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Study on the Leaching Status of Magnesium Nutrients in Soil and its Influencing Factors

Lei Shi[1,2,3,4], Liheng Xia[1,2,3,4]

[1] Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an 710075, China

[2] Institute of Land Engineering and Technology, Shaanxi Provincial Land Engineering Construction Group Co., Ltd., Xi'an 710075, China

[3] Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of natural resources, Xi'an 710075, China

[4] Shaanxi Provincial Land Consolidation Engineering Technology Research Center, Xi'an 710075, China

Abstract

Mg is one of the essential medium elements for plant growth and an essential mineral nutrient in agricultural production. In this paper, we summarize the past series of plant Mg nutrition studies and Mg leaching tests in field soils to reveal the leaching status of Mg elements in soils today and their influencing factors. According to the test results of 325 609 soils in the 2016 National Soil Testing and Formulation Program, Mg-deficient soils with exchangeable Mg content (Mgex) <50 mg-kg-1 accounted for 43.8% of soils in the country; among them, soils with 25-50 mg-kg-1 accounted for 7.64%, and those with Mgex <25 mg-kg-1 accounted for 36.14%, and soils in China had a more serious deficient The salinization, acid-alkalization, high heavy metal content and intense leaching of the soil were the important influencing factors for its lack of Mg supply. Positive effect factors of soil Mg leaching include soil exchange Mg content, type of fibrous root crop, light-textured soil, desorption of soil Mg, and weathering of parent material; negative effect factors include type of taproot crop, root secretion, biomass fixation, soil pH and organic matter, colloidal adsorption, and precipitation mineralization.

Keywords

Soil Magnesium; Leaching; Control Factors.

1. Introduction

Soil is the fatal and weak link in agricultural production. Soil first as a support for plant growth, its rich microbial diversity and the emission of domestic and industrial waste, combined with climate, agricultural operations (fertilizer supply, irrigation, mid-tillage loosening, etc.) is the main reason for the differences in the geotechnical conditions of different regions, so a variety of factors lead to a sharp increase in the environmental load of the soil. As the main contradiction of China in the new era has changed from the contradiction between people's growing material and cultural needs and backward social production to the contradiction between people's growing needs for a better life and unbalanced and inadequate development [1], agricultural production is the fundamental support for people's needs for a better life, and how to solve the problems of inefficient agricultural production and high environmental loads is imminent. In order to achieve the goal of 100%~110% growth in global food demand from 2005 to 2050, we must rely on the following three main actions in agricultural practice: 1) agricultural intensification in developed countries, 2) opening up of farmland in backward countries, and 3) the promotion and application of integrated soil-crop system (ISSM) in

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intensive production management, ISSM) in intensive production. [2,3] China is a large country with intensive agriculture, and the study of Bruinsma et al [4] showed that the fertilizer input (N+P2O5+K2O) of arable land in East Asia reaches 195 kg-ha-1, which is higher than the global average level of 92 kg-ha-1, and the potential of fertilizer saving is huge; meanwhile, the resultant air pollution [5], greenhouse gas emission problems [6], soil acidification [7], eutrophication of water bodies [8] and other problems are prominent and are increasingly becoming a research hotspot.

The theme of the World Soil Year 2017 is - Caring for the Earth begins with the land; and FAO suggests that the keys to soil health are 1) reducing forced migration, 2) mitigating and regulating climate change, 3) enhancing nutrients, 4) maintaining biodiversity, 5) providing clean water, and 6) achieving food security. [9] Reducing forced migration is at the top of the list of six important soil health components, and runoff losses and leaching losses are two fundamental pathways of mineral nutrient migration. In the past, a great deal of work on soil nutrient transport has centered on plant-essential macronutrients (nitrogen, phosphorus, and potassium), while Mg, as a meso-element, has not received much attention; Ismail et al. [10] pointed out that Mg-vegetable nutrition is gradually being forgotten in agricultural production. In recent years, more and more Mg deficiency symptoms are frequent on cash and food crops such as sugarcane, citrus, winter melon, papaya, leafy vegetables, etc., and the research work on Mg-vegetable nutrition has been gradually revived, and Mg is gradually becoming a limiting factor in the agricultural production of a large number of crops. [11].

The physiological functions of Mg-vegetable nutrition in plants are mainly expressed as: participation in carbohydrate transportation and distribution, protein synthesis, energy metabolism, RNA synthesis; Mg is the central atom of chlorophyll, which plays an important role in photosynthesis; and at the same time it has a better mitigating effect on light, heat, drought, low Ph, and heavy metal stresses. [12] At the same time there is also a greater relationship between Mg and human health, Mg is quite effective in relieving brain fatigue [13], treating angina and osteoporosis [14]. According to incomplete statistics, according to the recommended daily intake of Mg per capita of 320~420 mg set by the United States, 55% of the global population shows insufficient intake, of which 20% is in the state of extreme deficiency; only about 25% of the population is in the recommended range or higher than the recommended range. [15] In order to address the dual physiological needs of crops and humans for Mg, Mg biofortification in agricultural production is urgent. However, the biogeochemical processes of Mg in soil must be considered in the Mg biofortification work, so as to come to improve the uptake and utilization of Mg by plants for the ultimate purpose. This paper summarizes the input and output processes of Mg in the soil-crop system, and also analyzes the influencing factors of Mg loss in soil from the perspective of soil leaching, so as to provide a theoretical basis for future research on the efficient utilization of Mg in China.

2. Status of Mg Content in Soil

At the end of the last century, China's soil Mg content was relatively rich, and soil exchangeable Mg content (Mgex) in North China was in the range of 0.5% to 2%, with an average of 1%; in Northwest China, it was more than 3%; and in South China, it was 0.06% to 1.95%, with an average of 0.5%. And it showed a distribution pattern of decreasing from north to south and from west to east, but in general, the Mgex content was abundant. However, according to the results of 325 609 soil tests of the National Soil Testing and Formulation Fertilization Project in 2016, the soils with Mgex>500 mg-kg-1, 300-500 mg-kg-1, 200-300 mg-kg-1, 100-200 mg-kg-1, 50-100 mg-kg-1, 25-50 mg-kg-1, and <25 mg -kg-1 soils accounted for 13.83% (n=38452), 10.71% (n=53263), 8.95% (n=52083), 13.42% (n=75956), 9.31% (n=54507), 7.64% (n=42528), and 36.14% (n=98820), respectively. Mg-deficient soils (Mgex < 50 mg-kg-1)

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accounted for 43.8% of the total, and there has been a scarcity of Mg-supplemented nutrients in our soils. Analyzing the reasons may be the excessive application of NPK fertilizers plus irrational irrigation, as well as no or little application of middle and trace element fertilizers hobby, leading to the salinization, acid-alkali, heavy metal pollution and high-intensity washing phenomenon is serious in China's soils,[16] thus leading to a sharp decline in the content of Mgex in the soil, and even the scarcity of Mgex.

3. Current Status of Leaching Losses of Mg in Field Production

Pettersson et al [17] found that the leaching loss of Mg was 9.5, 20 kg-ha-1 in forest system and cropland system, respectively; Di et al [18] concluded that the leaching loss of Mg in grassland system could also reach 17.4 kg-ha-1; Jakobsen et al [19] showed in their study on two grain crops, wheat and maize, during winter, that the leaching of Mg from the soil could reach up to 42, 44 kg-ha-1 ; Poss et al [20] obtained similar findings on maize with a leaching loss of 45 kg-ha-1 of Mg nutrients; however, the study of Ylaranta et al [21] on barley reflected that the maximum leaching loss of Mg was recorded in the barley system under the same rainfall conditions (87 kg-ha-1), which was higher than that of the fallow land (35 kg-ha-1), and higher than that of the fallow land (35 kg-ha-1). of 35 kg-ha-1 in fallow and 1.67 and 1.29 times higher than that of 38 kg-ha-1 in grassland, respectively. Meanwhile, Jakobsen et al [19] showed that the Mg leaching losses in oilseed rape and soybean production were 42 and 45 kg-ha-1, respectively, in a vegetable system.Different rainfall, crop root types, and root secretions may be important factors contributing to the varying Mg leaching losses under different crop types. In general, there is still a lack of international field studies on soil Mg leaching losses.

4. Analysis of Factors Affecting Soil Mg Leaching Losses

4.1. Soil Condition Factor

pH Soil acidity and alkalinity are important influencing factors for mineral nutrient activation.Phillips et al[22] adjusted soil acidity and alkalinity by $Ca(OH)2$, and found that: the soil significantly increased the concentration of Mgex in the leaching solution and decreased the concentration of Mgex in the soil solution after adjusting the soil from pH 6.0 to 7.0.Wingen et al[23] obtained the results of the similar study, on red soil After adjusting pH 5.5 to 7.5, Mgex concentration in soil solution decreased by 50%. This indicates that soil Ph can directly affect the leaching loss of soil Mg, and at the same time, the leaching loss of Mg is increased with the increase of soil pH.

Organic matter Soil organic matter has a long-lasting type of fertilizer supply, balanced and strong buffering properties, and the results of long-term experiments by Piechota et al [24] showed that compared with the application of chemical fertilizers, the application of agricultural fertilizers can significantly increase the concentration of Mgex in each soil layer and reduce the leaching loss of Mg.

Texture The results of the field study by Koc et al [25] found that the lighter the soil texture, the more powerful the leaching loss of Mg. This is related to the poor fertilizer and water retention of light textured soils.

Moisture There are two factors that contribute to soil moisture, rainfall and irrigation. The results of Jakobsen et al [18] on winter wheat production showed that rainfall had a positive effect on Mg leaching losses. The Mg leaching loss reached 19 kg-ha-1 at a rainfall of 512 mm, and increased to 42 kg-ha-1 when the rainfall increased to 808 mm, which was one-fold higher. The results in the Gheysari et al[26] N leaching experiment found that the leaching loss of N increased with the increase in irrigation water; and with the increase in the supply of N nutrients, the leaching loss of N was also increased. It is not difficult to find that the two most

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fundamental mailbox factors of mineral nutrient leaching loss are: soil moisture and effective nutrient content in the soil. Therefore, to control the leaching of mineral nutrients, the final work will come down to how to effectively and efficiently control the soil moisture and the effective nutrient concentration in the soil.

4.2. Nutrient Uptake by Plants

Plant nutrient uptake and water uptake are simultaneous, but there are synergistic or antagonistic effects between different nutrient uptake; there are antagonistic effects between plant uptake of the same valence charge ions, while there are synergistic effects between uptake of anisotropic charge ions [27]. The presence of antagonistic plant uptake of Mg increases the risk of leaching loss of Mg from the soil when high amounts of ions such as H+, Al3+, K+ and NH4+ are present in the soil.

4.3. Fertilizer Management

Application of K fertilizer Seggewiss et al [28] showed that the subsequent increase in the supply of K fertilizer, the concentration of Mg in the soil solution rises, the presence of a large amount of K, the presence of a strong antagonistic effect on the uptake of Mg by the plant, and at the same time, K + competes for sites and lattices on the soil colloid with Mg2+ to inhibit the process of adsorption and immobilization of Mg2+. Secondly, the supply of K fertilizer promoted the downward movement of Mg in the soil. In short, the supply of large amounts of K fertilizer increases the loss of Mg leaching from the soil [20], but a quantitative description is lacking.

Application of Ca fertilizer Clay minerals are the main components of soil, in clay minerals, the ions allowed to enter the silica-oxygen tetrahedral lattice must meet the ionic ratio of ≤0.414, and the aluminum-oxygen octahedral ≤0.732. The ionic ratio of Mg2+ is 0.471, which is smaller than that of Ca2+ (0.707), and Mg2+ can be substituted for Ca2+ to enter into the aluminum-oxygen octahedral lattice easier and replace Al3+ in the homocrystalline displacement and immobilization. Al3+ and be immobilized; [29] however, as Ca2+ supply increases, it can alleviate the immobilization of Mg2+, and the Mg2+ concentration in the soil rises, increasing the risk of leaching loss of Mg2+. [30].

Different Mg fertilizer forms Different forms of Mg fertilizers have different transformation processes in the soil, and their uptake and utilization efficiencies are not consistent among different crops.Longanathan et al [31] showed on pasture that Mg sulfate was the worst applied, with 49% loss of Mg with runoff and leaching, and its biomobilization efficiency by pasture was about 25%; the loss of Mg fertilizers in slow- and controlled-release form was only about 10% In addition to a considerable portion being biomobilized by pasture, most of the Mg nutrients can be stored in the 0～7.5 cm soil layer for application to the next crop.

4.4. Crop Systems

Boysen et al [17] found that leaching losses of Mg in arable systems averaged 20 kg-ha-1 respectively, with leaching losses of 42, 87 and 42 kg-ha-1 in fibrous-rooted cropping systems such as wheat [19], barley [21] and oilseed rape [19], and leaching losses of 9.5, 45 and 45 kg-ha-1 in taprooted systems such as forest [18], maize and soybean [19]. Differences in crop root types and root secretions may be important factors contributing to the different Mg leaching losses under different crop types.

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