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NON-LINEAR EFFECT OF WATER-TABLE DRAWDOWN ON WATER AND NITROGEN USE EFFICIENCIES OF *CAREX MULIENSIS* HAND.-MAZZ. IN THE ZOIGE ALPINE WETLAND IN TIBETAN PLATEAU

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Abstract

This study explored the water and N use efficiencies of *Carex muliensis* in the alpine wetland along water-table gradient in the Tibetan Plateau. It was found that the water-table drawdown significantly influenced leaf $\delta^{13}C$ (water use efficiency, WUE) and C:N ratio (N use efficiency, NUE), and exhibited a non-linear correlation with WUE and NUE. The leaf $\delta^{13}C$ initially increased and then decreased with the deceasing water table, with a threshold of –40 cm. A trade-off was found between WUE and NUE in *C. muliensis*. Findings of this investigation offer insights into the relationship between the vegetation and hydrology, as well as, provide a scientific basis for the ecohydrological regulation and vegetation conservation in the alpine wetland.

Water use efficiency (WUE) and N use efficiency (NUE) represent the capacity of plants to take up and utilize water and N in the environments, which is intimately linked to the surviving strategy, environmental adaptability and competitiveness of plants (Dijkstra *et al.* 2016, Zeng 2023). Plants often have lower WUE in humid and sub-humid environments due to larger stomatal conductance and transpiration rates caused by higher soil moisture content (Zhang *et al.* 2023). Plants may maintain high WUE to reduce the impact of water deficit and improve their capacity to compete for water under drought conditions (Peri *et al.* 2012, Zeng 2023). However, a study revealed that the soil moisture had no impact on plant WUE (Dijkstra *et al.* 2016). Similarly, there have reports for a corresponding increase, decrease, or no discernible changes in plant NUE response to soil water (Su and Shangguan 2020, Hu *et al.* 2023, Zeng 2023). It should be noted that almost all of these studies were conducted on crop and grassland plants, and very few studies examined the relationship between plant WUE/NUE and soil water in wetland plants (Dijkstra *et al.* 2016, Guo *et al.* 2022, Zeng 2023).

The Zoige alpine wetland, located in the Eastern Tibetan Plateau, is the largest plateau peat swamp in the world (Gao *et al.* 2018). The water table of the wetland has decreased significantly in recent years due to climate change and human activity (Zeng *et al.* 2021). The patterns and processes of wetlands have changed noticeably; specifically, the morphological traits of plants are moving towards dwarfism (Zeng *et al.* 2021). *Carex muliensis* Hand.-Mazz., an endemic and dominant sedge species is widely distributed in the alpine wetland in the Tibetan Plateau (Dong *et al.* 2020). The existing research on *C. muliensis* is limited and primarily focused on the plant biomass and morphological characteristics (Dong *et al.* 2020, Zeng *et al.* 2021). However, it remains elusive how plants adjust WUE, NUE and their relationship to adapt to the water-table variety under the context of global change. Therefore, the present study was aimed to examine the leaf $\delta^{13}C$ and C:N ratio of *C. muliensis* in response to the declining water tables in the Tibetan Plateau.

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The study area was located in the Riganqiao wetland park in the Eastern Tibetan Plateau (33°05′N, 102°38′E, altitude 3500 m). This area has a continental plateau monsoon climate (Gao *et al.* 2018). The mean annual temperature was 1.1°C. The highest monthly mean temperature was 10.9°C in July and the lowest was –10.3°C in January. The mean annual precipitation was 753 mm. Vegetation in the alpine wetland was dominated by *Carex muliensis, Tongoloa gracilis* H.Wolff and *Caltha scaposa* Hook. f. & Thomson. The soil was classified as peat (Gao *et al.* 2018).

The water table of study area was high in the center and low at the edges. In total, six sites were selected along a water table transect from the center to the edge of the wetlands in August 2021. The mean annual water tables at these six sites were 18.9, 0.3, –23.5, –41.6, –58.3, and –79.0 cm (Zeng *et al.* 2021). Positive values represent the height of the water table above ground level, whereas negative values represent its depth below ground level. Three random (10 × 10) m plots were established at each site to collect the plant samples. In each plot, newly mature leaves of more than 30 plants of *C. muliensis* were collected. All leaf samples were oven-dried at 65°C for 48 hrs to constant weight and grounded using a mill before passing through a 60-mesh screen (Zeng 2023).

The elemental analyser (Elementar Vario Max, Langenselbold, Germany) was used to assess the plant leaf C and N concentration. Leaf $\delta^{13}C$ (isotope ratio of $^{13}C/^{12}C$) was analyzed using an isotope ratio mass spectrometer (Delta Plus, Thermo Finnigan, Berlin, Germany) interfaced with an elemental analyzer (Euro EA 3000, EuroVector, Milan, Italy). Plant WUE was defined as leaf $\delta^{13}C$ values according to the leaf $\delta^{13}C$ values reflected by the Ci:Ca ratio, an important physiological index concerning the stomatal behaviour and WUE (Peri *et al.* 2012). Plant NUE was calculated by the ratio of the leaf C:N, which indicates the plant C gain per unit N (Zeng 2023).

One-way ANOVA was conducted to test the effects of wetland water table on leaf $\delta^{13}C$, C, N and C:N ratios before carrying out the parametric tests. All data were checked for normality and homogeneity of the variances. Regression analysis was used to test the patterns in leaf $\delta^{13}C$, C, N and C:N ratio along the water table gradient. Statistical procedures were conducted using SPSS version 24.0 (IBM, Armonk, USA).

Across the water-table gradient, the mean values of leaf C and N contents of *C. muliensis* were found to be 450.84 and 17.32 g/kg, respectively. The data range for leaf C and N were 441.46 - 458.13 g/kg and 13.63 - 21.24 g/kg, respectively (Fig. 1). The leaf C stayed unchanged along the water table gradient (Fig. 1a). The water table significantly influenced the leaf N and exhibited a non-linear change with leaf N. The leaf N reached its peak when the water table was 58.3 cm below the surface (Fig. 1b).

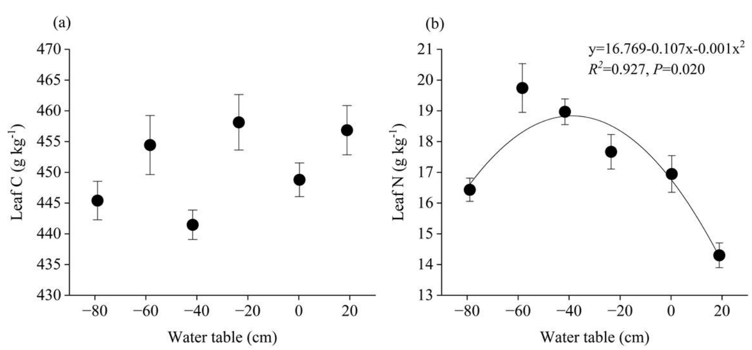

Fig. 1. Variation of leaf carbon (C) and nitrogen (N) contents along the water table gradient.

The leaf $\delta^{13}C$ and C:N ratio exhibited variations across all sites in the alpine wetland, ranging from –24.96 to –29.03 ‰ and 21.69 to 32.99, respectively, but their average values were –26.97 ‰ and 26.37, respectively. The relationship between the water table and the leaf $\delta^{13}C$ / leaf C:N exhibited a quadratic function (Fig. 2). The leaf $\delta^{13}C$ initially increased and subsequently decreased with the deceasing water table, with the threshold water table being –40 cm (Fig. 2a). The leaf C:N initially decreased and then increased with the deceasing water table, with a threshold of about 40 cm (Fig. 2b). Further, the leaf $\delta^{13}C$ exhibited a negative correlation with the leaf C:N ratio (Fig. 3).

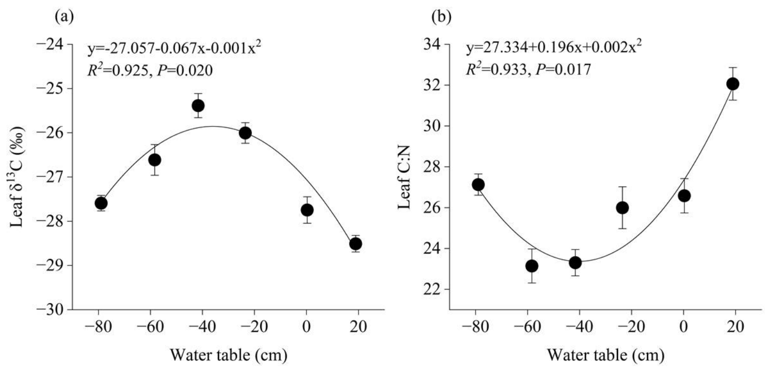

Fig. 2. Variation of Leaf $\delta^{13}C$ and leaf C:N ratio along the water table gradient.

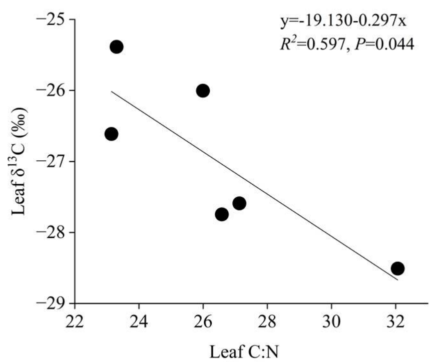

Fig. 3. Relationships between leaf $\delta^{13}C$ and leaf C:N ratio.

It was observed that the leaf C and N contents of *C. muliensis* responded differently to the water table drawdown in the present study. The leaf C content was almost unaffected by water table, in line with previous research (Zeng 2023), mainly due to the stable plant C composition and structural basis (Ågren 2008). Further, the leaf N content was strongly affected by water table, with an increasing and then deceasing trend.

A nonlinear response of NUE across water table gradients was observed in the alpine wetland in the present study. The leaf C:N decreased when water table declined from 20 cm to –40 cm, and then increased until 80 cm. Usually a decrease in plant NUE occurs when soil moisture conditions deteriorate (Dijkstra *et al.* 2016, Hu *et al*. 2023). Plants adapt to lower water table by increasing their N content, accordingly decreasing NUE, to promote the water uptake and utilization (Su and Shangguan 2020). When the water table exceeded –40 cm, with an increase in the drought severity, the plant was forced to utilize more efficiently limited water resources in the soil, thereby leading to a maximal NUE (Hu *et al.* 2023). The results indicated that *C. muliensis* could alter the absorption of N source, thus regulating the acclimation of this alpine plant to water deficit stress.

The present study revealed that the WUE and NUE of *C. muliensis* exhibited a nonlinear correlation with water table drawdown in the alpine wetland in the Tibetan Plateau, and there was a tradeoff between WUE and PUE in *C. muliensis*. The optimum water table for this alpine plant to make the best use of water sources and show highest WUE under water deficit was –40 cm. The findings of this study can have implications in the alpine wetland management, particularly in terms of degraded wetland restoration, for e.g., by maintaining the appropriate level of water depth according to drought severity, the optimization and balancing of NUE and WUE can be achieved. This can assist in gaining maximum benefits with special respect to ecosystem productivity.

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