

Research Progress of Phosphorus Fertilizer Utilization Efficiency in Soil

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Abstract

Phosphorus is one of the essential macrotrophic elements in plants. It plays an important role in physiological and biological processes such as energy metabolism, nucleic acid synthesis, photosynthesis and glycolysis. Phosphate mine is also a non-renewable mineral resource, to ensure high yield crop, our country pours a large amount of phosphate fertilizer into farmland every year. Therefore, it is imperative to study the mechanism of efficient utilization of phosphorus fertilizer and the technology of reducing weight. Therefore, how to improve the utilization efficiency of phosphorus fertilizer and soil cumulative phosphorus has become a major scientific problem related to the sustainable production of crops, the realization of weight loss and efficiency and the green development of agriculture. In this paper, the research progress on the efficient utilization of phosphorus fertilizer in soil at home and abroad was reviewed. Finally, the future research directions on the efficient utilization of phosphorus fertilizer in farmland soil were prospected.

Keywords

Soil; Phosphorus Fertilizer; Efficient Utilization.

1. Introduction

As one of the essential macrotrophic elements in plants, phosphorus plays an important role in physiological and biological processes such as energy metabolism, nucleic acid synthesis, photocooperation and glycolysis [1-2]. Phosphate mine is also a non-renewable mineral resource, to ensure high yield crop, our country pours a large amount of phosphate fertilizer into farmland every year. According to the statistics of China Agricultural Development Research report, phosphate fertilizer consumption in China has been stable at 11-12 million tons P₂O₅ in recent years, accounting for about 30% of the world's phosphate fertilizer consumption. According to this, it is estimated that China will run out of high grade phosphate ores in the next 20 years. As a result of the high consumption of phosphorus fertilizer, China has become one of the countries with the largest surplus of soil phosphorus in the world [3]. Due to the low utilization rate of crops and soil fixation, more than 70% of the fertilizer phosphorus applied to farmland becomes soil cumulative phosphorus or migrates to the environment along with surface runoff, which wastes resources and also leads to water

pollution. Has become a major problem restricting agricultural production and environmental sustainable development [4]. Therefore, it is imperative to study the mechanism of efficient utilization of phosphorus fertilizer and the technology of reducing weight. The year 2019 marks the 350th anniversary of the discovery of phosphorus, and people attach great importance to the depletion of phosphate mineral resources and the efficient utilization of phosphorus fertilizer [5].

Therefore, how to improve the utilization efficiency of phosphorus fertilizer and soil cumulative phosphorus has become a major scientific problem related to the sustainable production of crops, the realization of weight loss and efficiency and the green development of agriculture.

Since 2015, China has launched the "Action Plan for Zero Growth of fertilizer use by 2020". In 2018, the Ministry of Agriculture announced that "China has achieved zero growth of fertilizer use three years ahead of schedule" by promoting technologies such as soil testing and formula fertilization, integration of water and fertilizer, and organic substitution. In 2019, the No. 1 Central document put forward higher requirements of "carrying out agricultural fertilizer and medicine saving action to realize the negative growth of the use of chemical fertilizers and pesticides". Therefore, in order to meet the urgent needs of the country for the key core technologies of green agriculture, reduce the huge pressure on the agricultural ecological environment and ensure the sustainable development of China's crop industry, in China's crop production, The study of crop nutrient absorption and efficient utilization mechanism and way under large amount of drip irrigation is not only of great theoretical value, but also can provide technical support for agricultural economic development, ecological civilization construction and rural vitalization strategy.

2. Research Status and Analysis

2.1. Transformation Process and Mechanism of Phosphorus Fertilizer in Soil

Important progress has been made in soil organophosphorus and inorganic phosphorus classification and morphological transformation at home and abroad. Inorganic phosphorus in soil can be divided into calcium phosphate, aluminum phosphate, ferric phosphate and closed storage phosphorus [7]. In view of the large proportion of calcium phosphate in calcareous soil, soil calcium phosphate salt was classified as tertiary, and phosphate was extracted with mixed extract [8]. Ca₂-P is the most effective phosphorus form in calcareous soil, while Ca₈-P, Al-P and Fe-P are slow-acting phosphorus sources [9-10].

The availability and morphology of soil phosphorus mainly depend on the migration and transformation process of soil phosphorus. After phosphorus fertilizer enters the soil, it will be converted into different forms of phosphorus through the physical, chemical and biological interface chemical processes of soil colloid, and the effectiveness of phosphorus fertilizer will be reduced rapidly. The 32P test proved that the fixed amount of phosphorus fertilizer in soil would reach more than 50% within 15 days [11]. The process of phosphorus nullification mainly has two forms: adsorption fixation and chemical precipitation. In the initial stage of fertilization, adsorption fixation is the main method, and in the later stage, chemical fixation is gradually increased as the main method [12-14], in which the adsorption and desorption characteristics of soil phosphorus are most related to the availability and loss of soil phosphorus [15]. Raven and Hossner (1994a, b) [16-17] showed that compared with other characteristic parameters of soil adsorption and desorption, the maximum phosphorus desorption amount of soil had better correlation with phosphorus utilization of plants, and could better represent the plant availability of soil phosphorus. Shariatmadari [18] found that parameters of phosphorus desorption kinetics model and diffusion model were significantly correlated with biomass and phosphorus content of wheat. He et al. (1999) [19] found that

higher adsorption capacity of soil phosphorus is helpful to maintain soil phosphorus and reduce leaching loss of solution phosphorus.

Soil material composition and pH have significant effects on the adsorption and desorption characteristics of phosphorus [20]. The adsorption and analytical study of phosphorus in northeast black soil showed that when soil organic matter content reached a certain level ($> 75.3 \text{ g kg}^{-1}$) can significantly increase the adsorption capacity of soil phosphorus [21]. In calcareous soil, due to the high content of Ca^{2+} , Mg^{2+} and other base ions, chemical precipitation of phosphate fertilizer is more likely to occur compared with other soils [22-23]. Maguire et al. (2001)[24] showed that soil phosphorus saturation obtained by oxalic acid leaching could better indicate the long-term phosphorus release status of soil, while free amorphous Fe-Al oxide could indicate the continued phosphorus adsorption capacity of soil. Eriksson et al. (2016) [25] believed that the influence of pH on soil phosphorus availability largely depended on soil fertilization history and soluble Ca-P content.

The above analysis indicated that, affected by the composition and properties of soil materials, the fixed transformation and evolution process of available P in different soil and crop planting systems were different in the fields with long-term application of P fertilizer. Phosphorus fertilizer (calculated by P) accumulated 100 kg ha^{-1} , Xinjiang gray desert soil was 1.44 mg kg^{-1} , the national average 3.1 mg kg^{-1} [26]. However, limited by research methods and soil complexity, the in-situ dynamic process and morphological transformation of the phosphorus - soil interface reaction, as well as the coupling mechanism with phosphorus diffusion and migration, are rarely understood at present, especially the systematic understanding of the above interface process and transformation mechanism of phosphorus in soil with different properties is lacking. It is difficult to obtain effective control measures for phosphorus activation - fixation in soil of different regions and different planting systems.

2.2. Root (Rhizosphere) Process of Efficient Utilization of Phosphorus

Since phosphorus is difficult to move and easy to be fixed in soil, the key to improve the utilization efficiency of phosphorus fertilizer is to enhance the uptake capacity of phosphorus by crops (i.e. the activation, absorption and utilization capacity of phosphorus). The activation of P is mainly realized by the rhizosphere chemical (root secretion) and biological (phosphorus solubilizing microorganisms), inorganic chemical balance, water migration and other processes, and the absorption and utilization of available P is mainly completed by roots and mycelia. Under different P supply intensities, the release of root exudates and the response of root morphology and configuration form two major root morphology and physiological processes for efficient activated utilization of P by crops, which strongly affect the morphological transformation and biological availability of soil P [27].

However, the process of enhancing soil phosphorus activation based on rhizosphere acidification is significantly different among crop species [28]. The ^{32}P tracer test showed that the direct root pathway absorbed a high proportion of accumulated phosphorus from soil ($\text{Pdff/Pdfs } 0.13$), while the mycorrhizal pathway combined with the direct pathway significantly increased the proportion of phosphorus from fertilizer in cotton ($\text{Pdff/Pdfs } 0.5$)[29].

2.3. Regulation Approach of Efficient Utilization of Phosphate Fertilizer

Soil environment (such as water and phosphorus supply conditions) significantly regulated crop root morphology and configuration. The main research on soil phosphorus activation focuses on microorganisms and organic acids. The main activation mechanisms include the exchange adsorption, chelation, acid effect, adsorption site reduction response, ion bridge effect and other theories of organic acid substances [30,31], and the expansion of absorption area and secretion of organic acids and protons by arbuscular mycorrhizal fungi [32].

There are many explanations for the mechanism of phosphorus solubilizing microorganisms, including organic acid secretion, proton release, chelation, etc. [33,34]. At present, more researches on soil phosphorus activators include small organic acids such as oxalic acid, citric acid, tartaric acid and malic acid, large organic acids such as humic acid and lignin [35-38], as well as phosphorolytic bacteria and arbuscular mycorrhizal fungi [39,40]. There are few studies on the effect of new materials (such as modified biochar) on the ineffective inhibition of phosphate fertilizer, and its mechanism still needs further study [41].

Another way to improve the utilization rate of P fertilizer is to control the ineffective conversion of P fertilizer into soil. Within a certain range, organic matter can reduce the maximum phosphorus adsorption capacity of soil [42], thus preventing the ineffective process of phosphorus fertilizer application into soil. The addition of manure in addition to the application of phosphate fertilizer can significantly change the adsorption dynamic characteristics of soil and maintain a high Olsen P content in soil [43,44]. In addition, phosphorus adsorbed by biochar is a good available source of phosphorus, which can improve the phosphorus supply of soil [45]. The formation of aggregate structure helps to reduce soil phosphorus retention, thus improving the utilization efficiency of phosphorus fertilizer [46].

3. Discussion

To sum up, how to improve the utilization efficiency of phosphorus in crop production has become a major hot issue in the world. Further studies should be carried out on the transformation process and mechanism of main soil phosphorus in farmland, as well as the rhizosphere biological potential of efficient utilization of phosphorus. The transformation, migration and adsorption characteristics of phosphorus after phosphorus fertilizer enters different types of soil, as well as the agronomic threshold of available phosphorus in typical farmland soil, should be carried out through the matching mechanism of phosphorus fertilizer-soil-crop planting system. As soon as possible, the regulation and control technology system of crop phosphorus reduction and efficiency improvement under drip irrigation under film should be established to provide a new way for crop phosphorus reduction and efficiency improvement technology.

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