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Behavior of the growth in width of the wood (initial and final) of *Prunus avium* in the north west of Tunisia vis-à-vis the climate.

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Abstract
The influence of climatic factors (rainfall and temperature) on the growth in width of the initial wood and of the final wood of cherry (*Prunus avium*) makes it possible to reconstruct the past in order to understand the present, to characterize the climatic processes that govern the ecology and productivity of this species and to predict their future evolution responding to climate change in Tunisia. The dendroclimatological data used in this work come from four populations of wild cherry trees located in the north- west of Tunisia, in a humid bioclimate. The parameters measured in this study are (temperature and precipitation): the width of the initial timber and the final timber. The statistical analysis reveals that the formation of the initial wood is positively influenced by specifics months in each season of the year, such as autumn (November-October), winter (January-February), spring (March-May), and by maximum temperatures (January-February) precipitation. The ion format of latewood is positively correlated with precipitation in August and September. The analysis of the annual variations in the formation of the initial and final wood quite closely reflects the climatic variations and reveals the sensitivity of this species to the climate.

1. Introduction
Dendroclimatology is the branch of dendrochronology that utilizes absolutely dated and annually resolved growth layers in woody plants, such as trees, for the reconstruction and analysis of past climate variability [1,2,3,4,5]. Dendrochronological studies deals with the relationships between growth in ring width and monthly climate (temperature and precipitation). Thus, it is possible to identify the current vulnerability of species to climatic variations. Most often, these studies focus on species subjected to extreme climatic conditions where the relationships between climate and ring width are strong [6]. The width and density of annual growth rings may be considered as indicators of the productivity of forest ecosystems [7]. In fact, in the Mediterranean region, trees are generally more sensitive to the effect of the water balance than the heat balance [8]. In Tunisia, the *Prunus avium* has a high economic value as well as rare wood qualities. Its growth is relatively fast, which allows expecting a harvest in about 40-50 years. It is very sensitive to drought periods yet an average annual of temperature below 9°C limits its growth. *Prunus avium* is capable of adapting to varied climatic conditions, but remains demanding to ensure quality wood production [5]. Research on dendroclimatology in Tunisia is rare. In 1982, Aloui [9] was worked on dendroclimatology of zeen oak (*Quercus canariensis*) and Maritime pine (*Pinus pinaster*) in Kroumirie.

Akrimi in 1984 [10] carried out a study, which explained the relationship between production of Aleppo *pine* (*Pinus Halepensis*) and soils in the pine *grove* of Sakiet Sidi Youssef.
EL Khorchani [11] pointed out the impact of climate change on the productivity of Aleppo pine (*Pinus halepensis*) forests in Tunisia. Another dendroclimatological study of four populations of pinion pine (*Pinus pinea*) in Tunisia was demonstrated by Thabeet et al [4]. Further, Jdaidi et al [5] elucidated the influence of climatic variables on the width of blackberry rings (*Prunus avium*) in Kroumirie. Given this context, the aim of this study is to determine the relationship between the varied climate and the reliable growth in width of latewood and earlywood of cherry in Kroumirie.

2. Materials and methods

2.1. Study site

The study area is located in the forests of Tabarka and Ain Draham (Table 1) occupying mountainous areas. Indeed, by its mountainous relief in contact with the Mediterranean, it offers a development of the altitudinal stages at least as interesting, from the beaches and maritime rocks to the oak grove of Medio-European character of Djbel Gorra (1200m). The general altitude of the massif decreases from west to east.
The climate, belonging to the humid Mediterranean stage, ranges from the warm winter variant (lower sub-level) in the Tabarka region to the temperate winter variant (upper sub-level) in the Ain Draham region. According to data from the two meteorological stations of Tabarka and Ain Draham, the average annual precipitation varies from 980 to 1512 mm, while the mean annual temperature varies little from 11 to 13°C between the two sites (Figure 1-2).
The soil of the study area is formed from permeable bedrock (Numidian sandstone) and devoid of limestone. Sheltered by the forests of *Quercus Suber* and *Quercus faginea* in the lower mountain level, the soil presents itself with the characteristics of leached mull soils.
This forest is consisted of pure stands of cork oak and zeen oak on more than half in her surface. The rest of the parts are formed of a mixture of cork oak and zeen oak. The shrub layer is formed mainly by *Phillyera media* , *Rahmiinus alaternus* , *Smilax aspera* , *Pistacea lentiscus* , *Olea aleaster* , *Myrtus communis* , *Erica arborea* , *Calycotome villosa* , *Arbutus unedo* , *Viburnum tinus* , *Lavandula stoechas* , and *Cytissus triflorus* .

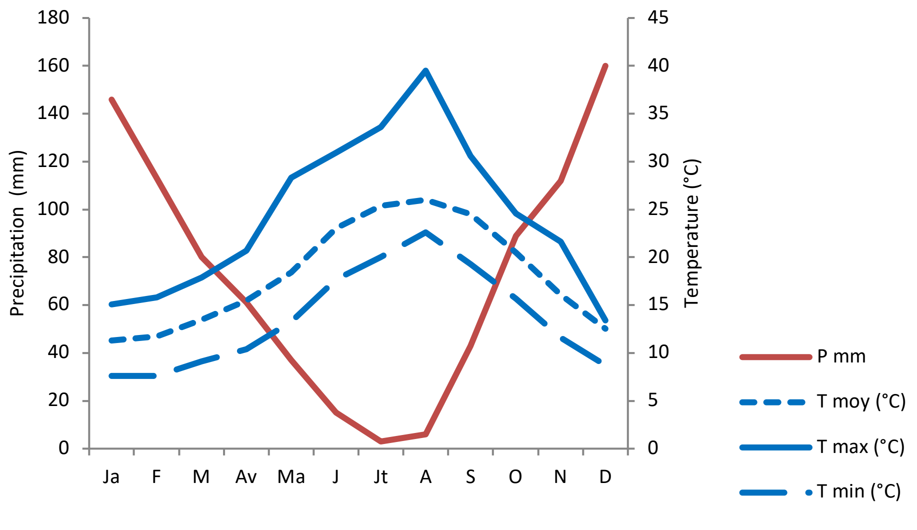

Figure 1. Ombrothermal diagram made from the average of temperature (°C), maximum temperature (T max), minimum temperature (T min), and precipitation (mm) of the stations of Tabarka (1930-2015)

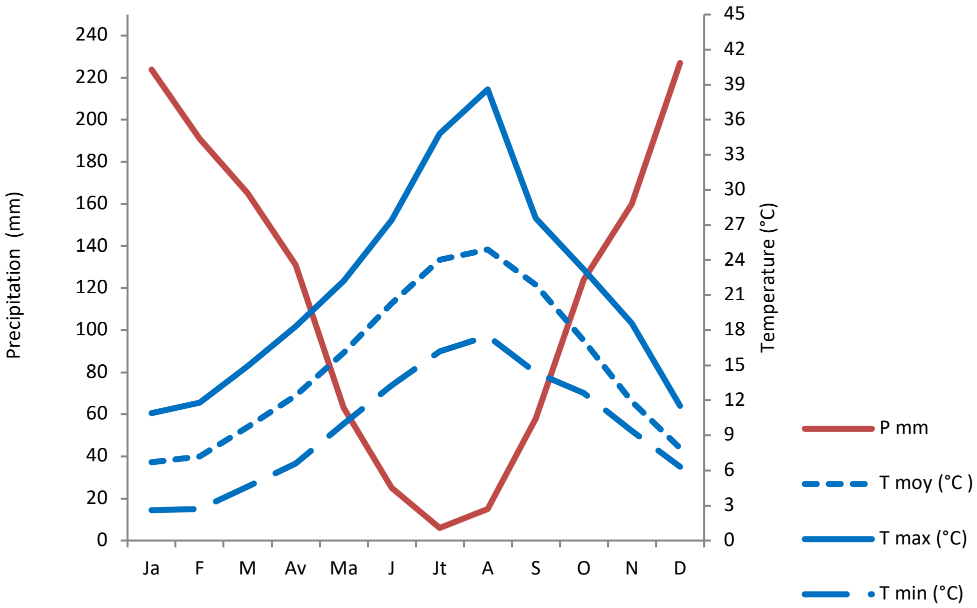

Figure 2. Ombrothermal diagram based on the average temperature (°C), maximum temperature (T max), minimum temperature (T min), and precipitation (mm) of the Ain Draham stations (1930-2015).

The experimental material comes from our four cherry stations (Kroufa, Malloula, Tbeinia and Souiniet). Our choice was directed towards dominant trees, not forked, with well balanced crown, surrounded by competitors of the same species, within a homogeneous group of wild cherry trees forming a massive effect and having a circumference of between 40 and 120 cm at 1.3 m from the ground. No information is available regarding human activities or fires (Table 1).

Table 1. The main characteristics studied of four populations of cherry

Study site		Bioclimatic floor	Exposure	Altitude (m)	Number of trees	Number of test specimens	Latitude and longitude
Tabarka	Kroufa	Lower wet	BORN	39 0	7	1 4	N36 ° 55'56 " E008 ° 56'47 "
	Malloula	Lower wet	N W	210	7	1 4	N36 ° 56'13 " E008 ° 46'33 "
Ain Draham	Tbeinia	Upper wet	N W	620	7	1 4	N36'46'13 " E008 ° 46'36 "
	Souiniet	Upper wet	N W	510	7	1 4	N36 ° 47'15 " E008 ° 48'15 "

2.2. Sampling

The material is taken directly from the standing tree using a Pressler auger (Figure 3). The most common measure is 40 cm for an internal diameter of 5 mm. Thus, we obtain a core of wood with 5 mm in diameter in which fine sections will be taken with a microtome. The carrots were taken in the radial direction of the trunk, from the bark to the pith. Due to the low representativeness of the cherry tree in the north- west of Tunisia, it was not possible to collect more than seven trees per station and for each tree, two cores were taken. The carrots were hovered on the ground, and immediately packed in wooden boxes. The name of the station, the number, and the diameter of the tree was marked in the boxes. After that, the carrots are stored at 4°C in the laboratory of the Sylvo-Pastoral Institute in Tabarka.

Figure 3. Manual coring using a presser auger, Photo: Jdaidi Nouri (15/12/2013 in Tbeinia)

2.3. Climate parameters

The climatic parameters commonly used to characterize the relation between thickness of wood (initial and final) and climate (P_{mm}, T_{max}, T_{min}, T_{avg}).

2.4. Measuring the thickness of the initial and final wood

Each core was planed, and then the widths of the wood were measured at the laboratory of Huelva University in Spain, by using a LINTAB 5 table connected to a Leica stereo microscope associated with TSAP-W software in Professional (Figure 4). Therefore, the accuracy was 0.001 mm. The series of ring widths then had to be corrected, in order to identify missing rings, false rings or simple measurement errors. For this reason, the principle used in this case was that of interdatation. A correction has been made whenever an offset is observed. Additionally, the measurement was carried out from the pith towards the bark, according to the direction of the growth of the tree [5].

Figure 4. Lintab5 measurement table and associated software TSAP WIN.
Photo: Jdaidi Nouri (02/20/2013 in Huelva Spain).

3. Statistical analyses

In order to study the influence of climatic variations on the initial and final wood of cherry, we applied the procedure of BOOTSTRAP. The functions responses were calculated with the Calrob (Bootstrap Regression/Calibration) program from PPPHALOS [12]. For The calculation process, we apply an orthogonalized regression between the dependent variable (series of ring thicknesses) and the explanatory variables or climatic regressions (precipitation, maximum temperatures,

minimum temperatures, and average temperatures). The overall significance of the response function is expressed by the ratio of the average correlation coefficient between the reconstructed climate variable and the real variable to its standard deviation, over the calibration period and the verification period. Moreover, in order to compare the response functions in their profile, the same quotients are coded from 0 to 3 values, which correspond to four levels of response to the involved climatic factors.
0: 0 ≤ coefficient / standard deviation ≤ 0.5 (significance level 90%),
1: 1.6 ≤ coefficient / standard deviation ≤ 1.9 (significance level 95%),
2: 2 ≤ coefficient / standard deviation ≤ 2.9 (significance level 99%),
3: coefficient / standard deviation> 3 (significance level > 99%).
In addition to the bootstrap procedure applied to the orthogonalized regression in the calculation of the response function, the processing of the field data was carried out using the XLSTAT 2020 software, while the confidence interval is 95%.

4. Results

4.1. Evolution of the growth in width of the wood (initial and final) according to the stations

The general appearance of the average chronologies by station (Figure 5-6) reveals that the average widths of the final wood and the initial wood in black cherry are maximum and can reach an average of 5 mm for the stations of Tbeinia and Souiniet. The Tabarka stations (Kroufa and Malloula) have an average final wood width of 3.5 mm (Figure 7-8). On the other hand, the average width of the initial wood varies from 0.7 to 1.3 mm for the two populations of Ain Draham (Tbeinia and Souiniet) and from 0.5 to 1.1 mm for the two populations of Tabarka (Kroufa and Malloula).

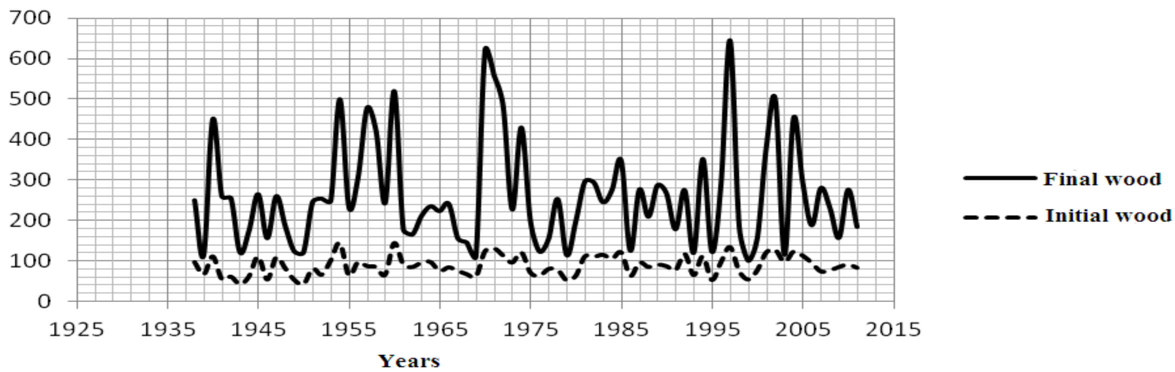

Figure 5. Evolution of the average width of initial wood and final wood (1/100 mm) of the Tbeinia population.

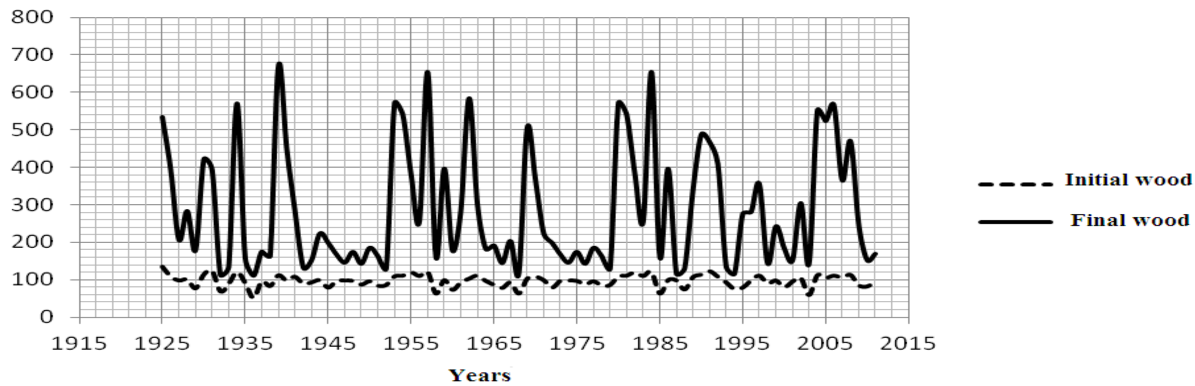

Figure 6. Evolution of the average width of the initial wood and the final wood (1/100 mm) of the Souiniet population.

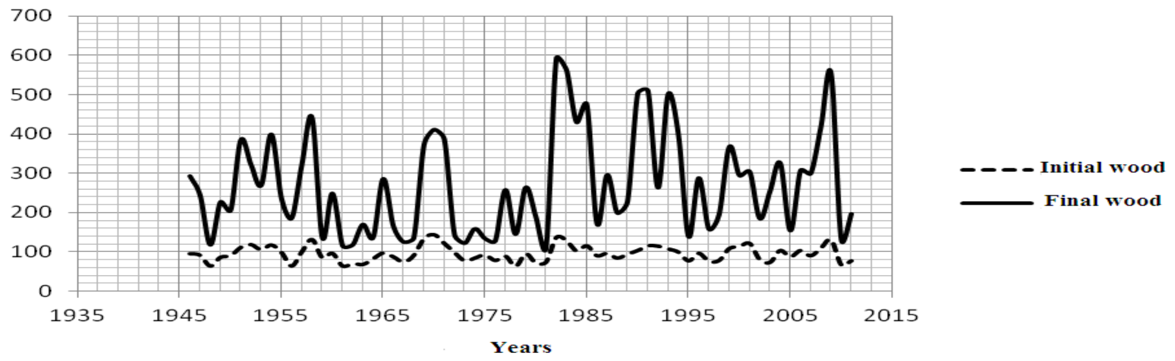

Figure 7. Changes in the average width of the initial wood and final wood (1/100 mm) of the population of Kroufa.

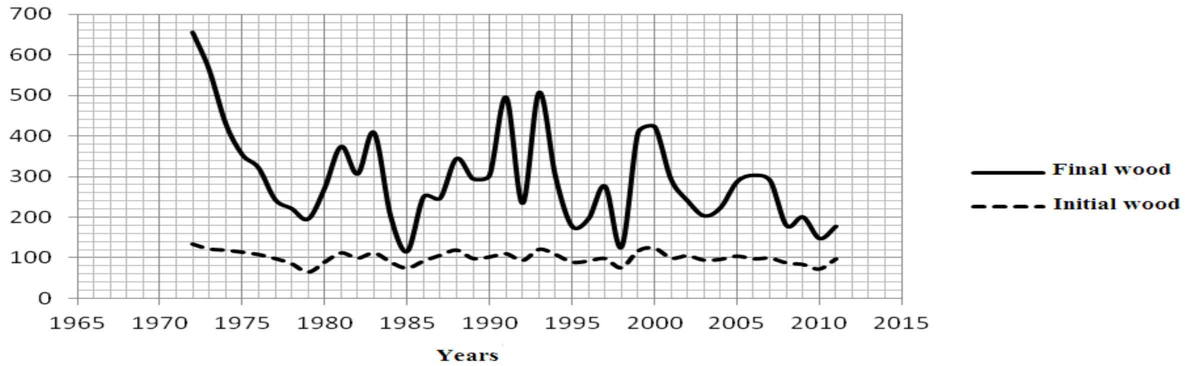

Figure 8. Evolution of the average width of the initial wood and the final wood (1/100 mm) of the population of Malloula.

4.2. Influence of climate on growth width of the initial and final wood of cherry

We calculated response functions of the average width of in each population to monthly climate variables (12 temperatures and 12 precipitation) of all the bioclimatic year, either e September of the previous year (n-1) to August of the current year (n). The response functions will be mainly evaluated by tow parameters. The First one is the degree of significance of each of the regression coefficients, which will inform us on the respective influence of temperature and precipitation on the interannual variations of the average width of the wood (intensity and direction of the relation). The second, the coefficient of determination (R^2), which informs us about the percentage of variance in the average width of the wood explained by the temperatures and the precipitations.

4.2.1. Relationship between precipitation and mean width of initial and final timber

The variations in the climate which explained the differences between the densitometry criteria from one year to another, indeed, very close correlations could be demonstrated between climatic characteristics and components of the average width of the wood of the same year (Table 2).

The precipitation (n-1) of October and the spring precipitation of year n are positively correlated with the initial wood thickness for tree 5 (Tbeina) and tree 3 (Kroufa), with

R^2 = 0.77 and 0.59. The spring rains act before the onset of the drought period (Figure 9). The positive influence of the precipitation of the autumn preceding the annual growth can be explained by the very important role of the fall waterfalls in replenishing the water reserve in the soil. Figure 9 shows graphs of the variations of the cumulative rainfall for the months August and September (n) and those of the width of the final wood of the cherry tree for the same years. The correlation coefficient was positive (tree 1 of Tbeinia) with $R^2 = 0.72$ and therefore we can predict that summer rainfall will result in the average clean width of the final timber.

Table 2. Significant response functions for precipitation of the mean width of the initial and final timber (with their coded values)

	Wtot		*AS*	*WE*	*JFM*	*My*	*SG*
Kroufa (BI)	1940-2011	a3				1	*
Tbeinia (BI)	1933-2011	a 5		3	1		**
Tbeinia (BF)	1936-2011	a1	2				**

Confidence code : 1 = 90 to 95% = * ; 2 = 95 to 99% = ** ; 3 => 99% = *** ; SG = Global significance ; BI = Average width of initial timber, BF = Average width of final timber ; a1 = tree 1 ; a3 = tree 3 ; a5 = tree5 ; AS : August , September ; ON : October, November ; J FM: January, February, March; Ma: May.

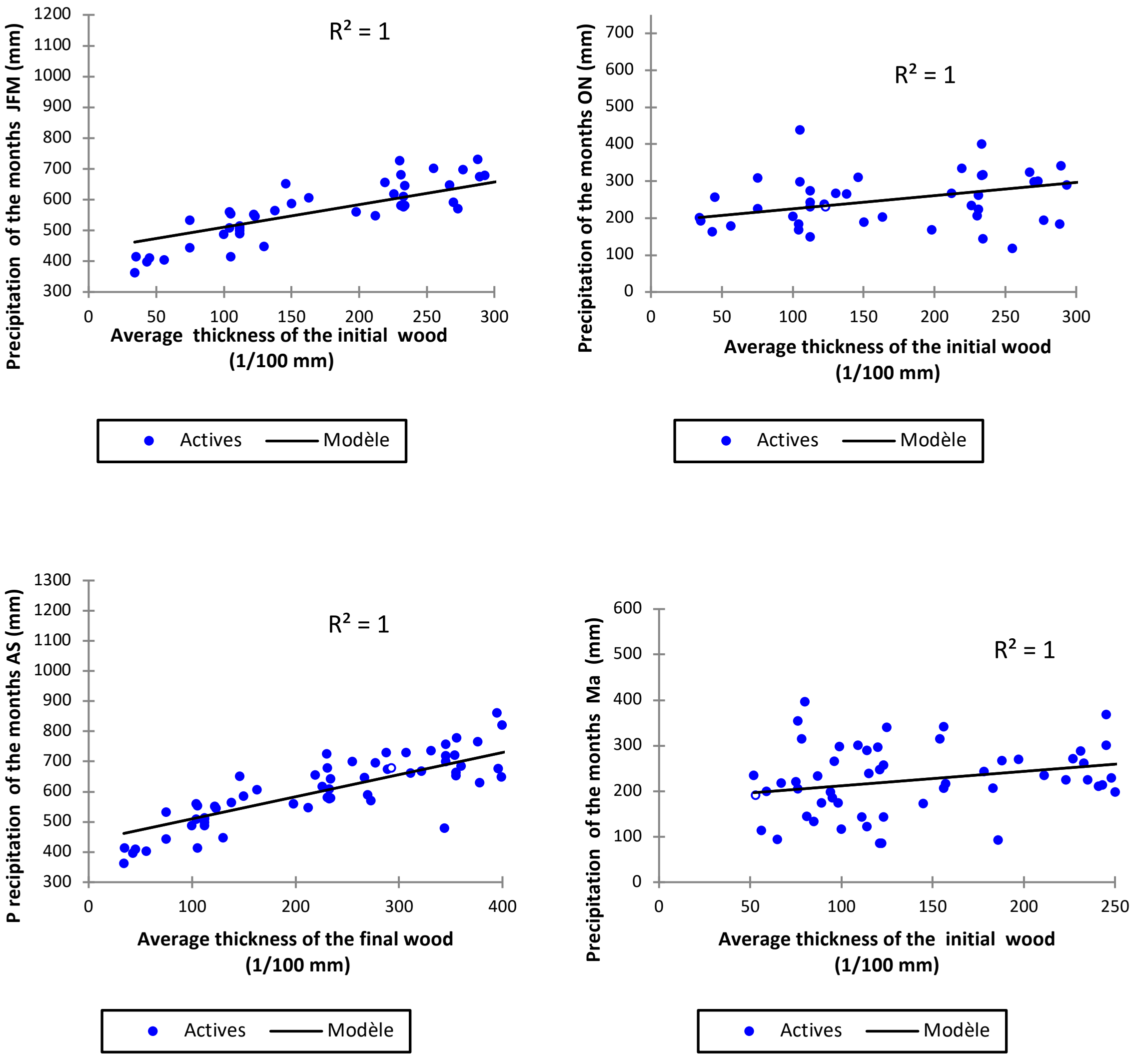

Figure 9. Linear correlation between the average width of the initial and final wood of the cherry tree and the monthly precipitations: A: tree 5 of Tbeinia during the months of October and November (ON); B: Tbeinia tree 5 during the months January, February and March (JFM); C: tree 1 of Tbeinia during the months of August and September (AS); D: Kroufa tree 3 during the month of May (Ma).

The effectiveness of rainfall for this population seems to be linked to the duration of the summer drought period; it begins in September in Ain Draham (three dry months). For Tabarka (five dry months), the precipitation at the end of summer would not have an influence on the formation of final wood.

The results obtained showed that the formation of the initial wood of the blackberry tree was determined by the spring and summer precipitations (April, May, and June) of the growing year and the autumn precipitations (October) of the previous year. The more abundant these rains, the more the radial growth of the tree are important. Moreover, latewood thickness is strongly correlated with precipitation in August and September, regardless of the populations studied.

4.2.2. Temperature and average width relationship of initial and final wood

The results are illustrated in the table where each population and each parameter are represented by a response function for each type of combination.

The maximum temperatures of April and June in Souiniet (Aïn Draham) are negatively correlated with the width of the fine wood al for tree a3 (Figure 10). However, the positive influence of the maximum temperature of s month in December and January of the year n on the formation of early wood is significant for the tree has 1 for the station of Malloula with $R^2 = 0.55$. An increase in temperatures at the beginning of winter allows the breaking of dormancy by simulating the secretion of hormones at the origin of the cambial reaction.

Table 3. Significant response functions for the maximum temperature for the mean width of the initial and final timber (with their coded values)

	Wtot		*D J*	*M*	*A Ma J*	*S.G*
Souiniet (BF)	1945-2011	a3			-2	**
Malloula (BF)	194 8-2011	a1	1			**

Confidence code : 1 = 90 to 95% = * ; 2 = 95 to 99% = ** ; 3 => 99% = *** ; SG = Global significance ; BI = mean width of the initial timber, BF = L mean width of the final timber; a1 = tree 1 ; a3 = tree 3 ; J : January; M: March ; D : December ; A Ma J: April, May, June.

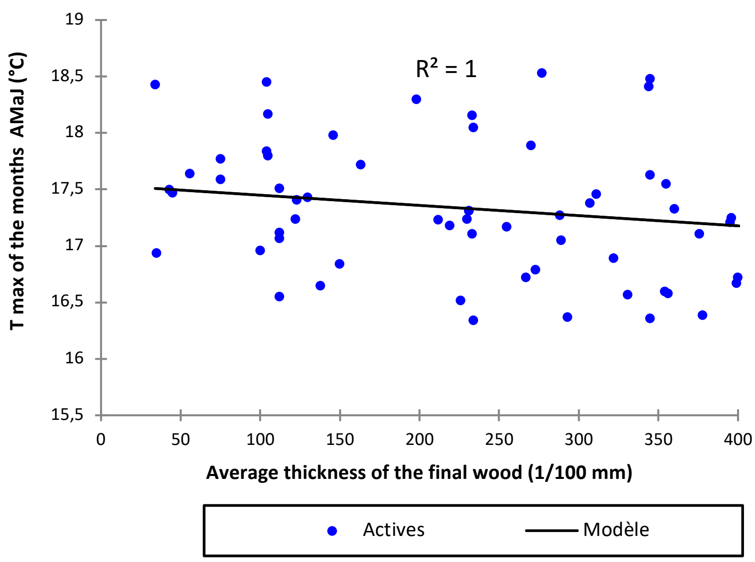

Figure 10. Linear correlation between the average width of the initial and final wood of the cherry tree and the maximum temperatures: tree 3 of Souiniet during the months of April, May and June (A Ma J).

5. Discussion

The results obtained in this study highlight the influence of climatic factors (average monthly, minimum and maximum temperatures, and monthly rainfall) on the width of the initial and final wood of *Prunus avium* in the north-west of Tunisia.

By analyzing the response functions between the climate and the average thickness of the initial and final wood of the Cherry tree, we can conclude that the precipitations of October (n-1) and those of the spring of the year n are positively correlated with the thickness of the initial wood. Also the average width of the initial wood is positively correlated with the temperatures of May; probably it can be explained by the photosynthetic metabolism's activation.

The correlation coefficient is positive of the cumulative rainfall for the months of August and September (n) and the initial and final wood, so it may be possible to predict that summer rains will carry them along with the thickness of the final wood. These results confirmed with the results found by Thabeet et al [4] on the Aleppo Peninsula in Tunisia, it showed a significant positive influence of rainfall in August and / or September of year n on latewood formation for Tabarka and Aïn Draham. Hence, the effectiveness of rainfall for these two populations seems to be linked with the duration of the summer drought period: it begins a month earlier, in August, in Tabarka (four dry months) compared to Aïn Draham (two and a half months secs), where it begins in September.

According to EL Khorchani [11], the direct effect of precipitation on the formation of the initial wood of Aleppo pine is limited to the months of October (t-1), April and, May. At the final wood level, the response of the stands is heterogeneous. In Tabarka, latewood is linked to rainfall from June to September meanwhile, in Aïn Draham latewood is linked to rainfall in April, May, and September. Thabeet et al [4] reported that the precipitations of October (n-1) and those of the spring of the year n are positively correlated with the thickness of the initial wood for Tabarka and Ain Draham. These spring rains act before the onset of the drought. The positive influence of the fall precipitation preceding the annual growth can be explained by the very important role of the fall waterfalls for the reconstitution of the water stock in the soil. According to Serre-Bachet [13], the contribution of spring precipitation to soil water reserves is decisive in the formation of wood during the phase of full vegetative activity.

The distribution of rainfall over the year is the most essential element of the precipitation growth relationship. The most stable and strongest relationship was found between growth and total monthly precipitation in the previous November and January. Spring drought is considered a primary growth-limiting factor in the high-altitude Mediterranean areas (Leburgeois et al [16]). In radiata pine inAustralia, and conifers more generally, rainfall is positively correlated with growth (Battaglia et al [17]), but fast growth often negatively correlates with wood density (Ivković et al [18]). According to Zywiec et al [19], for total monthly precipitation, during the whole analyzed period, there was a strong positive relationship between tree growth and precipitation in the previous November and current January. The relationship between precipitation in the spring and tree growth fluctuated and was rather weak in the studied period. The positive relationship between growth and total precipitation in the vegetative period was strongest for June, but it decreased in the late twentieth and early twenty-first centuries.

On the other hand, the maximum temperatures of the months of April and June are negatively correlated with the average width of latewood. According to Oberhuber et al [14] and [11], the well observed inverse relationships between during the month of April and May seem to be linked to a significant rise in temperatures, which further limits water resources.

A lack of water in spring can cause a reduction in the leaf area and consequently a decrease in the quantity of photosynthetic products essential for growth.
According Creber and Chaloner [15], does augmentation of the temperatures at the end of winter allows dormancy by simulating the secretion of hormones to the origin of the cambial reaction. Thabeet et al [4] reported that the temperatures of May in Aïn Draham are negatively correlated with the thickness of the initial wood of the Aleppo pine. According to El Khorchani [11], the maximum temperatures of spring (March-April-May) have a preponderant role in the densification of the initial wood; that is to say, high temperatures coincide with high densities. Recently, Zywiec et al [19] showed that the positive relationship between tree growth and mean temperature in autumn and winter (from previous October to December) strengthened in the second half of the studied period, coinciding with an increasing mean temperature trend; we found the same trend for February. There was no time trend in the relationship between tree growth and mean spring temperature, despite the increase of temperature in the last few decades.
Two deciduous species namely *Quercus ithaburensis* and *Quercus boissieri* from the southeastern Mediterranean showed abundant precipitation and low temperature from November to April benefit the xylem formation [20]. The dry years strongly limit vessels size and number in *Q. ithaburensis* compared to *Q. boissieri,* making one highly resilient and the other highly resistant. *Betula nana* L. vessel lumen area from western Greenland showed influence by spring and summer temperature, whereas vessel grouping was driven by winter temperature [21]. Similarly, Hollesen et al [22] documented that *Betula nana* growth is positively influenced by winter temperature as important as summer.
Populus tremuloides, a deciduous Canadian species vessel diameter showed strong relationships primarily with mean annual precipitation and less association with temperature. Also, vessels diameters were highly plastic in response to different environments and varied with summer moisture availability [23]. The temperate *Quercus robur* earlywood vessels were exclusively affected by temperature whereas they were more independent in the sub-Mediterranean *Quercus pyrenaica* [24]. A similar study was conducted in *Q. robur* from northern Poland and found vessel area to have a significant positive correlation to minimum winter temperatures to reduce damage to the root systems [25]. *Tectona grandis* earlywood vessels from Brazil showed a significant correlation with summer season temperature and precipitation for efficient water transport. They found spring conditions to have a direct influence on the formation of earlywood vessels suggesting warmer temperature to favor efficient water transporting system [26].

Conclusion

This dendroclimatological study of *Prunus avuim* play a major role to highlight the relationship between the formation of initial wood, final wood and the climate in the north west of Tunisia. The formation of the initial cherry wood reacts positively to fall (October-November) precipitation of the previous year, winter (January-February), and spring (March-May) precipitation of the growing year. Latewood width is strongly correlated with rainfall in late summer (August) and early fall (September). Also the fall of the rains during this period favors the reconstitution of the water stock in the soil. On the other hand, the formation of the initial wood is positively influenced by the maximum temperatures of the winter period (January-February).
The annual variation in the formation of the initial and final wood reflects quite closely the climatic variations and reveals the sensitivity of this species to the climate.

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Compliance with Ethical Standards:

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