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RESEARCH ARTICLE

Soil respiration in typical plant communities in the wetland surrounding the high-salinity Ebinur Lake

Yanhong LI (✉)[1,2], Mingliang ZHAO[1,2], Fadong LI[1,2,3,4]

1 Xinjiang Normal University, College of Geography and Tourism, Urumqi 830054, China
2 Key Laboratory of Xinjiang Uygur Autonomous Region, Xinjiang Laboratory of Lake Environment and Resources in Arid Area, Urumqi 830054, China
3 Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
4 College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100190, China

Abstract Soil respiration in wetlands surrounding lakes is a vital component of the soil carbon cycle in arid regions. However, information remains limited on the soil respiration around highly saline lakes during the plant growing season. Here, we aimed to evaluate diurnal and seasonal variation in soil respiration to elucidate the controlling factors in the wetland of Ebinur Lake, Xinjiang Uygur Autonomous Region, western China. We used a soil carbon flux automatic analyzer (LI-840A) to measure soil respiration rates during the growing season (April to November) in two fields covered by reeds and tamarisk and one field with no vegetation (bare soil) from 2015 to 2016. The results showed a single peak in the diurnal pattern of soil respiration from 11:00 to 17:00 for plots covered in reeds, tamarisk, and bare soil, with minimum values being detected from 03:00 to 07:00. During the growing season, the soil respiration of reeds and tamarisk peaked during the thriving period (4.16 and 3.75 $\mu mol \cdot m^{-2} \cdot s^{-1}$, respectively), while that of bare soil peaked during the intermediate growth period (0.74 $\mu mol \cdot m^{-2} \cdot s^{-1}$). The soil respiration in all three plots was lowest during the wintering period (0.08, 0.09, and -0.87 $\mu mol \cdot m^{-2} \cdot s^{-1}$, respectively). Air temperature and relative humidity significantly influenced soil respiration. A significant linear relationship was detected between soil respiration and soil temperature for reeds, tamarisk, and bare soil. The average Q_{10} of reeds and tamarisk were larger than that of bare soil. However, soil moisture content was not the main factor controlling soil respiration. Soil respiration was negatively correlated with soil pH and soil salinity in all three plot types. In contrast, soil respiration was positively correlated with organic carbon. Overall, CO_2 emissions and greenhouse gases had a relatively weak effect on the wetlands surrounding the highly saline Ebinur Lake.

Keywords Ebinur Lake, soil respiration, high salinity, soil temperature, soil moisture

1 Introduction

Soil respiration is an important element of the carbon cycle in terrestrial ecosystems and an important source of atmospheric CO_2. The emission of CO_2 from terrestrial ecosystems into the atmosphere constitutes one of the largest sources of carbon flux (Schlesinger and Andrews, 2000). Wetlands cover 1%–2% of the Earth's surface area (Matthews and Fung, 1987); however, the carbon stored in wetlands accounts for 11% of carbon stored in global soils (Franzen, 1992). Wetlands are organic carbon pools that serve as a source or sink of greenhouse gases. Therefore, wetlands are an important component of the global carbon cycle (Nahlik and Fennessy, 2016). Thus, it is important to protect the carbon stock of wetland soils to mitigate the continued increase of greenhouse gases entering the atmosphere. Arid and semi-arid land areas account for 41% of the global land area (Reynolds et al., 2007). These areas are highly fragile ecosystems that represent important components of the overall global ecological environment. Wetlands surrounding lakes perform several important functions in arid regions, including climate regulation, sandstorm mitigation, and biodiversity maintenance. However, soil salinization is a significant threat of desertification and ecological degradation in wetlands and arid regions (Wang and Jia, 2012; Herbert et al., 2015). In view of global warming and soil salinization, research on how carbon flux in arid regions and high-salinity

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E-mail: lyh0704@126.com

wetland soils affects the carbon budget of terrestrial ecosystems and global climate change has become a hot topic.

Brix et al. (2001) suggested that only 15% of the net assimilation rate of carbon in wetland plants is re-emitted to the atmosphere. Thus, wetland ecosystems might function as carbon sinks to inhibit rises in atmospheric CO_2. Research on *Carex* meadow growing near Poyang Lake (a freshwater lake) in China during the drawdown periods revealed the carbon flux released from the soil. In addition, soil respiration is highly correlated with atmospheric temperature and soil temperature (Hu et al., 2015). A study by Li et al. (2012) in Ngoring lakeside, which is the largest freshwater lake in the Qinghai Tibet Plateau, showed that the rate of carbon sequestration near the lake was significantly larger than that of carbon emissions during summer, leading to negative CO_2 fluxes. Wei et al. (2011) analyzed the diurnal and seasonal emission dynamics of the saline Lake Nam (Namtso) in China, and showed that soil temperature significantly affected CO_2 fluxes. Chen et al. (2014) demonstrated that during the growing seasons, alpine meadows and grasslands are sources of carbon, with soil moisture strongly regulating soil respiration. Yang et al. (2009) monitored soil respiration in various typical plant communities growing in the high-salinity, arid region of Ebinur Lake in China, and discovered that the diurnal soil respiration dynamics of reeds exhibit a single daily peak, with the soil functioning as a carbon source. However, it remains unclear whether soil functions as a source or sink of carbon in wetlands surrounding lakes in arid regions, as studies on these habitats remain limited compared to those in forests, grasslands, and farmland ecosystems.

This study aimed to investigate the soil respiration dynamics in the wetlands surrounding the high-salinity Ebinur Lake located in northwest China. The soil respiration of plots covered in reeds, tamarisk, or no vegetation (bare soil) was evaluated in parallel to measuring other parameters such as air humidity, air temperature, soil temperature, and moisture. Our main objectives were to: (i) understand the diurnal and seasonal dynamics of soil respiration in plots covered in reeds, tamarisk, and bare soil over different growing seasons, (ii) determine which factors influence soil respiration, and (iii) assess the greenhouse effect of the wetland surrounding Ebinur Lake. Our results are expected to provide new insights on how wetlands in arid regions contribute to regulating carbon fluxes.

2 Materials and methods

2.1 Site description

The study was conducted at Niaodao station in Ebinur Lake (82°36′–82°5′ E, 44°30′–45°09′ N, elevation 191 m), in the Xinjiang Uygur Autonomous Region of northwest China (Fig. 1). The local area is characterized by a typical arid continental climate that has clear diurnal and seasonal temperature variations and low precipitation. The mean annual temperature is 6°C–8°C, with maximum and minimum extreme temperatures of 44°C and −33°C, respectively. The mean annual precipitation and evaporation are approximately 100 mm and 1600 mm, respectively. Vegetation cover is patchy and soil salinization is severe. Quadrat surveys showed that the typical plant community is composed of reeds (*Phragmites australis*) and tamarisk (*Tamarix ramosissima*); thus, these two communities were selected for the current study. For comparison, a site with no vegetation (bare soil) was

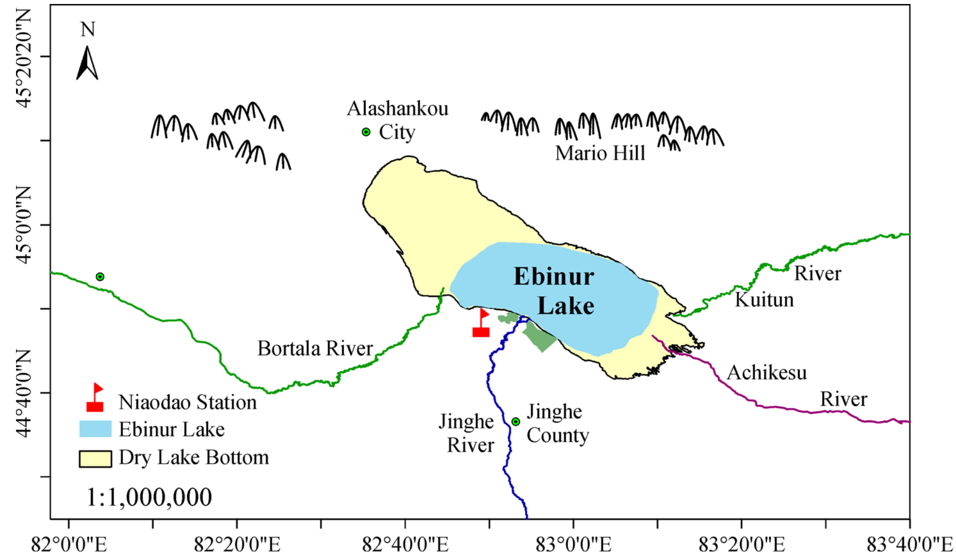

Fig. 1 Location of the study area.

Table 1 Characteristics of the soil in the study area

Plant community	pH	Salt content /(g·kg^{-1})	SOC /(g·kg^{-1})	Salinization type	Soil texture	Coverage	Average height/m
Reed	8.15±0.41	17.39±3.22	29.62±2.81	High salinity	Clay	70%	1.84
Tamarisk	7.98±0.55	44.63±24.37	12.89±4.53	Moderate salinity	Silt, clay	50%	1.79
Bare soil	8.01±0.67	5.03±1.98	2.91±2.24	Low salinity	Sand, fine sand	0%	0

Notes: SOC, soil organic carbon. The data represent the mean±standard error for three replicates.

selected. See Table 1 for the characteristics of the selected plots.

2.2 Measurement of soil respiration

Soil respiration was measured using a soil carbon flux automatic analyzer (LI-840A) with a chamber (Licor, USA) at the different growing periods of vegetation. These periods were: sprouting period (April), rapid growth period (May), intermediate growth period (June), heading period (August), withering period (October), and wintering period (November) in 2015 and 2016. In each plot, a stainless-steel collar (20 cm diameter, 12 cm height) with a groove was placed at random in the soil to a depth of about 5 cm. Three replicates were completed in the reed, tamarisk, and bare soil plots. To minimally disturb the soil, on the day before taking the measurement, the aboveground vegetation and litter were cut to ground level and the stainless-steel collar was inserted into the soil. The collar was then not moved during the measurement duration at each growth period (from April to November). During the course of measurements, the sampling chamber was placed into a groove of the stainless-steel collar and sealed with distilled water. Diurnal variation of soil respiration was measured for 6 min every 2 h from 09:00 on the first day to 08:00 on the second day at each growing period. The respiration rate between 09:00 and 11:00 in the morning and the average of the diurnal dynamic measurements were used to calculate the seasonal dynamic respiration.

2.3 Measurement of environmental factors

During field measurements, data on the air temperature and humidity of the near surface soil, soil temperature, and soil water content (at a depth of 5 cm) were also collected. Air temperature and humidity were measured with a SMART digital humidity & temperature sensor (AS817, Jumaoyuan Technology Co., Ltd, Shenzhen, China). Soil temperature was measured at a depth of 5 cm with an MS-10 soil temperature sensor (Rainroot technology Co., Ltd, Beijing, China). To determine soil water content, an oven-drying method was used. Soil samples were taken within a depth range of 0–5 cm. After drying, crushing, and filtering the soil through a 20-mm sieve, the total salt content of the soil (soil-to-water ratio of 1:5) was measured using drying method (Bao, 2005). pH values were determined by the 1:2.5 water method with a precision pH meter model (Hanna, USA). Soil organic matter (SOM) was determined by the potassium dichromate wet combustion procedure.

2.4 Data processing

All statistical procedures were processed using the software packages SPSS 16.0 (SPSS Inc., USA) and Excel (Microsoft Corp., 2007). Graphs were prepared using SigmaPlot 10.0 (SPSS Inc., USA). Q_{10} values were calculated by assuming that soil respiration increases with temperature every 10°C or the formula: $Q_{10} = e^{10b}$ (Luo et al., 2001). The effects of air temperature and humidity, soil temperature, soil water content, soil total salt content, soil pH, and soil organic carbon on soil respiration were assessed using a Pearson correlation analysis. Regression analysis models were used to explore the relationship between soil respiration and environmental factors.

3 Results

3.1 Diurnal dynamics of soil respiration in reed, tamarisk, and bare soil

The diurnal patterns of soil respiration rates of reed, tamarisk, and bare soil were similar at the different growing periods, showing asymmetrical, single-peak curves (Fig. 2). The peak value of soil respiration rates in reed, tamarisk, and bare soil occurred between 11:00–15:00, 11:00–17:00, and 13:00–17:00, respectively, across the various growing periods. The minimum values were recorded between 3:00–7:00, 3:00–7:00, and 3:00–5:00, respectively. Out of all growing periods, the greatest peak in soil respiration occurred at 13:00 during the heading period in reed and tamarisk habitats (5.56 and 5.01 μmol·m^{-2}·s^{-1}, respectively). For bare soil, soil respiration showed the greatest peak at 11:00 during the intermediate growth period (1.69 μmol·m^{-2}·s^{-1}). Diurnal mean soil respiration data showed that soil supporting reeds and tamarisk functioned as a carbon emitter at all growing periods, except in the wintering period when reeds became a weak carbon sink (−0.06 μmol·m^{-2}·s^{-1}). The bare soil consumed atmospheric carbon in some way, and became a carbon sink during the sprouting period (−0.46 μmol·m^{-2}·s^{-1}), rapid growth period (−0.02 μmol·m^{-2}·s^{-1}), withering period (−0.28 μmol·m^{-2}·s^{-1}), and wintering period (−0.99 μmol·m^{-2}·s^{-1}).

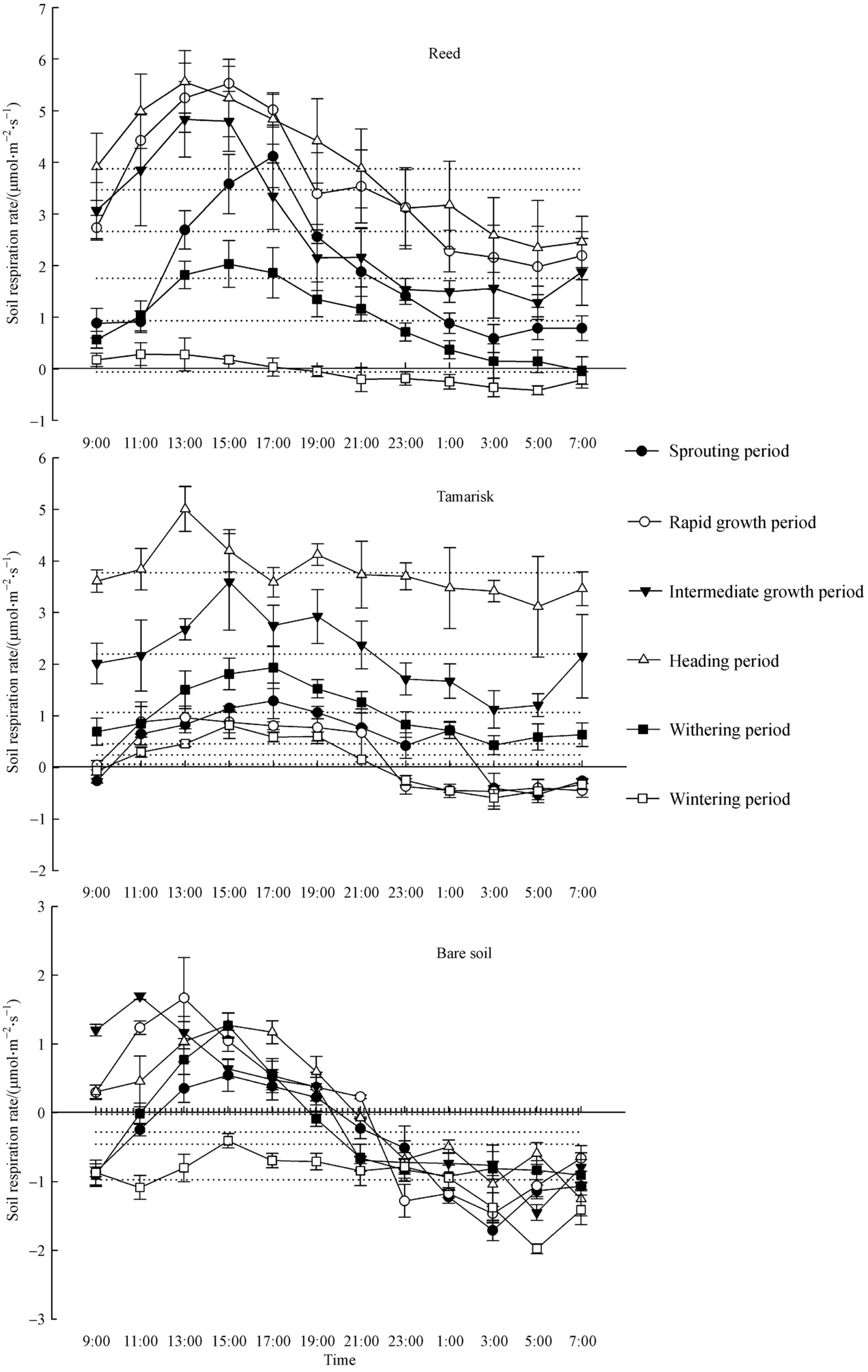

Fig. 2 Daily dynamics of the soil respiration rate of plots supporting reeds and tamarisk versus bare soil.

3.2 Seasonal dynamics of soil respiration in reed, tamarisk, and bare soil

Soil respiration in reed, tamarisk, and bare soil demonstrated clear single-peak seasonal dynamics (Fig. 3). The soil respiration rate of reed, tamarisk, and bare soil gradually ascended with increasing temperature during the sprouting period. Soil respiration of the reed and tamarisk habitats peaked during the thriving period (4.16 and 3.75 μmol·m^{-2}·s^{-1}, respectively), whereas that of bare soil peaked (0.74 μmol·m^{-2}·s^{-1}) during the intermediate growth period. During the withering period, soil respiration clearly declined, with the lowest values for reed, tamarisk, and bare soil occurring after the wintering period (0.08, 0.09, and −0.87 μmol·m^{-2}·s^{-1}, respectively). Throughout the entire monitoring period, the reed habitat had the highest soil respiration rate (2.17 μmol·m^{-2}·s^{-1}), followed by tamarisk (1.26 μmol·m^{-2}·s^{-1}), and bare soil (−0.07 μmol·m^{-2}·s^{-1}). The soil respiration of bare soil exhibited a net carbon sink effect during the sprouting, withering, and wintering periods.

3.3 Effects of air temperature and relative humidity on soil respiration

The soil respiration rate increased gradually with increasing air temperature; however, the soil respiration rate decreased gradually with relative air humidity (except during the wintering period for reed and bare soil) (Fig. 4 and Fig. 5). There were significantly positive correlations between the soil respiration rate and air temperature at different growing periods. In contrast, there were significantly negative correlations between the soil respiration rate and relative air humidity (except during the wintering period for reed and bare soil). The linear and exponential models fit the relationship between the soil respiration rate of the reed habitat and air temperature ($P < 0.05$ or $P < 0.01$) and relative humidity ($P < 0.05$ or $P < 0.01$, except during the wintering period) well. In these models, air temperature and relative humidity explained 35%–92.7% (mean: 74.8%) and 1.1%–92.1% (mean: 66.5%) of diurnal variation for soil respiration at the different growth periods of the reed habitat. Linear models matched the described relationship between the soil respiration rate of the tamarisk habitat with bare soil, air temperature, and relative humidity well. In these models, air temperature and relative humidity explained 48.7%–88.2% (mean: 64.8%) and 15.4%–95.3% (mean: 53.3%) of diurnal variation in the soil respiration of tamarisk habitat. In these models, air temperature and relative humidity explained 33.3%–91.1% (mean: 60.1%) and 9%–88.8% (mean: 57.4%) of diurnal variation in the soil respiration of the bare soil habitat. Thus, air temperature and relative humidity had different effects on the soil respiration rate.

3.4 Effects of soil temperature on soil respiration

Diurnal variation in soil respiration was significantly correlated with soil temperature at the 5 cm soil depth ($P < 0.01$ or $P < 0.05$) at the different growth periods. The

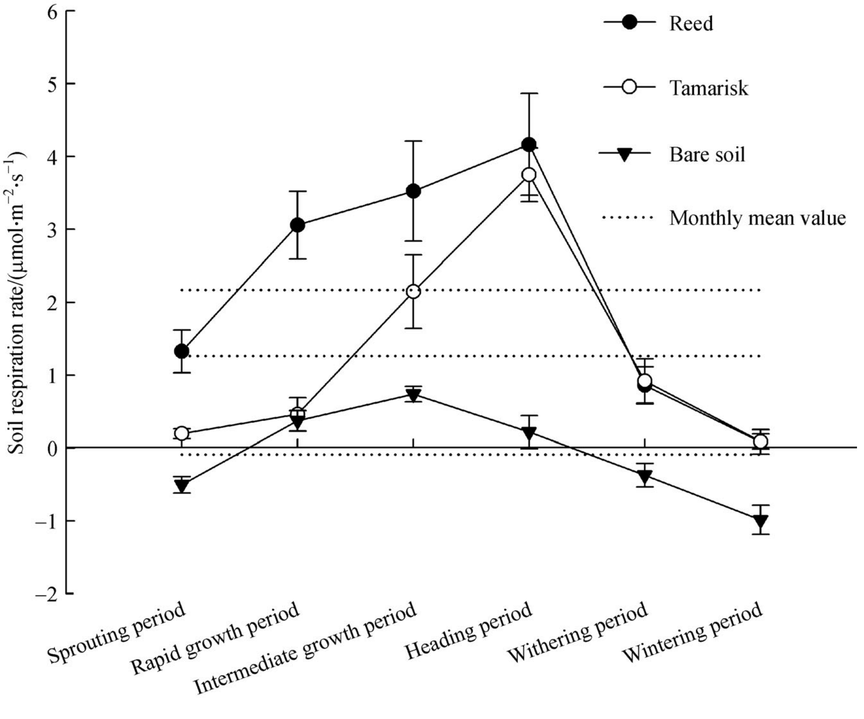

Fig. 3 Seasonal dynamics of the soil respiration rate of plots supporting reeds and tamarisk versus bare soil.

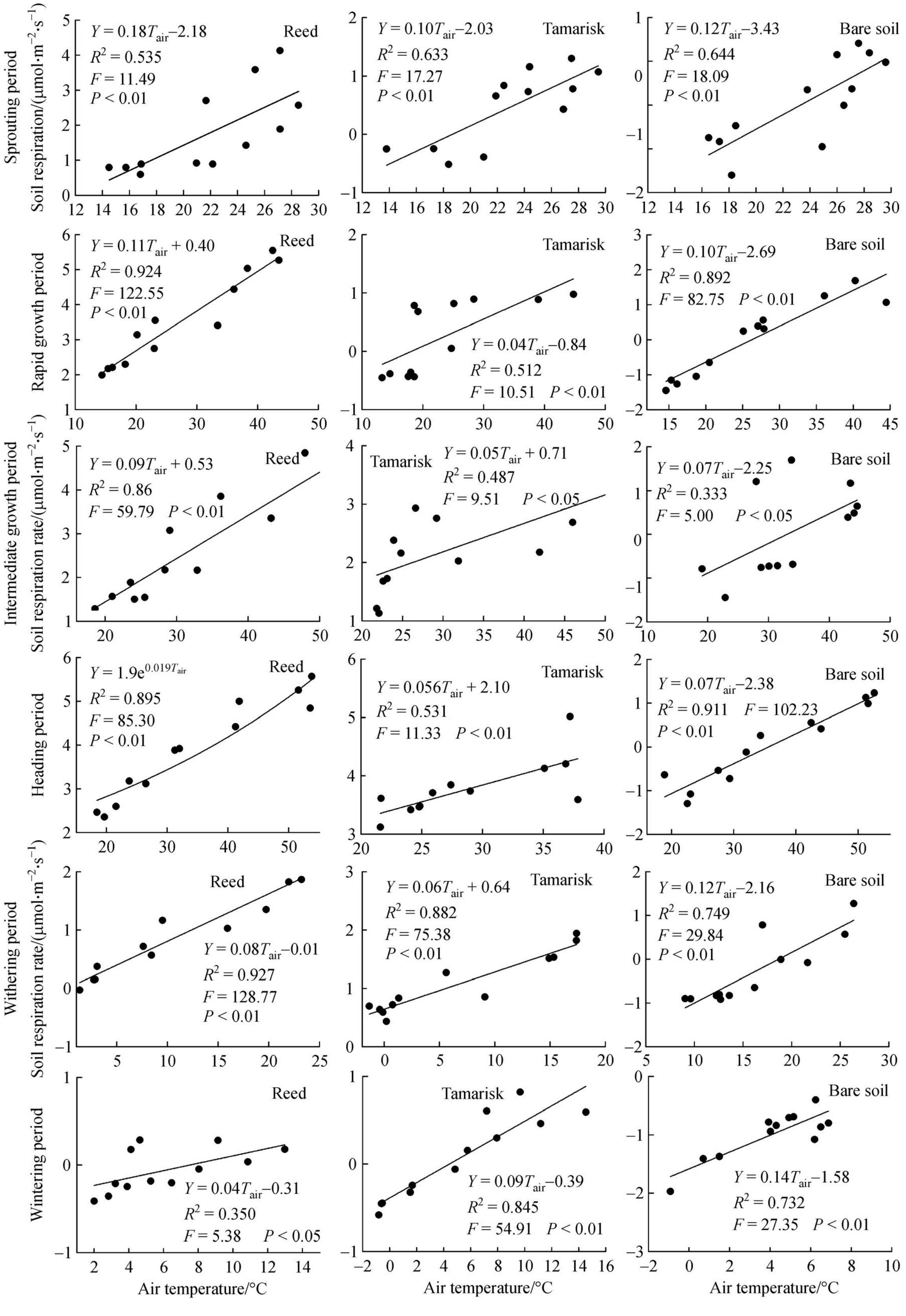

Fig. 4 Regression analysis between soil respiration rates and air temperature of plots supporting different growth periods of reeds and tamarisk versus bare soil. "Y" represents the soil respiration rate; "T_{air}" represents air temperature.

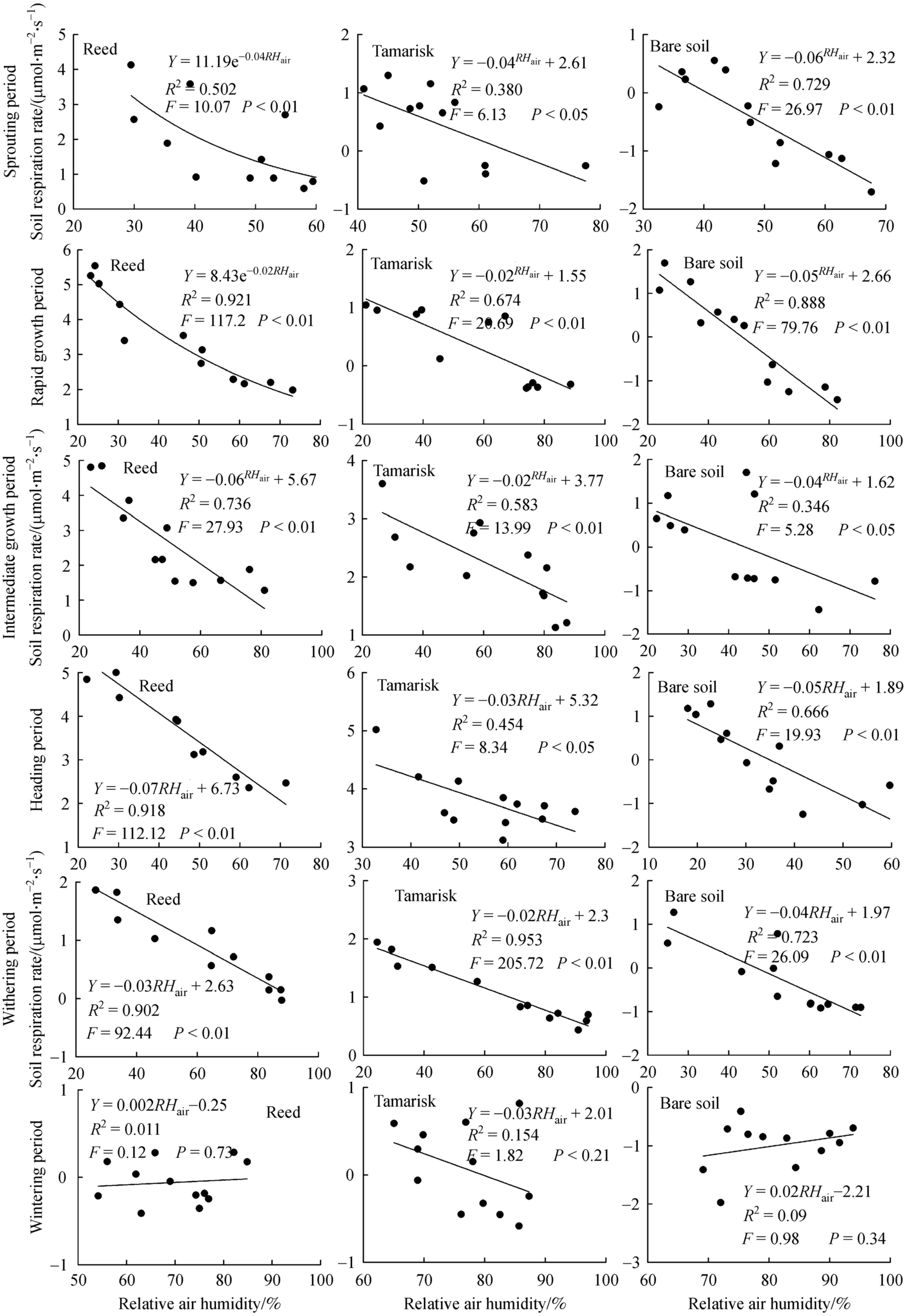

Fig. 5 Regression analysis for the soil respiration rates of plots supporting reeds and tamarisk at different growth periods versus bare soil, plus the relative humidity of air. "Y" represents the soil respiration rate, "RH_{air}" represents relative humidity of air.

soil respiration rate gradually increased with rising air temperature (Fig. 6). A clear linear relationship existed between the soil respiration rate and soil temperature at the 5 cm depth. For all growing periods combined, soil temperature explained 37.8%–88.1% (mean: 71.4%), 54.9%–95.1% (mean: 70.9%), and 39.1%–87% (mean: 67.7%) of variation in reed, tamarisk, and bare soil habitat, respectively. The soil respiration rate was significantly affected by soil temperature in this arid region. Under the different types of vegetation coverage, soil temperature differentially affected the soil respiration rate. The temperature sensitivity of soil respiration (Q_{10} value) reflects the response of soil respiration to changes in temperature. The Q_{10} value of reed and tamarisk soils were larger than those of bare soil. The average Q_{10} was 1.72, 1.62, and 1.49 for reed, tamarisk, and bare soils, respectively (Table 2).

3.5 Effects of soil moisture content on soil respiration

There was no significant correlation between soil respiration and soil moisture content at the various growth periods (Table 3), except for tamarisk soils during the heading period ($Y = 36.06W + 2.98$, $p < 0.05$, and "W" represents soil moisture content at 5 cm depth). Thus, soil moisture content was not the main factor controlling the diurnal dynamics of soil respiration.

3.6 Combined effects of air temperature, relative air humidity, soil temperature, and soil moisture content on soil respiration

Due to the complexity of soil respiration, the influence of other factors on the soil respiration rate has to be considered; temperature or moisture content should not only be considered. We carried out stepwise regression analysis on the relationship between soil respiration rate and four environmental factors (air temperature, relative air humidity, soil temperature, and soil moisture content) (Table 4). Different environmental factors affected the respiration rates of reed, tamarisk, and bare soil differently at the different growing periods. Diurnal variation in the soil respiration of the reed habitat was controlled by air temperature, soil temperature, and moisture content, which explained 31.5%–92.5% of the soil respiration rate at the different growth periods. Soil temperature, air relative humidity, and soil moisture content influenced the soil respiration rate of the tamarisk plant community, which explained 55.8%–94.7% of soil respiration at the different growth periods. Diurnal variation in the soil respiration of bare soil was controlled by soil temperature, air temperature, and relative air humidity, which explained 40.8%–90.2% of the soil respiration rate at the different growth periods. In all seasons, the main influencing factors of reed, tamarisk, and bare soil were air temperature, and soil temperature, respectively, which explained 94.9%, 99.7%, and 75% of soil respiration rates, respectively.

3.7 Effects of soil properties on soil respiration

The relationship of soil respiration with soil salt, pH, and the organic carbon content of the soil was analyzed in the reed, tamarisk, and bare soil (Table 5). The soil respiration rate was weakly negatively correlated with pH and salt ($P > 0.05$). Thus, the greater the salinity, the lower the emissions from soil respiration. The soil respiration rate was positively correlated with organic carbon content, with this relationship being significant in the reed plant community. Thus, higher organic carbon content in the soil might promote soil respiration emissions.

3.8 Global warming potential (GWP) of reed, tamarisk, and bare soil

In order to understand the ability of human beings to introduce greenhouse gases to the atmosphere and affect global climate change, the global warming potential (GWP) is usually adopted by the researchers (the GWP of CO_2 is 1). The GWP of reed, tamarisk, and bare soil in all seasons was equal to the cumulative CO_2 emission multiplied by 1. The GWP of reed, tamarisk, and bare soil was 650.58, 412.22, and -3.97 kg CO_2/hm^2, respectively. The GWP of bare soil at Ebinur Lake and compound rice fields in Hubei had negative values (Table 6), which contribute to reducing the greenhouse effect. In comparison, positive GWP were measured in other areas, which are expected to enhance the greenhouse effect. Our results showed that CO_2 emissions in the high-salinity wetlands surrounding Ebinur Lake are relatively small compared to other study sites, with a weak potential to enhance the greenhouse effect.

4 Discussion

4.1 Diurnal and seasonal dynamics of soil respiration

Diurnal variation in the soil respiration of reed, tamarisk, and bare soil produced single peak curves at the different growth periods. Overall, soil respiration peaked from 11:00 to 17:00, and troughed from 03:00 to 7:00, contrasting with previous studies (Jia et al., 2007; Yang et al., 2009). These differences may be due to differences in the timing of monitoring this parameter. The seasonal dynamics of soil respiration of reed, tamarisk, and bare soil also showed clear single peak curves. The highest soil respiration was recorded in the reed habitat, followed by the tamarisk and bare soil. The soil respiration of the reed habitat increased faster than that of the tamarisk or bare soil after sprouting period. This difference occurred because

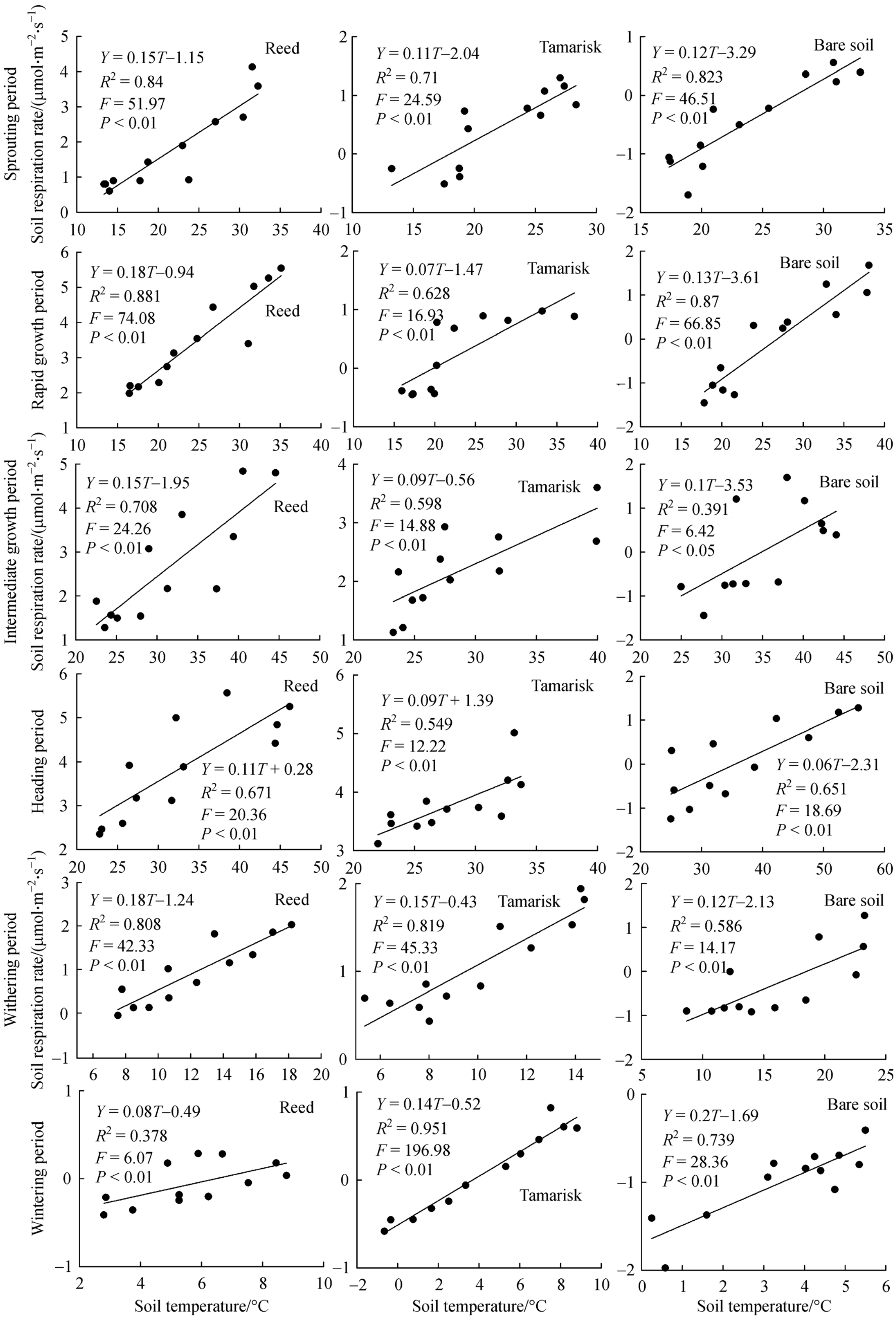

Fig. 6 Regression analysis for the soil respiration rates and soil temperature of plots supporting reeds and tamarisk at different growth periods versus bare soil. "*Y*" represents the soil respiration rate, "*T*" represents the soil temperature at 5 cm depth.

Table 2 Q_{10} value of soil supporting reeds and tamarisk at different growth periods versus bare soil

Growth period	Q_{10}		
	Reed	Tamarisk	Bare soil
Sprouting	2.34	1.65	1.52
Rapid growth	1.68	1.74	1.49
Intermediate growth	1.71	1.55	1.53
Heading	1.34	1.40	1.55
Withering	1.77	1.66	1.47
Wintering	1.52	1.71	1.41

Table 3 Correlation coefficients of the soil respiration rates of plots supporting reeds and tamarisk at different growth periods versus bare soil, using soil moisture content at 5 cm depth

Growth period	Reed	Tamarisk	Bare soil
Sprouting	0.054	−0.143	−0.388
Rapid growth	0.47	−0.319	0.416
Intermediate growth	0.289	0.438	0.381
Heading	−0.305	0.661*	−0.018
Withering	−0.194	−0.569	0.274
Wintering	0.569	0.037	0.008

Table 4 Combined effects of air temperature, air relative humidity, soil temperature, and soil moisture content on the soil respiration of plots supporting reeds and tamarisk at different growth periods versus bare soil

Plot type	Growth period	Regression equation	R^2	F	P
Reed	Sprouting	$Y=0.17T+0.13W-3.25$	0.925	68.55	<0.01
	Rapid growth	$Y=0.11T_{\mathrm{air}}+0.47$	0.921	128.46	<0.01
	Intermediate growth	$Y=0.11T_{\mathrm{air}}-0.54$	0.837	57.48	<0.01
	Heading	$Y=0.08T_{\mathrm{air}}+1.06$	0.926	128.95	<0.01
	Withering	$Y=0.06T_{\mathrm{air}}+0.06T-0.54$	0.952	110.17	<0.01
	Wintering	$Y=0.08T-0.50$	0.315	6.062	<0.05
	All seasons	$Y=0.13T_{\mathrm{air}}-0.79$	0.949	73.87	<0.01
Tamarisk	Sprouting	$Y=0.11T-2.04$	0.682	24.60	<0.01
	Rapid growth	$Y=-0.03RH_{\mathrm{air}}+1.56$	0.641	20.59	<0.01
	Intermediate growth	$Y=0.095T-0.56$	0.558	14.87	<0.01
	Heading	$Y=0.07T+0.28W+1.08$	0.722	15.30	<0.01
	Withering	$Y=-0.02RH_{\mathrm{air}}+2.3$	0.947	198.52	<0.01
	Wintering	$Y=0.139T-0.52$	0.947	196.13	<0.01
	All seasons	$Y=0.26T_{\mathrm{air}}-0.19T-0.77$	0.997	530.55	<0.01
Bare soil	Sprouting	$Y=0.08T-0.03RH_{\mathrm{air}}-0.94$	0.902	51.71	<0.01
	Rapid growth	$Y=0.10T-2.70$	0.881	82.75	<0.01
	Intermediate growth	$Y=0.48T-2.41$	0.408	8.59	<0.05
	Heading	$Y=0.07T_{\mathrm{air}}-2.39$	0.902	102.24	<0.01
	Withering	$Y=0.12T_{\mathrm{air}}-2.16$	0.724	29.84	<0.01
	Wintering	$Y=0.20T-1.69$	0.714	28.40	<0.01
	All seasons	$Y=0.204T-1.07$	0.75	11.97	<0.05

the soil of the reed plant community supports a higher organic carbon content, which provides adequate nutrition for the microbes. In comparison, the soil texture of bare soil is sandy. Dilustro et al. (2005) showed that, compared with sand, the respiration of clay soil is relatively high. Bare soil has little organic content and cannot retain water

Table 5 Correlation coefficients of the soil respiration rates of plots supporting reeds and tamarisk versus bare soil based on soil properties

Plot	pH value	Salt content	Organic carbon content
Reed	−0.655	−0.188	0.901*
Tamarisk	−0.12	−0.251	0.61
Bare soil	−0.52	−0.118	0.075

* Correlation is significant at the 0.05 level (two-tailed).

Table 6 Comparative analysis of the global warming potential (GWP)

Sample plot	Geographical position	Vegetation type	GWPs/ (kg $CO_2 \cdot hm^{-2}$)	Source
Ebinur Lake	Xinjiang of China	Reed	650.58	—
Ebinur Lake	Xinjiang of China	Tamarisk	412.22	—
Ebinur Lake	Xinjiang of China	bare soil	−3.97	—
Farmland	South Korea	Paddy	8.46×10^6	Haque et al. (2016)
Farmland	Iran	Sugar beet	2668.35	Yousefi et al. (2014)
Farmland	Chongqin of China	Maize	10465	Mu et al. (2013)
Farmland	America	Corn	272.78	Ghimire et al. (2017)
Farmland	Canada	Barley, wheat, canola, pea	1478.75	Goglio et al. (2014)
Farmland	Shanxi of China	Wheat, maize	22545.74	Chen et al. (2017)
Wetland	Fujian of China	Mangrove trees	4365.7	Wang et al. (2016)
Farmland	Hubei of China	Compound rice fields	−32911.6	Zhan et al. (2008)

well with rapid evaporation; consequently, bare soil had low soil respiration (Shurpali et al., 2008). During the heading period, the photosynthetic activity of reeds and tamarisk strengthen, with more photosynthetic products being transferred from the vegetation to the soil. Animals and microbes in the soil are active during this period, with the respiration of the plant root systems being stronger. Consequently, more CO_2 is released-into the soil, resulting in the peak detected for soil respiration during the heading period. The bare soil was extremely desiccated after the intermediate growth period, with very low soil moisture content (just 0.027%). Consequently, microbial activity in the bare soil decreased, leading to low organic carbon levels. Therefore, the soil respiration rate of bare soil peaked during the intermediate growth period. Negative soil respiration rates were recorded during the monitoring period for all soil, which might have been the result of stagnant microbial and root system activities when the temperature was low. As a result, during these periods, there was no CO_2 accumulation in the pores of the soil, leading to an imbalance between the soil pores and atmosphere, with the atmospheric CO_2 diffusing into the soil and being fixed by the soil. This hypothesis supports the observations of previous studies (Wang et al., 2015; Yang et al., 2017).

4.2 Effects of environmental factors on soil respiration

Temperature mainly affects the soil respiration rate by influencing the metabolic rate of soil microbes, the growth rate of the root system, and the decomposition rate of organic substances (Luo et al., 2001; Wan and Luo, 2003). Our results showed that changes in air and soil temperature primarily explained most of the diurnal and seasonal variations in soil respiration detected in reed, tamarisk and bare soil in habitats around Ebinur Lake. These findings were consistent with the relationships previously detected between soil respiration and temperature (Xie et al., 2008; Liu et al., 2016). The mostly linear dependence of diurnal and seasonal dynamics in the soil respiration of reed, tamarisk, and bare soil on air and soil temperature measured in the current study (Fig. 4 or Fig. 6) differed to the exponential model previously obtained for the *Carex* meadow in a freshwater lake (Hu et al., 2015). The temperature sensitivity (Q_{10} value) of reed (mean: 1.72) and tamarisk (mean: 1.62) soils was larger than that of bare soil (mean: 1.49). The root system in reed and tamarisk soils was more developed than that in bare soil. Boone et al. (1998) showed that the Q_{10} value of soil respiration increased with increasing root system complexity. For this reason, the Q_{10} value of bare soil was comparatively low. The Q_{10} values obtained in the current study were lower than the average Q_{10} values at the global scale (2.4) (Raich and Schlesinger, 1992) or for *Stipa* L. on the steppes of Inner Mongolia, China (2.16–2.98) (Qi et al., 2010). This difference might be attributed to air and soil temperature in combination with soil moisture content, root biomass, litter input, microbial population structure, and other seasonally fluctuating conditions and processes (Curiel Yuste et al., 2004). There was a significant negative correlation between soil respiration and air relative humidity, which consistented with the results of Murcia-Rodríguez et al. (2012).

Soil moisture content might affect soil respiration because microorganisms become dormant or die when soil moisture content is low (Conant et al., 2004). In this study, no significant positive or negative correlation was observed between soil moisture and soil respiration; thus, soil moisture content was not the main factor regulating variation in soil respiration. Previous studies detected a positive correlation between soil moisture and soil respiration in different ecosystems (Jia et al., 2007), while others obtained negative correlations and or no correlations at all (Reth et al., 2005; Yang et al., 2009). Kucera and Kirkham (1971) showed that both saturated and permanently wilting soil moisture content lead to stagnating soil respiration rates. When the soil moisture content (volume ratio) reaches 25%–30% or higher, the soil respiration function starts to increase. At our study site, the reed, tamarisk, and bare soil had the lowest moisture content during the heading period (0.01%, 0.06%, and 0.04%, respectively). However, soil respiration in reed and tamarisk peaked at the heading period; thus, soil moisture content had a lower influence on soil respiration than soil temperature. In addition, soil respiration responded differently to the soil moisture content in the three analyzed plant communities. This difference might be due to several factors, such as varying moisture requirements during the different periods of plant development, the depth distribution of the root system of plants, soil properties, and the effects of moisture on microbial activity in the soil (Davidson et al., 2000). In all seasons, the main factors that influenced the soil respiration of reed, tamarisk, and bare soil were air temperature, and soil temperature.

4.3 Effects of soil properties on soil respiration

The negative correlation between soil respiration and salt content was consistent with the results obtained by Setia et al. (2011) in the Tarim River basin (China). In addition, our findings were consistent with those of Rao and Pathak (1996). Therefore, compared with soil of pH 7, the emission of CO_2 from soil of pH 8.7 and pH 10 would be 18% and 83% lower, respectively. Consequently, higher salinization levels inhibit CO_2 emissions from the soil, because high salinity and high pH affect the microbial activity in the soil. When microbial activity is affected, the numbers of bacteria, fungi, actinomycetes, and algae also dwindle (Elgharably and Marschner, 2011; Mavi et al., 2012), negatively affecting soil respiration. There was a significant positive correlation between soil respiration and soil organic carbon content in the reed plant community. In comparison, no significant positive correlation was found in the tamarisk and bare soil plots. This difference occurred because the soil organic carbon bank is the main source of carbon that is decomposed by microbes in the soil. The quantity of soil organic carbon directly affects the microbial activity, which, in turn, affects the carbon emission processes of the soil (Wan et al., 2007).

Soil respiration is a complex process that is influenced by many factors. While relationships exist, irregularity also occurs. Thus, further studies are required on how soil respiration is influenced by microorganisms, biomass, and redox potential. It is necessary to obtain highly accurate insights to understand the mechanisms influencing soil respiration.

5 Conclusions

The soil respiration of typical plant communities (reeds and tamarisk) and bare soil were compared in a wetland surrounding a highly saline lake in the Xinjiang Uygur Autonomous Region of northwestern China. This research contributed new information on soil carbon cycling in arid regions. Our results showed that diurnal and seasonal variations of soil respiration in reed, tamarisk, and bare soil exhibited single peak curves at different growth periods. During the entire monitoring period, the reed habitat had the highest soil respiration rate, followed by tamarisk soil and bare soil. The net carbon sink was measured for diurnal and seasonal variations of soil respiration. At all growth periods, air and soil temperatures were the main influencing factors, followed by relative air humidity. The Q_{10} values of reed and tamarisk soils were greater than those of bare soil. However, soil moisture content was not the main factor influencing soil respiration in this study. Soil pH, salinity, and organic carbon content also influenced soil respiration. In conclusion, our results indicate that the high-salinity wetlands surrounding Ebinur Lake have relatively low CO_2 emissions compared to other areas, showing a low capacity to enhance greenhouse effects.

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