Spatial variability of leaf wetness under different soil water conditions in rainfed jujube (Ziziphus jujuba Mill.) in the loess hilly region, China (Postprint)

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Abstract

Leaf wetness provides a wide range of benefits not only to leaves, but also to ecosystems and communities. It regulates canopy eco-hydrological processes and drives spatial differences in hydrological flux. In spite of these functions, little remains known about the spatial distribution of leaf wetness under different soil water conditions. Leaf wetness measurements at the top (180 cm), middle (135 cm), and bottom (85 cm) of the canopy positions of rainfed jujube (Ziziphus jujuba Mill.) in the Chinese loess hilly region were obtained along with meteorological and soil water conditions during the growing seasons in 2019 and 2020. Under soil water non-deficit condition, the frequency of occurrence of leaf wetness was 5.45% higher at the top than at the middle and bottom of the canopy positions. The frequency of occurrence of leaf wetness at the top, middle and bottom of the canopy positions was over 80% at 17:00 18:00 (LST). However, the occurrence of leaf wetness at the top was earlier than those at the middle and bottom of the canopy positions. Correspondingly, leaf drying at the top was also latter than those at the middle and bottom of the canopy positions. Leaf wetness duration at the middle was similar to that at the bottom of the canopy position, but about 1.46–3.01 h less than that at the top. Under soil water deficit condition, the frequency of occurrence of leaf wetness (4.92%-45.45%) followed the order of top>middle>bottom of the canopy position. As the onset of leaf wetness was delayed, the onset of wet leaf drying was advanced and the leaf wetness duration was shortened. Leaf wetness duration at the top was linearly related (R2>0.70) to those at the middle and bottom of the canopy positions under different soil water conditions. In conclusion, the hydrological processes at canopy surfaces of rainfed jujube depended on the position of leaves, thus adjusting canopy structure to redistribute hydrological process is a way to meet the water need of jujube.

Full Text

Preamble

Spatial Variability of Leaf Wetness Under Different Soil Water Conditions in Rainfed Jujube (*Ziziphus jujuba* Mill.) in the Loess Hilly Region, China

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Abstract: Leaf wetness provides a wide range of benefits not only to individual leaves, but also to entire ecosystems and communities. It regulates canopy eco-hydrological processes and drives spatial differences in hydrological flux. Despite these important functions, little remains known about the spatial distribution of leaf wetness under varying soil water conditions. We measured leaf wetness at the top (180 cm), middle (135 cm), and bottom (85 cm) canopy positions of rainfed jujube (*Ziziphus jujuba* Mill.) in the Chinese loess hilly region, along with meteorological and soil water conditions during the growing seasons of 2019 and 2020. Under non-deficit soil water conditions, the frequency of leaf wetness occurrence was 5.45% higher at the top than at the middle and bottom canopy positions. The frequency of leaf wetness at all three positions exceeded 80% between 17:00–18:00 LST. However, leaf wetness onset occurred earlier at the top position compared to the middle and bottom positions, and correspondingly, leaf drying at the top was also delayed. Leaf wetness duration at the middle position was similar to that at the bottom, but approximately 1.46–3.01 hours shorter than at the top. Under soil water deficit conditions, the frequency of leaf wetness occurrence (4.92%–45.45%) followed the order: top > middle > bottom. As the onset of leaf wetness was delayed, the onset of drying was advanced and the overall duration shortened. Leaf wetness duration at the top was linearly related ($R^2 > 0.70$) to that at the middle and bottom positions under different soil water conditions. In conclusion, the hydrological processes at the canopy surfaces of rainfed jujube depend on leaf position, suggesting that adjusting canopy structure to redistribute hydrological processes represents a potential strategy for meeting the water needs of jujube.

Keywords: canopy position; leaf wetness; rainfed jujube; soil water condition; loess hilly region

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1 Introduction

Plant leaf wetness is a natural phenomenon occurring when leaves are wetted over their lifetimes by rain, dew, fog, or irrigation [?]. Leaf wetness can increase leaf water potential [?], reduce transpiration rate and vapor pressure deficit, and consequently decrease water loss, alter water balance, maintain carbon dioxide absorption, and improve water use efficiency at the ecosystem scale. Thus, leaf wetness benefits plants, communities, and ecosystems [?, ?, ?]. Although triggered by various forms of precipitation, leaf wetness is primarily driven by dew in arid regions [?, ?]. In arid and semi-arid areas, dew represents a common and significant water source, accounting for 4.5%–77.0% of total precipitation [?, ?]. In the Chinese loess hilly region, dew-driven leaf wetness can reach as high as 60.0% [?].

Leaf wetness duration (LWD) is defined as the period from wetting to drying of water on a leaf surface. It serves not only as a parameter expressing leaf wetness, but also as an index reflecting plant functions such as leaching, deposition, energy balance, and reproduction [?, ?]. LWD affects plant susceptibility to pathogens and the primary productivity of agro-ecosystems [?]. Both measurement and modeling are used to obtain LWD [?, ?]. However, no uniform standard currently exists for measuring LWD [?], and model simulations are sensitive to changes in input parameters [?]. Parameters with different time steps can induce uncertainties and errors in model results [?].

Research on LWD has predominantly focused on crops and grasslands, with monitoring positions limited to the top of the canopy [?, ?, ?]. Only a few studies have monitored LWD at different canopy positions [?]. In reality, due to complex canopy structure and variable micro-meteorology, canopy wetness exhibits both temporal and spatial variability [?, ?]. Modeled or measured LWD at the top or other single canopy positions cannot fully reflect the overall state of leaf wetness [?]. Moreover, few studies have examined canopy wetness distribution in forest ecosystems [?]. Climate change significantly affects LWD; for example, dew formation is highly sensitive to relative humidity and temperature [?], and climate warming will reduce LWD in arid and semi-arid areas [?, ?]. Under climate change, reduced LWD will affect water use and energy distribution at different canopy positions, with significant consequences for ecosystem function [?, ?]. Therefore, predicting ecosystem functional capacity may largely depend on understanding spatial variations in leaf wetness [?].

Jujube (*Ziziphus jujuba* Mill.) is a traditional tree crop in China that has been widely cultivated under rainfed conditions in the semi-arid loess hilly region for thousands of years. Due to its high drought tolerance and considerable economic benefits, jujube represents the main economic plantation in the loess hilly region, covering an area of 1\$×10^{6}\$ hm^{2} [?, ?]. Because rainfall cannot fully meet vegetation water demands in this region, soil desiccation has become the dominant hydrological phenomenon [?]. The mechanisms of water use and regulation in jujube under dry soil conditions have been widely studied [?, ?, ?,

?, ?, ?, ?]. Recent studies have shown that dew has positive eco-hydrological effects on dryland jujube [?], serving as a critical potential water source that makes considerable contributions to the canopy energy budget [?]. However, under dry soil conditions, the spatial distribution of leaf wetness at different jujube canopy positions remains unclear. Clarifying this spatial distribution can deepen our understanding of hydrological processes at the canopy level and guide water management decisions in jujube and similar crop plantations. Thus, the objectives of this study were to: (1) analyze the state and dynamics of leaf wetness at different jujube canopy positions; (2) explore the duration of leaf wetness at different canopy positions; and (3) determine the relationships between these parameters.

2.1 Study Area

The study was conducted at the Jujube Demonstration Base in Mizhi County, Yulin City, Shaanxi Province (38°11 N, 109°28 E) at an elevation of 1049 m. The region has a semi-arid climate with rainfall concentrated in July, August, and September. Mean annual precipitation is 452 mm, with an annual mean temperature of 9°C, solar radiation of 162 W/m^2, and a frost-free period of 160 days. The soil profile in the 0–500 cm layer consists of loess soil with moderate permeability and uniform texture (7.7% silt, 47.8% sand, and 44.5% clay), and a bulk density of 1.29-1.31 g/cm^3. Available nitrogen, phosphorus, and potassium in the 0-200 cm soil layer are 30.12, 1.56, and 89.33 mg/kg, respectively. In the upper 100 cm soil layer, field capacity and wilting moisture content are 22.06 and 6.66 cm^3/cm^3, respectively. The average groundwater table lies below 50 m from the soil surface.

The experimental plot covered 2.7 hm^2. Dwarf jujube trees were planted in 2003 under rainfed conditions on 25° east-facing terraced land [Figure 1: see original paper]. Trees were arranged in rows spaced 3 m apart with an interrow spacing of 2 m. The mean trunk diameter was 8 cm at 20 cm above the soil surface, with three main bifurcate branches maintained at approximately 80 cm above the soil surface. Jujube trees were pruned every 21 days during the growing season to maintain a tree height of about 2.0 m and canopy size of 2.2 m × 2.2 m. The experiment was conducted during the growing seasons of 2019 and 2020 . Meteorological factors monitored during the study period are summarized in Table 1.

Table 1 Average values of meteorological factors during the growing seasons in 2019 and 2020

Growing period	7 May–16 Oct
T2m (°C)	
RH2m (%)	
v2m (m/s)	
Precipitation (mm)	

Note: T2m, air temperature at 2 m above the soil surface; RH2m, relative humidity at 2 m above the soil surface; v2m, wind speed at 2 m above the soil surface.

Fig. 1 (a) Dwarf jujube trees on the 25° east-facing terraced land; (b) leaf wetness measurement sensors.

2.2 Leaf Wetness Measurement

Dew and rainfall days during the experiment accounted for 60% and 20% of the total observation period, respectively. Light rainfall represented over 50% of rainfall days [Figure 2: see original paper]. Light rainfall was intermittent, with dew often forming between rain events, making it difficult to determine whether leaf wetness resulted from rain or dew. Rainfall data from a nearby weather station were used to exclude rain-induced leaf wetness, ensuring that only dew-induced leaf wetness was analyzed.

Various sensors exist for measuring leaf wetness, composed of different materials and operating on different principles [**?**]. Consequently, no unified standard for measuring leaf wetness has been established [**?**]. Leaf wetness is often caused by dew, which requires surface temperature to be lower than dew-point temperature. However, differences in dew duration measurements arise from variations in when the instrument surface temperature reaches or falls below the dew-point temperature, introducing biases in some instruments. This study employed dielectric Leaf Wetness Sensors (LWS, Decagon Devices Inc., Pullman, WA, USA) to measure jujube leaf wetness. LWS exhibits similar thermodynamic characteristics to real leaves, enabling more accurate measurement of leaf wetting time than other instruments [**?**]. Visual and tactile observation methods [**?**, **?**] were used to validate LWS measurements. The threshold value was set at 455 raw counts, as this value most accurately reflected jujube leaf wetness in our study. When LWS wetness threshold exceeded 455 raw counts, leaves were considered wet; below this value, they were considered dry [**?**].

Three jujube trees were randomly selected for leaf wetness monitoring using LWS sensors. Sensors were deployed at 0° relative to the horizontal plane with tips pointed northward [**?**]. Sensors were installed at the top (180 cm), middle (135 cm), and bottom (85 cm) canopy positions of each tree, with one sensor per position, totaling nine LWS sensors. Signals were automatically recorded every 15 minutes by EM50 data loggers (Decagon Devices Inc., Pullman, WA, USA) connected to the sensors.

Daily LWD was calculated as the sum of leaf wetness time over 24 hours, from 18:00 LST to 18:00 the following day. Equation (1) was used to calculate daily LWD from three replicates, with the average value representing the final daily LWD for each canopy position:

$$LWD = \sum_{i=1}^{n} t_i$$

where LWD is the daily leaf wetness duration (h), t is the measured duration of the ith leaf wetness event (h), and n is the total number of leaf wetness events per day.

2.3 Soil Water and Meteorological Factors

Soil water content in the 20, 40, and 60 cm soil layers was measured using GS3 sensors (Decagon Devices Inc., Pullman, WA, USA) placed 30 cm from jujube tree trunks, totaling nine sensors for the three selected canopies. Sensors were connected to EM50 data loggers (Decagon Devices Inc., Pullman, WA, USA), recording soil water content every 15 minutes concurrently with LWS sensors. Given long-term soil water deficits in rainfed jujube, we categorized soil water in the 0–60 cm layer [Figure 2: see original paper] based on relative extractable water ( ). Using the threshold value (0.4) determined by Chen et al. (2014) for jujube plantations in the loess hilly region, we categorized soil water status as: water stress for < 0.4 and non-stress for > 0.4. was calculated using the following equation [**?**]:

$$\theta_e = \frac{\theta - \theta_w}{\theta_c - \theta_w}$$

where is the relative extractable water in the 0–60 cm soil layer, is the average soil water content in the 0–60 cm layer (%), _w is the wilting moisture content (%), and _c is the soil field capacity (%).

Three VP-4 sensors (Decagon Devices Inc., Pullman, WA, USA) were placed at the top, middle, and bottom canopy positions to monitor canopy temperature (T) and relative humidity (RH). Data were automatically logged every 15 minutes by EM50 data loggers (Decagon Devices Inc., Pullman, WA, USA). Dynamic changes in T and RH at different canopy positions are shown in Figure 3 [Figure 3: see original paper]. Relative humidity (RH_2 , %), air temperature (T_2 , °C), wind speed (v_2 , m/s), and rainfall were monitored at 2 m above the soil surface using an automated meteorological weather station (RR-9100, Yugen Technology Co., Ltd., China) installed in the experimental field, with data collected every 30 minutes.

Soil water at the three measurement layers fluctuated with rainfall, showing larger variations at the 20 cm layer and greater stability at the 40 and 60 cm layers. Soil water deficit days accounted for 46.11% in 2019 and 49.69% in 2020 of the total monitoring period, while non-deficit days accounted for 53.89% in 2019 and 50.31% in 2020 [Figure 2: see original paper]. RH and T at different canopy positions followed similar temporal trends but varied between years. From 21:00 to 07:00 the following day, canopy RH was 1.49%–6.29% higher in

2019 than in 2020, while from 08:00 to 18:00, canopy RH was 3.03%-7.41% lower in 2019 than in 2020. Canopy T was 1.05°C-2.38°C higher in 2019 than in 2020 from 07:30 to 18:30 [Figure 3: see original paper].

2.4 Statistical Analyses

All statistical analyses were conducted using SPSS 16.0 (SPSS, Chicago, USA). Significant differences in LWD at different canopy positions under the same soil water condition were tested using multiple comparisons with LSD post-hoc tests at $P = 0.05$. The significance of differences in LWD at the same canopy position under different soil water conditions was analyzed using t-tests at the 5% probability level. Regression analysis was used to determine correlations between LWD and canopy position, with mean absolute difference (MAD) and mean difference (MD) employed to compare LWDs at different canopy positions [**?**].

3.1 Frequency of Leaf Wetness

The frequency of leaf wetness was higher at the top than at the middle and bottom canopy positions of jujube [Figure 4: see original paper]. Under non-deficit soil water conditions (> 0.4), the frequency of leaf wetness at the top was 9.52% higher than at the middle and 8.73% higher than at the bottom in 2019 [Figure 4a: see original paper]. In 2020, these differences were 1.40% and 2.16%, respectively [Figure 4b: see original paper]. Under deficit soil water conditions (< 0.4), the frequency of leaf wetness at the top was 4.76% and 3.97% higher than at the middle and bottom in 2019 [Figure 4a: see original paper], and 1.76% and 5.58% higher in 2020 [Figure 4b: see original paper].

The frequencies of leaf wetness at the middle and bottom canopy positions varied between years. With precipitation of 436 mm in 2019 , the frequency of leaf wetness was lower at the middle than at the bottom under both soil water conditions [Figure 4a: see original paper]. With precipitation of 333 mm in 2020 , the frequency was higher at the middle than at the bottom.

The onset time of leaf wetness and the end time of leaf drying differed among canopy positions [FIGURE:4c and d]. Under > 0.4 conditions, leaf wetness onset at the top occurred at 20:00-21:00 with a frequency of 8.70%-44.44%, while onset at the middle and bottom occurred at 20:45-21:30 with frequencies of 5.80%-31.48%. Leaf drying at the top occurred at 10:15-11:00 with a frequency of 15.94%-22.22%, while drying at the middle and bottom occurred at 09:00-10:15 and 08:45-09:30, with frequencies of 17.39%-21.81% and 15.94%-20.37%, respectively. The frequency of leaf wetness at the top, middle, and bottom reached maximum values of 87.01%, 85.45%, and 81.48% at 05:00-06:00. Under < 0.4 conditions, leaf wetness onset was delayed and drying was advanced, with reduced frequencies. Onset at the top occurred at 21:00-23:15 (9.83%-19.67% frequency), while onset at the middle and bottom occurred at 22:00-00:00 (4.92%-20.00% frequency). Drying at the top occurred at 08:15-10:00

(13.11%-23.64% frequency), while drying at the middle and bottom occurred at 07:15-09:00 and 07:45-08:30, respectively (13.11%-21.81% frequency). Maximum frequencies at the top, middle, and bottom were 45.45%, 41.81%, and 38.18%, respectively, occurring at 06:15-06:45. The frequency of leaf wetness at any given time and canopy position was higher under > 0.4 than under < 0.4 conditions [FIGURE:4c and d].

3.2 Leaf Wetness Duration (LWD)

LWD was higher at the top than at the middle and bottom canopy positions, while LWDs at the middle and bottom were similar [Figure 5: see original paper]. In 2019, LWDs at the top were 8.60 h under > 0.4 conditions and 6.60 h under < 0.4 conditions, which were 3.01 h and 2.68 h longer ($P < 0.05$; > 0.4) than at the middle and bottom positions, respectively. In 2020, LWDs at the top were 11.10 h (> 0.4) and 6.16 h (< 0.4), which were 1.17 h and 1.46 h longer ($P > 0.05$; > 0.4) and 1.09 h and 0.60 h longer ($P > 0.05$; < 0.4) than at the middle and bottom positions, respectively. LWDs at all positions were higher under > 0.4 than under < 0.4 conditions [Figure 5: see original paper]. In 2019, LWDs at the top, middle, and bottom were 2.00 h, 0.56 h, and 0.81 h longer under > 0.4 than under < 0.4 conditions ($P > 0.05$). In 2020, these differences were 4.94 h, 4.86 h, and 4.08 h, respectively ($P < 0.05$).

3.3 Correlation Among LWDs at Different Canopy Positions

Strong linear correlations existed between LWDs at the top and middle positions and between LWDs at the top and bottom positions, with coefficients of determination (R^2) ranging from 0.70 to 0.94. The fitting effect was better in 2020 than in 2019, with R^2 values 0.11-0.24 higher in 2020, though LWD remained greater at the top than at the middle and bottom positions [Figure 6: see original paper].

A detailed analysis of spatial variability is presented in Table 2 . The onset of leaf wetness occurred 0.38 h and 0.49 h earlier (> 0.4) and 0.44 h and 0.76 h earlier (< 0.4) at the top than at the middle and bottom positions, respectively. Mean absolute differences (MADs) for onset time averaged 1.67 h and 2.05 h (> 0.4) and 1.27 h and 1.55 h (< 0.4), respectively. Leaf drying occurred 1.61 h and 2.37 h later (> 0.4) and 1.40 h and 1.56 h later (< 0.4) at the top than at the middle and bottom positions, respectively. MADs for drying time averaged 2.30 h and 2.37 h (> 0.4) and 1.74 h and 1.84 h (< 0.4), respectively.

Fig. 4 Relative days (a and b) and frequencies (c and d) of leaf wetness at different jujube canopy positions under soil water deficit (< 0.4) and non-deficit (> 0.4) conditions in 2019 and 2020. , relative extractable water.

Fig. 5 Leaf wetness duration (LWD) at different canopy positions under soil water deficit (< 0.4) and non-deficit (> 0.4) conditions in 2019 (a) and 2020 (b). Different lowercase letters indicate significant differences at different canopy positions within the same soil water condition ($P < 0.05$); different uppercase letters indicate significant differences under different soil water conditions within the same canopy position ($P < 0.05$). Lower and upper whiskers denote the 10th and 90th percentiles, respectively; top and bottom box boundaries denote the 75th and 25th percentiles, respectively; solid dot in box denotes the mean value; solid horizontal line in box denotes the median value; , relative extractable water.

Fig. 6 Correlations among leaf wetness durations (LWDs) at different canopy positions under soil water non-deficit (> 0.4; a and b) and deficit (< 0.4; c and d) conditions in 2019 and 2020. , relative extractable water.

Table 2 Mean difference (MD) and mean absolute difference (MAD) between the time of onset and drying of leaf wetness at different canopy positions in 2019 and 2020

Position	MD (h)	MAD (h)	MD (h)	MAD (h)
	Onset	Drying	Onset	Drying
	> 0.4	> 0.4	< 0.4	< 0.4
Top/Middle				
Top/Bottom				
Average				

Note: , relative extractable water.

4.1 Leaf Wetness Characteristics

Leaf wetness has greater ecological significance than the total amount of water stored in leaves [?, ?]. When leaves are wet, a thin water layer or droplets forms on leaf surfaces, serving as a supplementary water source that can be absorbed by leaves [?]. Kidron and Starinsky (2019) found that water stored in leaves is primarily $CaSO_4$ water type, with total dissolved ion (TDI) concentrations of 88-758 mg/L. The ionic composition of leaf-stored water is generally higher than that of rainwater, and leaf absorption of this water is affected not by dew amount but by LWD [?]. Our results showed that LWD was higher at the top than at the middle and bottom canopy positions [Figure 5: see original paper], consistent with previous studies on LWD in rainforest, apple, soybean, grape, and corn plantations [?, ?, ?, ?, ?]. However, our results differ from those for coffee, cotton, and banana plantations [?, ?].

Prolonged leaf wetness facilitates water movement into leaves [?] while enabling nutrient absorption [?]. Water absorbed by leaves promotes cell expansion by increasing turgor pressure, thereby stimulating stem and leaf growth [?]. Thus, leaf wetness affects both plant physiology and canopy microclimate.

The leaf wetness sensors in this study were oriented northward [?, ?, ?]. Instrument orientation affects leaf wetness measurements; for example, grape leaves facing southwest typically begin wetting earlier and dry later than those facing northeast [?], and tomato leaves facing east dry 20 minutes later than those facing north, south, or west [?]. Citrus LWD was higher on the west side than on the east side [?], but our results showed significant linear correlations between LWDs at different jujube canopy positions in the north-facing orientation.

4.2 Factors Driving Leaf Wetness

The interaction between climate factors and plant community structure and composition influences leaf wetness. Planting density, plant height, tree age, canopy structure, canopy microclimate, field management, and other factors affect radiation interception and balance at the canopy, resulting in variable leaf wetness and drying patterns across canopy positions and times [?, ?, ?].

Batzer et al. (2008) found that overhanging leaves of trees such as apple create a barrier that reduces radiant and convective heat loss from the ground, delaying surface cooling in the lower canopy. Thus, overhanging leaves can delay dew formation in the lower canopy, resulting in shorter LWD at lower positions. When leaf temperature in open positions falls below dew-point temperature for up to 6 hours at night, understory leaves remain below dew-point temperature for only 1 hour [?]. Rowlandson et al. (2015) observed that at low planting density, the whole plant undergoes radiative cooling at nearly the same rate, making dew deposition more uniform with no time difference in leaf wetness among canopy layers. For example, tomato leaf wetness begins at the top and progresses downward, with drying following a similar pattern [?]. However, dwarf jujube has dense spacing with a canopy structure similar to apple, resulting in higher LWD at the top than at the middle and bottom positions [Figure 5: see original paper]. Moreover, leaf wetness began earlier and drying occurred later at the top than at the middle and bottom positions [FIGURE:4; TABLE:2].

Substrate temperature and water vapor source are also key parameters influencing leaf wetness [?, ?]. Climate factors such as RH and T are primary drivers of leaf wetness in jujube plantations [?]. However, RH and T at different jujube canopy positions were similar under the same soil water condition, with maximum temperature differences of 0.35°C and maximum RH differences of 1.72% [Figure 3: see original paper]. Soil water deficit reduced the frequency of leaf wetness occurrence in rainfed jujube, consistent with previous findings [?, ?, ?]. Figure 4 showed that relative days of leaf wetness under soil water deficit conditions were 16.43%-24.22% fewer than under non-deficit conditions. Soil water affected LWD in rainfed jujube, with LWDs at the top, middle, and bottom positions being 0.56–4.94 h longer under non-deficit than under deficit conditions. Even with less rainfall and low soil water, differences in LWD under different soil water conditions were evident [Figure 5: see original paper]. However, soil water is not a limiting factor in humid areas or densely planted areas, where the water vapor source for leaf wetness originates primarily from the atmosphere rather than soil. Wen et al. (2012) found that dew water in densely spaced crops and grasses (*Stipa klinderi*, *Agropyrus aestivum*, and *Frigida frigida*) came from the atmosphere (98%) at the top, with only 2% originating from soil evaporation.

5 Conclusions

Leaf wetness affects hydrological processes at the canopy surface and is driven by climate factors and plant community structure and composition. The frequencies of leaf wetness occurrence at different canopy positions under non-deficit soil water conditions were higher than those under deficit conditions. The frequency at the top was higher than at the middle and bottom positions. The onset of leaf wetness at the middle and bottom positions occurred later than at the top, while drying at the middle and bottom occurred earlier than at the top. Although differences in leaf wetness among positions were identified in jujube, the redistribution of water and nutrients in those leaves and the resulting water use efficiency remain unclear. Future studies should analyze the mechanisms of water use from leaf wetness at different positions. In conclusion, the hydrological processes at the canopy surfaces of rainfed jujube depend on leaf position, suggesting that adjusting canopy structure to redistribute hydrological processes represents a strategy for meeting jujube water needs.

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Note: Figure translations are in progress. See original paper for figures.