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Short Communication

Daily Cyclic Changes in Water pH of Flooded Rice in the Mississippi Delta and Black Belt

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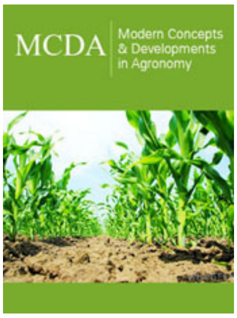

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Introduction

Mississippi (MS) Delta is the primary rice-producing area in the state of Mississippi. The soil type in these fields (Sharkey soil), often has a pH of around 8.2. How does rice grow in such high soil pH? We selected two rice paddies (Figure 1) in the RR Foil Plant Science Research Center, Mississippi State University, situated on the MS Black Belt, and a soil pH of 8.2 for pH measurements. A cyclic pH change in a single day was found in the waters used for flooding the rice paddies. The RR Foil Plant Science Research Center is a 725-acre row-crop farmland in the northeast region of Mississippi State University. It has a typical soil of the Mississippi Black Belt with Selma Chalk outcrops at its south and north boundaries. The thickness of the soil is no more than 2m on the Selma chalk basement. The soil has high native fertility and usually contains carbonate particles and montmorillonite.

A pond on the farm acts a source of irrigation for the farm (Figure 1). Near the southeastern corner of the pond, two rice paddies, R1, and R2 (Figure 1) were selected for pH measurements. Besides rice, the primary weed is ducksalad. The water for flooding the rice comes from the pond and has a pH of around 9. The paddy and pond waters were sampled in 20mL vials with caps at 7:30am, 12:30pm, 5:00pm, and 7:30pm in August 2019. The pHs were measured by a SympHony B10P pH meter in lab within one hour after sampling. The muddy water samples near the soil-water boundary were centrifuged, and the supernatants were decanted into 20mL vials for pH measurements. Soil pH was measured following the USDA protocol [1].

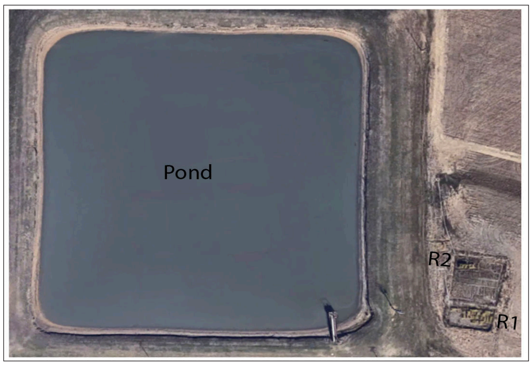

Figure 1: The irrigation pond at RR Foil Plant Science Research Center, Mississippi State University, provides water for the adjacent rice paddies, R1 and R2. The pond water is supplemented with groundwater with a pH of 8.4-8.5, and precipitation with a pH ~4.2. The current pond water pH is around 9.

Result and Discussion

The changes in the rice paddy during the daytime (Figure 2) is generally parallel to the trend in changes in temperature during daytime; with the lowest in the morning, highest in the early afternoon, and then dropping down in the evening. This correlation might reflect the negative correlation of CO_2 solubility with temperature, which is approximately linear. The highest temperature in the early afternoon leads to lowest dissolved CO_2, and hence highest pH around the day, or vice versa. The lab measured soil pH was 8.2, and the rice paddy flooding water came from the pond with a pH of around 9. The pH of the flooding water in the rice paddies was lower than both the soil pH and the original pond water pH, except at noon when the temperature was high. The primary reason for the lowered pH is soil CO_2 production from respiration. Xu et al. [2] used isotope technique and found that root-derived respiration contributed 85-92% of bulk soil respiration in rice paddy [2]. Hence, the rice and ducksalad root respiration, and minor non-rhizomicrobial respiration supplied CO_2 to lower the paddy water pH in this case.

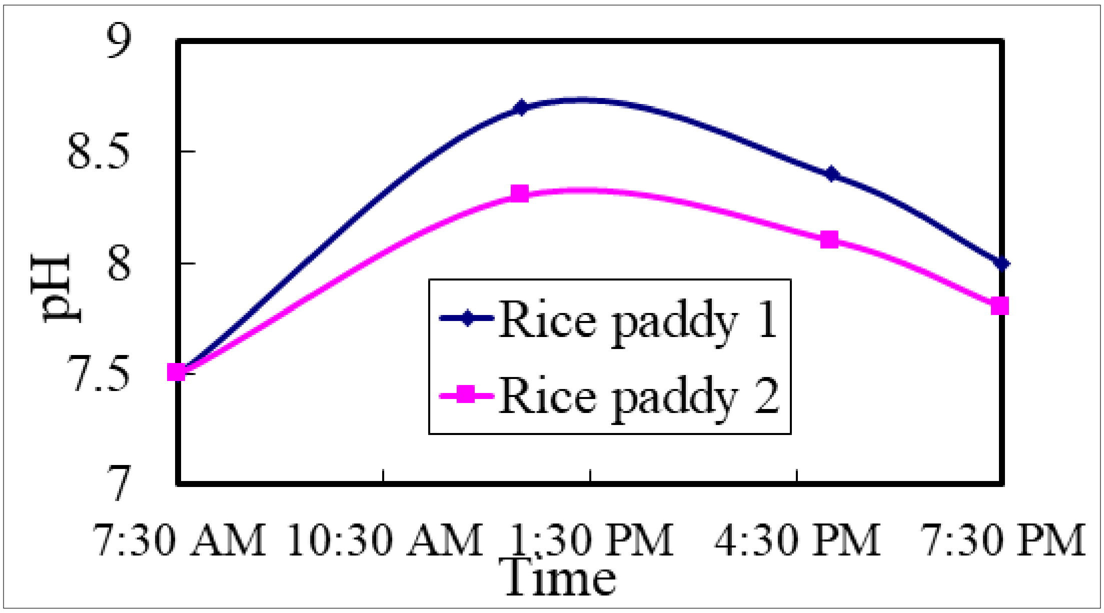

Figure 2: The pH of the water used for flooding the rice paddies changes in the daytime. The pH in both rice paddy 1 and 2 showed a similar trend, with the lowest pH in the morning and highest pH in the early afternoon, and then dropping down in the evening.

The water depth in the rice paddy was around 3 inches, with little changes in pH being observed along the water column. This suggests that convection along the water column is present except at the bottom. Even when the paddy water pH was at 8.7 around noon, the bottom water around the soil-water boundary remained at a pH of 7.6. The primary CO_2 source was from root respiration in the soil. The transport of CO_2 from roots to the water column depends on diffusion [3], which requires a CO_2 concentration gradient. The hence higher CO_2 concentration is expected in the rice rhizosphere. Since the lowest pH of paddy water was 7.45 (in the morning), the rice rhizosphere pH is expected to be lower than 7.45. Oh et al. [3] estimated soil CO_2 concentration as 10-100 times of air CO_2 concentration due to soil respiration [2]. For this case if we assume rice rhizosphere CO_2 concentration as 41,000ppmv (air CO_2 concentration is taken as 410ppmv) and the rice rhizosphere air pressure as 1atm, then CO_2 partial pressure P_{CO2} is 0.041atm.

The solubility product K_{sp} of $CaCO_3$ is taken as $10^{-8.35}$, the water autoionization constant is taken as 10^{-14} and the Henry's law constant K_H is taken as $10^{-1.495}$. From the carbonate equilibrium, the rice rhizosphere pH is calculated as 6.87. Although the highest CO_2 concentration [2] is used, Oh et al. [3] referred to bulk soil CO_2 concentration, and did not consider CO_2 diffusion gradient around rhizosphere. Considering rice roots are the main CO_2 source in this case, the rice rhizosphere in-situ pH of 6.87 is more reasonable. After 24 hours or longer in lab to reach equilibrium with air CO_2, all the rice paddy waters showed a pH of 8.3-8.5; the pond water pH was 8.5-8.7. Both showed oversaturation with calcite whose equilibrium pH (with air CO_2) is 8.3. This indicated that both sets of waters were potential sinks for CO_2. The pond water was absorbing air CO_2 as no abundant plants grew in the pond and provided CO_2 from their respiration. The rice and ducksalad root respiration with minor non-rhizomicrobial respiration contributed to the CO_2 levels in the paddy waters.

Conclusion

The pH of rice paddy flooding water was found to change in a single day with the lowest pH in the early morning, and the highest pH in the early afternoon. From carbonate equilibrium, pH is negatively correlated with dissolved CO_2, while dissolved CO_2 is controlled by temperature which is negatively correlated with CO_2 solubility. Hence, the pH fluctuates with temperature on the same day. The paddy flooding water pH could be lower than the soil pH and the initial flooding water pH because of higher CO_2 supply from the paddy soil than the air CO_2. The primary source of the soil CO_2 is rice and weed root respiration with minor non-rhizomicrobial respiration. High pH was observed around noon/high temperature because CO_2 was released from water due to lower solubility. Even around noon, the pH at the soil-water boundary was still as low as 7.5-7.6. The in-situ pH of the rice rhizosphere was even lower due to higher CO_2 concentration at the rhizosphere forming a diffusion gradient to the flooding water. The pH was possibly around 6.87

in this case. Derivation of the rhizosphere in-situ pH is important because the in-situ pH is critical to rice (crop) health and yield, and it is different from the lab measured soil pH due to higher CO_2 concentration and partial pressure.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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