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OVERVIEW OF BIOFERTILIZERS AND ITS APPLICATION IN CHINESE CABBAGE

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ABSTRACT Agricultural production has always been a fundamental component of the global food supply, underpinning both economic stability and human nutrition. To meet the increasing demands of a rapidly growing population, it is crucial to enhance the efficiency and yield of various food crops. This paper aims to explore the untapped potential of biofertilizers in boosting the production of Chinese cabbage, an essential vegetable in many diets worldwide. The study will begin by defining biofertilizers, discussing their various types and complex compositions, and examining the specific growth characteristics of Chinese cabbage. Subsequently, it will analyze the effects of biofertilizers on Chinese cabbage from multiple perspectives, including growth promotion, nutrient supply and absorption, and the enhancement of biological resistance to environmental stresses. The findings from this research are expected to facilitate the broader application of biofertilizers and significantly elevate the production levels of Chinese cabbage, thereby contributing to global food security and sustainable agricultural practices.

Keywords: *Biological fertilizer; Chinese cabbage; Production; Agricultural application; Yield*

INTRODUCTION

Chinese cabbage originated in China, where its cultivation can be traced back to the late Yuan and early Ming dynasties, as documented in historical records. Today, China boasts some of the highest resource varieties, cultivation areas, total production, and output value of Chinese cabbage in the world. China serves as the primary global supply and processing base for Chinese cabbage (Ji et al., 2020, Wang et al., 2020), and its production has become a significant agricultural industry within the country (Zhang et al., 2022, Jaeger, 2022). As the economy develops and people's living standards improve, the demand for high-quality vegetables continues to rise. Consumers increasingly favor organic vegetables that are free from pollution and pesticide residues, which places greater emphasis on soil fertility and nutrient content in vegetable cultivation (Murtaza et al., 2024, Muhammad Tahir, 2024).

During vegetable cultivation, the use of chemical fertilizers remains excessive and overly concentrated. This practice leads to issues such as soil acidification, compaction, salinization, nutritional imbalances, and groundwater pollution. Consequently, these problems significantly affect both the yield and quality of vegetables, diminishing their market competitiveness and hindering the overall development of the vegetable industry (Zhang et al., 2022)

Definition and type of biofertilizers

Biofertilizers are a category of fertilizers derived from natural organic materials, primarily composed of organic waste, animal and plant residues, and microbial products. In contrast to conventional chemical fertilizers, biofertilizers represent a sustainable alternative that utilizes organic resources found in nature while minimizing adverse effects on soil health and the environment (Chuan et al., 2019). Biological fertilizers can be classified into various types based on their sources and compositions:

Organic material fertilizer

Biofertilizers are primarily composed of organic waste, such as farm and household kitchen waste, animal and plant waste, straw, and wood chips. These organic materials undergo decomposition and fermentation, resulting in the production of nutrient-rich organic matter. The resulting fertilizer is abundant in organic carbon, nitrogen, phosphorus, potassium, and other essential nutrients. It plays a crucial role in enhancing soil structure and improving nutrient supply (Wei et al., 2016).

The microbial products

Biofertilizers encompass organic substances, bacteria, and bacterial products that are generated through microbial fermentation. These microorganisms collaborate with the roots in the soil, facilitating the release and absorption of nutrients. Moreover, they aid in suppressing soil-borne diseases and enhancing the stress resistance of crops (Lindsey et al., 2020)

The seaweed fertilizer

Seaweed fertilizer, derived from marine plants like seaweed, is a type of biological fertilizer. It is abundant in trace elements, amino acids, and growth hormones, which effectively stimulate plant growth and enhance crop yield. Additionally, seaweed fertilizer improves the soil's water retention capacity and permeability (Li et al, 2020).

Biochar

Biochar is a carbonaceous material produced from plant residues or animal waste through high-temperature pyrolysis. It possesses excellent porosity and adsorption properties, which contribute to enhancing soil structure, water and fertilizer retention capabilities, and mitigating soil acidification (ZHANG et al., 2021)

COMPOSITION AND MECHANISM OF ACTION OF BIO-FERTILIZERS

The composition and mode of action of biofertilizers are crucial factors that determine their positive effects on plant growth and yield. Biofertilizers primarily consist of organic substances, microorganisms, and bioactive compounds, which play key roles in promoting plant health and productivity (Hussain et al., 2024, Kalsoom and Ahmed, 2023, Ur et al., 2024).

Organic matter

Organic substances serve as a fundamental component of biofertilizers and are typically derived from the decomposition and fermentation of organic waste. These substances are abundant in essential nutrients such as carbon, nitrogen, phosphorus, potassium, and others, which provide the necessary building blocks for plant growth. Moreover, organic substances contribute to enhancing soil structure, improving the retention of water and fertilizers in the soil, and ultimately promoting plant growth rates and yields (Wei et al., 2016).

Microorganisms

Biofertilizers contain a diverse array of microorganisms, including bacteria, fungi, and other beneficial soil microbes. These microorganisms establish a symbiotic relationship with plant roots in the soil, working in harmony to enhance nutrient uptake and promote root growth. They accomplish this by decomposing organic matter, fixing nitrogen, and supplying essential nutrients like amino acids, vitamins, and growth hormones that are vital for plant development (Zhang et al., 2022)

Bioactive substances

In addition to microorganisms, biofertilizers also contain bioactive substances, including plant hormones, enzymes, and growth factors. These substances play a crucial role in regulating various plant growth and development processes. They facilitate seed germination, promote seedling growth, and contribute to flowering and fruit formation.By regulating these vital processes, bioactive substances in biofertilizers enhance plant productivity, increase crop yield, and improve overall crop quality (ZHANG et al., 2021)

GROWTH CHARACTERISTICS OF CHINESE CABBAGE

Growth Habits

Chinese cabbage growth is influenced by various environmental conditions, including temperature, light, moisture, soil, minerals, and air (Stoleru et al., 2012). It thrives in soil that is rich in organic matter, has good water retention capacity, and is well draining. The ideal soil for Chinese cabbage is slightly acidic with a pH range of 6.5 to 7.0 (Niemiec, 2014). Adequate light, water, and carbon dioxide are also essential for its growth. It is important to ensure that the soil is fertile, loose, and has good permeability. It is not recommended to cultivate Chinese cabbage in poorly drained clayey soil (Mahmood, 2024, Qadeer et al., 2023, Younus et al., 2024).

Temperature Condition

Chinese cabbage is well adapted to cold weather and exhibits strong resistance to low temperatures. Its growth period is relatively long, and the temperature requirements vary at different stages of growth. Ideally, the temperature range for optimal growth is between 5 to 25℃, with an average temperature of (17 ± 5) ℃. Growth is hindered when the temperature drops below 5℃, while temperatures above 25℃ can negatively influence growth. Slow growth can occur when temperatures fall below 10℃ (Chuan et al., 2019). A suitable temperature differential between day and night, along with ample sunshine, promotes the production, storage, and accumulation of nutrients, resulting in tightly formed heads, high yields, and excellent quality for the Chinese cabbage (Beutel et al., 2021, Zittel et al., 2020). The bulb period marks a phase of rapid growth, characterized by vigorous development of the Chinese cabbage, during which it has the highest water demand. To maintain optimal soil moisture, the water content at a depth of 20 cm should not fall below 20% to adequately support the rapid growth of the leaf bulb and ensure both yield and quality. Additionally, it is important to choose planting areas that have good drainage and irrigation systems, a clean water source, and flat terrain (Bonanomi et al., 2015, Zhu et al., 2024). Watering should be done in the evening or at night when temperatures have cooled down. After rainfall, it is important to promptly remove excess water to lower the relative humidity in the field, ideally maintaining it between 60% and 80%, as excessive humidity can hinder cabbage growth (Briški et al., 2012, Zhang et al., 2024). From the beginning to the middle of the bulb development stage, it is crucial to maintain an appropriate level of soil humidity.

Light Conditions

Chinese cabbage thrives in sunlight, making it a long-day vegetable that requires ample light throughout its growth cycle. Sufficient light enhances the photosynthetic efficiency of Chinese cabbage, promoting the generation, conversion, and transport of nutrients, which in turn provides a continuous supply of nourishment for the plants (Rashid et al., 2024, Mushtaq et al., 2024). Particularly during the vegetative growth period, the average daily light duration should exceed 8 hours. Under optimal light conditions, the plants exhibit thick leaves with high chlorophyll content, strong growth, and reduced disease incidence (Chuan et al., 2019, Teng et al., 2024)

Edaphic Condition

Chinese cabbage has a straight root system characterized by well-developed roots that possess strong nutrient absorption capabilities. This makes it well suited for high or flat terrain with a rich organic matter content, deep and loose soil layers, good water and fertilizer retention, effective drainage, and ample sunlight (Zeng et al., 2024, Saeed et al., 2024). It is advisable to avoid planting in clayey soils with poor drainage. The optimal pH range for soil is between 6.5 and 7.0, indicating that neutral to slightly acidic soil conditions are best for Chinese cabbage. Therefore, planting in excessively alkaline soils is not advisable (Chuan et al., 2019, Teng et al., 2024). The main roots of Chinese cabbage are well-developed and primarily located within the top 25 cm of the soil, enabling efficient absorption of both water and nutrients.

Requirement of Fertilizer

Chinese cabbage thrives on fertilizer, benefiting from a long growth period and a high nutrient absorption capacity, which contributes to its substantial yields. During its growing phase, it requires an increased amount of fertilizer. Testing has shown that approximately 1.8 to 2.6 kg of nitrogen, 0.8 to 1.2 kg of phosphorus, and 3.2 to 3.7 kg of potassium are absorbed for every 1000 kg of Chinese cabbage produced. Among the nutrients, potassium is absorbed in the greatest quantity, followed by nitrogen, calcium, phosphorus, magnesium, boron, and other essential elements (Gelaye, 2024, Stoleru et al., 2012)

EFFECT OF BIO-FERTILIZER ON CHINESE CABBAGE

Improve crop traits and increase crop yield

Biological fertilizers are rich in organic matter and essential nutrients, which support the growth and development of crops by providing the necessary assimilates. Additionally, the beneficial microorganisms present in these fertilizers facilitate nutrient metabolism, continuously supplying the nutrients required for crop growth. Furthermore, biological fertilizers can enhance a plant's photosynthetic capacity and improve the transport of materials between tissues, promoting fruit development. Studies have demonstrated that the nitrate content in vegetables grown with biofertilizers is approximately 20% lower than that in those cultivated with traditional fertilizers. This reduction highlights the importance of biofertilizers in promoting the development of green crops (Ji et al., 2020, Shi-Wen et al., 2000).

Improve and repair the farmland soil

In contrast to ordinary chemical fertilizers, a key characteristic of biological fertilizers is their ability to repair and enhance soil quality. They achieve this by increasing the content of organic matter and mineral elements in the soil through the metabolic activities of beneficial microorganisms, ultimately leading to improved soil fertility. For instance, microorganisms that solubilize phosphate and potassium can partially decompose the insoluble forms of phosphorus and potassium in the soil, making them more accessible for plant absorption and utilization. This process enhances the supply of essential nutrients for crops and contributes to the overall improvement of soil fertility. Simultaneously, the use of biofertilizers can reduce reliance on chemical fertilizers, which in turn enhances the self-recovery capacity of the crop-growing environment and helps to reverse the decline in soil fertility (Liu et al., 2021, Shi et al., 2021).

Enhance the stress resistance of crops

Biological fertilizers can be produced through the metabolic activities of beneficial bacteria or their interaction with crops, which induces the synthesis of resistance mechanisms in plants. These mechanisms include the production of biologically active substances that enhance plant tissue's antioxidant enzyme activity and promote the synthesis of materials that aid in repairing damage. As a result, crops are better equipped to withstand diseases, pests, drought, and salt stress (Luo et al., 2023, Shah et al., 2023)

Assist plants in absorbing nutrients

Biological fertilizers contain microorganisms that facilitate nutrient absorption in plants. For example, VA mycorrhizal fungi extend the reach of plant roots into the soil, enabling them to access nutrients that would otherwise be unavailable. Additionally, these microorganisms aid in the absorption of essential elements such as zinc, copper, and calcium. Some insoluble phosphates in the soil can be dissolved by organic and inorganic acids produced through the metabolism of phosphate-solubilizing bacteria. Furthermore, research has demonstrated that these bacteria can also produce phosphatase enzymes, which facilitate the hydrolysis of organic phosphates, thereby enhancing their absorption and utilization by crops (Qiu et al., 2013, Teng et al., 2024)

Improve the soil ecological environment

Improving the ecological environment of the soil is another key feature of biofertilizers. For instance, actinomycete-based biofertilizers can enhance the community structure of microorganisms in the rhizosphere, creating a more favorable growth environment for crops. This, in turn, helps to reduce the incidence of soil-borne fungi and other diseases (Rana et al., 2020, Shi et al., 2021). During the cultivation of Angelica, the number of fungi and bacteria in the soil can increase, enhancing the abundance of beneficial microbial populations. This improvement contributes to greater resistance and higher yields of Angelica (Qi et al., 2021, Sifola et al., 2024) The application of enzymes and other biological fertilizers in American ginseng cultivation can enhance the abundance of beneficial microorganisms that aid in pathogen control and metal adsorption. Additionally, this practice helps reduce the prevalence of pathogenic microorganisms and decreases the occurrence of root-knot nematodes (Qiu et al., 2013, Zhu et al., 2024)

CONCLUSION

Biofertilizers play a vital role in enhancing the growth and yield of Chinese cabbage by promoting growth, supplying essential nutrients, providing trace elements, boosting stress resistance, and improving the overall ecological environment. Consequently, their use holds significant promise for advancing global food security and fostering sustainable agricultural development practices worldwide. However, current research on biofertilizers remains insufficient, necessitating further studies and practical applications to fully realize their potential benefits and advantages. We need to deepen our understanding of how various types of biofertilizers and their application methods impact crop production across different regions and diverse environmental conditions. This comprehensive knowledge will be crucial for maximizing the benefits of biofertilizers, improving agricultural productivity, and contributing positively to the broader ecological balance.

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