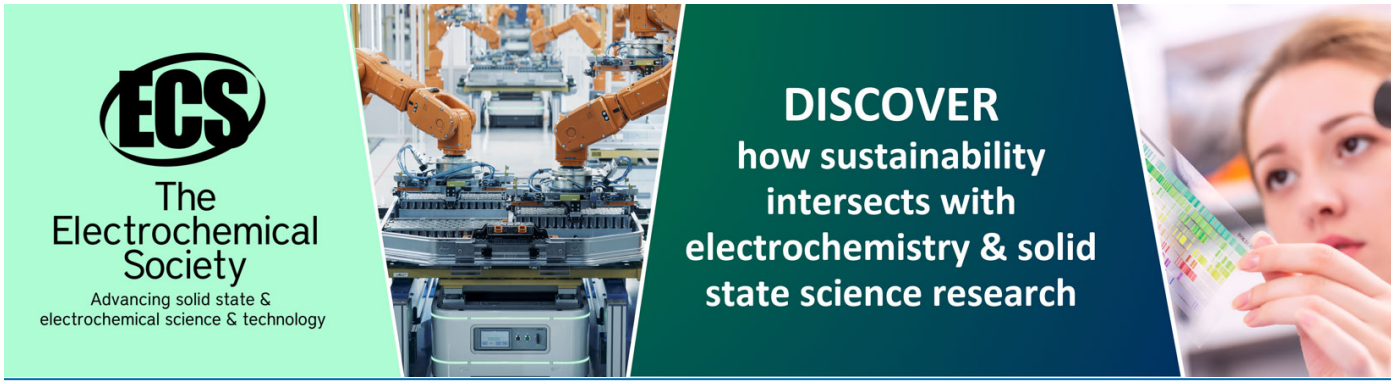
Effect of Soil Magnesium on Plants: a Review



Effect of Soil Magnesium on Plants: a Review

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Abstract. Magnesium is very important to plants. Magnesium deficiency which is coursed by excess fertilization and excess irrigation and leads to declining production and quality appears more and more frequently. In addition to provide theory basis for magnesium inputs to correct magnesium deficiency, this paper described the effects of magnesium on plant, the magnesium contents and the factors that affect it in soil and plant.

1. Introduction

Facility agriculture gradually removed traditional agriculture from natural constraints, broke the seasonal nature of traditional agriculture, and brought counter-seasonal listing of agricultural products to further meet the diversified and multi-level consumer needs. It also developed into a major form of vegetable cultivation in northern China. Currently, Shaanxi has an area of more than 143,000 hm^2 and is also rapidly increasing at an annual rate of 13,000 hm^2. As a result, the cultivation of facilities has become one of the major ways for farmers to increase their incomes and agricultural economic development in many areas.

Tomato is the main crop cultivated in greenhouse, farmers in order to ensure the yield, mast water Shuiqin's traditional management patterns prevail. Excessive irrigation and fertilization not only increase production costs, waste of resources, but also cause nutrient leaching and imbalance, polluting groundwater. With the cumulative accumulation of nitrogen, phosphorus and potassium nutrients in sunlight greenhouse soil at the same time, in recent years, our field survey found that the cultivation of soils in our province often appear tomato magnesium deficiency symptoms in 2012 in Shaanxi Yangling Demonstration Zone Dazhai Township and Wuquan Zhenwan Mu facilities and cultivation base, autumn and winter greenhouse crop (autumn stubble) 70% of tomatoes typical symptoms of magnesium deficiency. This is in line with the people's previous understanding that calcareous soil is rich in magnesium and is not prone to magnesium deficiency. The viewpoint that magnesium deficiency mainly occurs in southern acid soils is inconsistent. In the meantime, once the tomato is lack of magnesium, it is very difficult to replenish the chlorosis symptoms of the magnesium fertilizer late leaves, and the lack of magnesium has seriously affected the yield and quality of the tomato.

2. The Role of Magnesium

2.1. Physiological Role in Photosynthesis

Mg participates in the formation of chlorophyll and is an essential element for the normal structure of chloroplast. Its proportion accounts for about 2.7% of the chlorophyll molecular weight. However, whether the lack of chlorophyll content in Mg plants is due to Mg deficiencies in the synthesis of chlorophyll is not yet elucidated. Some studies suggest that the lack of chlorophyll content in Mg leaves is not due to lack of magnesium needed for the synthesis of chlorophyll molecules, but due to the obstruction of protein synthesis. In recent years, the research suggests that the damage of reactive oxygen species under the stress of Mg is the main reason for the decrease of chlorophyll content and the loss of greening and yellowing of the leaves. Magnesium ions at lower concentrations can induce thylakoid membrane stack formation of grana, is conducive to capture light energy transfer energy. At the same time, Mg2+ can regulate the distribution of excitation energy between chloroplast PsⅡ and PSI and increase the ratio of relative fluorescence yield of PsⅡ to PS I, so that plants can convert more light energy into chemical energy. In addition, Mg2+ may maintain a certain conformation of the antenna chromophore reaction centers and certain electron carriers on the molecular level and maintain their close contact at the molecular level to ensure efficient absorption, transfer and conversion of light energy [1]. Li Yan et al. studied the effects of magnesium deficiency on the photosynthesis of longan. The results showed that: magnesium deficiency decreased photosynthetic pigment content, chloroplast light absorption capacity, apparent quantum yield and carboxylation efficiency, and increased the light compensation point and CO_2 compensation point, the light saturation point and the saturation point of CO_2 decreased. The decrease of Fv / Fo, Fv / Fm and Fd / Fs of Chl.a indicated that the decrease of PSⅡ activity: The decrease of F685 / F736 ratio indicated that magnesium deficiency reduced the excitation energy in The ability to distribute between two light systems [2].

2.2. The Activation of the Enzyme

Magnesium is a plant activator of many enzymes. Almost all phosphorylases and kinases require Mg^{2+} activation. Mg^{2+} promotes the hydrolysis of ATP or ADP and releases phosphoric acid and energy. It also activates ATPases, promotes phosphorylation, and synthesizes more ATP. According to Briskin et al., Activation of ATPase is achieved through the bridging effect of Mg^{2+}, that is, Mg^{2+} forms a bridge between the pyrophosphate structure of ATP or ADP and the enzyme molecule. The activation of ATPase is mediated by this complex Caused by the ATPase can use this complex to transfer high-energy phosphinyl [3]. Magnesium is required for the basic processes of energy transfer such as photosynthesis, glycolysis, three-shuttling, and respiration, and magnesium is obligatory for the activation of phosphokinase, Phosphotransferase, Enolase, the activation of dehydrogenase in the thirteenth acid cycle, the activation of magnesium can be replaced by manganese. Mg^{2+} can activate RuBP shuttle enzyme. The combination of Mg^{2+} and RUBP shuttle enzyme increases its Km and Vmax for CO_2. Under illumination, Mg in the chloroplast thylakoid membrane enters the matrix, whereas H^+ enters the thylakoid from the matrix, providing the optimum conditions for the action of the RuBP shuttle enzyme, ie, higher M+ concentration and pH greater than 6, Promoting CO_2 fixation and assimilation [4,5]. Magnesium is also an activator of chloroplast matrix fructose 1, 6-diphosphoacetate and sedoheptulose-1, 7-diphosphate cleaving enzyme, which increases the pH and Mg^{2+} concentrations in the chloroplast matrix and also activates these two enzymes. Activation of these two enzymes have promoted the operation of photosynthetic rings and promote photosynthesis.

2.3. Increased Crop Yield and Improved Crop Quality

Magnesium demand for crops can be expressed as the absorption coefficient, the absorption coefficient of magnesium is greater than other elements, the larger amount of magnesium absorbed by crops, indicating that the demand is also high, reflecting the main status of magnesium in the crop. In recent years, the phenomena of plant magnesium deficiency have emerged one after another and have

become an important factor that limits plant yield and quality. Jiang pointed out that magnesium has a significant effect on increasing the yield and quality of crops such as flue-cured tobacco, sugar cane, banana, eggplant vegetables, peanuts, tea, citrus and soybean, early rice, late rice, astragalus, corn and millet [6].

Li Yan and other studies have shown that magnesium deficiency of rice sugar and starch decreased significantly, only about 30% of normal rice [7]. After testing, there is a clear correlation between the amount of magnesium in rice and the content of sugar-starch, indicating that magnesium has a significant effect on the metabolism of carbohydrates. Inadequate supply of carbohydrate at the booting stage of rice will reduce the effective spike, and the seed setting rate and grain weight will decrease, which will lead to the decrease of rice yield. Through the application of magnesium fertilizer can increase the soil exchangeable magnesium content, increase soil magnesium saturation and increase the amount of magnesium in plants, effectively improve the rice yellow leaf disease; the same time, magnesium supplement, As a result, economic traits such as effective panicle, grain number per spike, seed setting rate and 1000-grain weight were significantly improved and the yield was increased significantly, reaching extremely significant level. Li Shimin studies have shown that magnesium has a significant impact on the nutritional quality of rice, rice magnesium can significantly increase the protein content of rice, with increasing magnesium content of protein content increased; amylose and white content decreased. When sufficient magnesium was supplied, the crude protein and total amino acids in brown rice increased obviously, and the contents of two kinds of limiting amino acids, lysine and threonine, of cereal protein also increased, which had the potential to improve the nutritional quality of rice a certain meaning. Li Xiaoming Studies have shown that the application of mineral magnesium fertilizer can significantly improve the rice invade, chlorophyll content at jointing and heading than the conventional NPK fertilizer increased by 0.43-0.96 percentage points; effective stamen increased by 10.7%; rice yield increased by 40.7%; rice protein content Increase by 0.32 percentage points; then the amylose and the white content will decrease [8]. Zhang Ju-ping Studies have shown that magnesium deficiency inhibited the growth of the root system of Chinese cabbage, the roots sparse and yellowish, but no rotten odor "in a certain range, increasing the concentration of magnesium in the nutrient solution can significantly promote the Chinese cabbage plant Growth, increased leaf length, increased yield, increased vitamin C content and improved quality[9] .Zhu Yongxing studies have shown that magnesium deficiency disappears gradually after water-soluble magnesium sulfate fertilizer is applied to tea plantations with deficient magnesium production, with an average increase of 9.8-13.6% Spraying foliar fertilizer test results on average yield of 20.8%. Magnesium can also significantly improve the quality of tea, amino acids, caffeine and water extract content [10]. Zhao Bing Studies have shown that the application of magnesium fertilizer can significantly increase the late growth of tomato chlorophyll content, plant height and fruiting quantity, and the fruit yield and biomass yield increase effect; activated MgO magnesium fertilizer treatment of tomato leaf chlorophyll content, plant height And the number of fruiting is obviously better than the treatment of MgO only; fruit yield and biomass increased significantly, and better than MgO treatment [11].

3. Magnesium in the Soil

3.1. Soil Magnesium Content

The average magnesium content in the earth's crust is 219 g/kg. Due to the weathering of the magnesium-bearing minerals, magnesium is leached. The average magnesium content in the soil is 5 g/kg. The content of magnesium in the soil varies greatly from 0.5 g/kg to 40 g/kg, but most of the soil magnesium content of 3-25g / kg. The total magnesium content in southern China is generally 0.6-19.5 g/kg, an average of about 5g / kg; northern soil magnesium content is generally 5-20 g/kg, with an average of about 10g / kg, the general sand 0.5 g/kg , Clay 5 g/kg. Baiyue Lu studies have shown that: China's soil available magnesium content from 1.2 mg/L to 4468.9 mg/L range, the average content of 320 mg/L. According to the soil nutrient evaluation index of soil system research method, the content

of soil available magnesium in our country is 8%, the soil in the lack of condition is 13%, and the medium level is 33% In rich and very rich state accounted for 34% and 12% respectively. 54% of the soil requires different levels of supplementary magnesium fertilizer. The areas with low effective magnesium in China are mainly located in the area south of the Yangtze River. The major provinces are Fujian, Jiangxi, Guangdong, Guangxi, Guizhou, Hunan and Hubei provinces. According to our country soil effective magnesium content judgment, each year our country soil needs to supplement 9.84 million tons of magnesium fertilizer. In addition, the content of magnesium in the soil is also related to the formation process of the parent soil, the abundance, degree of weathering and leaching of the organic matter in the soil. The soils developed in granite, sandstone and shale have less magnesium content, and the soils generally developed from magmatic igneous rocks with more iron-bearing magnesia are generally rich in magnesium. In wet areas with high temperature, the degree of weathering is high, and the content of soluble magnesium Easy to loss, reduce the amount of magnesium, on the contrary, dry and cold, leaching low areas, more magnesium in the soil. Looking at the total amount of magnesium in the soil of our country, there is a trend of decreasing from west to east as the climate conditions change from north to south. The content of soil profile lower than the upper. In the northern region, magnesium content in soils is generally high due to the high magnesium content in the soil parent material, combined with the cold and low leaching climate. However, in recent years, with the large-scale application of chemical fertilizers such as N, P and K, the continuous increase of crop yields, the increasing consumption of magnesium in soil and the less and less amount of farmyard manure, Lack of magnesium nutrition [12-15]. Therefore, plant magnesium deficiency has now extended from the south to the north, from cash crops to field crops.

3.2. Effectiveness and Affecting Factors of Magnesium in Soil

Root interception, diffusion and mass flow are the three main ways magnesium is supplied to the soil in the soil, the main way being the mass flow. Magnesium is generally only dissolved in aqueous solution to migrate, so mineral magnesium, magnesium and organic magnesium in the soil will not migrate into the soil until they are converted to water-soluble magnesium. The rate of movement of magnesium in soil is related to soil texture, rainfall, lime application, and application of chemical fertilizers [16]. It is generally believed that it is easy to migrate in neutral to acidic soil and difficult to migrate in cohesive soil. With large rainfall, the content of water-soluble magnesium in soil increases and the mobility of magnesium increases. When lime and superphosphate are used in soil, Magnesium will reduce the speed of movement. Magnesium ions in the soil around the outer shell with a thick layer of hydration, so the negative charge on its attraction is not strong, resulting in magnesium leaching easily in the soil, is one of the elements in the soil easily leached. Climatic heat and humidity, PH value small, heavy rainfall, the application of lime, superphosphate and potassium chloride will aggravate the loss of alternative magnesium, salinization in arid land study pointed out that for the newly reclaimed red soil drylands, the soil magnesium Supply depends mainly on the total magnesium content of the soil, cation exchange capacity and pH. Li Shimin et al. Also found that the soil factors affecting the quantity of early available yellow soil in Guizhou yellow soil are mainly pH, exchangeable calcium, available phosphorus, and exchangeable aluminum; followed by exchangeable potassium, physical clay and organic matter, of which pH and Available phosphorus the most important [17]. The research also shows that after potassium is applied to the soil, the absorption of magnesium in the plants is obviously reduced, meanwhile it is affected by nutrients such as P and S. The amount of substitutional magnesium in clay is higher than that in sand. Neutral soil is higher than acid soil. Soils with high organic matter content are larger than those with low organic matter content. General acid sandy soil, red and yellow soil prone to magnesium deficiency, the more coarse texture, the stronger the acid, the less conducive to maintaining the cations, so its soil replacement magnesium content is low. Yang Li studies have shown that the exchangeable magnesium content of different soil followed by the highest level of alluvial soil > saline soil > Shajiang black soil > cinnamon soil > coarse bone soil > brown soil. The distribution of exchangeable magnesium in the soil profile has the trend of changing with depth. The exchangeable magnesium content of the topsoil is lower than other

levels. Subtropical humid climate zone in southern China, abundant rainfall, gravity irrigation, leaching of magnesium in the soil is more serious. Due to the influence of bioclimatic conditions, most of the magnesium-containing minerals in the soil have been decomposed, the magnesium content is generally low, and the antagonistic action of Al^{3+}, H^{+}, K^{+} and Ca^{2+} ions makes the soil magnesium providing potential low. Magnesium content of soil in northern China is high, generally do not lack magnesium. However, Chen Zhujun and other studies have shown that winter and spring crops in winter and spring in Guanzhong region of Shaanxi Province crops such as tomatoes, cucumbers magnesium deficiency frequently occur, the main reason may be due to excessive fertilization caused by K^{+}, Ca^{2+}, Mg^{2+} plasma imbalance [18-20].

3.3. The Interaction between Potassium and Magnesium

The effectiveness of magnesium nutrition in plants depends not only on the content of available magnesium in the soil, but also on the various ions in the soil, and more on the antagonism of various ions in the plant. Much has been said about the antagonism of potassium and magnesium. Some scholars think that the more potassium applied plants absorb less magnesium, the same, the more magnesium, plants also reduce the absorption of potassium. It has been experimentally shown that in the nutrient solution culture, potassium inhibition of soybean magnesium absorption. Some foreign research data show that potassium inhibits the absorption of magnesium by various crops. It has been observed that high levels of K^{+} lead to insufficient Mg^{2+} in apple leaves. When K^{+} is present in the nutrient solution, the absorption of Mg^{2+} by soybeans is particularly rapid [21]. Studies by Ohno and Gunces indicate that the antagonistic position of potassium and magnesium lies in the transport of magnesium from root to shoot. Due to the increased supply of potassium in the nutrient solution, the magnesium content in wheat shoots decreased, while the magnesium content in the roots was unaffected. The absorption antagonism of potassium and magnesium is not only manifested in inhibiting the absorption of magnesium by the root system, but also hindering the transportation of Mg^{2+} from the root system to the aerial part. However, some researchers also point out that potassium can aggravate magnesium deficiency only when the soil is extremely deficient in magnesium. According to the study, the reason for lack of magnesium rubber is due to the low nutrient content of soil magnesium and the antagonism of K^{+} on the other hand. Studies have shown that the effect of potassium concentration on the absorption of magnesium is very large. R. P. Narwal's research pointed out that the potassium concentration of 25 mg/L, the relationship between potassium and magnesium synergistic relationship. There are many studies that low potassium levels, the low amount of magnesium can promote plant potassium absorption, when the soil of magnesium has been able to meet the normal crop growth and development needs, while the lack of potassium, the application of magnesium fertilizer relative to reduce the crop potassium The absorption of magnesium in plants is much higher than that of potassium. When potassium is abundant, the application of magnesium fertilizer shows a positive effect. When both potassium and magnesium in the soil can not meet the reproductive needs of the crop, the application of potassium fertilizer will lead to crop magnesium deficiency [22-24]. The general lack of magnesium in soil in our province, magnesium fertilizer on a variety of crops have increased production, the effect of potassium and magnesium with the application, but also many tests prove. When potassium is high in soil or potassium is applied, inhibition of magnesium absorption may stem from two aspects: on the one hand, cationic competition effect, especially potassium, inhibits magnesium absorption. Because K^{+} as a monovalent ion-pair colloid has a lower affinity for divalent Mg^{2+} than exchangeable Mg and thus inhibits the utilization of Mg^{2+}, it reduces plant-to-plant uptake when there is more K^{+} in the soil Magnesium absorption; the other may be due to the Mg^{2+} from the root to the ground part of the transport process blocked. Because of the particularly high affinity of high levels of Mg^{2+} for the binding units on the root plasma membrane in mineral nutrients absorbed in the form of cations. Therefore, the other cations strongly compete with Mg^{2+}, thus greatly reducing the absorption rate of Mg^{2+}.

3.4. The Interaction between Calcium and Magnesium

It is generally accepted that the application of calcium reduces the absorption of magnesium by the crop. According to Wu Xun reported, due to the antagonism between ions, tea tree magnesium absorption is often greatly affected by calcium. Plant magnesium content decreased, that excessive accumulation of Ca^{2+} in the plant inhibited the absorption of Mg^{2+}, thereby reducing the magnesium content of plants. There have been many experiments that showed that with the increase of Ca^{2+} in culture medium, the absorption of Mg^{2+} significantly inhibited. And Jin Yan and other experiments pointed out that when the $Ca^{2+} > 1000$ mg/L, the content of magnesium in tobacco leaves still less than 1/3 of the control; and the increase of Mg^{2+} content in the culture medium, the leaf calcium content showed a downward trend. However, some experiments show that Ca^{2+} does not antagonize or assist with Mg^{2+} within a certain range of calcium concentration, and Mg^{2+} absorption rate is almost stable at different calcium concentrations. May be due to Mg^{2+} in the body with mobility, can be used, so a relatively wide concentration of magnesium reaction. The level of soluble calcium can affect magnesium absorption. Lagarof and Pitman planted barley at different calcium and magnesium ratios for 9 days. The concentration of calcium and magnesium was constant at 20 mmol/L, which may be close to that of arid soil about 10 times that of leached soil. The study found that calcium the level of magnesium has a significant impact on the absorption. In contrast, however, Mass and Ogata grew at corn concentrations of 1-2.5 mmol/L with only a slight reduction in magnesium absorption at a magnesium concentration of 2.5 mmol/L. It can be speculated that when the concentration of calcium and magnesium is less than 5 mmol/L, the plant is actively absorbing magnesium. Therefore, the evaporation rate has almost no effect on the absorption of magnesium. Under this condition, the magnesium absorption rate may also have little effect on calcium concentration [25.26]. However, when the concentration of soluble magnesium and calcium is 20 mmol/L or more, and is a complete transpiration plant, its absorption is completely energy independent. Therefore, the Ca/Mg ratio absorbed by the plant is similar to the Ca/Mg ratio in solution. Because at this concentration, both calcium and magnesium are passively absorbed. Therefore, for leached soils, the Ca/Mg ratio has little effect on crop uptake of magnesium as long as the concentration of magnesium in the solution is sufficient rather than high to result in passive absorption. Under these conditions, it is possible that the crop is actively absorbing magnesium and relying on transpiration. In the more arid regions, the concentration of salt in the soil solution is higher. The crops may absorb calcium and magnesium passively. Therefore, for arid areas with a high Ca/Mg ratio, the reduction of Mg in the crop may be caused because the absorption mechanism changes with the concentration of Ca and Mg in the solution.

4. Research Prospect

The magnesium deficiency in crops mainly occurs in the south. Therefore, there are many studies on the mechanism of magnesium deficiency in crops and the factors that affect the availability of magnesium in the south. However, there are many different opinions and no conclusive conclusions can be drawn. At present, the crop of calcareous soil in northern China also frequently appears magnesium deficiency phenomenon, but the mechanism and mechanism of magnesium deficiency on calcareous soil with relatively more magnesium and less research on how to correct it effectively, therefore, how to apply rationally on calcareous soil Magnesium fertilizer has a high research value and great significance.

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