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Anatomical Characteristics of the Xylem of *Populus euphratica* at Different Groundwater Burial Depths in the Lower Tarim River (China) and Its Response to Temperature Extremes

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Abstract: The anatomical characteristics of xylem and their relationship with temperature during the year can be studied at the cellular scale by using micro-coring technology and the wood anatomy method. In this study, we used *Populus euphratica* Oliv. trees with different groundwater burial depths in the lower Tarim River as the research subjects. Micro-core samples of *Populus euphratica* were collected near two sampling sites, TY1 and TY2, which have different groundwater burial depths. We analyzed the differences in xylem anatomical characteristics and their relationship with extreme temperatures under these varying groundwater conditions using wood anatomy methods. The results showed that the anatomical parameters at TY1, with a higher groundwater table, were greater than those at TY2, which had a lower groundwater table. Specifically, the conduit density, total conduit area, average conduit area and maximum conduit area of *Populus euphratica* xylem were significantly and positively correlated with both maximum and minimum temperatures. The principal components of xylem parameters at TY1, with the higher water table, were significantly and positively correlated with both maximum and minimum air temperatures. In contrast, the principal components of xylem parameters at TY2, with the lower water table, were not significantly correlated with either maximum or minimum air temperatures. The sensitivity analysis indicated that the sensitive maximum air temperature for the principal component parameter index change of *Populus euphratica* xylem was 34.1 °C, and the sensitive minimum air temperature was 16.1 °C. Therefore, different moisture conditions affected the sensitivity of xylem parameter growth to temperature, with the temperature threshold for *Populus euphratica* xylem growth being between 16.1 °C and 34.1 °C.

Keywords: *Populus euphratica*; micro-coring technique; xylem anatomy; wood; groundwater depth; extreme temperature response

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1. Introduction

As a crucial component of the ecosystem, forests play a major role in the global carbon cycle [1,2]. In recent years, the intensification of global warming has led to changes in ambient temperature [3], causing alterations in the physiological structure and function of trees, which directly affect their role in the carbon cycle [4]. Therefore, understanding the effects of temperature changes on the physiological structure of trees is crucial for assessing their role in carbon sequestration and protecting forest ecosystems. In recent years, the tree ring anatomical technique, which monitors the activities of the cambial layer and the radial growth changes of the xylem, has become an increasingly important research tool for scientists [5]. Among the methods of ecological monitoring of tree whorls, the micro-coring technique is a bio-micrographic method that reproduces the processes of dormancy of the tree's cambial layer, the radial growth of cambial cells, cell wall thickening and xylem production through the creation of paraffin sections. This technique accurately reflects the dynamic changes in the parameters of the tree's xylem vessels throughout the year and their responses to the temperature factors [6,7]. Changes in temperature affect the formation and development of the vessels [8]. Therefore, using the micro-coring and wood anatomy method to obtain the characteristics of xylem conduit parameters—such as number, area and density—over the annual sequence of trees, and analyzing the relationship between these xylem parameters and temperature, can better reflect the growth changes of xylem and its relationship with temperature.

A significant number of studies have been conducted on the dynamics of xylem growth in tree rings and its relationship with the environment. Moisture conditions have been found to be a crucial factor affecting xylem growth, influencing the process of xylem formation by affecting the diameter and size of xylem cells and the rate of cell division [9,10]. Inadequate moisture conditions hinder the growth of new branches in trees and indirectly affect the rate of xylem cell division [11]. Gruber [12] found in their study of European red pine (*Pinus densiflora*) that environments with poor moisture conditions lead to a shortening of the period of xylem activity. It has been observed that not only do moisture conditions affect xylem growth, but temperature is also an important factor influencing the activity of the cambial layer at the beginning of the growing season. Temperature affects the timing of cambial activation, the cycle of activity and the rate of cell division [13]. Gricar [14], in their study of Norway fir (*Abies alba*), found that low temperatures lead to a shortening of the activity cycle of the cambial layer. Reza [15], studying spatial temperature variations, concluded that low-elevation beech (Fagus) started and ended cambial activity earlier than high-elevation beech. Alexander [16] found that temperature changes may affect the melting of snow and ice at high latitudes, as well as the thawing time of the soil, thereby impacting cambial activity. In recent years, more studies have focused on the relationship between xylem and temperature in *Populus euphratica* Oliv. which significantly affects its growth [17]. Additionally, there is a lag in *Populus euphratica*'s response to temperature changes [18]. However, most previous studies on the radial growth of *Populus euphratica* have been based on the width of the tree rings. Very few studies have examined the differences in the xylem conduit characteristics of *Populus euphratica* under different moisture environments and their relationship with temperature at a more precise, microscopic scale.

Populus euphratica is an important community-forming species in desert riparian forests along the lower Tarim River [19], playing a crucial role in stabilizing these ecosystems. This study aims to investigate the anatomical characteristics of *Populus euphratica* xylem and its relationship with temperature extremes under different groundwater burial depths in the lower Tarim River using wood anatomy methods. The goal is to reveal the physiological mechanisms of *Populus euphratica* growth and adaptation to the environment and to provide a scientific basis for the conservation, management and restoration of *Populus euphratica* forests in the lower Tarim River.

2. Materials and Methods

2.1. Study Area

The Tarim River, located in northwestern China, stretches for a total length of 2137 km, making it the longest inland river in China [20]. The sampling site for this study is situated in the Yingsu section of the lower Tarim River. The study area experiences an arid climate with high evaporation rates, and the average annual precipitation ranges from 17–42 mm, characteristic of a typical warm temperate desert arid zone [21]. The main tree and shrub species include *Populus euphratica* and multi-branched tamarisk (*Tamarix ramosissima Ledeb*), while herbaceous plants include reed (*Phragmites australias Trin*) and camel thorn (*Alhagi spaysifolia Shap*) [22]. To highlight the effect of different groundwater levels on xylem conductance parameters, the sampling sites for this study were chosen from TY1, located close to the river, and TY2, located further away from the river. The exact locations of the sampling points are shown in Figure 1.

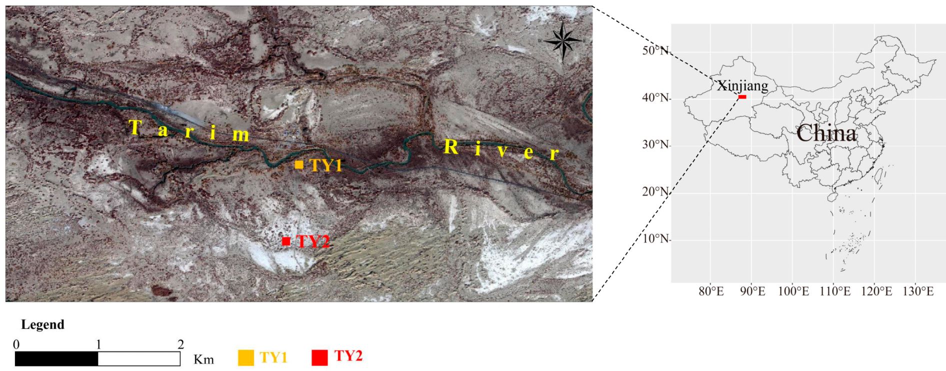

Figure 1. Map of sampling point locations.

2.2. Experimental Designs

In this study, five *Populus euphratica* trees of similar diameter at breast height (DBH) and age were selected near two sampling sites, TY1 and TY2, which had different groundwater burial depths, during the 2020 poplar growing season (April–October). Micro-core samples were collected using a microgrowth cone (Trephor) at a distance of 1.3 m from the ground at the DBH of *Populus euphratica* trees. Sampling was performed once a week, with 2–3 samples collected each time and a 3 cm distance between consecutive samples. In total, 250 samples were collected. To ensure consistency, the sampling location and direction remained the same before and after the second sampling. Additionally, a "Z" type sampling method was employed, moving from top to bottom, to minimize bias caused by differences in growth rates due to varying collection directions. Following collection, samples were immediately placed in FAA solution for preservation.

2.3. Sample Processing

After removing the samples from the FAA solution, they were scored in the vertical direction of the vascular tubes before being placed in the embedding box and dehydrated in low-concentration ethanol solutions (30% ethanol, 50% ethanol, 70% ethanol, 85% ethanol) for 90 min and high-concentration ethanol solutions (95% ethanol, 100% ethanol I, 100% ethanol II) for 60 min, respectively. This process replaces plant tissues with water, and the samples were then embedded after steps such as limonene transparency and wax dipping. A rotary slicer (LEICA RM2255, Wetzlar, Germany) was utilized to cut the samples into 8 µm slices, and the paraffin slices were fixed on slides after the process of spreading and fishing. The sections were then dried, dehydrated, stained and washed, following specific steps for sample processing as outlined in the exploration of the method of paraffin sectioning of microtubercoles [5]. After staining, the sections were sealed with neutral gum and photographed under a 100× microscope for observation (Figure 2). As sampling was conducted using a fixed-point continuous method, all xylem anatomical parameters were measured using cumulative parameter values, meaning each measurement was cumulative from the previous annual cycle. Image-ProPlus 6.0 was utilized to measure the main indicators of xylem parameters, such as number, density, average/total area and maximum/minimum area of xylem ducts of *Populus euphratica*. The indoor processing procedure for the samples is detailed in Figure S1.

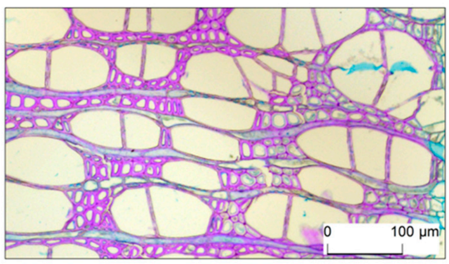

Figure 2. Anatomical structure of the xylem of *Populus euphratica* Oliv. in the lower Tarim River.

2.4. Data Processing

Groundwater bathymetry data for the study area were provided by the Tarim River Authority, while temperature data were obtained from monitoring data collected at the Tieganlik meteorological station on the lower reaches of the Ta River. All measurements were synchronized with the time of each sampling.

Excel 2010 software was used for statistics and data processing, and SPSS 21.0 software was utilized for correlation analysis between each parameter of Populus euphratica xylem anatomy and maximum and minimum air temperature. To eliminate the influence of the tree's own growth rhythm, the xylem parameter data were standardized. Firstly, the principal components of the xylem parameters were extracted through principal component analysis, and the principal component data of the xylem parameters were standardized using the ratio method to obtain a new principal component parameter sequence [18]. The xylem principal component parameter index (Ii) was calculated as the ratio of the measured value (Wi) to the predicted value (Yi) read from the growth trend curve during the year, with the formula Ii = Wi/Yi. The obtained xylem principal component parameter indices were polynomially fitted to the maximum and minimum air temperatures using Origin 2018 software. The first-order derivative of the function obtained from the fit, using the sensitivity analysis method, was utilized to determine the rate of change of the function. The point where the second-order derivative was zero and the third-order derivative was not zero was used as the inflection point of the function. This point was then used as the sensitivity point of xylem change with temperature and humidity after denudation [23].

3. Results

3.1. Intra-Annual Variation in Groundwater Depth and Temperature

The depth of groundwater and the maximum and minimum temperatures at the sampling sites during the growing season of *Populus euphratica* in 2020 are depicted in Figure 3. At sampling site TY1, the groundwater depth varied from 3.22 to 4.79 m, with an average value of 4.01 m. Meanwhile, at sampling site TY2, the groundwater depth ranged from 4.41 to 6.68 m, with an average value of 5.67 m. Overall, the depth of groundwater at sampling site TY1 was shallower than that at sampling site TY2. Moreover, the trend of changes in groundwater depth over time during the poplar season was consistent, with a shallower depth in the early part of the season compared to the late part. During the growing season of *Populus euphratica* in 2020, the fluctuations in maximum air temperature at the sampling sites ranged from 25.3 to 39.38 °C, with an average of 32.5 °C. Additionally, the variations in minimum air temperature at the sampling sites ranged from 7.88 to 21.71 °C, with an average of 15.8 °C. Overall, the changes in maximum and minimum temperatures over time exhibited a pattern of initially increasing and then decreasing.

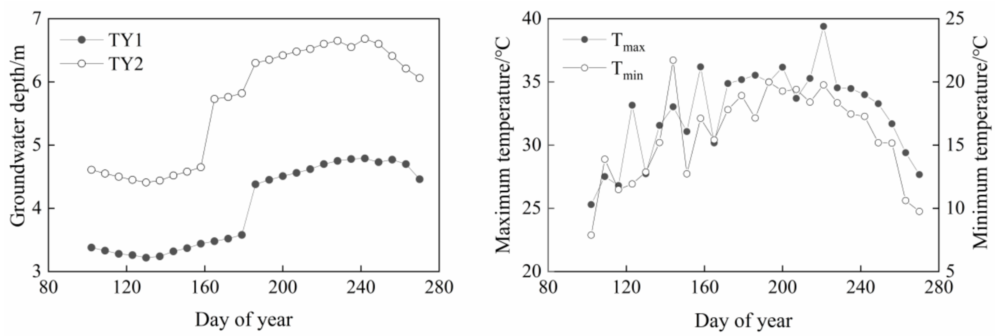

Figure 3. Changes in groundwater depth of burial and maximum temperature and maximum temperature at sampling sites during the 2020 growing season.

3.2. Intra-Annual Growth Changes in Xylem Anatomical Characteristics of Populus euphratica Oliv.

From the number of conduits (Figure 4a), there was little difference in the number of conduits between TY1 and TY2 during the growing season, and both showed a linear growth trend. Regarding conduit density (Figure 4b), TY2 was greater than TY1 at the beginning of the Populus euphratica growing season, and both exhibited a rapid growth stage. However, after DOY186, TY1 surpassed TY2. In terms of total conduit area (Figure 4c), the total area of TY1 was greater than TY2, and both showed a linear growth trend. Minimum conduit area (Figure 4d) indicated rapid growth for both TY1 and TY2, shown at the beginning of the growing season, with TY1 consistently larger than TY2 throughout the growing season. For average conduit area (Figure 4e), both TY1 and TY2 experienced a rapid growth phase at the beginning of the growing season, with TY1 surpassing TY2 after DOY144. Lastly, in terms of maximum conduit area (Figure 4f), TY1 exceeded TY2 at the beginning of the growing season. From the maximum conduit area (Figure 4f), both TY1 and TY2 exhibited a rapid growth trend at the beginning of the growing season, with the maximum conduit at both sites showing fluctuating changes after DOY106. Considering the entire growing season of Populus euphratica, all xylem conduit parameters in TY1, which had a higher water table, were larger than those in TY2, which had a lower water table, throughout the growing season (Table 1).

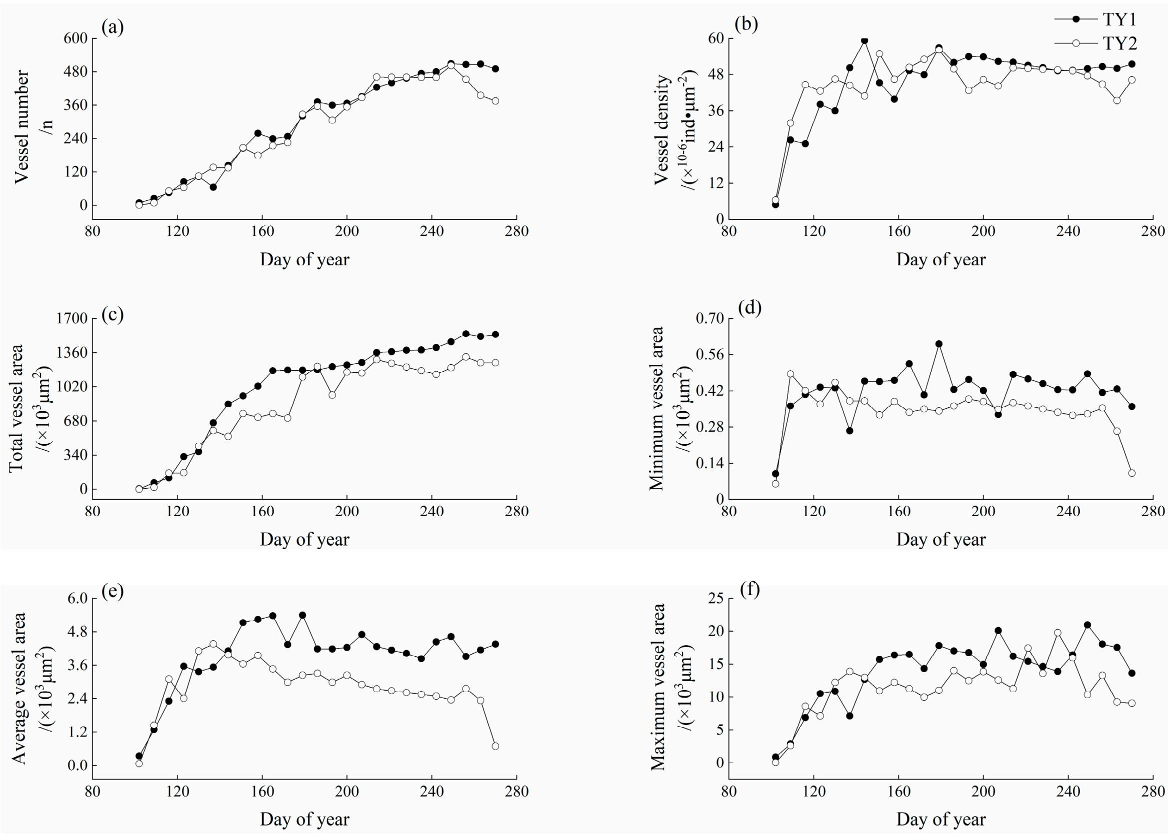

Figure 4. Annual growth changes of catheter characteristics. Vessel number (**a**); Vessel density (**b**); Total vessel area (**c**); Minimun vessel area (**d**); Average vessel area (**e**); Maximun vessel area (**f**).

Table 1. Characteristics of xylem conduits in *Populus euphratica* at different sampling sites.

Site	Tree Age	DBH	Vessel Number	Vessel Density	Total Vessel	Maximum Vessel Area	Average Vessel Area	Minimum Vessel Area
	a	cm	n	($\times 10^{-6}$ ind·μm^{-2})	($\times 10^3$ μm^2)	($\times 10^3$ μm^2)	($\times 10^3$ μm^2)	($\times 10^3$ μm^2)
TY1	40.81	24.67	300.95 ± 172.80	45.81 ± 11.98	1032.15 ± 489.55	13.95 ± 4.96	3.97 ± 1.17	0.42 ± 0.09
TY2	45.00	28.45	283.44 ± 162.59	45.11 ± 9.57	862.74 ± 435.12	11.45 ± 4.12	2.82 ± 0.99	0.34 ± 0.09

Note: Tree age and DBH (diameter at breast height) use mean; xylem conduit characterization parameters are expressed using mean ± standard deviation.

3.3. Anatomical Characteristics of Populus euphratica Xylem in Relation to Maximum and Minimum Air Temperatures

In the relationship between Populus euphratica xylem anatomical parameters and maximum air temperature, maximum air temperature exhibited a significant positive correlation with Populus euphratica xylem anatomical parameters, except for the minimum conduit area in TY2 (Figure 5). In the relationship between Populus euphratica xylem anatomical parameters and minimum air temperature, minimum air temperature demonstrated a significant positive correlation with *Populus euphratica* xylem anatomical parameters, except for the number of conduits in TY1. Therefore, Populus euphratica xylem conduit density, total conduit area, mean conduit area and maximum conduit area were found to be more sensitive to changes in maximum and minimum air temperature.

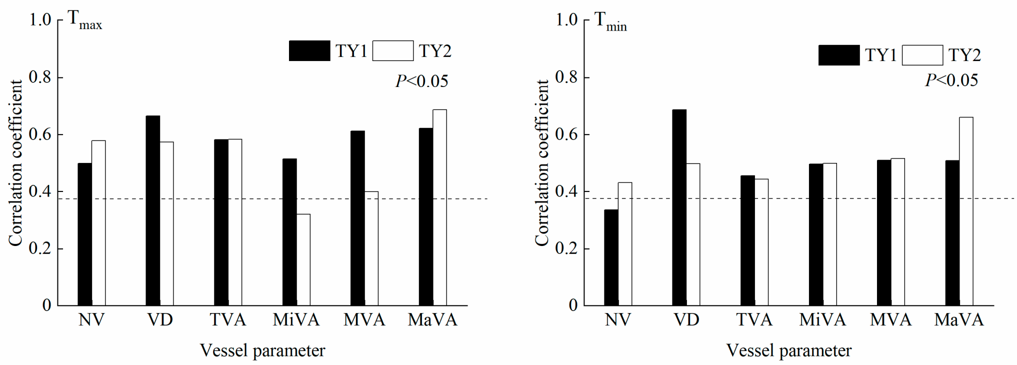

Figure 5. Correlation coefficients between xylem conduit parameters and air temperature in *Populus euphratica*. NV: vessel number; VD: vessel density; TVA: total vessel; MiVA: minimum vessel area; MVA: average vessel area; MaVA: maximum vessel area.

3.4. Relationship between the Main Components of Xylem Anatomical Parameters and Air Temperature in Populus euphratica

Principal component analysis of the xylem anatomical parameters of *Populus euphratica* under different water table conditions (Figure 6) revealed that sample site TY1, characterized by a higher water table depth and better moisture conditions, exhibited a first principal component and second principal component, explaining a total of 91.80% of the variance, with the first principal component accounting for 76.8% and the second principal component for 15%. This indicates that the xylem conduit parameters of *Populus euphratica* play a more central in responding to the growth environment under relatively favorable moisture conditions. The first principal component contains information about maximum conduit area (0.97) and total conduit area (0.93), while the second principal component contains information about minimum conduit area (0.70) and number of conduits (−0.45). Sample site TY2 had a lower groundwater burial depth and poorer moisture conditions, with the first principal component and second principal component explaining a total of 86.46% of the variance. The first principal component accounted for 54.83%, and the second principal component accounted for 31.62%. This suggests that the response of the xylem conduit parameters of *Populus euphratica* to the growth environment is also more concentrated under relatively poor moisture conditions. Among them, the first principal component contained the information about maximum conduit area (0.91) and conduit density (0.87), while the second principal component contained information about minimum conduit area (0.80) and average conduit area (0.72). Detailed data from the principal component analysis are in Tables S1 and S2.

The first principal components extracted from the xylem anatomical parameters of the two sample sites were correlated with the maximum and minimum air temperatures at the sample sites after accounting for growth rhythms. The first principal components of the xylem of the two sample sites with different water tables were positively correlated with the air temperature factor. Specifically, the first principal component of TY1 with a higher water table was highly significantly positively correlated with the maximum air temperature ($p < 0.01$) and significantly positively correlated with the minimum air temperature ($p < 0.05$). In contrast, the first principal component of TY2, with a lower water table, was not significantly correlated with maximum and minimum air temperature.

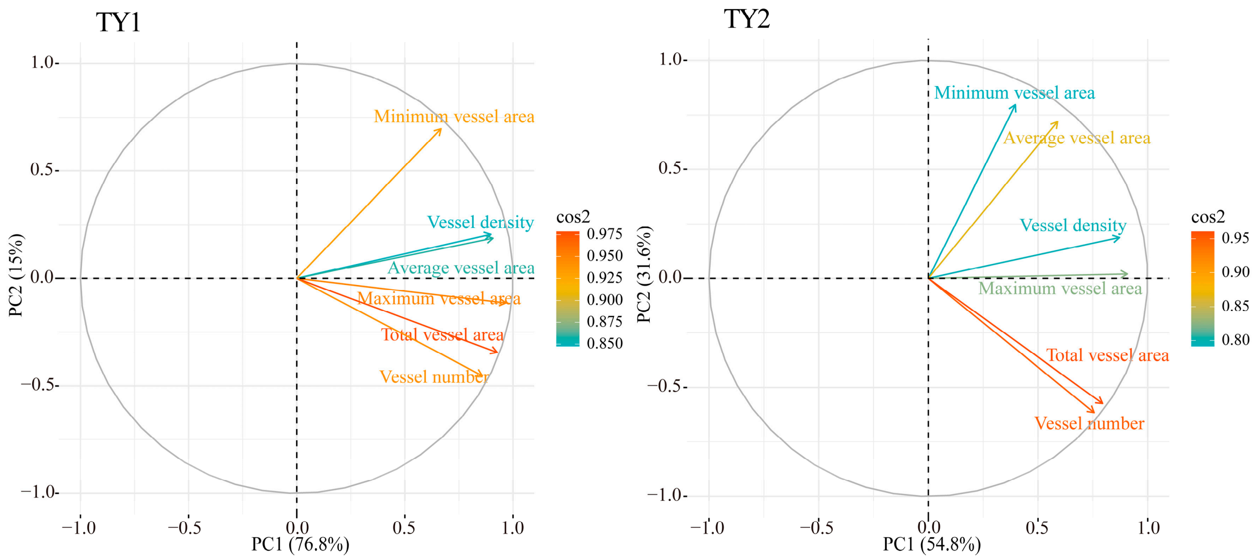

Figure 6. Principal component analysis of xylem parameters of *Populus euphratica*.

The TY1 xylem anatomical parameter indices were fitted to maximum and minimum air temperatures as a function of temperature (Figure 7), and the fitted equations passed the 99% significance test. From the above analyses, it can be observed that the xylem principal component parameter indices changed with the maximum and minimum air temperatures in a basically consistent trend, both increasing significantly with the rise in air temperature. However, once the air temperature reached a certain value, the change in xylem principal component parameter indices became minimal. The sensitivity analysis of the fitted polynomial function revealed that the sensitive maximum temperature for the change of xylem principal component parameter index of *Populus euphratica* was 34.1 °C, and the sensitive minimum temperature was 16.1 °C.

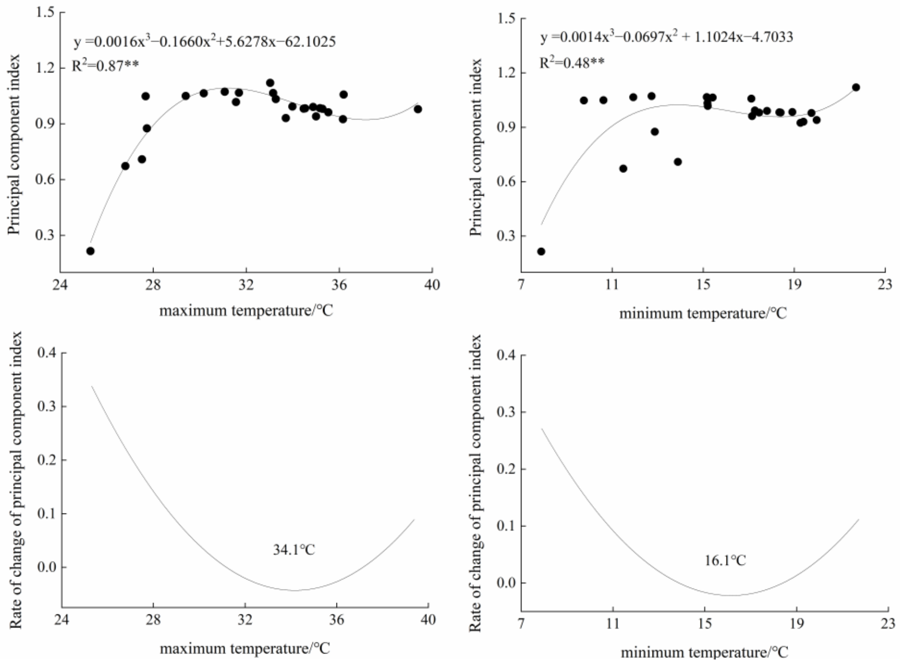

Figure 7. Relationship between main components of xylem of *Populus euphratica* and temperature and humidity and its change rate. **: $p < 0.01$.

4. Discussions

4.1. Annual Variation in the Anatomical Characteristics of Populus euphratica Xylem

The radial growth of diffuse-porous wood trees mainly depends on the number of vessels [24]. The number of vessels in TY1 is greater than that in TY2, indicating that the radial growth of TY1 is greater than that of TY2. The different groundwater depths resulted in varying moisture conditions for TY1 and TY2. The radial growth of TY1, which had better moisture conditions, was faster than that of TY2. The research of Chen [25] also showed that groundwater depth is negatively correlated with the radial growth of *Populus euphratica*. Additionally, the average vessel area of TY1 is larger than that of TY2. A smaller vessel area can reduce embolism and enhance hydraulic safety [26]. Yuan [27] also reached a similar conclusion in their study of temperate forests in northeast China. Vessel morphology affects water transport in the xylem of plants and is primarily influenced by water conditions [28].

The environment affects the function and structure of trees by influencing their physiological processes and, thus, xylem formation. In response, trees can adjust their physiology to adapt to environmental changes [29,30]. In this study, the total vessel area of TY1, with a higher groundwater level, was generally larger than that of TY2, which had a lower groundwater level. This is because TY1 is closer to the river, resulting in a higher groundwater level and better water conditions. The relatively sufficient water supply increases the cell expansion rate and turgor pressure [31], leading to a larger total vessel area in TY1 compared to TY2. Additionally, it was observed that after DOY242, the number of vessels stopped increasing. This may be due to the cessation of cell division in the formation layer before the end of the growing season, allowing enough time for the cells that have completed division to differentiate and mature [32]. The present study showed that all parameters of xylem conduits are higher in TY1, which has a higher water table, compared to TY2, with a lower water table during the growing season. It is generally believed that favorable water conditions promote xylem cell growth. Since TY1 is closer to the river and has a higher water table, the better water supply conditions directly or indirectly affected xylem growth. Consequently, all parameters of xylem anatomy were higher in TY1 than in TY2, which is consistent with the conclusions of other studies [33,34].

4.2. Anatomical Characteristics of Populus euphratica Xylem in Relation to Growing Season Temperatures

The growth process of trees is an adaptation to environmental changes, and many studies have shown that trees respond and adapt to these changes [35,36]. It has been shown that temperature affects characteristics of xylem conduits by influencing the physiological processes in trees [37]. Xylem layer activity begins when the ambient temperature exceeds the minimum threshold temperature for xylem activity, and changes in temperature also affect the length of the growing season [38]. Higher temperatures early in the growing season increase the number and size of xylem vessels, thereby improving water conduction capacity [39]. In this study, we found varying degrees of positive correlations between xylem conduit characteristics and air temperature in the two sample plots, indicating that increased temperature is favorable for xylem growth. This finding aligns with the results obtained by Zheng in their study of water hyacinth in northeast China [33]. The present study area, located in the Tarim River region, differs from northeast China in terms of altitude, soil fertility and climatic conditions, which may account for some differences in findings. However, temperature does influence the growth rates of the phloem cells by affecting cell division, which in turn impacts xylem growth. It has also been shown that in arid regions, moisture is the main limiting factor for tree growth [40], with significant correlations between vascular area and precipitation in xylem anatomy [41], while the correlation with temperature is not significant [42]. In this study, vascular density, total vessel area, mean vascular area and maximum vessel area of xylem in the two sampling points were found to be significantly positively correlated with maximum and minimum temperatures. The difference from previous research findings may be due to the study area being located in an arid area but near the riverbank, which provides relatively good moisture conditions. Additionally, the temperature conditions in this area are well-suited for the growth of *Populus euphratica*, facilitating an increased photosynthetic rate and the growth of xylem cells, thereby positively effecting the characteristics of the xylem vessels. A comparison of the correlations between xylem parameters and maximum and minimum temperatures at TY1 and TY2 showed that both sites exhibited a stronger correlation with maximum temperature than with minimum temperature. This suggests that maximum temperature has a greater impact on the growth of *Populus euphratica* during the growing season. Yuan [43] indicated that minimum temperature is more restrictive for the radial growth of red pine. However, the primary limiting factor for *Populus euphratica* growth is moisture [44]. As temperature increases, evaporation at the sampling site intensifies, accelerating soil moisture loss and reducing the water available for *Populus euphratica* growth, which subsequently affects its growth.

Differences in moisture environment resulted in varying sensitivities of *Populus euphratica* xylem characteristics to temperature. TY1, with better moisture conditions, responded more sensitively to temperature changes than TY2, which had poorer moisture conditions. Zolfaghar's study on the xylem growth of Eucalyptus australis in relation to groundwater conditions also found that better-hydrated trees responded more sensitively to environment changes [45]. The stress water level for *Populus euphratica* growth in the lower Tarim River was identified as 4.71 m [23]. This means that the growth of *Populus euphratica* was stressed when the groundwater depth exceeded 4.71 m. Comparing the groundwater depth data within the growing seasons, it was found that TY1 began to experience water stress from DOY221 and TY2 from DOY165. TY1 experienced water stress later and for a shorter period, contributing to its greater sensitivity to temperature compared to TY2. The analysis concluded that the temperature range suitable for the growth of *Populus euphratica* xylem was 16.1~34.1 °C. Within this range, the accelerated melting of snow and ice increased river runoff, recharging the groundwater and providing better water conditions for tree growth. Concurrently, the increase in air temperature enhanced the trees' respiration and photosynthesis, promoting growth [46]. However, when the temperature exceeded 34.1 °C, the growth rate of xylem decreased significantly. This may be because, while higher temperatures promote cell growth, they also affect the activity of biological enzymes and the tree's metabolic processes. Increased temperature boosts respiration, leading to higher material consumption by the tree. Consequently, the tree adapts to the high temperature environment by closing stomata on its leaves, indirectly affecting respiration, transpiration and photosynthesis, thus significantly reducing the xylem growth rate [47,48]. Qin [49] and others found that high temperatures affected the metabolic processes and activities of biological enzymes in *Populus euphratica*. Additionally, high temperatures impacted the respiration, transpiration and photosynthetic rates of *Populus euphratica* [47], thereby limiting its growth. In this study, the sensitive minimum temperature for the changes in the component parameters of the xylem of *Populus euphratica* was found to be 16.1 °C. Low temperatures also affected the metabolic processes and enzyme activities of *Populus euphratica* to varying degrees, leading to stomatal closure and impacting respiration, photosynthesis and other physiological functions [50], which, in turn, affects its growth. When the water table is too low, the reduced evaporation and photosynthesis capacity in a low-temperature environment weaken photosynthesis and respiration, hindering the normal growth of *Populus euphratica*. This explains why the growth of *Populus euphratica* in TY2, with a lower water table, is not as robust as in TY1.

5. Conclusions

The study of the anatomical characteristics of *Populus euphratica* xylem under different groundwater conditions in the Yingsu section of the lower Tarim River led to the following conclusions:

The xylem growth condition of TY1, which had a higher groundwater level, was better than that of TY2, which was farther from the river. This indicates that the intra-annual growth variation of *Populus euphratica* xylem conduits is influenced by the moisture environment. Xylem conduit density, total conduit area, average conduit area and maximum conduit area were more sensitive to changes in maximum and minimum air temperatures. Furthermore, moisture conditions affected xylem parameter growth to air temperature. The sensitivity of *Populus euphratica* xylem principal component parameter index change sensitivity index to maximum air temperature was 36.1 °C, while its sensitivity to the minimum air temperature was 16.1 °C. Therefore, the temperature range suitable for the growth of *Populus euphratica* xylem is 16.1 and 36.1 °C. Understanding this temperature range can help predict the growth of *Populus euphratica* under environmental changes, such as climate change, and provide a scientific basis for the protection and restoration of *Populus euphratica* in the lower Tarim River. Future studies will utilize longer time scales and expand the research scope to obtain more reliable results.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/f15071087/s1, Figure S1: The process of sample handling; Table S1: Principal component information of xylem anatomical parameters of *Populus euphratica*; Table S2: Contributions of factors to the first and second principal components of the xylem anatomical parameters of *Populus euphratica*.

Author Contributions: Conceptualization, J.C. and M.Y.; methodology, J.C.; software, J.C. and Q.H.; validation, J.C.; investigation, J.C., Q.H. and X.P.; resources, M.Y.; data curation, M.Y.; writing—original draft preparation, J.C. and Q.H.; writing—review and editing, J.C. and M.Y.; project administration, M.Y. All authors have read and agreed to the published version of the manuscript.

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