The Effects of Calcium-Magnesium-Boron Fertilizer on the Growth Characteristics, Yield, and Quality of Cabbage

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Abstract: *Cabbage is a nutritious vegetable, rich in essential nutrients for the human body, such as Vitamin C, carotenoids, and dietary fiber. However, during its growth and development, cabbage is susceptible to environmental factors. The lack of essential elements like calcium and magnesium can lead to slow growth, reduced yield, and poor quality. Therefore, improving cabbage production efficiency has become a focal point of current research. Calcium-magnesium-boron fertilizer, as a new type of plant nutrient, offers several advantages, such as promoting plant growth, enhancing resistance to stress, and improving soil structure. This study aims to explore the effects of calcium-magnesium-boron fertilizer on the growth characteristics, yield, and quality of cabbage, in order to provide effective technical support for cabbage production.*

Keywords: *Calcium-magnesium-boron fertilizer; cabbage; growth characteristics; yield; quality*

Introduction

Cabbage is an important vegetable widely grown worldwide, providing rich nutrition for people's daily diet. However, with the continuous increase in population and the growing demand for higher food quality, issues related to cabbage yield and quality have become more prominent. To meet market demand, agricultural production must seek more efficient cultivation management methods. Calcium-magnesium-boron fertilizer, as a significant plant nutrient, is widely applied in vegetable cultivation. Studies on the effects of calcium-magnesium-boron fertilizer on crop growth show that it promotes root development, enhances leaf photosynthesis, and regulates the synthesis of plant hormones.

1. Characteristics of Calcium-Magnesium-Boron Fertilizer

1.1 High Nutrient Content

Calcium-magnesium-boron fertilizer is a high-efficiency, comprehensive fertilizer that contains rich primary nutrients, such as nitrogen, phosphorus, and potassium, as well as a higher proportion of magnesium and boron. This high nutrient content makes calcium-magnesium-boron fertilizer an ideal fertilizer for various crops. Nitrogen is a basic element for plant growth, essential for forming proteins and nucleic acids, and plays a crucial role in plant development. Phosphorus is necessary for root growth and fruit formation, participating in the regulation of various physiological processes, such as energy transfer and enzyme activity regulation. Potassium is an important nutrient for plants, critical for enhancing resistance to stress, promoting fruit enlargement, and improving quality. Magnesium, as a core component of chlorophyll, is indispensable in plant photosynthesis. It enhances the photosynthetic efficiency of plants and promotes the absorption of other nutrients. Boron plays a key role in cell wall formation, pollen tube elongation, and sugar transport, significantly contributing to the flowering and fruit-setting rate.

The reasonable combination of these major nutrients in calcium-magnesium-boron fertilizer can meet the nutritional requirements of crops at different growth stages, promote crop development, and increase yield. Furthermore, this fertilizer also features nutrient slow-release and high absorption efficiency, reducing nutrient loss and environmental pollution, thereby improving fertilizer utilization. Whether in the cultivation of staple crops, economic crops, or fruits and vegetables,

calcium-magnesium-boron fertilizer enhances plant physiological functions, boosts resistance, and improves yield and quality, providing an efficient, eco-friendly solution for agricultural production.

1.2 Unique Micronutrient Ratio

Calcium-magnesium-boron fertilizer has a well-balanced ratio of magnesium and boron, fully utilizing the synergistic effects of these two micronutrients. Magnesium is an essential component of chlorophyll and plays a vital role in photosynthesis. It promotes chlorophyll synthesis, improves photosynthetic efficiency, and enhances the process of converting light energy into chemical energy, thus promoting plant growth. Magnesium also regulates the activity of various enzymes, affecting physiological processes such as carbohydrate synthesis and metabolism. Additionally, magnesium helps balance the absorption and utilization of other minerals, such as calcium and potassium, which helps maintain nutrient equilibrium within the plant, improving disease and pest resistance and enhancing crop yield and quality.

Boron, another essential micronutrient, is involved in the synthesis and stability of plant cell walls. It is indispensable in cell division and expansion. During the reproductive growth phase, boron plays a crucial role in pollen germination and pollen tube elongation, directly affecting flowering, pollination, and fruit-setting rates. Boron also regulates the transport of sugars and amino acids, facilitating the efficient movement of nutrients from source organs to storage organs, promoting fruit development and enlargement. Furthermore, the collaboration between boron and magnesium in the plant improves nutrient absorption by the roots, enhancing crop nutrient utilization. Therefore, the balanced combination of magnesium and boron in calcium-magnesium-boron fertilizer not only strengthens the fertilizer's overall nutritional function but also ensures multiple protections for healthy crop growth.

1.3 Superior Fertilizer Longevity

Calcium-magnesium-boron fertilizer employs specialized compound technology that allows nutrients to be released gradually, extending the fertilizer’s effectiveness. This slow-release mechanism increases nutrient utilization efficiency and reduces the nutrient loss typically associated with rapid nutrient release from traditional fertilizers, which helps mitigate soil and water pollution risks. This prolonged efficacy reduces the need for frequent fertilization, significantly lowering labor and economic costs, saving time and resources for growers, and providing essential support for the development of green agriculture.

A single application of calcium-magnesium-boron fertilizer can supply plants with nutrients over an extended period, ensuring that crops receive the nutrients they need throughout the entire growth cycle. This long-term supply mechanism is particularly suitable for field crops, fruit trees, and other long-term crops, ensuring nutrient demands during critical growth stages are met, thus promoting healthy growth and high-quality output. Additionally, the slow-release property of calcium-magnesium-boron fertilizer prevents nutrient overload, which can cause "fertilizer burn" and protects the microbial environment and structure of the soil, further enhancing the soil’s sustainable productivity.[1]

Due to its nutrient longevity and environmentally friendly features, calcium-magnesium-boron fertilizer is widely used in agricultural production and has become the preferred fertilizer for many producers. Whether in high-yield cereal crop cultivation or in improving the quality of fruits and vegetables, this fertilizer shows significant advantages. Especially in the context of promoting energy efficiency, environmental sustainability, and sustainable agriculture, calcium-magnesium-boron fertilizer plays a vital role in driving modern agricultural development.

1.4 Adjustment of Soil pH

Calcium-magnesium-boron fertilizer, rich in calcium, has strong alkalinity, while boron has some acidity. Therefore, the application of calcium-magnesium-boron fertilizer can, to some extent, adjust the pH of the soil, reducing its acidity and increasing its alkalinity, thus improving the soil environment and creating a more suitable growth environment for crops. Soil pH significantly impacts plant growth and nutrient absorption. By applying calcium-magnesium-boron fertilizer, the soil pH can be adjusted to create a more favorable environment for plant growth, increasing the availability of nutrients in the soil and enhancing crop nutrient uptake and yield.

2. Effects of Calcium-Magnesium-Boron Fertilizer on the Growth Characteristics of Cabbage

2.1 Plant Growth and Development

The application of calcium-magnesium-boron fertilizer significantly impacts the growth and development of cabbage plants. First, it can promote seed germination and seedling emergence. Research has shown that the calcium in the fertilizer can help alleviate soil acidity to some extent, improving the soil environment and thus promoting seed germination and seedling growth. Furthermore, calcium-magnesium-boron fertilizer also has a notable effect on the development of the plant's root system. Calcium, as one of the essential nutrients for plant growth, promotes root branching and elongation, enhancing the plant's ability to absorb water and nutrients. In addition, boron plays a regulatory role in root tip cell division and lateral root formation, further promoting the healthy development of the root system.[2]

2.2 Leaf Growth

The application of calcium-magnesium-boron fertilizer positively affects cabbage leaf growth. Calcium is an important component in the construction of leaf cell walls. By increasing the calcium content in plants, calcium-magnesium-boron fertilizer enhances the stability and resistance of the cell wall, helping improve the plant's resistance to pests and diseases, and reducing the damage caused by such threats. Additionally, boron contributes to the synthesis and stabilization of the cell wall, which helps maintain the normal growth and structure of the leaves, ensuring their integrity.

2.3 Photosynthesis and Light Energy Utilization

Calcium-magnesium-boron fertilizer can influence cabbage photosynthesis and light energy utilization efficiency. Calcium activates auxiliary enzymes involved in photosynthesis, regulating the activity of photosynthetic enzymes and affecting the rate of photosynthesis. Additionally, calcium regulates the distribution of photosynthetic products, thereby improving the conversion and utilization efficiency of light energy. Magnesium, a central component of chlorophyll, plays a crucial role as a catalyst in photosynthesis. As such, the application of calcium-magnesium-boron fertilizer increases chlorophyll content in plant leaves, improving photosynthesis efficiency and enhancing the plant's ability to utilize light energy.

2.4 Yield and Quality

Both calcium and magnesium are essential nutrients for plant growth and have a significant impact on yield and quality. First, calcium participates in regulating many physiological processes, such as cell division, cell elongation, and nutrient transport, all of which directly influence plant growth and yield formation. Furthermore, calcium improves cabbage's resistance to stress, enhancing the plant's adaptability to adverse conditions and ensuring yield stability. Magnesium, being a component of chlorophyll, directly affects photosynthesis and the synthesis of photosynthetic products, which in turn influences yield and quality. Boron, which participates in the regulation of enzyme activities within the plant, influences various metabolic processes, indirectly affecting cabbage quality.

2.5 Stress Resistance

Calcium acts as a secondary messenger in plants, involved in signaling under stress conditions. It regulates the expression of stress-related genes, thereby enhancing the plant's resistance to adverse environmental factors. Calcium also stabilizes cell membranes, increasing their resistance to stress. Magnesium contributes to the synthesis and activity regulation of various antioxidant enzymes, helping to eliminate free radicals and reduce oxidative damage caused by stress. Boron helps balance plant hormones, enhancing plant growth regulation and stress tolerance. In summary, the application of calcium-magnesium-boron fertilizer significantly enhances the stress resistance of cabbage, helping reduce the adverse effects of stress on plant growth and yield.[3]

3. Effects of Calcium-Magnesium-Boron Fertilizer on Cabbage Yield

3.1 Promoting Plant Growth and Development

Calcium-magnesium-boron fertilizer is rich in essential nutrients such as nitrogen, phosphorus, and potassium, which are necessary for cabbage growth. Nitrogen is the foundation for protein and nucleic acid synthesis in plants and plays a key role in driving plant growth. Phosphorus is vital for enzyme activity regulation and energy transfer processes. Potassium helps regulate plant osmotic pressure and water balance, which are crucial for increasing crop yield. The balanced ratio of these nutrients in calcium-magnesium-boron fertilizer ensures that cabbage plants can efficiently absorb nutrients, promoting rapid growth and thereby increasing yield. Additionally, the application of this fertilizer activates plant hormone signaling, stimulating cell division and elongation, which increases plant size and height. Moreover, boron, a micronutrient, plays an important regulatory role in the synthesis of plant cell walls, enhancing their stability and strength. This helps increase the overall mechanical strength of the cabbage plant, allowing it to better withstand adverse environmental conditions such as wind and rain, ensuring smooth growth and development.

3.2 Improving Nutrient Utilization Efficiency

The micronutrients magnesium and boron in calcium-magnesium-boron fertilizer play an important role in promoting nutrient absorption and utilization in plants. Magnesium, a key component of chlorophyll, is essential for photosynthesis and improves light energy utilization efficiency. Chlorophyll absorbs sunlight and converts it into the chemical energy needed by the plant, and magnesium acts as a catalyst in this process, enhancing the efficiency of photosynthesis. Therefore, the application of calcium-magnesium-boron fertilizer increases chlorophyll content in cabbage leaves, improving photosynthesis efficiency and thereby enhancing the plant's ability to absorb and utilize nutrients. Similarly, boron plays a key role in nutrient transport and distribution within the plant. It regulates sugar metabolism and hormone synthesis, influencing nutrient distribution and transport. By increasing the root system’s ability to absorb nutrients and optimizing nutrient distribution within the plant, calcium-magnesium-boron fertilizer helps improve nutrient utilization efficiency, which in turn increases both the yield and quality of cabbage.

3.3 Increasing Fruit Quantity and Quality

Adequate nitrogen, phosphorus, and potassium promote flower bud differentiation and flowering processes, increase pollen tube germination and fertilization, leading to the formation of more fruits. These primary nutrients participate in the reproductive growth processes of plants, ensuring sufficient nutrition and allowing cabbage to successfully reproduce and produce more fruits. In addition to the primary nutrients, boron in calcium-magnesium-boron fertilizer plays a crucial role in fruit development and quality formation. Boron regulates hormone synthesis and signaling within the plant, directly affecting fruit enlargement and maturation. It promotes cell division and elongation, helping increase fruit size and weight. Additionally, boron increases the sugar and vitamin content in fruits, improving taste and nutritional value.[4]

3.4 Improving Yield Stability

Calcium-magnesium-boron fertilizer enhances the plant's resistance to environmental stress, such as improving disease resistance and drought tolerance, ensuring a relatively stable yield even under harsh conditions. Calcium plays an important role in regulating various enzyme activities in plant growth and development. During stress conditions like pest infestation or drought, calcium activates the plant’s defense mechanisms, enhancing its resistance to disease and drought, reducing the adverse effects of stress on plant growth, and ensuring stable yields. Furthermore, magnesium in calcium-magnesium-boron fertilizer plays a vital role in stress adaptation. Magnesium contributes to the synthesis and regulation of antioxidant enzymes, which helps eliminate free radicals and reduce oxidative damage caused by stress, further enhancing the plant’s stress resistance and ensuring consistent yield performance.

4. Effects of Calcium-Magnesium-Boron Fertilizer on Cabbage Quality

4.1 Improving Taste and Flavor

For instance, calcium has a certain promoting effect on the dietary fiber content and quality in plants. Dietary fiber is a type of cellulose that cannot be digested by the human digestive tract, and it plays an important role in gut health and the prevention of chronic diseases. The application of calcium-magnesium-boron fertilizer can increase the dietary fiber content in cabbage, improving its quality and thus enhancing its taste and flavor. Additionally, the trace element selenium in calcium-magnesium-boron fertilizer also influences the taste and flavor of cabbage. Selenium is an essential trace element with significant antioxidant and anticancer properties. Cabbage is one of the excellent sources of selenium, and the use of calcium-magnesium-boron fertilizer can increase its selenium content, thereby enhancing its nutritional value and flavor.

4.2 Increasing Nutrient Content

The primary nutrients in calcium-magnesium-boron fertilizer, such as nitrogen, phosphorus, and potassium, have a significant impact on plant growth, development, and the quality of yield. During the growth of cabbage, the supply of these primary nutrients plays a key role in increasing its nutrient content. Additionally, the trace element boron in calcium-magnesium-boron fertilizer promotes the accumulation of nutrients in cabbage. Besides the aforementioned primary nutrients, calcium-magnesium-boron fertilizer also contains other trace elements. For example, iron is an indispensable micronutrient for plant growth; it is involved in activating enzymes and redox reactions within the plant and plays an important role in improving the nutritional quality of cabbage. Furthermore, trace elements such as zinc and copper in calcium-magnesium-boron fertilizer also promote cabbage growth and the accumulation of nutrients.[5]

4.3 Improving Appearance Quality

The application of calcium-magnesium-boron fertilizer has a positive impact on the appearance quality of cabbage. Boron, for example, is involved in the synthesis and stabilization of plant cell walls, increasing the rigidity of the cell walls, making cabbage leaves more crisp and tender. The crispness of cabbage leaves directly affects the eating experience, and the role of boron makes cabbage easier to chew and digest, thus improving the overall eating comfort. Additionally, calcium helps enhance the firmness and post-harvest storage stability of cabbage, reducing damage during transport. Even after long-distance transport, cabbage retains its appearance and freshness, ensuring consumers receive high-quality products. The application of calcium-magnesium-boron fertilizer improves the appearance quality of cabbage, making it more popular in the market and enhancing its competitiveness.

4.4 Increasing Disease Resistance

For instance, selenium plays a role in various metabolic processes within the plant, enhancing its antioxidant and disease resistance capabilities. Furthermore, trace elements such as manganese, magnesium, and cobalt in calcium-magnesium-boron fertilizer promote metabolic activities within the plant, strengthening the plant’s immune system and disease resistance mechanisms. These trace elements help increase cabbage's resistance to diseases and reduce the impact of diseases on cabbage yield and quality, ensuring stable yield and quality. In addition, the use of calcium-magnesium-boron fertilizer can influence the number and types of microorganisms in the soil, indirectly affecting cabbage health and quality. Calcium-magnesium-boron fertilizer increases the number and variety of beneficial microorganisms in the soil while reducing harmful microorganisms, promoting ecological balance and healthy soil development. This, in turn, contributes to improving the yield and quality of cabbage.

Conclusion

In cabbage production, the scientific and rational use of calcium-magnesium-boron fertilizer is an effective way to improve both yield and quality, reduce production costs, and protect the ecological environment. Furthermore, future research and application of calcium-magnesium-boron fertilizer should be strengthened, exploring more efficient, environmentally friendly, and economical application methods and formulations, to provide higher-quality vegetable products for agricultural production and

consumers.

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