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Simulation of changes in some soil properties as affected by water level fluctuation in an inland salt marsh

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Abstract

An 87-day simulation experiment was conducted to test the effects of water level fluctuation on soil properties of an inland salt marsh. The simulated wetland was periodically flooded for 15 days with consistent water levels of 10cm above the wetland surface soil and then drained to 0cm for 9 days. Soil samples were collected from the 0 to 30 cm depth with 10cm intervals at days of 0, 39 and 72 after a 15-day pre-incubation. Total nitrogen (TN), total phosphorus (TP), soil organic matter (SOM) and pH were determined during the experimental period. Results showed that TN content was much higher in surface soils than other soil layers during the whole incubation period, especially at the second inundation period (54 days), and TN greatly increased in the soil layers above 20cm with increasing incubation time. However, the SOM content in each soil layer showed a consistent tendency of "decreasing followed increasing" with increasing incubation time. Compared to other soil layers, SOM content in surface soils were generally higher during the simulation periods. TP content in upper soils (0-20cm) consistently increased over the course of incubation time, while those in deeper soils (20-30cm) decreased. Soil pH values showed similar changing tendencies to SOM content over the incubation experiment, while they generally increased with depth.

Keywords：Incubating experiment, Alternating inundation, Total phosphorus, Salt-marsh, Xianghai wetland

1. Introduction

Nitrogen (N) and phosphorus(P) are important nutrition elements contributing to plant growth and production [1, 2], while high nutriant concentrations will pose a risk to water quality management [3, 4] and result in an entrophication problem to many rivers and coastal wetlands [5, 6]. Conley et al. (2009) [7]

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reported that improvements in water quality of fresh water and most coastal marine ecosystems require reductions in both nitrogen and phosphorus inputs. Soil organic matter (SOM) is a key indicator of the soil quality and is related to some important biochemistry processes of nitrogen and phosphorus and thus plays an essential role in water quality, wetland functions, and restoration projects [8, 9]. SOM, nitrogen and phosphorus biogeochemistry in wetland ecosystems can be controlled by many environmental factors such as the extra inputs, flooding, inundation water levels or water table [8, 10, 11]. In recent years, many studies have focused on the dynamic changes of SOM, N and P in fresh water systems, surface and surface flow wetlands, shallow-flooded peatlands and coastal salt wetlands, while little information is available on their changes in inland salt marshes [8, 11, 12-14].

The objectives of this simulation experiment are to investigate the changes of total nitrogen, total phosphorus, soil organic matter and pH (TN, TP, SOM, and pH) at different soil layers under water level fluctuations.

2. Methods

2.1. Site description

The Xianghai wetland is located in Xianghai National Nature Reserve, which is located at the downstream of the Houlin River catchment ($44^o55'$~$45^o09'$N, $122^o05'$~$122^o35'$E) and near the west of the Songnen Plain. The altitudes of this region vary from 156 to192m on a slope slightly tilted from the west to the east. It lies in the semiarid grassland region of the northern temperate zone and has the continental monsoon climate with distinctive dry and wet seasons. The dry season runs from November to April, and the wet season lasts from June to September. The annual mean air temperature is 5.1°C and an annual water deficit is 1,536.8 mm/year due to four times more evaporation (1,945mm/year) than precipitation (408.2mm/year) [15-17].

2.2. Incubation experiment and analysis

Soils were collected from 0 to 50cm depth in three sampling sites with obvious salinity and alkalinity in the research area, and then all soils were returned to the lab and completely mixed together. After the mixed soils were filled into the incubation container, *Carex* was planted in the container. The simulation experiment was conducted in a microcosm. The incubation temperature was 30°C at daytime and 25°C at night. The simulated wetland was periodically flooded and maintained with a 10cm water level above the wetland surface soils for 15 days and then drained to 0cm; and soil was over wetted for 9 days. Soil samples were collected from 0 to 30 cm depth with 10cm intervals at days of 0, 39 and 72 after 15-day pre-incubation. Total nitrogen (TN) was measured with the Kjeldahl method [18], and total phosphorous(TP) was determined by the Mo-Sb colorimetry. Soil organic matter (SOM) was determined by the potassium dichromate volumetric method, soil pH was measured using the electrical conductivity method (soil: water=1:5) [19, 20].

3. Result and Discussion

3.1. The content changes of total nitrogen and total phosphorus

After the 15-day pre-incubation, little differences of TN content were observed between different soil layers (fluctuated at 200mg/kg). After 54 days of the experiment, TN content showed a sharp increase in surface soils and a moderate increase in bottom soils, while they slightly decreased in the subsurface soils (fig.1-a). At the end of the experiment (87 days), TN content increased dramatically in substrata soils, while decreasing slightly in both surface soils and bottom soils. Compared to other soil layers, there is much higher TN content in the surface soils. Bai et al. [16, 20] also reported that surface soils had a higher content of TN and decreased with the depth along the soil profile in intermittent and perennial flooded wetlands. With increasing incubation time, the TN content increased sharply in those soils above 20cm, and very little change occurred in the bottom soils. The decrease in TN content might be associated with N mineralization, as ammonification and nitrification is the primary N transformation in the alternating aerobic-anaerobic treatments within 10 cm of the soil surface, which will lead to NH_4+-N converted to NO_3^--N, and then the loss of N will occur due to denitrification processes [21]. However, the increased N may come from the extra input from vegetation or irrigated water [20, 22].

At the first sampling time, the value of TP was in the order of bottom soils > subsurface soils > surface soils, showing a gradual increase along soil profiles. This is not in agreement with the results reported by Malhi et al. (2003) [23] and Vadas et al. (2005) [24] in which most P concentrated in the top soil layers, and usually from 0-15 or 0-20 cm deep, while typically there was much less P in deeper soils. Over the course of the experiment, TP contents increased slightly in the top 20cm of soils before 54 days of incubation; after that they increased sharply. However, TP content decreased gradually in the bottom soils below 20cm during the incubation time (Fig.1-b). TN content was much higher compared to TP during the whole incubation periods. This might be associated with inundation. Craft and Chiang (2002) [25] also suggested that soil water logging will promote the accumulation of TN more than that of TP.

3.2. The content changes of soil organic matter and pH

During the experiment, SOM content was higher in surface soils (1900mg/kg) than those in other soil layers (fig.1-c). This is consistent with the result reported by Shaffer and Ernst (1999) [7], and Bai et al. (2005a) [16] that SOM contents gradually decreased with depth in naturally occurring wetlands and intermittent flooded wetlands. SOM at all three soil layers increased sharply from 0 to 54-day incubation, spiked at 54-day incubation while decreasing gradually after 54-day incubation. However, all three soil layers showed an increase in SOM contents over the incubation time. The accumulated SOM at the middle incubation time was related to flooding and plant litter input [16]. Esteves et al. (2001) [26] also presented evidence that SOM was difficult to be mineralized and decomposed under the long anaerobic conditions. Moreover, soil organic matter accumulation was a slow process [27], leading to the slower increase in SOM compared to TN.

Similarly, soil pH value showed a changing tendency of decreasing after increasing (fig.1-d). This is associated with soil organic nitrogen transformation and SOM decomposition. Ammonia nitrogen arising from soil organic nitrogen mineralization will contribute to higher soil pH values [20], while nitrate nitrogen from proceeding nitrification and denitrification will result in low soil pH. All soil pH values were higher than 8.6, which indicated an alkaline soil environment. However, it is noted that soil pH values increased with depth along the soil profile. This was caused by the wetting and drying cycles and salt leaching [19].

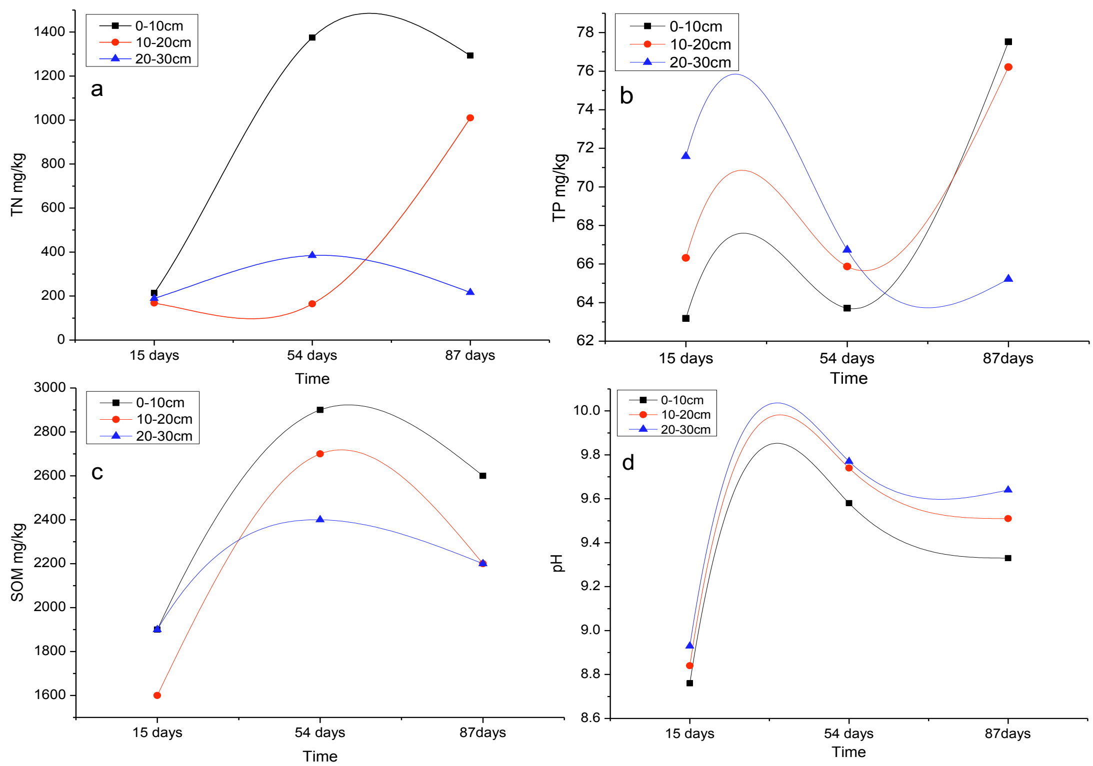

Fig. 1 The changes of soil properties (a-total nitrogen; b- total phosphorus; c- soil organic matter; d- pH)

4. Conclusion

Surface soils showed much higher TN and SOM content, while lower TP and soil pH values. TN and SOM contents decreased with depth along soil profiles, while soil pH increased. TP contents also showed an increase before the 54-day incubation time, while they decreased with depth after the sampling date. Soil pH values and SOM content showed a similar changing tendency in each soil layer, with the consistent change of 'deceasing after increasing' over the incubation time. The findings of this study are meaningful to the wetland ecological restoration, as well as the eutrophication controlling.

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