INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
19–0068/2019/22–6–1385–1392
DOI: 10.17957/IJAB/15.1211
http://www.fspublishers.org

***Full Length Article***

# Effects of Transient Flooding on Leaf Litter Decomposition: A Case Study of *Populus euphratica* Leaf in an Arid Area

**Yuhai Yang[1,2†], Honghua Zhou[1,2†], Zhaoxia Ye[1,2], Chenggang Zhu[1,2] and Yaning Chen[1,2*]**
[1]*State Key Laboratory of Desert and Oasis Ecology, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China*
[2]*University of Chinese Academy of Sciences, China*
[*]For correspondence: chenyn@ms.xjb.ac.cn; yangyh@ms.xjb.ac.cn
[†]These authors contributed equally to this work and should be considered co-first authors

## Abstract

Litter fall decay constitutes a momentous source of nutrients for plant uptake. The change of mass, carbon, nitrogen, phosphorus, and potassium of fresh leaf litter of *Populus euphratica* in transient flooding, control and soil covering treatments was measured using litterbags in a desert riparian forest in a field decomposition experiment for a period of 640 d. The leaf litter mass, carbon, nitrogen, phosphorus, and potassium concentration exhibited different fluctuations with time in different treatments. Varied responses to transient flooding were also found. The transient flooding is shown to promote *P. euphratica* leaf litter decomposition compared to that in no-disturbance conditions. It is also demonstrated that transient flooding can alter the process of nutrient release in leaf litter. © 2019 Friends Science Publishers

**Keywords**: Litter; Nutrient; Leaf; Forest; Decomposition

## Introduction

Litter stored on the forest floor constitutes an input-output system of nutrients, and primary productivity, energy flow and nutrient cycling in forest ecosystems are mainly regulated by the rates of falling and decay of litter (Bray and Gorham, 1964; Thomas *et al.,* 2014). Litter decomposition is a fundamental ecological process and plays a critical role in carbon and nutrient cycling in terrestrial and aquatic ecosystems (Olson, 1963; Pandey *et al.,* 2007; Taylor *et al.,* 2007). It is a complex process with obviously different release rates of various nutrients and a crucial source of inorganic ions for plant uptake, and thus any disturbance that affects this process exert pervasive effects on ecosystem functioning. Leaf litter may account for 22–81% of the annual production of plant litter (Bani *et al.,* 2018). As a primary part of plant litter, decomposition of leaf litter has received considerable attention in tropical and subtropical forests (Alhamd *et al.,* 2004; Goya *et al.,* 2008). In previous studies, researchers mainly focused on environmental conditions, litter quality and decomposing organisms, which act a pivotal component of the decomposition process, generating patterns of temperature, moisture, and nutrient availability that affect organic matter decay (Aerts, 1997; Cornwell *et al.,* 2008; Li *et al.,* 2014). Few researches have focused on the effect of microenvironmental changes due to disturbances, such as transient flooding, on decomposition of forest litters. It is essential to understand the leaf litter decomposition process over time under disturbances in forest ecosystem.

The desert riparian forest is a momentous vegetation type for inland river valleys in arid zones, which forms a natural ecological barrier that protects the oases' development, stabilizes river channels, maintains the ecological balance of river basins, and helps form fecund forest soil (Ling *et al.,* 2015; Rajput *et al.,* 2016). *P. euphratica* Oliv., as a predominant species in desert riparian forest ecosystems, is found in the arid and semi-arid deserts of Mid-Asia. It is not only a vulnerable species among the first group of 388 endangered or rare plants in China, but also an invaluable forest genetic resource in urgent need of global protection (Yang *et al.,* 2015). China possesses the largest range and number of *P. euphratica,* which comprises 61% of the global *P. euphratica* forest (Wang, 1996; Ling *et al.,* 2015). Moreover, the natural *P. euphratica* forest in the Tarim River Basin, Xinjiang, accounts for 54% of the global and 89% of China's *P. euphratica* area, and constitutes an essential tree genetic resource (Ling *et al.,* 2015). However, over recent decades, approximately half of the natural *P. euphratica* forest, especially in the lower reaches of the Tarim River, has disappeared due to water change and interference of human activities in China (Yang *et al.,* 2015). In the lower reaches of the Tarim River, the regeneration and conservation of desert riparian *P.*

**To cite this paper:** Yang, Y., H. Zhou, Z. Ye, C. Zhu and Y. Chen, 2019. Effects of transient flooding on leaf litter decomposition: a case study of *Populus euphratica* leaf in an arid area. *Intl. J. Agric. Biol.,* 22: 1385–1392

*euphratica* forest are mainly affected by disturbances of river flooding and groundwater table level rise along the main channel of the Tarim River (Ling *et al.,* 2015). In the lower reaches of the Tarim River, the desert riparian *P. euphratica* forest can be subject to disturbances by the river flooding prior to 1970. However, from 1970–2000, it could not be disturbed by flooding from run-off of the lower reaches of the Tarim River because it dried up since the 1970s. After 2000, it is only subject to disturbances by transient flooding during water delivery, which was an integrated plan that involves water delivery to the lower reaches of the river (Chen *et al.,* 2013) to prevent continued deterioration of desert riparian forest along the main channel of the lower reaches of the Tarim River.

Riparian zones in floodplains are occasionally or periodically disturbed by flood events (Amlin and Rood, 2001). This disturbance, of which the timing, frequency, intensity, and duration are determined by a flow regime, greatly influences reproduction, survival, growth, community structure, and even patterns of riparian vegetation (Friedman and Lee, 2002; Corenblit *et al.,* 2009; Stromberg *et al.,* 2010). Although many studies of *P. euphratica* have addressed the population dynamics, photosynthesis, water usage, and response to abiotic factor stress in adult *P. euphratica* (Chen *et al.,* 2012; Han *et al.,* 2013; Rajput *et al.,* 2015; Yang *et al.,* 2015, 2017), few comprehensive investigations have been performed on influences of flooding on *P. euphratica* litter decomposition which may have pervasive effects on ecosystem functioning. It is not yet clear whether flooding is beneficial to *P. euphratica* leaf litter decomposition in arid areas. Therefore, a 640 d *in situ* field-based experiment was conducted to determine the decomposition rate and nutrient release/immobilization of *P. euphratica* leaf litter in the lower reaches of the Tarim River. The dynamic of mass, and release/immobilization of carbon, nitrogen, phosphorus, and potassium in fresh fallen leaves of *P. euphratica* were evaluated. The objectives of this research were to elcuidate the decay pattern of leaf litter from *P. euphratica* under transient flooding. The hypotheses in this study were as follows: (1) leaf litter mass loss and nutrient release/immobilization pattern of each nutrient differs due to decomposition time; and (2) transient flooding influence leaf litter decomposition patterns and phases.

## Materials and Methods

### Sample Preparation and Decomposition Experiment

In October 2015, fresh abscised leaves of *P. euphratica* were gathered when most of the leaves had fallen in the lower reaches of the Tarim River. After the removal of contaminating debris, the intact leaves were dried at 50°C for 24 h, and only whole leaves were subsequently stored at room temperature. The leaf litter decomposition experiment was carried out in the field in the lower reaches along the main channel of the Tarim River to measure leaf litter decay and nutrient release/immobilization. The litterbags with dimensions of 25 × 15 cm were made of polyethylene nets (1 mm mesh size). Each bag was filled with 10.0 g leaves. The litter decomposition experiment was established on November 11, 2015. Three litter decomposition treatments were set up: (1) control: litterbags placed on the ground; (2) flooding: litterbags fixed on the ground and immersed in water 5 h (simulating a transient flooding); and (3) soil covering: litterbags covered with soil during the experiment period (Simulating a shallow sand-buried disturbance). The control and soil covering treatments exhibited a common existing state of leaf litter in the lower reaches of the Tarim River. In all, 40 litterbags were placed on the flat surface area by utilizing metal pins to avoid shifting, and to ensure a proper contact between organic soil layers and litterbags in the *P. euphratica* forest at 20 m intervals. The *in situ* experiment lasted up to 640 d. Three litterbags were retrieved from each treatment after 173, 290, 380, 470, 560, and 640 d post-installation, respectively. All of the litterbags were sent to the laboratory. All exogenous material, such as soil particles and roots were removed when the residual leaf litter in each litterbag was carefully cleaned by hand, and then oven-dried at 65$^{o}$C until the mass stabilized, and weighed to determine the dry mass.

### Assessment of Mass Loss

The decomposition rate was reflected by leaf litter mass. The leaf litter mass loss was represented by remaining mass measured for each litterbag at each sampling time.

### Elemental Analysis

The initial chemical composition of leaf litter was analyzed by taking a sample of the leaf litter at 0 d. For the retrieved leaf litter, the oven-dried residual leaf samples were ground and sieved through a 0.5 mm mesh in order to analyze total carbon, nitrogen, phosphorus, and potassium concentrations. The carbon concentration was measured by a total organic carbon analyzer. The nitrogen concentration was evaluated using a semi-micro Kjeldahl method. To measure phosphorus concentration, 0.2 g litter sample was digested in a 10 ml triacid mixture (nitric, perchloric, and sulphuric acid; 5:1:1), and then cooled. The concentration of phosphorus in the digested solution was measured by using the ammonium molybdate stannous chloride method. Content of potassium in the digested solution was tested with a flame atomic absorption spectrophotometer following $HClO_4$-$HNO_3$ digestion (Lu, 1999).

### Data Analysis

One-way analysis of variance (ANOVA) with LSD test was used to test leaf litter mass and nutrient concentration differences among different treatments in the same decomposition time. Significant results were assumed for *P*

$< 0.05$. Using the same analysis method, the leaf litter mass and nutrient concentration among different incubation times for each treatment were analyzed, and significant results were assumed for $P < 0.05$. These analyses were carried out using SPSS 13.0 for Windows (S.P.S.S. Inc., Chicago, Illinois, USA).

## Results

### Mass Loss

The mass loss dynamics of leaf litter in different treatments are shown in Fig. 1. Although there are similar cycles, the periods of mass change are different. In the control treatment, five sequential phases were identified within 640 d: firstly, it remained constant within 0–173 d; secondly, it decreased significantly ($P < 0.05$) within 173–290 d; thirdly, it remained constant within 290–470 d; fourthly, it decreased significantly within 470–560 d ($P < 0.05$); and fifthly, it remained constant within 560–640 d. In the flooding treatment, five sequential phases were found: firstly, it slightly decreased within 0–173 d ($\underline{P} < 0.05$); secondly, it sharply decreased within 173–290 d ($P < 0.05$); thirdly, it slightly changed within 290–380 d; fourthly, it remained constant within 380–560 d; and fifthly, it decreased significantly within 560–640 d ($P < 0.05$). In the soil covering treatment, five sequential phases were identified: firstly, it remained constant within 0–173 d; secondly, it sharply decreased within 173–290 d ($P < 0.05$); thirdly, it slightly increased within 290–380 d; fourthly, it decreased within 380–560 d; and fifthly, it remained constant within 560–640 d.

### Temporal Changes in Nutrient Concentrations of Leaf Litter

**Carbon:** The carbon concentration change of leaf litter had various sequential phases with time in different treatments for a period of 640 d (Fig. 2). In the control treatment, five sequential phases were found: firstly, it increased significantly within 0–173 d ($P < 0.05$); secondly, it decreased significantly within 173–290 d ($P < 0.05$); thirdly, it increased significantly within 290–380 d ($P < 0.05$); fourthly, it remained constant within 380–560 d; and fifthly, it decreased significantly within 560–640 d ($P < 0.05$). In the flooding treatment, five sequential phases were identified: firstly, it remained constant within 0–290 d; secondly, it decreased significantly within 290–380 d ($P < 0.05$); thirdly, it increased significantly within 380–470 d; fourthly, it remained constant within 470–560 d; and fifthly, it decreased significantly within 560–640 d. In the soil covering treatment, it remained constant within 0–640 d.

**Nitrogen:** The nitrogen concentration change of leaf litter exhibited different fluctuations with time in different treatments (Fig. 3). In the control treatment, five sequential phases were identified: firstly, it decreased significantly within 0–173 d ($P < 0.05$); secondly, it increased significantly within 173–290 d ($P < 0.05$); thirdly, it remained constant within 290–380 d; fourthly, it decreased significantly within 380–470 d ($P < 0.05$); and fifthly, it remained constant within 470–640 d. A rapid nitrogen increase occurred within 173–290 d ($P < 0.05$) in the control treatment. In the flooding treatment, five sequential phases were identified: firstly, it decreased significantly within 0–173 d ($P < 0.05$); secondly, there was an obvious increase within 173–290 d ($P < 0.05$); thirdly, it remained constant within 290–380 d; fourthly, it increased significantly within 380–560 d ($P < 0.05$); and fifthly, it decreased within 560–640 d. In the soil covering treatment, it showed two phases: firstly, it remained constant within 0–560 d; and secondly, it increased significantly within 560–640 d.

**Phosphorus:** The phosphorus concentration change of leaf litter exhibited different fluctuations with time in different treatments (Fig. 4). In the control and flooding treatments, the same three sequential phases were identified: firstly, it remained constant within 0–290 d; secondly, there was a significant change within 290–380 d ($P < 0.05$); and thirdly, it remained constant within 380–640 d. In the soil covering treatment, four sequential phases were found: firstly, there was no significant change within 0–380 d; secondly, an significant increase occurred within 380–470 d ($P < 0.05$); thirdly, it decreased significantly within 470–560 d ($P < 0.05$); and fourthly, there was no significant difference within 560–640 d.

**Potassium:** The potassium concentration of leaf litter exhibited different fluctuations with time in different treatments (Fig. 5). In the control and flooding treatments, the same three sequential phases were found: firstly, there was no change with 0–173 d; secondly, it significantly decreased within 173–290 d ($P < 0.05$); and thirdly, it remained constant within 290– 640 d. In the soil covering treatment, five sequential phases were identified: firstly, it increased significantly within 0–173 d ($P < 0.05$); secondly, it decreased significantly within 173–380 d ($P < 0.05$); thirdly, it increased significantly within 380–470 d ($P < 0.05$); fourthly, it decreased within 470–560 ($P < 0.05$); and fifthly, it remained constant within 560–640 d.

### Effect of Transient Flooding on Leaf Litter Mass and Carbon Concentration

The mass and carbon concentration of leaf litter had different responses to disturbances (Fig. 6) during decomposition. At 173, 470, 560 and 640 d, there was no obvious difference in the remaining mass among the three treatments. At 290 d and 380 d, however, the remaining masses of leaf litter in the control and soil covering treatments were significantly different to that in the flooding treatment ($P < 0.05$). For carbon concentration of leaf litter, at 173 d, there was no obvious difference among the three treatments. At 290, 380, 470, 560 and 640 d, there was an obvious difference between the control and flooding treatments and the soil covering treatment ($P < 0.05$).

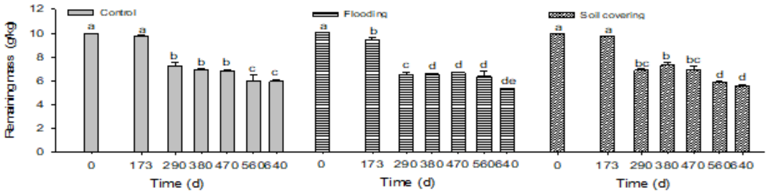

**Fig. 1:** Temporal changes in leaf litter remaining mass in different treatments. Within each graph, histograms with the same letter indicate that the value was not significantly different ($P < 0.05$). Control: litterbags placed on the ground (no disturbance); flooding: litterbags fixed on the ground and immersed in water for 5 h (simulating a flooding disturbance); soil covering: litterbags covered with soil during the experiment period (Simulating a shallow sand-buried disturbance). Values are means + SE

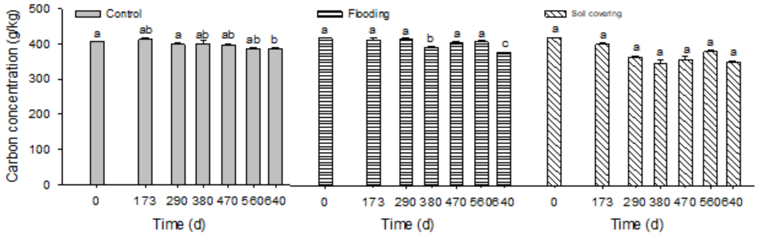

**Fig. 2:** Temporal changes in carbon concentration of leaf litter in different treatments. Within each graph, histograms with the same letter indicate that the value was not significantly different ($P < 0.05$). Control: litterbags placed on the ground (no disturbance); flooding: litterbags fixed on the ground and immersed in water for 5 h (simulating a flooding disturbance); soil covering: litterbags covered with soil during the experiment period (Simulating a shallow sand-buried disturbance). Values are means + SE

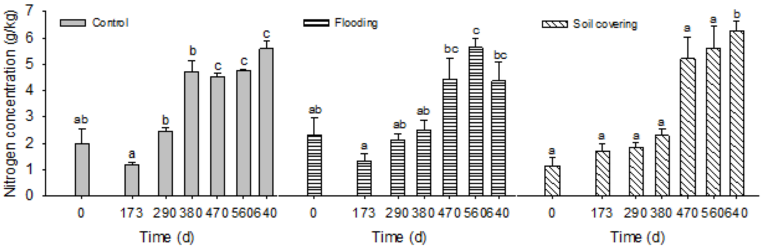

**Fig. 3:** Temporal changes in nitrogen concentration of leaf litter in different treatments. Within each graph, histograms with the same letter indicate that the value was not significantly different ($P < 0.05$). Control: litterbags placed on the ground (no disturbance); flooding: litterbags fixed on the ground and immersed in water for 5 h (simulating a flooding disturbance); soil covering: litterbags covered with soil during the experiment period (Simulating a shallow sand-buried disturbance). Values are means + SE

### Effect of Transient Flooding on Nitrogen, Phosphorus, and Potassium Concentration

The nitrogen, phosphorus, and potassium concentration of leaf litter had different responses to disturbances (Fig. 7). At 173, 290, 380, 470 and 640 d, the nitrogen concentration in the control and flooding treatments was significantly different to that in the soil covering treatment ($P < 0.05$). At 640 d, there was an obvious difference among the three treatments ($P < 0.05$). At 173, 290 and 380 d, the phosphorus concentration in the control and flooding treatments was significantly different to that in the soil covering treatment ($P < 0.05$). At 470 and 560 d, there was no obvious difference among the three treatments. At 640 d, there was an obvious difference between the control and the flooding and soil covering treatments ($P < 0.05$). For potassium concentration, at 173, 470, 560 and 640 d, there was an obvious difference between the control and flooding treatments and the soil covering treatment ($P < 0.05$). At 290 and 640 d, there was an obvious difference among the three treatments.

## Discussion

### Effect of Transient Flooding on Leaf Litter Mass

In dryland ecosystems, mass loss differences are relevant to litter decomposability during diverse incubation periods (different fractions of labile and less readily decomposed organic material) and seasonal variation in decomposing environments in terms of moisture, temperature, or solar radiation (Erdenebileg *et al.,* 2018). The initial stage, comprising several weeks, was characterized by the highest *in situ* mass loss rate, followed by soluble

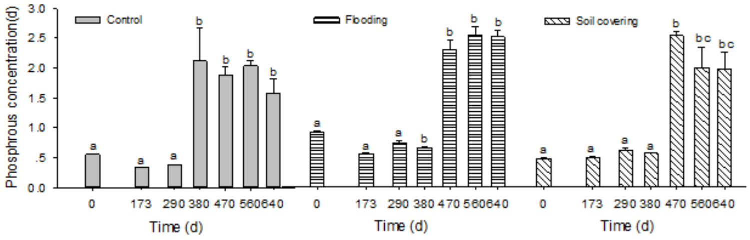

**Fig. 4:** Temporal changes in phosphorus concentration of leaf litter in different treatments. Within each graph, histograms with the same letter indicate that the value was not significantly different (*P* < 0.05). Control: litterbags placed on the ground (no disturbance); flooding: litterbags fixed on the ground and immersed in water for 5 h (simulating a flooding disturbance); soil covering: litterbags covered with soil during the experiment period (Simulating a shallow sand-buried disturbance). Values are means + SE

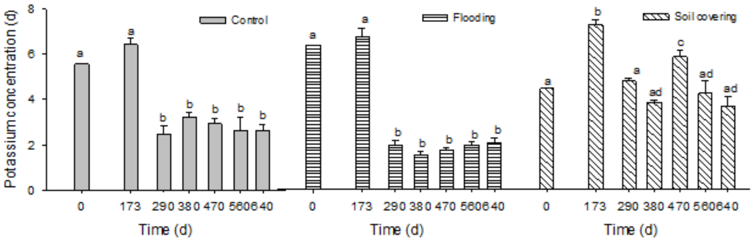

**Fig. 5:** Temporal change in potassium concentration of leaf litter in different treatments. Within each graph, histograms with the same letter indicate that the value was not significantly different (*P* < 0.05). Control: litterbags placed on the ground (no disturbance); flooding: litterbags fixed on the ground and immersed in water for 5 h (simulating a flooding disturbance); soil covering: litterbags covered with soil during the experiment period (Simulating a shallow sand-buried disturbance). Values are means + SE

carbon losses, and correlated with a seasonal fluctuation of this maximum mass loss rate. The subsequent second stage was characterized by slight changes in the mass loss rate (Ngao *et al.*, 2009). Decomposition dynamics of *Cistus incanus* and *Myrtus communis* leaf litter, cellulase and xylanase activity patterns during the early stage of decomposition were more affected by season and its impact on soil moisture availability than by changes of litter quality (Fioretto *et al.*, 2000, 2001, 2007). Temperature and moisture constitute the most important controls on litter mass loss (Cusack *et al.*, 2009). Moisture conditions could make litter decompose rapidly (Hobbie *et al.*, 2010), which is confirmed by our findings. In the current study, the pattern of remaining mass over time suggests that decaying leaves were affected by transient flooding, which confirmed the first hypothesis. Within 0–173 d, less leaf litter mass changed in the control and soil covering treatments, but changed in the flooding treatment, which indicated that environmental factors, such as low temperature (Fig. 8) and less than 50 mm of annual precipitation likely inhibited photochemical and microbial degradation after the experiment installation, but flooding can promote the decomposition process and cause complex changes in leaf litter mass during the decomposition period in the lower reaches of the Tarim River. The processes occurring during the initial stage of litter decomposition were thought to affect the subsequent stage (Berg and Meentemeyer, 2002; Ngao *et al.*, 2009). In this study, the remaining mass decreased with time in all treatments (Fig. 1), and a rapid decrease and a slow decrease in all treatments occurred within 173–290 d and 470–560 d, respectively. This rapid decrease may be ascribed to non-lignified carbohydrates and soluble substances, *e.g.*, hemicelluloses and cellulose decomposed by saprotrophic fungi, and the slow decrease may be primarily attributable to lignin and lignified cellulose remaining in this decomposition phase (Alhamd *et al.*, 2004).

The litter decay process is clearly vital for maintaining soil productivity and fertility in forests. Most data of mass loss are from short term researches, and are used such data to predict long term patterns of decomposition from early decomposition rates in some models. However, early decomposition rates are not precise indicators of decomposition completeness and cautioned against using decay constants generated from early decay rates (Grayston and Prescott, 2005). In the current study, the early decay rates were obviously different from the later decay rates in the three treatments, which means that mass loss data of leaf litter from long-term studies are very critical for accurate assessments of environmental effects in forest management in the future.

## Effect of Transient Flooding on Leaf Litter Nutrient Concentration

Nutrient content in decaying leaves fluctuates over time between immobilization and release, and net retention of dry

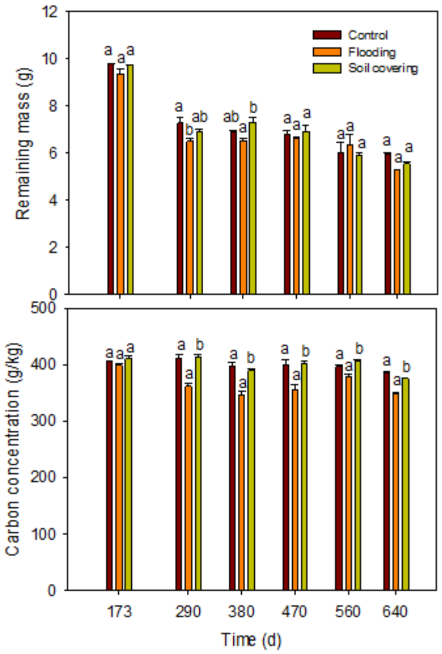

**Fig. 6:** Difference of leaf litter remaining mass and carbon concentration among three treatments in different decomposition times. Within each graph, histograms with the same letter indicate that the value was not significantly different ($P < 0.05$). Control: litterbags placed on the ground (no disturbance); flooding: litterbags fixed on the ground and immersed in water for 5 h (simulating a flooding disturbance); soil covering: litterbags covered with soil during the experiment period (Simulating a shallow sand-buried disturbance). Values are means + SE

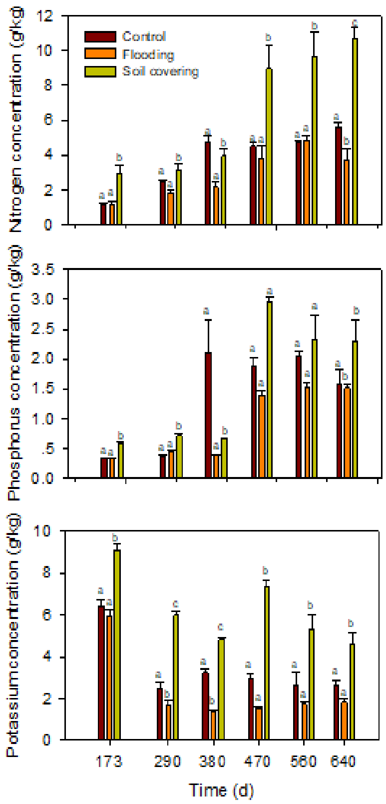

**Fig. 7:** Difference of leaf litter nitrogen, phosphorus, and potassium concentration among three treatments in different decomposition times. Within each graph, histograms with the same letter indicate that the value was not significantly different ($P < 0.05$). Control: litterbags placed on the ground (no disturbance); flooding: litterbags fixed on the ground and immersed in water for 5 h (simulating a flooding disturbance); soil covering: litterbags covered with soil during the experiment period (Simulating a shallow sand-buried disturbance). Values are means + SE

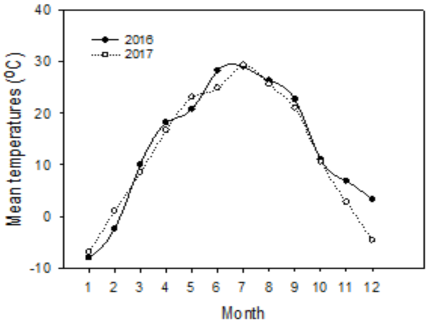

**Fig. 8:** Monthly temperature at the study site, in 2016 and 2017. The data were collected from the weather station nearest to the study area

matter tends to vary with soil type (Alhamd *et al.*, 2004). Release/immobilization occurs in various ways over time depending on nutrient fluidity, concentration, and biological action, as well as the activity of organisms and the physical environment (Goya *et al.*, 2008). Initial nitrogen concentration was the best predictor of net nitrogen immobilization and release in leaves during decomposition (Arunachalam *et al.*, 2005). Gosz *et al.* (1973) reported that nitrogen dynamics in decomposing leaf litter exhibited three sequential phases: (1) the initial release stage dominated by leaching; (2) is the net gain stage with nitrogen imported into the residual material through microbial activity; and (3) is the net loss stage with the nutrient mass absolutely decreased in the decomposing leaf litter. Absolute increments of nitrogen and phosphorus occurred in the decomposition process of *Eucalyptus* spp., litter decomposition process (Corbeels *et al.*, 2003). In this study, complex phases of nitrogen and phosphorus dynamics of leaf litter revealed that the nutrients of leaf litter do not always maintain the same change rule in the decomposition process, but rather changes with disturbances during decomposition (Figs. 3, 4). In the present investigation, nitrogen concentration variations of leaf litter after 640 d incubation exhibited two or three stages, such as leaching, net gain and net loss, in all treatments. It also decreased within 0–173 d in the control and flooding treatments, which indicated that net nitrogen release occurred within this phase of decomposition. Moreover, it was high for the control and flooding treatments within 290–640 d compared with that at 0 d, which indicated that net immobilization occurred within 290–640 d. For the soil covering treatment, it increased within 0–640 d, which suggested that only net immobilization occurred. The different time period of nitrogen net gain and net loss occurring among three treatments showed that disturbances, such as transient flooding, can affect the decomposition process of leaf litter, which confirmed the second hypothesis.

Litter quality is considered the most important controlling factor of decomposition at local scales (Hobbie, 2005). Physical leaf properties (*e.g*., leaf roughness, thickness, and toughness) affected leaf litter decay (Bakker *et al.,* 2011; Cizungu *et al.,* 2014). For similar organic materials, habitat differences in microclimate were not sufficiently large to affect decomposition (Heraldo and William, 2005). However, the remaining mass of *P. euphratica* leaf litter in our study was higher than that of *Populus tremuloides* Michx. (Preston *et al.,* 2000) after a year of decomposition, which suggested that the mass loss rate of leaf litter in the *P. euphratica* forest ecosystem is slower. Furthermore, the leaf litter decomposition process was different in the flooding treatment and soil covering treatment in this study, which indicated that flooding and soil covering may affect leaf litter decomposition even if the leaf litter has the same quality. The flooding may cause changes in microclimate that are sufficient to affect the activity of decomposer organisms that, in turn, affect the leaf litter decomposition. In this study, transient flooding can promote the decomposition of leaf litter, which indicates that flooding is very crucial for desert riparian forest systems to maintain the nutrient cycle in arid area. It is suggested to implement autumn irrigation or tillage in the management of crop land and artificial forests, which can accelerate the decomposition process of litter and promote the nutrient cycle.

## Conclusion

The change of mass, carbon, nitrogen, phosphorus, and potassium of fresh leaf litter of *P. euphratica* in transient flooding was measured using litterbags in a desert riparian forest in a field decomposition experiment for a period of 640 d. Leaf litter mass, carbon, nitrogen, phosphorus, and potassium concentration had different fluctuations with time in different treatments. The mass, carbon, nitrogen, phosphorus, and potassium of leaf litter exhibited different responses to flooding and soil covering. The results demonstrate that transient flooding can promote leaf litter decomposition.

## Acknowledgements

This work was financially supported by the National Natural Science Foundation of (grant no. U1803101, U1703101, 41371503) and Science and Technology Service Network Initiative Project of Chinese Academy of Sciences (KFJ-STS-ZDTP-036).

## References

Aerts, R., 1997. Climate, leaf litter chemistry and leaf litter decomposition in terrestrial ecosystems: A triangular relationship. *Oikos,* 79: 439–449

Alhamd, L., S. Arakaki and A. Hagihara, 2004. Decomposition of leaf litter of four tree in a subtropical evergreen broad-leaved forest, Okinawa Island, Japan. *For. Ecol. Manage.,* 202: 1–11

Amlin, N.A. and S.B. Rood, 2001. Inundation tolerances of riparian Willows and Cottonwoods. *J. Amer. Water Resour. Assoc.,* 37: 1709–1720

Arunachalam, A., K. Upadhyaya, K. Arunachalam and H.N. Pandey, 2005. Litter decomposition and nutrient mineralization dynamics in two bamboo species growing in a 9-year-old ‘‘jhum’’ fallow. *J. Trop. For. Sci.,* 17: 33–44

Bakker, M.A., G. Carreño-Rocabado and L. Poorter, 2011. Leaf economics traits predict litter decomposition of tropical plants and differ among land use types. *Funct. Ecol.,* 25: 473–483

Bani, A., S. Pioli, M. Ventura, P. Panzacchi, L. Borruso, R. Tognetti, G. Tonon and L. Brusetti, 2018. The role of microbial community in the decomposition of leaf litter and deadwood. *Appl. Soil Ecol.,* 126: 75–84

Berg, B. and V. Meentemeyer, 2002. Litter quality in a north European transect versus carbon storage potential. *Plant Soil,* 242: 83–92

Bray, J.R. and E. Gorham, 1964. Litter production in the forests of the world. *Adv. Ecol. Res.,* 2: 101–157

Chen, Y.J., W.H. Li, J.Z. Liu and Y.H. Yang, 2013. Effects of water conveyance embankments on riparian forest communities at the middle reaches of the Tarim River. *Ecohydrology,* 6: 937–948

Chen, Y.P., Y.N. Chen, C.C. Xu and W.H. Li, 2012. Groundwater depth affects the daily course of gas exchange parameters of *Populus euphratica* in arid areas. *Environ. Earth Sci.,* 66: 433–440

Corbeels, M., A.M.O. Connell, T.S. Grove, D.S. Mendham and S.J. Rance, 2003. Nitrogen release from eucalypt leaves and legume residues as influenced by their biochemical quality and degree of contact with soil. *Plant Soil,* 250: 15–28

Corenblit, D., J. Steiger, A.M. Gurnell and R.J. Naiman, 2009. Plants intertwine fluvial landform dynamics with ecological succession and natural selection: a niche construction perspective for riparian systems. *Glob. Ecol. Biogeogr.,* 18: 507–520

Cornwell, W.K., J.H.C. Cornelissen, K. Amatangelo, E. Dorrepaal, V.T. Eviner, O. Godoy, S.E. Hobbie, B. Hoorens, H. Kurokawa, N. PérezeHarguindeguy, H.M. Quested, L.S. Santiago, D.A. Wardle, I.J. Wright, R. Aerts, S.D. Allison, P.V. Bodegom, V. Brovkin, A. Chatain, T.V. Callaghan, S. Díaz, E. Garnier, D.E. Gurvich, E. Kazakou, J.A. Klein, J. Read, P.B. Reich, N.A. Soudzilovskaia, M.V. Vaieretti and M. Westoby, 2008. Plant species traits are the predominant control on litter decomposition rates within biomes worldwide. *Ecol. Lett.,* 11: 1065–1071

Cizungu, L., S. Jeroen, H. Dries, W. Jean, M. Daniel, V.C. Oswald and B. Pascal, 2014. Litterfall and leaf litter decomposition in a central African tropical mountain forest and Eucalyptus plantation. *For. Ecol. Manage.,*326: 109–116

Cusack, D.F., W.W. Chou, W.H. Yang, M.E. Harmon, W.L. Silver and The LIDET Team, 2009. Controls on long-term root and leaf litter decomposition in neotropical forests. *Glob. Change Biol.,* 15: 1339–1355

Erdenebileg, E., X.H. Ye, C.W. Wang, Z.Y. Huang, G.F. Liu and J.H.C. Cornelissen, 2018. Positive and negative effects of UV irradiance explain interaction of litter position and UV exposure on litter decomposition and nutrient dynamics in a semi-arid dune ecosystem. *Soil Biol. Biochem.,* 124: 245–254

Fioretto, A., S. Papa, A. Pellegrino and A. Fuggi, 2007. Decomposition dynamics of *Myrtus communis* and *Quercus iles* leaf litter: Mass loss, microbial activity and quality change. *Appl. Soil Ecol.,* 36: 32–47

Fioretto, A., S. Papa, G. Sorrentino and A. Fuggi, 2001. Decomposition of *Cistus incanus* leaf litter in a Mediterranean maquis ecosystem: mass loss, microbial enzyme activities and nutrient changes. *Soil Biol. Biochem.,* 33: 311–321

Fioretto, A., S. Papa, E.C. Curcio, G. Sorrentino and A. Fuggi, 2000. Enzyme dynamics on decomposing leaf litter of *Cistus incanu*s and *Myrtus communis* in a Mediterranean ecosystem. *Soil Biol. Biochem.,* 32: 1847–1855

Friedman, J.M. and V.J. Lee, 2002. Extreme floods, channel change, and riparian forests along ephemeral streams. *Ecol. Monogr.*, 72: 409–425

Gosz, J.R., G.E. Likens and F.H. Bormann, 1973. Nutrient release from decomposing leaf and branch litter in the Hubbard Brook Forest, New Hampshir. *Ecol. Monogr.,* 43: 173–191

Goya, J.F., J.L. Frangia, C. Péreza and F.D. Teab, 2008. Decomposition and nutrient release from leaf litter in *Eucalyptus grandis* plantations on three different soils in Entre Ríos, Argentina. *Bosque*, 29: 217–226

Grayston, S.J. and C.E. Prescott, 2005. Microbial communities in forest floors under four tree species in coastal British Columbia. *Soil Biol. Biochem.*, 37: 1157–1167

Han, L., L.Q. Xi, J.Q. Wang, H.Z. Wang and Z.R. Yu, 2013. Life history characteristics and spatial distribution of *Populus* pruinosa population at the upper reaches of Tarim River. *Acta Ecol. Sin.,* 33: 6181–6190

Heraldo, L.V. and F.L. William, 2005. Influence of habitat, litter type, and soil invertebrates on leaf-litter decomposition in a fragmented Amazonian landscape. *Oecologia,* 144: 456–462

Hobbie, S.E., 2005. Contrasting effects of substrate and fertilizer nitrogen on the early stages of litter decomposition. *Ecosystems,* 8: 644–656

Hobbie, S.E., J. Oleksyn, D.M. Eissenstat and P.B. Reich, 2010. Fine root decomposition rates do not mirror those of leaf litter among temperate tree species. *Oecologia,* 162: 505–513

Ling, H., P. Zhang, H. Xu and X. Zhao, 2015. How to regenerate and protect desert riparian *Populus euphratica* forest in arid areas. *Sci. Rep.,* 5: 1–12

Li, S., W.Y. Liu, D.W. Li, Z.X. Li, L. Song, K. Chen and F. Yun, 2014. Slower rates of litter decomposition of dominant epiphytes in the canopy than on the forest floor in a subtropical montane forest, southwest China. *Soil Biol. Biochem.,* 70: 211–220

Lu, R.K., 1999. *Soil argrochemistry analysis protocoes.* Beijing: China Agriculture Science Press (In Chinese)

Ngao, J., F. Bernhard-Reversat and J. Loumeto, 2009. Changes in *Eucalypt* litter quality during the first three months of field decomposition in a Congolese plantation. *Appl. Soil Ecol.,* 42: 191–199

Olson, J.S., 1963. Energy storage and balance of producers and decomposer in ecological systems. *Ecology*, 44: 322–331

Pandey, R.R., G. Sharma, S.K. Tripathi and A.K. Singh, 2007. Litterfall, litter decomposition and nutrient dynamics in a subtropical natural oak forest and managed plantation in northeastern India. *For. Ecol. Manage.,* 240: 96–104

Preston, C.M., J.A. Trofmymow and Canadian Intersite Decomposition Experiment Working Group, 2000. Variability in litter quality and its relationship to litter decay in Canadian forests. *Can. J. Bot.,* 78: 1269–1287

Rajput, V.D., M. Tatiana, Y.N. Chen, S. Svetlana, A.C. Victor and M. Saglara, 2016. A review on salinity adaptation mechanism and characteristics of *Populus euphratica*, a boon for arid ecosystems. *Acta Ecol. Sin.*, 36: 497–503

Rajput, V.D., Y.N. Chen and M. Ayup, 2015. High Salinity on physiological and anatomical indices in the early stages of *Populus euphratica* growth. *Russ. J Plant Physiol.,* 2: 229–236

Stromberg, J.C., M.G.F. Tluczek, A.F. Hazelton and A. Hoori, 2010. A century of riparian forest expansion following extreme disturbance: spatiotemporal change in *Populus/Salix/Tamarix* forests along the Upper San Pedro River, Arizona, U.S.A. *For. Ecol. Manage.,* 259: 1181–1189

Taylor, B.R., C. Mallaley and J.F. Cairns, 2007. Limited evidence that mixing leaf litter accelerates decomposition or increases diversity of decomposers in streams of eastern Canada. *Hydrobiologia,* 592: 405–422

Thomas, K., C.M. Jijeesh and K.K. Seethalakshmi, 2014. Litter production, decomposition and nutrient mineralization dynamics of *Ochlandra setigera*: A rare bamboo species of Nilgiri Biospher Reserve, India. *J. For. Res.,* 25: 579–584

Wang, S.J., 1996. The Status, Conservation and Recovery of Global Resources of *Populus euphradica*. *World For. Res.,* 6: 37–44 (In Chinese)

Yang, Y.H., Y.N. Chen, W.H. Li, C.G. Zhu and M. Waqas, 2017. Inoculation of *Funneliformis mosseae* to enhance desiccation tolerance of *Populus euphratica* seedling in hyper-arid region. *Intl. J. Agric. Biol.,* 19: 983–991

Yang, Y.H., Y.N. Chen, W.H. Li and C.G. Zhu, 2015. Effects of progressive soil water deficit on growth, and physiological and biochemical responses of *Populus euphratica* in arid area: A case study in China. *Pak. J. Bot.,* 47: 2077–2084

**[Received 15 Jan 2019; Accepted 19 Jul 2019; Published (online) 22 Dec 2019]**