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Impact of Weather Conditions on The Development of Taurus Cedar and Anatolian Black Pine Plantations

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ABSTRACT

Plantation forestry primarily aims to enhance the production of high-quality timber. This research focuses on evaluating the effect of various climatic factors (such as relative humidity, annual precipitation, average, minimum and maximum temperatures) on the growth parameters (including tree height, breast height diameter and base diameter) of Taurus cedar (*Cedrus libani* A. Rich.) and Anatolian black pine (*Pinus nigra* Arn. subsp. *pallasiana* (L.) Holmboe). This study was conducted in two adjacent plantations established in 1995, with data collected over a three-year period (2022-2024). To assess growth patterns, 30 trees from each plantation were randomly selected and monitored. Climatic data were sourced from Türkiye's general directorate of meteorology and climatology. Analysis of variance (ANOVA) revealed that growth and climate parameters were statistically similar ($p>0.05$) for both species, except for tree height, which showed significant differences in Taurus cedar. The Spearman rank correlation analysis identified a strong and statistically significant relationship ($p<0.05$) between temperature variables (minimum, maximum, and average) and the growth traits of both tree species. On the other hand, relative humidity and annual precipitation showed no significant correlations ($p>0.05$). The findings underscore the critical role of temperature in influencing tree growth within plantation forestry, offering valuable insights for sustainable forest management practices.

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Introduction

Türkiye forestlands, encompassing 23.4 million hectares, exhibit significant variation in productivity, with recent national inventories categorizing 41% (approximately 9.65 million hectares) as unproductive. Notably, specific tree species such as Taurus cedar (*Cedrus libani* A. Rich.) and Anatolian black pine (*Pinus nigra* subsp. *pallasiana* (L.) Holmboe) collectively occupy 5.9 million hectares of this forested area (OGM, 2025). Recent data reveals that 1.3 million hectares of these species' stands are designated as unproductive, highlighting disparities in productivity across different forest types (Table 1). This distribution underscores the need for targeted silvicultural strategies to enhance forest management and productivity in regions dominated by these ecologically and economically significant species.

Anatolian black pine and Taurus cedar are important forest tree species ecologically and economically in Turkish forestry because of large natural distribution and commercial wood product. They have been extensively utilized in Turkish forestry plantations (Ayan et al., 2017) for converting unproductive forests into productive ones. However, numerous biotic and abiotic factors (Özbey & Bilir, 2023; Kartal & Bilir, 2022; Yazıcı, 2018; Yazıcı et al., 2022;) may influence the success of afforestation practices, while the impact of climatic factors on growth performance have not been thoroughly studied for these species. In this research, the impacts of particular climatic conditions on the development performance of Anatolian black pine and Taurus cedar plantations were examined over a three-year span, aiming to enhance plantation practices for these significant tree.

Materials and Methods

Study Area and Data Acquisition

Growth data including diameter at base (D_0), diameter and breast height ($d_{1.30}$) and tree height (H) was collected from adjoining plantations (Figure 1) established in 1995 of Anatolian black pine and Taurus cedar (37°31'25'' N latitude, 30°31'40'' E longitude, 1050 m altitude) during three consecutive years (2022-2024) (Figure 2). In each plantation, thirty trees were randomly selected and marked to monitor growth characteristics, with climatic data sourced from the general directorate of meteorology and climatology of Türkiye for the relevant years. The distance between permanent meteorology station (37°85'54'' N latitude, 30°36'83'' E longitude, 870 m altitude) and the plantation area was about 10 km.

Table 1. Forest inventory of the species and Türkiye

Species	Productive (ha)	Degraded (ha)	Total (million ha)
Pinus nigra	2.8	1.3	4.1
Cedrus libani	0.4	0.1	0.5
Türkiye	13.7	9.7	23.4

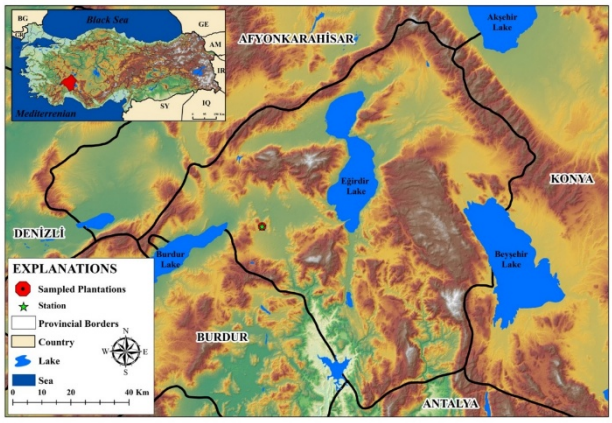


Figure 1. Study Area



Figure 2. Sampled Anatolian black pine (left side) and Taurus cedar (right side) plantations

Data Analysis

In this study, the analysis of variance (ANOVA) model was applied using SPSS software (SPSS 2011) to compare the characteristics across the years. The assessment of environmental conditions was carried out using monthly data for each year.

$$Y_{ij} = \mu + C_i + e_{ij} \quad (1)$$

Where Y_{ij} observed measurement from the j^{th} tree/month in the i^{th} year, μ denotes the overall mean, C_i signifies the uncontrolled factor of the i^{th} year, and e_{ij} accounts for the error. Relationships between growth and climatic variables were analyzed using Spearman's rank correlation, based on yearly averages and species data, within the SPSS software package (SPSS, 2011).

Results and Discussion

Meteorological Conditions

The averages of climatic characteristics for the years are presented in Table 2. It can be observed that No significant contrasts were among the years in terms of climatic characteristics (Table 2, Figure 3). This finding is supported by the analysis of variance results, which indicated that the years were similar ($p>0.05$) in climatic characteristics. However, as expected, there were notable differences among months within each year due to seasonal variations (Figure 3). For example, the highest average temperature was recorded in August (26.5°C) across all years, while the lowest average precipitation occurred in the same month (2.0 mm/kg/m²). These consistent climatic patterns suggest that the characteristics did not change drastically over a short period (Table 2).

The temperature trends observed in the studied years generally align with findings from earlier studies on Taurus cedar (Atalay, 1987; Boydak, 2003; Boydak & Çalıkoğlu, 2008) and Anatolian black pine (Atalay, 1977). However, the total yearly precipitation in the study area tended to be less than the findings reported in earlier studies for both Taurus cedar (Atalay, 1987; Boydak, 2003; Boydak & Çalıkoğlu, 2008) and Anatolian black pine (Atalay, 1977). Long-term annual total precipitation in the study area ranged from 447 mm to 619 mm (Atalay, 1987), emphasizing the need for localized forestry management techniques to alleviate climate change impacts.

Growth Characteristics

The averages ($\bar{X}$) and coefficients of variation (CVs) for the growth characteristics of the species and years are provided in Table 3. Anatolian black pine exhibited higher growth performance compared to Taurus cedar for the measured characteristics (Table 3). This finding aligns with previous studies by Özel et al. (2018) and Özbey & Bilir (2023) in plantations of these species. It is expected that Anatolian black pine begins its growth period at lower temperatures than Taurus cedar (Atalay, 1977, 1987), resulting in a longer growth period for Anatolian black pine.

Significant differences ($p<0.05$) were observed between the species for the growth characteristics based on the analysis of variance results.

Table 2. Averages of the climatic characteristics for the years

Characteristics	Years		
	2022	2023	2024
Maximum temperatures (°C)	27.2	27.4	28.3
Minimum temperatures (°C)	-1.0	0.3	1.3
Average temperatures (°C)	13.4	14.0	15.3
Annual precipitation (mm=kg/m^2)	27.6	37.2	23.0
Relative humidity (%)	59.5	64.0	57.6

Table 3. Averages ($\bar{X}$) and coefficients of variation (CV) for tree height (H), diameter at base (D_0), and diameter and breast height ($d_{1.30}$) in the species and years

	Pinus nigra						*Cedrus libani*					
	$\bar{X}$			CV %			$\bar{X}$			CV %		
	22	23	24	22	23	24	22	23	24	22	23	24
H (m)*	10.6	11.1	11.5	17.8	16.8	16.0	8.2^{a}	8.5^{ab}	8.9^{c}	11.7	10.6	10.1
D_0 (cm)	32.2	32.8	33.6	15.0	14.5	14.0	20.4	21.2	22.0	15.6	15.1	14.0
$d_{1.30}$ (cm)	25.7	26.4	27.4	18.6	18.0	17.2	15.7	16.5	17.2	15.6	14.8	14.2

*; Same letters are not significantly different among the years.

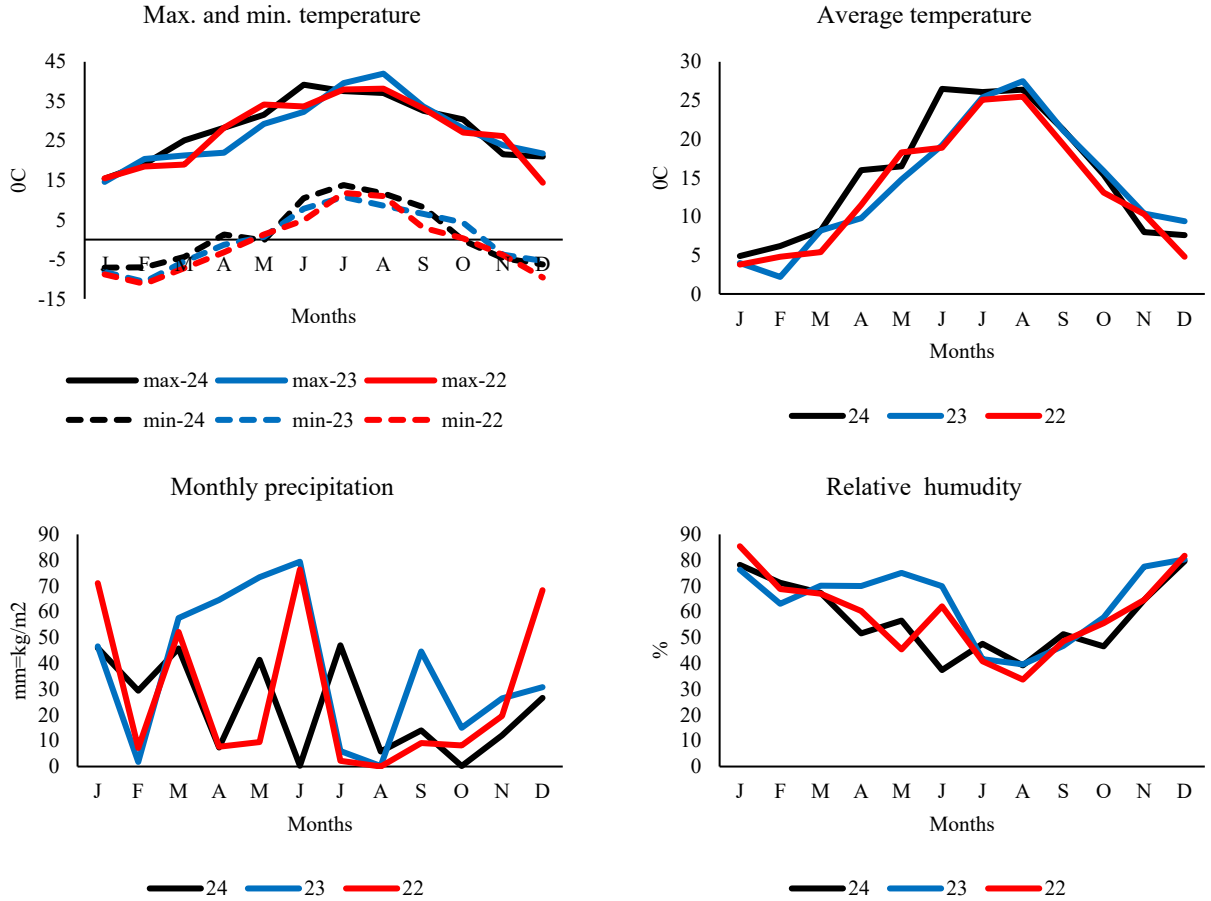


Figure 3. Monthly climatic characteristics for the years

The analysis also indicated that the growth characteristics were similar ($p>0.05$) across the years within each species, except for tree height in Taurus cedar ($p < 0.05$). The variation among individual growths decreased as the plantations aged (Table 3, Figure 4). However, numerous biotic and abiotic factors could influence the growth performance of the plantations (Gezer & Yücedağ 2006; Kartal & Bilir 2022; Özbey & Bilir 2023; Özel et al. 2018; Yazıcı 2018; Yazıcı et al. 2022).

Correlations

Annual correlations among the growth characteristics were significant ($r>0.7$; $p< 0.05$) for both species. Similar relationships have been reported in other forest tree species (Bilir, 2004, 2021; Bilir et al., 2018; Eser, 2024), suggesting these findings could be useful in plantation forestry for these species. Spearman's rank correlation coefficients revealed that temperatures (minimum, maximum, and average) had highly significant ($p < 0.05$) relationships with the growth characteristics of both species, unlike annual total precipitation and relative humidity ($p>0.05$).

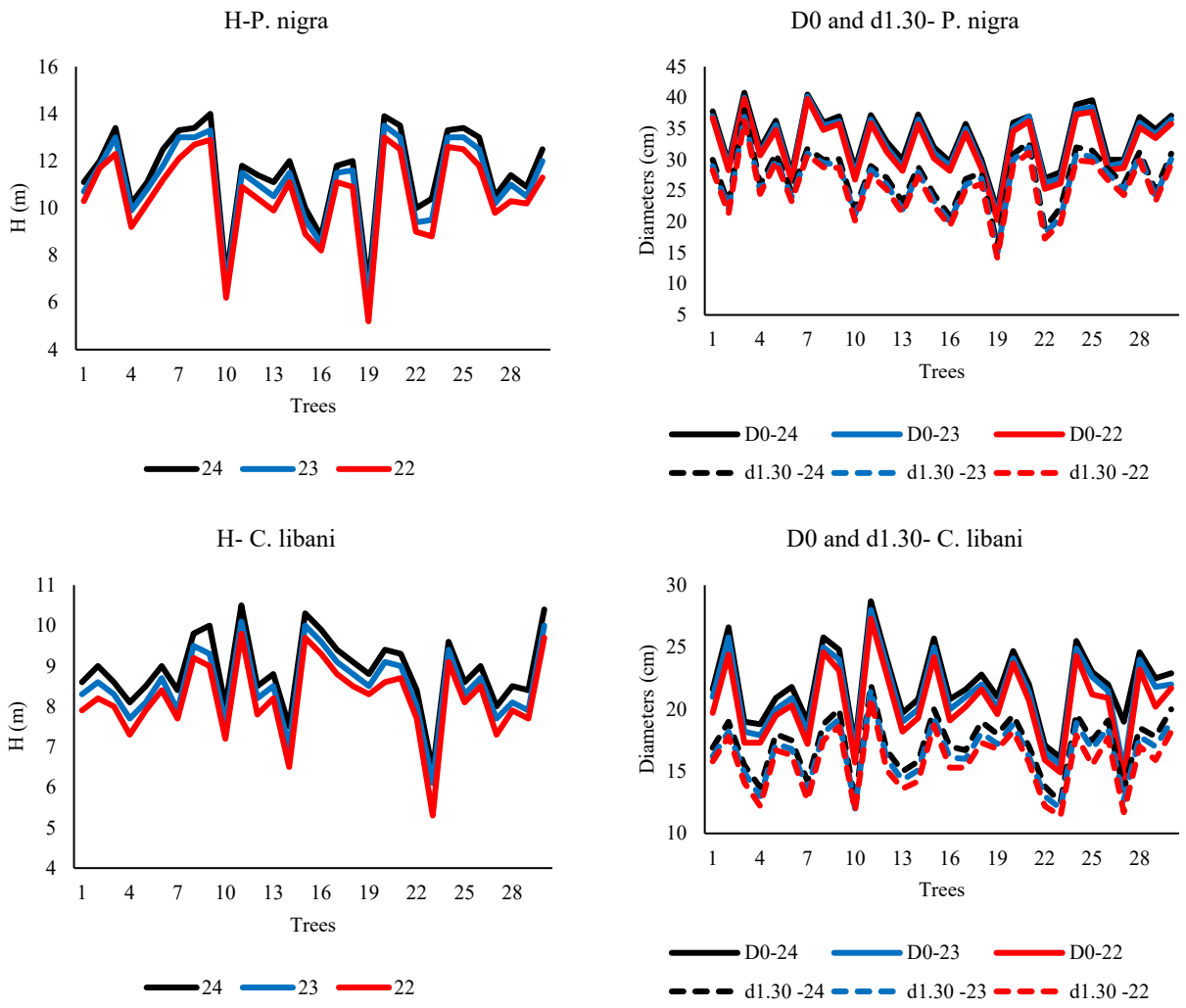


Figure 4. Individual growth characteristics for the species and years

These results are consistent with Wiersman's equation (1963), which links temperature to the estimation of vegetation periods. Partanen et al. (1998) reported Temperature has been demonstrated to significantly influence bud burst in Norway spruce (*Picea abies* L.). Çetin et al. (2018) highlighted that climatic factors could play a significant role in forecasting other plant characteristics, including future growth performance.

Conclusions

The findings of this study can serve as a guide for selecting and estimating growth performance of these species in plantation areas. While the study was conducted in a limited area and over a short period, the species have extensive natural and artificial distributions and long rotation ages. Therefore, further studies across various regions and age groups of the species are necessary to provide more accurate conclusions.

Declarations

Ethical Statement

The author confirms that this study did not require ethics committee approval or any special permissions. The research was conducted without causing any harm to the environment.

Acknowledgment

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Conflict of Interest

The author declares no conflict of interest or competing interests related to this study.

Authors' Contributions

Conceptualization, Methodology, Data Analysis, Writing, Initial Draft Preparation. The author has reviewed and approved the final manuscript.

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