Bulgarian Journal of Agricultural Science, 19 (No 2) 2013, 274-281
Agricultural Academy

REDUNDANCY ANALYSIS REVEALING RELATIONSHIP BETWEEN WATER-SALINITY AND THE ECO-PHYSIOLOGICAL RESPONSES OF *PHRAGMITES AUSTRALIS* IN MOMOGE WETLAND, CHINA

C. N. DENG [1,2], X. L. PAN[2*] and F. Q. CHANG[1]

[1] *Key Lab of Plateau Lake Ecology & Global Change, College of Tourism and Geographic Science, Yunnan Normal University, Kunming 650500, P. R. China*

[2] *Key Lab. of Biogeography and Bioresource in Arid Land, Xinjiang Institute of Ecology and Geography, Chinese Academy of Science, Urumqi 830011, P. R. China*

Abstract

DENG, C. N., X. L. PAN and F. Q. CHANG, 2013. Redundancy analysis revealing relationship between water-salinity and the eco-physiological responses of *Phragmites australis* in Momoge Wetland, China. *Bulg. J. Agric. Sci.,* 19: 274-281

Based on the measured data in June, 2010, the redundancy analysis (RDA) were used to analyze the variations of eco-physiological responses of *Phragmites australis*, identify the key environmental factors and their patterns influencing the variation of the growth of *Phragmites australis* in Momoge wetland, China. The results showed that various environmental factors led to great changes in eco-physiological responses of *Phragmites australis*. All selected environmental factors explained 59.3% of the variation of eco-physiological responses of *Phragmites australis*. Na^+ concentration was the most important environmental factor, which possessed 62.9% of the variation, and water depth was the second key environmental factor, which possessed 25.8% of variation of *Phragmites australis*. Na^+ influenced eco-physiological characteristics of *Phragmites australis* by the intergration. Water depth controlled eco-physiological characteristics of *Phragmites australis* by influencing the plant height, coverage, biomass and the maximum photosynthesis efficient (F_V/F_M). The value of pH was the last environmental factor possessing 11.8% of the variation in the total variance, and influencing the plant height and biomass. Additional research is needed to find management strategies for the restoration of *Phragmites australis.*

Key words: Redundancy analysis, Environmental factors, Eco-physiological responses, *Phragmites australis,* Momoge Wetland

Introduction

Water table and salinity are the two main environmental factors that affect plant growth and productivity in wetlands (Mitsch and Gosselink, 2000; Cui et al., 2010). Optimum water depth can enhance the photosynthesis of plants and increase the biomass production (Davis et al., 2009; Richards et al., 2011). Growth and productivity of salt-sensitive plant in wetland decrease with increasing salinity. High concentrations of salt leads to the morphological and physiological changes, retards the photosynthesis of plant and decreases the plant height and biomass (Jampeetong and Brix, 2009; Trites and Bayley, 2009). Eco-physiological responses of wetland plants to change of water depth and salinity have been well documented (Salter et al., 2007; Cui et al., 2008). However, the effects of water depth and salinity are not equally important in the process of plant growth. Though many researchers have investigated the plant responses to water depth and salinity, the interactive effect of water depth and salinity on wetland plants has not been well known.

E-mail: dengchunnuan@yahoo.com.cn; xiangliangpan@163.com

Momoge Wetland is an inland-wetland locating on the West edge of Songnen Plain in China. Being the stopover and reproduction habitats of Siberian White Crane and other endangred waterfouls, Momoge wetland is a nation-level natural reserve area. Fore several decades, Momoge wetland has been threatened by severe drought and water shortage because of the global climate change and water resource engineering. Water and soil salinity has been increasing, vegetation degradation has been intensified, and the habitats for rare and endangered birds have thus been threatened. The issues that Momoge wetland faces have drawn growing attention from many international organizations including WWF, GEF and ICF (Pan et al., 2006). It is very important to understand the complex relationship between vegetation and environment factors for the wetland vegetation restoration. Redundancy analysis is chosen in this study because it is a useful technique for analyzing the relationship between vegetation and environment.

In this study, the relationship between *Phragmites australis* and water depth and salinity were mainly discussed by redundancy analysis (RDA) as follows: 1) the eco-physiological responses of *Phragmites australis* to various water depths and salinities; 2) How much information of the growth of *Phragmites australis* can be explained by these environmental factors? 3) Is there a determinative factor affecting the growth of *Phragmites australis*? 4) What extent in importance can be found in these environmental factors to the plant growth? Solving these problems can not only enrich the quantitative research contents about the vegetation growth and environment factors in wetland, but also has been helpful in protection and restoration of wetland vegetation in practice.

Material and Methods

Site description

Momoge wetland lies along NenJiang river at long. 122°27'-124°04'E. by lat. 45°42'-46°8'N (Figure 1). It is one of the largest wetland in Western Jilin province, China, providing habitats and stopover for some rare and endangered waterfowls, such as oriental stork, Siberian white crane (Pan et al., 2006). This region has an average annual precipitation of 394 mm, and an average annual evaporation of 1553 mm. The total area of wetland is 14.4 $\times 10^4$ hm^2. As an inland wetland, the salinity has been increasing because of frequent drought and great evaporation. For example, the electrical conductivities for Yangsha lake and Etou lake in Momoge wetland are 2350μs/cm, and 3890μs/cm, respectively (Yao et al., 2010). The water pH ranges from 7 to 10. The reed swamp, the most important habitat type for waterfowl in Momoge wetland, accounts for 41.7% of total area. Reed swamps shrank continuously due to water shortage and salinization.

Sampling methods and data collection

Three typical areas with low/middle/high salinity in Momoge wetland were selected in June 2010. Quadrats of 50 cm × 50 cm were randomly chosen according to the water depth and salinity. Water samples were collected with the mixture of three samples for water quality analysis. Water depth was measured by a scale.

The average heights of *Phragmits australis* were measured with a scale and the numbers of plants were counted. The coverage was estimated by visual observation. The aboveground biomass were collected, dried to constant weight in a blasting oven (80°C), and then weighted.

The third full-expanded leaf was used for fast chlorophyll fluorescence measurements with a portable fluorometer (FP100, PSI, Brno, Czech Republic). A visible light band peaking at 475 nm excited fluorescence. Fast fluorescence transients induced by actinic light were recorded at sampling intervals varying from 10 μs to 10 ms. Plant leaf was dark-adapted for 3 min before fluores-

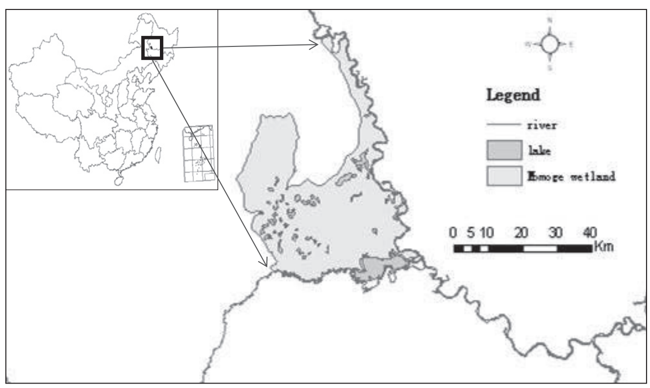

Fig. 1. The geographical location of Momoge Wetland, in Jilin Province, China

cence measurement. Finally, the chlorophyll content of the same leaf was measured with a CCM-200 chlorophyll content meter (Opti-Sciences, Tyngsboro, MA, USA).

Statistical analysis

Data analysis of variance was performed using the SPSS software (Version 16.0). Redundancy analysis (RDA) was carried out, based on detrended correspondence analysis (DCA), for eco-physiological responses of *Phragmites australis*. RDA was appropriate for the analysis if the length of ordination axes in DCA was relatively low (<3); otherwise the canonical correspondence analysis (CCA) would be the suitable method (Jan and Petrš, 2003). The measured environmental factors, including water depth, the concentration of Na^+, Cl^-, HCO_3^- and pH value, were adopted as the explanatory variables. In the preliminary analysis environmental factors with an inflation factor larger than 20 were removed (Beyene et al., 2009), thus water depth, Na^+ and pH were remained as environmental factors in the research. The inclusive forward selection procedure was employed for sorting out the factors explaining the most variance in the species data and then, Monte Carlo test with 499 permutations was carried out for significance testing of the selected environmental factors. The correlation between individual environmental factor and eco-physiological responses patterns of *Phragmites australis* was analyzed using T-test. All multivariate analyses were performed by using the software CANOCO, Version 4.5 for Windows (ter Braak, 1989). The results of RDA were visualized in the form of ordination diagrams in the Canodraw for Windows program. Variables are represented as symbol such as lines with arrows pointing in the direction of maximal variation. Variables with lines close to each other and headed in the same (opposite) direction are highly positively (negatively) correlated. Two lines at a 90-degree angle indicate that the corresponding variables are uncorrelated.

Results and Discussion

Eco-physiological responses of Phragmites australis to changes of environmental factors

The data of water salinity in the three study areas were shown in Table 1. There are great differences in the water salinity among the three study areas. In the low salinity area, the value of Na^+ content was 31.9 mg/L, the electric conductivity was 160 µs/cm, the value of pH was 6.8, and the total salinity content was 238.8 mg/L. In the middle and high salinity areas, values of these parameters were much higher than those in the low salinity area.

The eco-physiological parameters of *Phragmites australis* grown in various environmental gradients were summarized in Table 2. All he indexes of *Phragmites australis* were sensitive to the change of environmental factors. The values of plant height, coverage, biomass, chlorophyll content, the maximum photosynthesis efficiency (F_V/F_M) and the maximum performance index (PI_{ABS}) increased with water depth in low and middle salinity water bodies. In the low and middle salinity condition, the increase of water depth increased photosynthesis, the number of plant and enhanced the growth and productivity of reed. The plant height is almost the same in different water depth in high salinity area. The number of plant and biomass decreased with increasing water depth in high salinity. The growth of reed inhibited by high salinity was well documented, and the minimum concentration of salinity caused inhibitory effect were different (Al-Garni, 2006; Zhang et al., 2008). Zhang et al. (2008) reported 0.6% salinity retarded the growth of reed. The chlorophyll content, the maximum photosynthesis efficient (F_V/F_M) and the maximum performance index (PI_{ABS}) increased along with the increase of salinity, it may be concluded that the photosynthesis was promoted by higher salinity up to 1000mg/L. According to previous literature, limits of salt tolerance of reed vary widely between 5 and

Table 1
The value of concentration of ions, EC, and pH in three study areas

Salinity gradient	Na^+, mg/L	Ec, µs/cm	pH	Total salinity content, mg/L
Low salinity	31.9	160	6.8	238.8
Middle salinity	80.4	406	7.7	732.3
High salinity	258.5	797	8. 6	930.1

65‰ (Hellings and Gallagher, 1992; Zhang et al., 2008) , However, in many reports, the chlorophyll content and photosynthesis rate were less influenced (Jampeetong and Brix, 2009; Antonellini and Mollema, 2010) or even be promoted by low salinity (Song et al., 2010). Vasquez et al. (2006) found that 100 mM NaCl promoted the growth of reed and increased the dry mass of plant while 200 mM NaCl inhibited the growth of reed. Song et al. (2010) reported that the chlorophyll content of reed increased in <0.5% NaCl and decreased in >0.5% NaCl. It was suggested salinity (<1000 mg/L) promoted the photosynthesis and the synthesis of chlorophyll content.

Identification of key environmental factors

RDA enables the identification of the environmental factors that can best explain the variance pattern of the response of *Phragmites australis*. In order to determine to what extent the three environmental factors affected the eco-physiological responses of *Phragmites australis*, RDA was performed. The eigenvalues associated with the axis and the reed responses-environment correlation indicates the satisfactoriness of the environmental factors explain the *Phragmites australis* responses. These results were listed in Table 3. The first two canonical axes explained 38.8% and 20.1% of the variation in the response of *Phragmites australis*, respectively. All four significance canonical axes explained 78.8% variation in response of *Phragmites australis*. It implies that axes 1-4, especially by axis 1 and 2, can explain the most variation of *Phragmites australis*. Monte Carlo tests for the first and all canonical axes were highly significant (p<0.01), indicating that three composting environmental factors

Table 2
Eco-physiological characteristics of *Phragmites australis* in various water-salinity gradients (n=3)

Salinity	Water depth, cm	Height, cm	Coverage, %	Number of plant, per m^2	Biomass, g/m^2	Chlorophyll content	F_V/F_M	PI_{ABS}
low	0	69	30	564	297.4	15.3	0.62	0.35
	5	82.3	40	452.5	422.3	17.3	0.69	0.52
	15	106	49	396.5	523.6	23.9	0.7	0.61
	25	120.3	60	423.5	1185.4	25.5	0.75	2.09
middle	0	80.7	40	396	433.8	19.2	0.75	1.5
	5	89.7	50	428	616.9	27	0.74	1.19
	15	111	55	440	854	21.3	0.76	1.33
	25	134.3	70	344	848	24.1	0.77	1.6
high	15	41.8	25	233.5	107.67	31.4	0.77	2.64
	20	41.2	30	352	185.74	18.52	0.7	1.01
	25	44.2	10	205.5	86.28	32.36	0.78	2.32
	30	44.3	10	178	87.44	38.57	0.78	3.81

Table 3
The redundancy analysis results of environmental factors and species on axis 1-4

Redundancy analysis results	axis 1	axis 2	axis 3	axis 4
Eigenvalues	0.388	0.201	0.004	0.195
Species-environment correlations	0.89	0.772	0.239	0
Cumulative percentage variance of species data	38.8	58.9	59.3	78.8
Cumulative percentage variance of species-environment relation	65.4	99.3	100	0
Sum of all engenvalues	1			
Sum of all canonical eigenvalues	0.593**			
Water depth-species correlation	-0.273	-0.635	-0.114	0
Na^+-species correlation	-0.853	-0.22	0.003	0
pH-species correlation	-0.795	-0.316	0.044	0

** p<0.01.

were important in explaining the eco-physiological responses of *Phragmites australis*. The sum of all canonical eigenvalues retained 59.3% of the total variance, which indicated that the three environmental factors can explain 59.3% variation of *Phragmites australis*. The value of correlation between the responses of *Phragmites australis* and environmental factors on the first two canonical axes retained 0.890 and 0.772, respectively. The first two RDA axes had 65.4% and 33.9% of reed responses-environment correlation. Hence, they could be used to explain the relationship between the environmental factors and reed response parameters. Table 3 showed that there were significant negative correlation between water depth and the reed responses data on axis 2, significant negative correlation between Na^+/pH and reed responses on axis 1, indicating that water Na^+/pH influenced the reed responses on axis 1, while water depth affected axis 2.

In order to identify which environmental factor might be the driver of changes in the responses of *Phragmites australis*. Table 4 showed the importance of environmental factors in descending order with significance testing results. Na^+ was the most important environmental factor, which explained 62.9% of the variation in the total change variance of reed, and water depth was the second key environmental factor, which explains 25.3% of the variation, and pH was the last important factors with 11.8% of explanation. This implies that Na^+ and water depth, as the most important factors, played a key role in explaining the change variance of reed responses, which were the key environmental factors. The results suggested that the concentration of Na^+ was the important environmental factors, which negatively affected the plant growth significantly, and it had extracted 62.9% of the environmental information. Water depth and salinity have been noted as potentially important factors determining plant growth in wetlands. Many studies demonstrated the negative effect of increasing salinity on density, height, stem diameter, biomass of reed (Asaeda et al., 2003; Wang et al. 2006). The negative effect of increasing salinity was significant for shoot length, and the belowground to aboveground biomass ratios decreased with increasing salinity (Mauchamp and Mesleard, 2001; Soetaert et al., 2004). Similarly, Salter et al. (2007) suggested that the salinity might restrict the range of water regimes tolerated by aquatic plants. In the higher salinities, *Melaleuca ericifolia* seedlings are intolerant of waterlogging and submergence and died rapidly after 5-week exposure to this combination of environmental stressors. Increasing salinity and water depth would reduce plant growth and survivorship. However, the relationship between water-salinity and *Phragmites australis* was less demonstrated. As salinity increased, the response of plant to water depth would change.

Influence of individual environmental factor on eco-physiological responses of reed

T-values biplot gave the statistical significance between each environmental factor and eco-physiological characteristics of *Phragmites australis*. It was shown in Figure 2. that there was positive correlation among the plant growth height (A) , coverage (B) and plant biomass (D), and they are positively correlated to the axis 1 of responses of *Phragmites australis*. There was a positive correlation among the chlorophyll content (E), the maximum photosynthesis efficiency (F_V/F_M) and the maximum performance index (PI_{ABS}), and they were negatively related to the axis 2 of responses of *Phragmites australis*. The number of plant (C) was positively correlated to the biomass (D), but negatively correlated to the chlorophyll content (E). Among the environmental factors, the value of Na^+ content was positively correlated to pH but negatively correlated with the axis 1. The water depth was negatively correlated to the axis 2 of responses of *Phragmites australis*, and the information was further confirmed in Table 3.

T-values biplot between water depth and eco-physiological characteristics of *Phragmites australis* was shown in Figure 3. Water depth factor mainly dropped in the range of axis 2 and negatively correlated with the axis 2 (Figure 3). The lines and arrows of plant height (A), coverage (B), biomass (D), and F_V/F_M(F) fully dropped in the circle of water depth, indicating that water depth was significantly positively correlated with plant height, coverage, biomass, and F_V/F_M ($p<0.05$) (Figure 3). The lines and arrows of plant maximum performance index (G, PI_{ABS}) and the chlorophyll content (E) was same direction with water depth but fell out the range of water depth circle, implying that water depth was positively correlated with the plant maximum per-

Table 4
Importance and significance level of environment variables

Environmental factor	Importance rank	Importance	*p*-value	% variance explains
Na^+	1	0.373	0.002	62.9
Water depth	2	0.15	0.004	25.3
pH	3	0.07	0.022	11.8

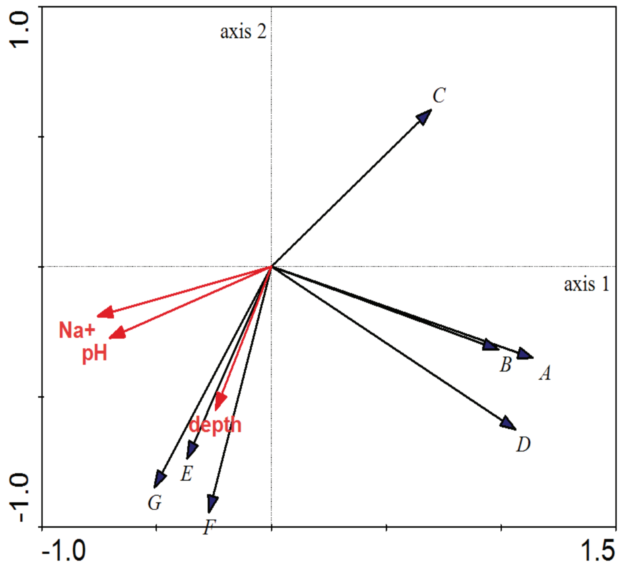

Fig. 2. Redundancy analysis results for environmental factors and the eco-physiological characteristics of reed (A: growth height; B: coverage; C: number of plant; D: biomass; E: the chlorophyll content; F: F_V/F_M; G: PI_{ABS}. Red arrow: environmental factors; Black arrow: eco-physiological characteristics)

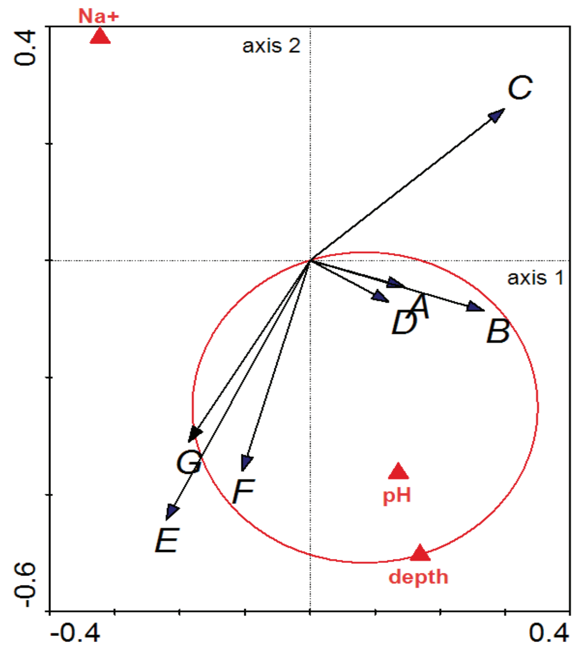

Fig. 3. T-test results for water depth influencing eco-physiological characteristics of *Phragmites australis* (red circle : positive correlation)

formance index and the chlorophyll content, but not reached the significant level. The number of plant (C) dropped out the circle of water depth, suggesting that the number of plant has no significant correlation with the water depth factor. These results indicated that the plant growth, biomass, coverage and the photosynthesis index (maximum photosynthesis efficiency and maximum photosynthesis performance index) increased with the increase of water depth. It was in accordance with previous investigation (Cui et al., 2006; Engloner and Papp, 2006).

T-values biplot between Na^+ content and eco-physiological characteristics of *Phragmites australis* was shown in Figure 4. There was no circle of Na^+ in Figure 4, indicating all of the indexes of eco-physiological characteristics of *Phragmites australis* were not correlated with the concentration of Na^+. However, the results in Table 4 suggest that the concentration of Na^+ was the most important environmental factors which negatively affected the plant growth significantly, and it had extracted 62.9% of the environmental information. The inconsistency could be explained that the Na^+ significantly influenced the reed responses as a whole not by individual parameter. In addition, at the middle salinity, the plant growth, photosynthesis and productivity of reed were better than those in low or high salinity.

T-values biplot between pH value and eco-physiological characteristics of *Phragmites australis* was shown in Figure 5. The lines and arrows of plant height (A) and biomass (D) fully dropped in the circle of pH value, in-

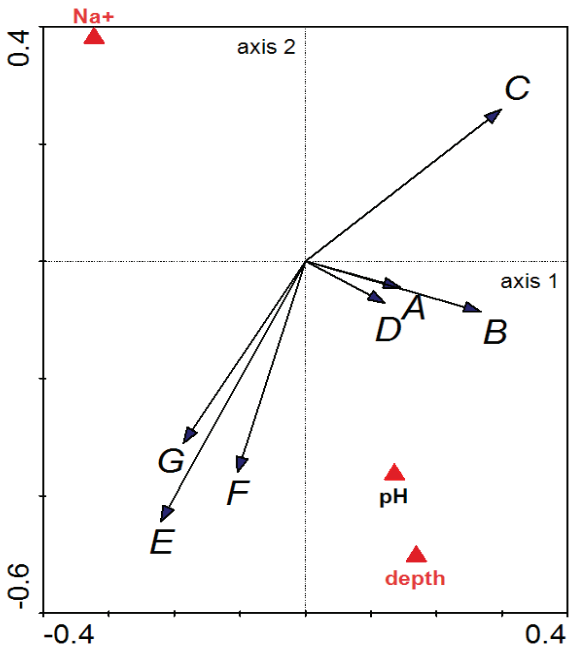

Fig. 4. T-test results for Na+ influencing eco-physiological characteristics of *Phragmites australis*

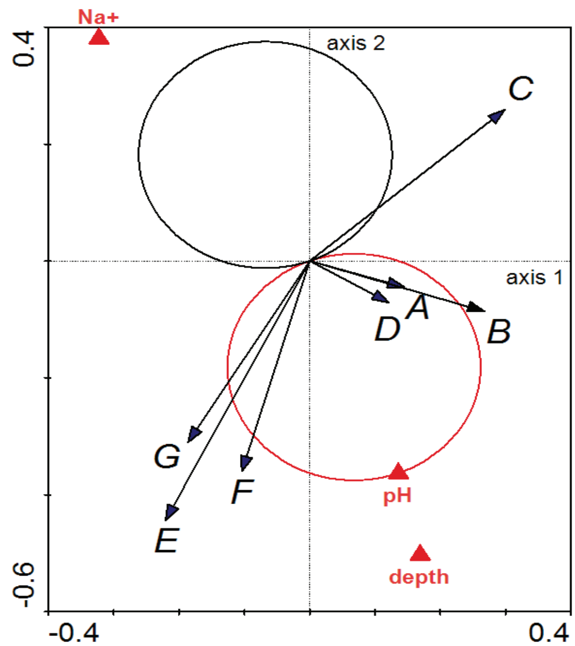

Fig. 5. T-test results for pH value influencing eco-physiological characteristics of *Phragmites australis* (red circle: positive correlation; black circle: negative correlation)

dicating that pH was significantly positively correlated with plant height and biomass ($p<0.05$) (Figure 5). The lines and arrows of coverage (B), chlorophyll content (E), F_V/F_M(F), and plant maximum performance index (G, PI_{ABS}) were in same direction with pH but dropped out the range of pH circle, implying that pH was positively correlated with these indexes, but did not reach the significant level. The lines and arrow of number of plant (C) was in same direction with pH but dropped out the range of pH dashed circle, implying that pH was negatively correlated with plant number, but not reached the significant level.

Conclusion

This investigation identified the key environmental factors influencing eco-physiological characteristics of *Phragmites australis* in Momoge wetland in Jilin Province, China. The results showed that all selected environmental factors accounts for 59.3% of the variation of eco-physiological characteristics of *Phragmites australis*. Na^+ was the most important environmental factor possessing 62.9% of environmental information, and water depth was the second key environmental factor possessing 25.3% environmental information. Na^+ influences eco-physiological characteristics of *Phragmites australis* as a whole. Water depth controls eco-physiological characteristics of *Phragmites australis* by influencing the plant height, coverage, biomass and F_V/F_M. pH is a minor environmental factor possessing 11.8% of the variation in the total variance, and influencing the plant height and biomass. Additional research is needed to find management strategies for the restoration of *Phragmites australis*.

Acknowledgements

This work was supported by Program of 100 Distinguished Young Scientists of the Chinese Academy of Sciences and National Natural Science Foundation of China (U1120302, 21177127 and 4090300D0301).

References

Al-Garni, S. M. S. Al-Garni, 2006. Increasing NaCl-salt tolerance of a Halophytic plant *Phragmites australis* by Mycorrhizal Symbiosis. *American-Eurasian J. Agric. & Environ. Sci.* **1** (2): 11-126 (2006).

Antonellini, M. Antonellini and P. N. Mollema, 2010. Impact of groundwater salinity on vegetation species richness in the coastal pine forests and wetlands of Ravenna, Italy. *Ecological Engineering,* **36**: 1201-1211.

Asaeda, T. Asaeda, J. Manatunge, T. Fujino and D.Sovira, 2003. Effects of salinity and cutting on the development of *Phragmites australis*. *Wetlands Ecology and Management*, **11**: 127-140.

Beyene, A., Beyene, T. Addis, D. Kifle, W. Legesse, H. Kloos and L. Triest, 2009. Comparative study of diatoms and macroinvertebrates as indicators of severe water pollution: Case study of the Kebena and Akaki rivers in Addis ababa, Ethiopia . *Ecological indicators*, **9** (2): 381-392.

Cui, B. Cui, Q. He and X. Zhao, 2008. Ecological thresholds of *Suaeda salsa* to the environmental gradients of water table depth and soil salinity. *ACTA ECOLOGICA SINICA*, **28** (4): 1408-1418 (in Chinese).

Cui, B. Cui, Q. Yang, K. Zhang, X. Zhao and Z. You, 2010. Responses of saltcedar (*Tamarix chinensis*) to water table depth and soil salinity in the Yellow River Delta, China. *Plant Ecology,* **209** (2): 279-290.

Cui, B., Cui, X. Zhao, Z. Yang , B. Chen, N. Tang and X. Tan, 2006. The response of reed community to the environment gradient of water depth in the Yellow River Delta. *ACTA ECOLOGICA SINICA*, **26** (5):1533-1541(in Chinese).

Davis, C., A. Davis, J. R. Bidwell and K. R. Hickman, 2009. Effects of hydrological regimes on competitive interactions of *Schoenoplectus fluviatilis* and two co-occurring wetland plants. *Aquatic Botany*, **91**: 267-272.

Engloner, A. I. Engloner and M.Papp, 2006. Vertical differences in *Phragmites australis* culm anatomy along a water depth gradient. *Aquatic Botany*, **85**: 137-146.

Hellings, S. E. Hellings and J. L. Gallagher, 1992. The effects of salinity and flooding on *Phragmites australis*. *Journal of Applied Ecology*, **29**: 41-49.

Jampeetong, A., Jampeetong and H. Brix, 2009. Effects of NaCl salinity on growth, morphology, photosynthesis and proline accumulation of *salvinia natans. Aquatic Botany,* **91**: 181-186.

Jan, L. Jan and M. Petrs, 2003. Multivariate Analysis of Ecological Data using CANOCO. *Cambridge University Press*, Cambridge.

Mauchamp, A. Mauchamp and F. Mesleard, 2001. Salt tolerance in *Phragmites australis* populations from coastal Mediterranean marshes. *Aquatic Botany*, **70(1)**: 39-52.

Mitsch, W. J., Mitsch and J. G. Gosselink , 2000. Wetlands. New York: John Wiley & Sons, Inc..

Pan, X. Pan, D. Zhang and Q. Liu, 2006. Interactive factors leading to dying-off *Carex tato* in Momoge wetland polluted by crude oil, Western Jilin, China. *Chemosphere*, **65**: 1772-1777 .

Richards, J. H. Richards, T. G. Troxler, D. W. Lee and M. S. Zimmerman, 2011. Experimental determination of effects of water depth on *Nymphaea odorata* growth, morphology and biomass allocation. *Aquatic Botany*, **95**: 9-16.

Salter, J. Salter, K., Morris, P. C. E. Bailey and P. L. Boon, 2007. Interactive effects of salinity and water depth on the growth of *Melaleuca ericifolia* Sm. (Swamp paperbark) Seedlings. *Aquatic Botany*. **86** : 213-222.

Soetaert, K. Soetaert, M. Hoffmann, P. Meire, M. Starink, D. van Oevelen, S.V. Regenmortel and T. Cox, 2004. Modelling growth and carbon allocation in two reed beds (*Phragmites australis*) in the Scheldt estuary. *Aquat. Bot.,* **79**: 211-234.

Song, J. Song, Y. Yang, L. Nie, Y. Zhang and Z. Liu, 2010. Comparative study on physiological characteristics of salt tolerance between *Phragmites communis* and *Puccinellia tenuiflora*. *Tianjin Agricultural Sciences*, **16** (6): 10-12(in Chinese).

ter Braak, C. J. F. ter Braak, 1989. "CANOCO-An extension of DECORANA to analyze species-environment relationships. *Hydrobiologia*, **184** (3): 169-170.

Trites, M. Trites and S. E. Bayley, 2009. Vegetation communities in continental boreal wetlands along a salinity gradient: implication for oil sands mining reclamation. *Aquatic Botany*, **91**: 27-39.

Vasquez, E., A. Vasquez, E. P. Glenn, G. R. Guntenspergen, J. J. Brown and S. G. Nelson, 2006. Salt Tolerance and Osmotic adjustment of *Spartina alterniflora* (Poaceae) and the invasive M haplotype of *Phragmites australis* (Poaceae) along salinity Gradient. *American Journal of Botany*, **93** (12): 1784-1790.

Wang, Q. Wang, C. Wang, B. Zhao, Z. Ma, Y. Luo, J. Chen and B. Li, 2006. Effects of growing conditions on the growth of and interactions between salt marsh plants: implications for invasibility of habitats. *Biol. Invas.,* **8:** 1547-1560.

Yao, S. Yao, B. Xue, X. Lu and H. Xiang, 2010. The hydrochemical Characteristic of Lakes in Songnen Plain. *Wetland Science*, **8** (2):169-175 (In Chinese).

Zhang, S. Zhang, C. Guo, F. Su, T. Wang, Y. Wang and L. Wang, 2008. Effect of salinity on the growth of reed. *Journal of Shenyang Agricultural University,* **39** (1): 65-68(in Chinese).

Received June, 2, 2012; accepted for printing March, 2, 2013.