Spatiotemporal Response of Populus euphratica Leaf Yellowing Period to Climate Change and Regional Differences Postprint

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Abstract

Using daily mean temperature data from 41 ground meteorological stations in Populus euphratica distribution areas across Chinese oases over the past 57 years, and employing methods such as linear trend analysis, ArcGIS inverse distance weighted (IDW) interpolation, Morlet wavelet power spectrum, Mann-Kendall test, and correlation analysis, this study analyzes the spatiotemporal characteristics, regional warming response, and differences of the leaf yellowing period of Populus euphratica in Chinese oases. The results indicate that: over the past 57 years, both the start and end dates of leaf yellowing of Populus euphratica in Chinese oases have been significantly delayed, and the leaf yellowing period has shown a prolonging trend, with changing tendency rates of 0.72 d · (10a)-1, 1.39 d · (10a)-1 (0.05), and 0.66 d · (10a)-1, respectively; the start and end dates of leaf yellowing exhibit a spatial pattern of gradually advancing from southwest to northeast; among them, the Qaidam Oasis shows the most significant delaying trend, while the southern Xinjiang Oasis shows an insignificant trend. Except for northern Xinjiang, the leaf yellowing period shows a gradually shortening pattern from south to north, with significant spatial differences; and there exist short periods of 2.2 a, 3.0 a, and 5.2~5.6 a, respectively, which coincide with the atmospheric circulation period of 2~4 a and the El Niño period of 2~7 a; the start/end dates and duration of leaf yellowing underwent abrupt changes in 2003, 1990, and 1961, respectively, with variations across different oasis regions; in the study area, the start/end dates and duration of leaf yellowing of Populus euphratica are significantly correlated with the monthly mean temperature of the preceding period (June–August and July–September) and the monthly mean temperature of the current months (September–November), with correlation coefficients of 0.703, 0.697, and 0.715 (0.001), respectively. This reflects that the leaf yellowing period of Populus euphratica in Chinese oases responds to global climate warming with both sensitivity and regional differences.

Full Text

Preamble

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1 Introduction

1.1 Study Area

The study area encompasses the distribution range of *Populus euphratica* in Chinese oases, located between 34°25 -48°10 N and 73°40 -109°08 E [Figure 1: see original paper]. This region features a temperate arid continental climate characterized by abundant light and heat resources, with an accumulated temperature 10°C exceeding 1500°C, annual precipitation below 200 mm, and total solar radiation of approximately 5.04×10 MJ · m 2. The area includes various oasis types such as the Qaidam Oasis and southern Xinjiang oases.

1.2 Data and Methods

1.2.1 Data Sources Daily average temperature data from 41 meteorological stations within the *P. euphratica* distribution area in Chinese oases were collected for the period 1960–2016. These data were obtained from the China Meteorological Data Service Center (http://www.cma.gov.cn/). The phenological data for *P. euphratica* leaf yellowing were derived from field observations and published literature [Figure 2: see original paper].

1.2.2 Analytical Methods The study employed multiple analytical techniques including multi-year trend analysis, inverse distance weighted (IDW) interpolation, Morlet wavelet power spectrum analysis, Mann-Kendall mutation testing, and correlation analysis. These methods were used to examine the spatiotemporal patterns of *P. euphratica* leaf yellowing and its relationship with climatic factors.

2 Results

2.1 Temporal Trends in Leaf Yellowing Phenology

Over the past 57 years, the start and end dates of *P. euphratica* leaf yellowing have been significantly postponed, while the leaf-yellowing period has gradually extended. The trend rates were 0.72 days · decade 1, 1.39 days · decade 1 (0.05), and 0.66 days · decade 1, respectively. The average duration of the leaf-yellowing period was 4.1 days, with the most significant delay occurring after 1996.

2.2 Spatial Patterns of Phenological Changes

Along a southwest-northeast transect across Chinese oases, the start and end dates of leaf yellowing showed clear spatial differentiation [Figure 3: see original paper]. The postponement trend was most pronounced in the Qaidam Oasis but not evident in southern Xinjiang oases. In northern Xinjiang, the leaf-yellowing period became shorter along a south-north gradient, with extremely significant spatial disparity.

2.3 Cyclical Characteristics

Wavelet analysis revealed that the start and end dates of *P. euphratica* leaf yellowing exhibited cyclical patterns of 2.2–5.6 years (0.05) [Figure 5: see original paper]. These cycles were consistent with 2–4-year atmospheric circulation patterns and 2–7-year El Niño events. The short cycles of 2–7 years were particularly prominent in the 1960s–1970s and 1990s–2010s.

2.4 Mutation Analysis

Significant mutations in the leaf-yellowing phenology occurred in 2003, 1990, and 1961 [FIGURE:6, TABLE:2]. However, the timing of these mutations varied among different oases. The start date mutations primarily occurred in 2003, 2007, 2011, and 2015, while end date mutations were concentrated in 1979, 1980, and 2005.

2.5 Correlation with Temperature

The start and end dates and duration of the leaf-yellowing period showed significant positive correlations with mean monthly temperatures during June–August, July–September, and September–November, with correlation coefficients of 0.703, 0.697, and 0.715 (0.001), respectively [Figure 7: see original paper]. The relationships with maximum monthly temperatures were also significant, with coefficients ranging from 0.588 to 0.715.

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3 Discussion

The results demonstrate that *P. euphratica* leaf-yellowing phenology is highly sensitive to global warming, with significant regional variations. Key findings include:

(1) Over the 57-year study period, the start and end dates of leaf yellowing were postponed at rates of 0.72 and 1.39 days $\cdot$ decade^{1}, respectively, while the period extended at 0.66 days $\cdot$ decade^{1} (0.05). The spatial pattern showed earlier phenology along a southwest-northeast transect, with southern Xinjiang oases showing different trends compared to northern regions.

(2) The spatial distribution of leaf-yellowing changes exhibited distinct regional characteristics, with the Qaidam Oasis showing the most significant delays. The cyclical patterns of 2.2–5.6 years align with atmospheric circulation and El Niño cycles, indicating the influence of large-scale climate patterns.

(3) Mutation analysis identified critical transition years in 2003, 1990, and 1961, though these varied regionally. The significant correlations between leaf-yellowing phenology and temperature (r=0.703-0.715, 0.001) confirm temperature as a primary driver of phenological changes.

(4) The strong correlations with June–August and July–September temperatures suggest that summer warming directly influences the timing and duration of autumn leaf senescence in *P. euphratica*. The regional differences highlight the importance of local environmental conditions in modulating the response to global climate change.

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Abstract

This study analyzed the spatiotemporal response of *Populus euphratica* leaf-yellowing period to climate change and its regional differences using daily average temperature data from 41 meteorological stations in Chinese oases during 1960–2016. Methods including multi-year trend analysis, inverse distance weighted (IDW) interpolation, Morlet wavelet power spectrum, Mann-Kendall mutation test, and correlation analysis were applied. Results revealed that the start and end dates of *P. euphratica* leaf yellowing were postponed over the last 57 years, with the leaf-yellowing period gradually prolonged. The change trend rates were 0.72, 1.39 (0.05), and 0.66 days·decade^{1}, respectively, showing that the start and end dates became earlier along a southwest-northeast transect of Chinese oases. The postponement trend was most obvious in the Qaidam Oasis but not in southern Xinjiang oases. In addition to northern Xinjiang, the leaf-yellowing period became shorter along a south-north transect, with extremely significant spatial disparity. There were 2.2-, 3.0-, and 5.2–5.6-year short cycles of the start and end dates of leaf yellowing, consistent with 2–4-year atmospheric circulation and 2–7-year El Niño events. Mutations of the start and end dates and periods of leaf yellowing occurred in 2003, 1990, and 1961, respectively, but they differed among different oases. There were significant correlations among the start and end dates and period of leaf yellowing and mean monthly temperatures during June–August, July–September, and September–November, with correlation coefficients of 0.703, 0.697, and 0.715 (0.001), respectively. The results showed that the response of *P. euphratica* leaf-yellowing period to global warming was sensitive and regionally different.

Keywords: *Populus euphratica*; leaf-yellowing period; spatiotemporal response; regional difference; Chinese oasis