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Research Progress of Soil Acidification and Irrigation Technology in Southern China

FU Xian^{1*}, YANG Runyi²

Doctor Lecturer, School of Civil Engineering, Hunan City University, Yiyang, Hunan 413000, China¹

Student, School of Civil Engineering, Hunan City University, Yiyang, Hunan 413000, China²

ABSTRACT: In view of the increasingly serious soil acidification and the gradual reduction of water resources in the southern region, this paper summarizes the domestic and foreign research on acidified soil improvement technologies. Soil improvement technologies include chemical substance improvement, environmentally friendly improvement and comprehensive improvement technologies. The research status of irrigation technology at home and abroad is reviewed. Irrigation technology includes conventional irrigation technology and water-saving irrigation technology ("thin and shallow wet sun" irrigation, intermittent irrigation, controlled irrigation, rain-saving water-saving irrigation, etc.). It briefly analyzes the current domestic and foreign insufficiency of soil acidification improvement and water-saving irrigation technology, and briefly puts forward the direction that urgently needs in-depth research, hoping to provide reference for the research direction of acidified soil improvement and water-saving irrigation comprehensive technology.

KEYWORDS: Soil acidification; chemical substance improvement; environment-friendly improvement; comprehensive improvement technology; conventional irrigation technology; water-saving irrigation technology.

1. INTRODUCTION

The area of acid soil is expanding continuously in China. The area of strong acid soil (pH < 5.5) has increased from 169 million mu to 226 million mu now [1]. The natural acidification process of soil is relatively slow, but in recent decades, due to the impact of high input, high output and intensive production activities, the process of soil acidification has been greatly accelerated, seriously harming the ecological environment and agricultural production. The problem of soil acidification has become one of the urgent scientific problems to be solved in China's farmland soil [2]. It is of great significance to take effective measures to improve farmland acidification soil, curb the continuous acidification of soil, and maintain the soil acidity at a low level in south China for the implementation of sustainable agricultural development in China.

China's water resources account for 6% of the global water resources, but per capita only 2200 cubic meters, China has become one of the world's per capita water resources of the poorest countries. The contradiction between supply and demand of water resources is very prominent in China. In the previous water management of agricultural irrigation, more attention was paid to water supply management, but water saving and water conservation measures were relatively weak in the irrigation utilization efficiency. China is a big agricultural country, and more and more water is used in agriculture. However, due to the serious waste of water resources in farmland irrigation, the efficiency of farmland irrigation water is low. Therefore, it is exceedingly crucial to work out reasonable agricultural water-saving safeguard measure to change this situation, which is to alleviate the shortage of water resources and guarantee the healthy and steady development of agriculture [3].

II. RESEARCH STATUS OF SOIL ACIDIFICATION IMPROVEMENT

2.1 Chemical Improvement

Lime and limestone powder are commonly used and effective amendments for improving acidified soil. Applying a certain amount of lime or limestone powder on the acidified soil can neutralize the acidity of the soil, improve the soil

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*First author (corresponding author): Fu Xian (1992-), female, lecturer, doctor, mainly engaged in agricultural water and soil resources utilization and water and soil environment regulation research. E-mail: chengyuanfuxian@163.com.



effectively, improve the physical and chemical properties of the soil, restore and increase the comprehensive production capacity of the soil [4]. Studies have shown that the application of soil conditioners such as lime and quicklime on acidified soil can increase the soil pH to varying degrees [5]. Studies have also shown that lime can quickly and effectively reduce the acidity of acidified soil, and can also supplement the available calcium in the soil to meet the needs of plant growth, but long-term application of lime will lead to soil acidification [6]. The use of minerals and industrial waste such as phosphogypsum, dolomite, phosphate rock powder, fly ash and alkali slag can also reduce soil acidity, but the minerals often contain toxic metal elements, so the risk of pollution should be paid attention to when applying them [7].

2.2 Environmentally Friendly Improver

Long-term application of organic materials with high alkalinity, such as organic fertilizer, not only has a good buffer effect on soil pH, but also can release alkaline substances to neutralize soil acidity and improve soil pH value [8-9]. Studies have shown that long-term application and increased application of organic fertilizers can enhance the acid-base buffering performance of soil, reduce the content of exchangeable cations in soil, and alleviate the process of soil acidification [10]. It was also found that after long-term application of organic fertilizer, neutral molecules formed by anions dissociated from weak acid functional groups of organic matter in soil (carboxyl protonation) were the main mechanism to improve soil pH buffering ability. Carboxyl protonation led to the decrease of effective cation exchange ability in soil, the increase of base cations, and the enhancement of soil anti-acidification ability [11]. Studies have shown that long-term application of organic fertilizer can significantly increase the content of organic matter and slow down soil acidification [12]. Some studies have also found that the application of biochar has a good effect on the improvement of acidified soil, which can neutralize the acidity in the soil. The more biochar is applied, the more obvious the improvement effect of soil acidification is [13]. Studies have also shown that the application of silicon calcium potassium magnesium fertilizers can supplement the mineral elements lost in farmland soil, while regulating soil acidity and alkalinity, improving soil structure, and improving crop yield and quality [14].

2.3 Comprehensive Improvement Technology

The application of lime in combination with the return of winter green fertilizer, commercial organic fertilizer, straw to field and other organic fertilizer cultivation measures can improve soil pH value, increase soil organic matter content, improve soil physical and chemical properties, and enhance soil acid-base buffering ability and fertilizer retention performance [1]. The application of inorganic amendments such as lime with organic fertilizer, straw or straw biomass charcoal in a certain proportion can neutralize soil acidity, improve soil fertility and maintain the balance of soil nutrients [15]. The combined application of biomass ash, bone meal and alkaline slag has been tested. The test results show that the combined application of the three amendments increases the pH value of the aged soil [16]. The causes of soil acidification are complex, and comprehensive measures should be taken to control the acidified soil. While applying lime and other amendments to reduce the soil acidity, organic and biological fertilizers should also be applied to optimize the soil structure and increase the buffer capacity of the soil [17]. Some studies have shown that adding soil conditioner [18] and Canadian calcium carbonate volcanic salt rock [19] to constant fertilization can improve soil pH, increase soil organic matter, total nitrogen and effective nutrient content, and thus improve acidic soil.

III. RESEARCH STATUS OF IRRIGATION TECHNOLOGY

3.1 Conventional Irrigation Techniques

Rice is a typical aquatic food crop. In the process of planting, flood irrigation is usually used to meet the water demand of plant growth, so the water consumption is very large. The traditional cultivation technology mode is used to long-term submerged irrigation in the later stage of rice growth, which consumes a lot of water and affects the formation of yield and quality [20]. Therefore, there are few single studies on conventional irrigation technology. Most of the studies compare flooding irrigation with other water-saving irrigation. The research shows that flooding irrigation has a large amount of irrigation water, a large amount of drainage, a large amount of leakage, a low yield [21-22], a high degree of agricultural non-point source pollution, a low fertilizer utilization rate [22], a large amount of greenhouse gas emissions [23], and a large number of rice diseases and insect pests [24-25].

3.2 Water-saving Irrigation Technology

Many scholars continue to study water-saving irrigation techniques suitable for rice. According to different soil types, topography and climate conditions, a variety of water-saving irrigation techniques have been proposed, mainly including "thin and shallow wet sun" irrigation, intermittent irrigation, controlled irrigation and water storage[26].

The irrigation mode of "thin, shallow, wet, and sun", that is, shallow water turns green, thin water tillering, drying in the late tillering stage, shallow water promotion from jointing to heading stage, and moist drying in the mature stage, so as to minimize the water consumption among trees[27]. The "thin and shallow wet sun" irrigation mode is the most widely used in China. The research of some scholars showed that compared with long-term flooding model, "thin and shallow wet sun" irrigation model reduces the water displacement by about 20% and the yield increased by about 5% [21], and the ammonium nitrogen loss of surface drainage reduces by 27.7% [28], which effectively inhibits CH₄ emission, promotes N₂O emission of the paddy field and reduces the comprehensive greenhouse effect of rice field [29].

Intermittent irrigation can reduce the water consumption of rice, significantly reduce the irrigation amount of rice, reduce the overflow loss, and improve the utilization rate of rainfall. Moreover, long-term intermittent irrigation has a more significant effect and better water-saving effect [30]. Studies have shown that intermittent irrigation can effectively reduce the amount of irrigation water, the frequency of irrigation and drainage, improve the efficiency of irrigation water use, and stabilize the yield of rice [31]. Compared with conventional irrigation, intermittent irrigation reduced total nitrogen and total phosphorus emissions, and increased nitrogen use efficiency [32]. The ecological effects of intermittent irrigation have been studied, and the results show that intermittent irrigation can significantly improve the diversity of weed community, effectively inhibit the growth of dominant species of weeds [33], effectively improve the diversity of natural enemies community in paddy fields, and reduce the diversity of pest community [34].

Intermittent irrigation with rain storage has significantly reduced the amount of irrigation and drainage, and the number of irrigation and drainage, which has obvious effects of saving water, reducing emissions, and improving the effective utilization rate of rainfall. It has a strong promotion and application space in rainy areas in southern China [35]. Researchers have carried out research on the effect of alternating wet and dry irrigation on the growth and development of rice, and it is clear that alternate wet and dry irrigation can improve the nutrient absorption and utilization of the root system, thereby promoting high and stable rice yields [36], and has the effect of improving quality and efficiency [37].

IV. SUMMARY AND OUTLOOK

In recent years, there have been many achievements in the research on the principle and mechanism of soil acidification, the improvement of acidified soil and the screening of amendments. However, soil acidification is a long-term and complicated process, and long-term localized experiments should be done, and acidified soil improvement technology should be studied systematically. At present, the improvement of acidified soil is still dominated by the application of chemical amendments, and the amendments are single. Therefore, it is necessary to study new amendments or improvement methods which are efficient, sustainable and ecological, and put forward comprehensive regulation technology of acidification improvement under the cooperative application of a variety of amendments and reasonable management of water and fertilizer.

Nowadays, there have been many researches on the selection of water-saving irrigation mode for rice. However, the selection of water-saving irrigation mode for rice field basically only considers the single factor of maximizing the benefit of water-saving and yield-increasing, without considering the ecological and environmental benefits of rice field. With the rapid development of water-saving irrigation, more and more attention is paid to the ecological environment. The comprehensive effects of water-saving irrigation, excellent fertilizer, increased yield and ecological environment should be considered in the research of water-saving irrigation, and the mutual feed-mechanism between water-saving irrigation and excellent fertilizer, increased yield and ecological environment should be deeply studied through multi-disciplinary crossing, so as to put forward the comprehensive regulation model of water-saving and excellent fertilizer. In addition, we can make full use of modern information technology to research and design the intelligent control system of water-saving irrigation, and put forward the optimal comprehensive control mode of water-saving and fertilizer in rice field by adopting the method of multi-criteria evaluation.

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