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Soil Chemical Properties at Different Toposequence and Fertilizer under Continuous Rice Production–a Review

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Abstract. Toposequence and fertilizer are two important factors which affect the changes of soil chemical properties. It is meaningful for studying the spatial variability of soil chemical properties, especially soil nutrients, such as soil pH, available phosphorus (P), exchange potassium (K), exchangeable calcium (Ca) and exchangeable magnesium (Mg) in the hilly area with different toposequence and bunding systems. Changes of soil chemical properties under different toposequential positions or fertilizer treatments were discussed. Factors that affect soil chemical were proposed in addition to guide agriculture production. This review would provide guidance of soil nutrients management and soil improvement and crop production.

1. Introduction

Chemical properties of soils, such as soil pH, organic matter, available phosphorus, cation exchange capacity play as an index of soil quality. Soil pH is a measure of soil acidity or alkalinity. It influences not only crop yields, crop suitability, but also activity of soil microorganism and availability of micronutrients [1]. With low pH are there easily a phosphate deficiency and aluminum and manganese toxicity. Phosphorus acts as one of the limiting nutrients for crop production. Phosphorus and potassium are taken up through plant roots from soil solution to enhance crop growth [2]. Magnesium is associated with chlorophyll. It offers to plants mainly as available form. The amount differs in different soil types [3]. Calcium can prevent soil acidity through liming and limit the activity of enzymatic cofactor [4]. Too much sodium content in soil causes salinity, which appears in approximately 33% of the irrigated land all through the world [5].

Due to more positive function of nutrients, farmers prefer more fertilizer application to improve crop yield, which sometimes become a burden for both soil and environment. Over decades many researches had discussions about the influence of cropping systems and managements on chemical properties of the cultivated soils. It is announced that the changes of soil P might be caused by agricultural managements, such as time, rate, method of application [6]. Loss and leaching of P from agriculture soil to water surfaces results in eutrophication [7]. Long-term rice cropping increased soil available P significantly but decreased soil pH [8]. Exchangeable K tended to reduce under long-term rice cultivation due to low-input or high potential of leaching [9], magnesium and calcium losses fiercely due to leaching.

Thus there is a great need to assess soil chemical properties. Under continuous rice production, farmers should pay more attention on the changes of soil chemical properties in order to prevent from soil degradation and erosion. By understanding the relationship between soil chemical property and crop management is it helpful for our agriculture land to keep healthy, for sustainable crop production and for friendly environment. The review of literature aims to summarize: (1) Long-term changes of soil chemical properties under different topose-quential positions; (2) Long-term changes of soil chemical properties under fertilizer treatments.

2. Long-term changes of soil chemical properties under different toposequential positions

Due to different ecosystems rice is divided into upland rice and lowland rice [10]. Upland rice is grown in an aerobic soil environment without standing water and watered mainly by rainfall, while lowland rice is watered by irrigation or rainfall and most are grown in submerged soils. It has been already verified that rice in upland often associated with poor soil fertility, low available P and severe soil acidity [11]. Moreover, salinity caused by erosion due to poor management could also influence lowland soil through runoff-water [12].

In lowland position is there always water excess or deficit during cropping season [13], which determine soil nutrient availabilities. Because of the relative complex soil environment are there over decades numerous findings focusing on lowland rice, especially on rainfed lowland rice. Compared with upland rice is rice in rainfed lowland with higher yield and suffers less from diseases and drought [10].

2.1. pH

In lowland, flooding has significant effect on soil nutrients. Rice in lowland is grown characteristically in anaerobic soil with low redox potential. On one hand, more available forms are washing off from particles. On the other land, nutrients lost due to high potential of leaching. It was announced that soil pH could become neutral as a result of flooding in lowland rice area [14]. In acid soils, reduction of iron and manganese oxides depletes H^+ resulting in the increasing in soil pH.

$$Fe_2O_3 + 6H^+ \leftrightarrow 2Fe^{2+} + 3H_2O$$

$$MnO_2 + 4H^+ +2e- \leftrightarrow Mn^{2+} +2H_2O$$

In alkaline soils pH decreases mainly caused by decomposation of organic matter [10]. During the decomposition of organic matter a large number of carbon dioxide are produced and dissolve into water as HCO_3^- and $CO3^{2-}$. As a result H^+ is produced. More details were shown by Patrick & Reddy and Hinsinger et al. [15].

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \leftrightarrow 2H^+ + CO_3^{2-}$$

2.2. Available P

In flooding area soil redox potential is quite low with a range of -250 to -300 millivolts [16], which induces sequence of reduction process: ferredoxin and MnO_2 convert into ferrodoxin and Mn^{2+} [14]. Ferric photostat could reduce to more soluble ferrous form [17]. Due to this reason is there very common to appear available P and iron toxicity in lowland [18]. Available P content in soil decreases as soon as possible if soil dries [19].

2.3. Soil exchangeable cations

The reduction condition in lowland causes a displacement of K ions from non-exchangeable form to soil solution [20], and the flooded water can also increase the diffusion rate of K. Oppositely, there is no significant change of Ca, Mg concentration in flooded soils. When soil acidic is too high, lime is provided, which supply Ca and Mg [10].

3. Long-term changes of soil chemical properties under fertilizer treatments

In order to improve rice yield, farmers prefer more fertilizer application which sometimes becomes a burden for ecosystem. The loss of soil nutrients always associated with low nutrient use efficiency and may cause environmental problems, such as groundwater pollution.

3.1. pH

Some studies demonstrated that organic manure could alleviate soil acidification as a buffer over years [21]. With fresh cattle manure application soil pH increased immediately but reduced in some manure-amended soil [22]. Wang et al. proved that the application of organic manure could improve soil acidity by increasing the soil organic matter [23], promoting the soil maturation. The effect of manure on soil pH depends on the manure source and soil characteristics.

The use of mineral fertilizer alone results in soil acidity and nutrient imbalance, such as continuous application of nitrogen alone could reduce soil pH [24]. Lime increased soil pH immediately due to release OH^- and Ca^{2+} meanwhile consume H^+ in soil [25]. Someone indicated that nitrogen is the main nutrient affecting soil pH, the changes of pH depends on the type of provided nitrogen fertilizer. Kirk et al. [19] and Imas et al. [26] explained that if plants take up N as NO_3^- form, roots may export HCO_3^- and raise the pH of soil, but if N is supplied as $NH4^+$ form then H^+ will be released and cause a decrease of pH.

3.2. Available P

Manure induces in releasing of organic acid thus increases the desorption of P, at the same time improves soil available P content and crop residues [27]. Soil available P increased significantly under NP, NPK fertilizer treatments after 21 year application while under N alone treatment it declined [24]. An excessive long term application of P could accumulate large amount of soil P both in organic and inorganic pools [28]. NPK treatments can also lead to a significant increase of available P [29]. Phosphorus fertilizer contributes to saturate the content in surface and enhance the concentration of soluble P in soil [30].

3.3. Soil exchangeable cations

Under organic fertilizer treatment increased soil exchangeable Ca by 20% and reduced exchangeable Mg and K content [24]. Oppositely said soil contents of Ca and Mg were significantly enhanced by manure [28]. More exchangeable content may due to decomposition of manure. Application of manure alone or combined with P fertilizer under crop cultivation increased Mg and K. Inorganic fertilizer (fertilizer N) reflected in enhancing of soil available K content. Application of P fertilizer alone increased Mg and K. As a conclusion, the different results might be caused by different study sites, fertilizer sorts and amount, and crop sorts and yield. There might be other more reasons.

4. Conclusion

Soil fertility and chemical properties play an important role for plant production, as well as for soil erosion. Thus, under continuous rice production, there is a great need to assess soil chemical properties. As two important factors, toposequence and fertilizer have both spatial and temporal effect on soil pH, available P, exchangeable K, Ca and Mg. Nothing but understanding the long term changes of soil chemical properties in different toposequences and bunding systems could help for agriculture production and provide guidance of soil nutrients management and soil improvement and crop production.

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