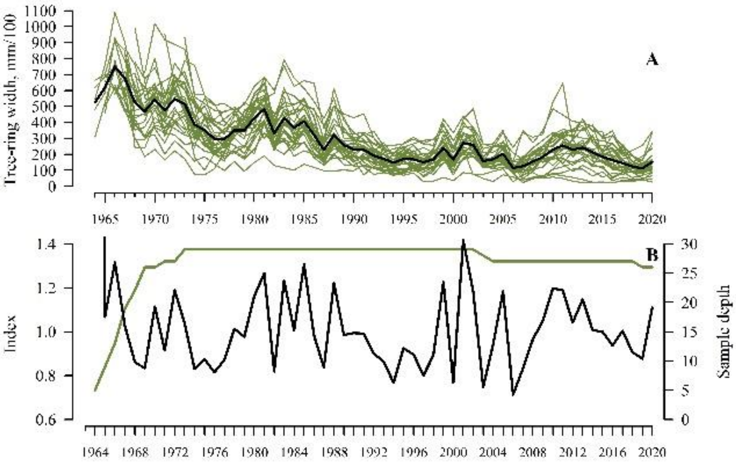

Figure 4. Tree-ring width measurements (A) and residual chronology (B) for Japanese walnut. Green lines indicate individual measurements (A) and sample depth (B).

A positive signature year was detected in 1981, which was described by increased summer precipitation amounts and temperatures. Then, in 1982, a negative signature year followed. The decrease could be attributed to the latest spring frost ever recorded in Latvia (in June), given that walnuts are sensitive to spring frosts (Marazzi *et al*., 2022). Another negative signature year was detected in 1987. This year was characterized by very low temperatures, especially at the beginning of the year. This was followed by growth suppression from 1988 until 1998. A slight increase in growth occurred at the age of 35 (year 1999). For other walnut species (*Juglans nigra*), this period is known to be the peak phase of diameter growth (Nicolescu *et al*., 2020). In 2003, Europe experienced an intense drought, leading to a decline in growth. Similarly, in 2006, when differences in growth patterns among trees became apparent, likely due to high temperatures in the summer.

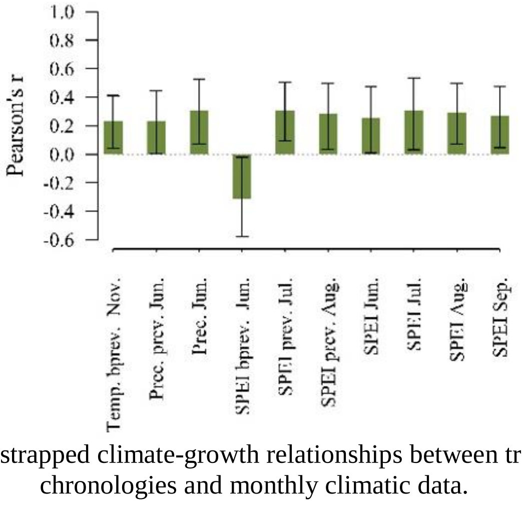

Figure 5. Bootstrapped climate-growth relationships between tree-ring width chronologies and monthly climatic data.

Tree-ring width chronology ‘Figure 4B’ exhibited correlation ‘Figure 5’ with 10 meteorological factors, with only one having a negative correlation (SPEI before the previous June). The majority of the correlating meteorological factors were SPEI in the present and preceding summer months. Similarly, studies on other walnut species, such as English walnut (*Juglans regia*), have identified a positive correlation between radial growth and summer precipitation (Winter *et al*., 2009). The strongest correlation was detected with SPEI before the previous June, SPEI in July, and precipitation in June, yet overall the correlation coefficients were similar and weak, ranging from 0.22 to 0.31. However, when all correlating factors were analyzed together, only two factors were evaluated as significant, including precipitation in the previous June ($p = 0.032$) and SPEI in the previous July ($p = 0.036$). This highlights the importance of summer precipitation and indicates some carry-over effects. Carry-over effects have been detected in other studies as well (Winter *et al*., 2009). The marginal R values (R2m) indicated that meteorological factors account for 11% of the TRW variance. When considering conditional R (R2c), which incorporates other factors, 52% of the variance was explained. This indicates a larger variation between years rather than among individual trees, with meteorological factors not being the main drivers of this variation.

Conclusions

1. The main meteorological factors affecting Japanese walnut growth in Latvia are precipitation in the previous and current summers.
2. Signature years highlight the negative effect of low temperatures and summer droughts on the growth of Japanese walnuts.
3. A significant variation in TRW between years was evident and was not explained by meteorological factors alone, suggesting a non-stationary relationship.

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