Study on the effect of organic fertilizers for enhancing the yield and quality of the white cabbage *(Brassica oleracea var. Capitata f. alba)*

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Abstract. White cabbage (Brassica oleracea var. capitata) is a widely cultivated vegetable with significant nutritional value and economic importance. The influence of fertilizers, particularly organic fertilizers, on the yield and quality of white cabbage has garnered considerable attention in agricultural research. These fertilizers contribute to improved soil structure, enhanced nutrient availability, and balanced microbial communities, thereby fostering optimal conditions for plant growth. Furthermore, organic fertilizers have been found to positively influence the quality attributes of white cabbage, including increased levels of essential nutrients such as vitamin C, enhanced total phenolic content, and heightened antioxidant activity. These improvements in quality not only enhance the nutritional value of the crop but also confer additional health benefits to consumers. Through an analysis of current studies, this paper provides insights into the potential benefits, challenges, and future directions in utilizing organic fertilizers to enhance white cabbage production sustainably.

1. Introduction

Vegetables play a crucial role in maintaining the health, well-being, and longevity of individuals. Cabbage, as a prominent vegetable crop, is widely consumed across different cultures due to its availability, palatability, and acceptability. As a result, it has become a popular option among many customers worldwide [1].

Cabbage is rich in nutrients, carbohydrates (about 90% dry weight), contains various trace elements, vitamins, minerals, and etc. [2]. The pleasant scent and sweet flavor of cabbage are linked to the presence of glucosinolates in their makeup. According to various sources, the overall glucosinolate content in white cabbage ranges from 1.05 to 70.56 μmol/g dry weight [3]. Since the byproducts of glucosinolate hydrolysis reactions (such as oxazolidines, thiocyanates, nitriles, epithionitriles, and isothiocyanates) can display diverse pharmacological properties, these compounds hold significance for human well-being [4]. The primary glucosinolates found in white cabbage are allyl isothiocyanate (AITC), iberine (IB), and indole-3-carbinol, respectively [5]. During the fermentation of cabbage, one can observe the presence of sulforaphane, allyl isothiocyanate, iberine, iberine nitrile, allyl cyanide, and ascorbigen in its composition [6].

In addition to glucosinolates and their derivatives, white cabbage presents a substantial amount of phenolic compound. The primary group of polyphenols found in white cabbage is flavonoids, which includes hydroxycinnamic acids and flavonols (hydroxycinnamic acids, flavonols) [8]. Various studies using the Folin-Ciocalteu method have reported the total content of polyphenols in white cabbage, as shown in Table 1. The functional quality and phytochemicals found in cabbage heads are heavily impacted by environmental conditions.

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Table 1. Total polyphenol content in white cabbage has been studied by various researchers

Total content of polyphenols	Extract	Data source
153 ± 21 lg GAE g^{-1} fw	Acetone/water (70:30)	[9]
1107 ± 57 mg FAE $(100\ g)^{-1}$	70 % Ethanol	[10]
15.06 ± 4.7 mg GAE $(100\ mL)^{-1}$	Cabbage juice	[11]
110.2–153.3 mg GAE $(100\ g)^{-1}$ fw	80 % Methanol	[12]
3.32– 29.70 GAE mg $(100\ g)^{-1}$ fw	70 % Methanol	[13]

Due to its valuable phytochemical content, cabbage is used as an effective treatment for a number of disorders. In traditional medicine, fresh cabbage leaves are applied topically to wounds, cuts, and gout-related aching joints. The leaf juice is also used topically to relieve toothaches. The sauerkraut juice is recognized for its laxative properties. Given that cabbage is high in vitamins and can successfully correct deficiencies, it is often advised for nutritional assistance in the treatment of numerous disorders in modern healthcare practices. Moreover, its high fiber content has a beneficial impact on intestinal activity by promoting bowel movement and inducing relaxation. Furthermore, scientific investigations have demonstrated that extracts from white cabbage possess anti-inflammatory characteristics attributed to their antioxidant components.

Despite remarkable development in the agricultural production sector, raising vegetable crop productivity remains a crucial problem in agricultural production. It should be noted that the yield of agricultural plants is an integral indicator of effective soil fertility, and its level is determined by a complex combination of a whole range of soil, biological and weather factors, the crop fertilization system, the set and pattern of their rotation in crop rotation. In order to achieve optimal yield and quality of white cabbage, as well as other plant varieties, it is essential to ensure that plants receive sufficient nutrients. Insufficient levels of specific nutrients can disrupt the plant's metabolic processes and result in observable changes in the structure, size, and color of leaves and stems. Continuous cultivation of agricultural crops depletes soil nutrients, necessitating the use of fertilizers to meet plants' macro and micro element requirements. It is important to recognize that different types of fertilizers have varying effects on crop productivity and soil fertility indicators. Understanding the specific characteristics of different fertilizers can significantly impact the increase in yield and quality of cultivated crops such as cabbage. This article explores the botanical and biological attributes of white cabbage and examines the influence of organic fertilizers on its growth and development.

2. Plant Morphology, Growth and Development

White cabbage (*Brassica oleracea* var. *capitata f. alba* L.) is a biennial plant that undergoes a two-year life cycle. During the first year, it forms a head of cabbage, and in the second year it produces a flowering stem and seeds. White cabbage has a well-developed root system, which spreads mainly in the soil layer up to 40–50 cm (Figure 1). The life cycle of cabbage encompasses seed germination, seedling emergence, rosette and root growth, leaf mass accumulation, root system development, organ formation, inflorescence formation, flowering, fruit development, and seed ripening (Figure 2). Cabbage is resilient to cold temperatures and has moderate light requirements but requires ample moisture.

Fig. 1. Cabbage morphology and flowering

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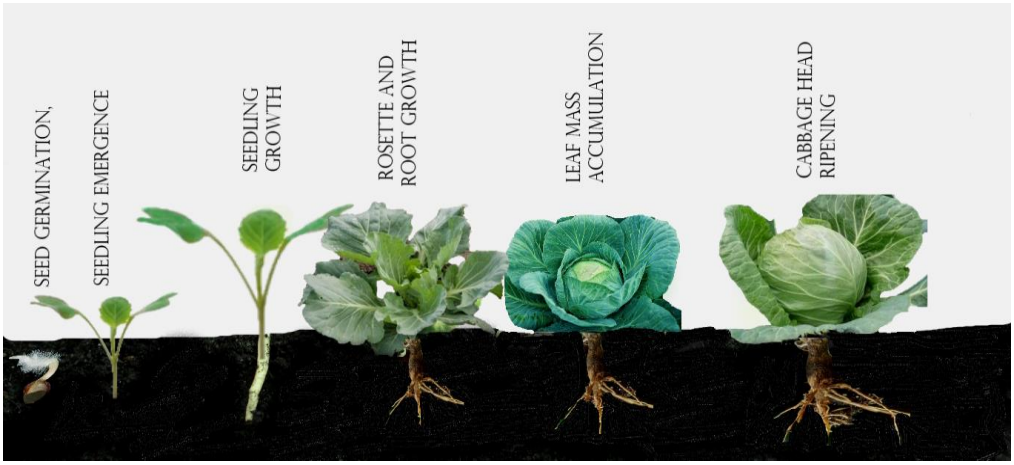

Fig. 2. Cabbage first year life cycle (authors work)

Cabbage is a significant contributor to the removal of nutrients among vegetable crops. The nutritional requirements of cabbage vary across different stages of its development. The highest nutrient consumption by this crop occurs during the formation of cabbage heads. The utilization of organic fertilizers influences diverse physiological processes in white cabbage plants, resulting in enhanced growth and development. Since organic fertilizers are made of materials derived from plants and animals that break down into minerals and release carbon dioxide into the ground layer—which is essential for plant photosynthesis—cabbage grows very well on them. Furthermore, organic fertilizers have a positive impact on the water and air nutrition of plants, foster the proliferation of soil bacteria and microorganisms that engage in symbiotic relationships with vegetable crop roots, and aid in accessing available nutrients. Nonetheless, to effectively utilize fertilizers and ensure balanced plant nutrition, it is crucial to investigate the biological characteristics of cabbage and conduct a comprehensive analysis of soil nutrient content and pH to determine the most suitable fertilizer for a specific area.

3. Soil Fertility and Nutrient Uptake

Cabbage is able to thrive in a variety of soil types, with the exception of very light sandy and gravelly soils that have poor moisture retention. The most suitable soil for cabbage cultivation is fertile loam with a light structure and low-lying peat bogs, as these soils can effectively retain moisture while remaining highly permeable to air. The optimal pH level for cabbage growth is within the range of 6.4–7.0.

Cabbage has a high demand for nitrogen, phosphorus, and potassium, as well as a lower need for calcium, magnesium, and small amounts of microelements such as boron, manganese, and molybdenum. The plant's nutrient requirements change depending on its growth stage. Specifically, during the seedling period, it requires readily available basic nutrients. After transplantation into the soil, cabbage requires increased nitrogen to support root system recovery and assimilation apparatus development. During the intensive growth phase of the cabbage head, it requires phosphorus and potassium. Understanding the specific roles of each nutrient is essential for providing adequate nutrition to the plant. Nitrogen is essential for proteins and chlorophyll production. Its deficiency results in pale green leaves and stunted growth. Phosphorus is crucial for proteins and plays a key role in cell division. Insufficient phosphorus delays head formation, flowering, and seed ripening while causing changes in leaf size and color. Potassium supports protein metabolism and enhances plant resistance to environmental stressors. Calcium plays a significant role in the development of roots and leaves, and its deficiency can result in soil acidity, stunted growth, leaf discoloration, and increased susceptibility to clubroot in cabbage plants. Cabbage contains small amounts of microelements such as boron, molybdenum, and manganese, which are involved in enzymatic reactions, redox processes, photosynthesis, and carbohydrate and protein metabolism. The presence of optimal nutrient availability and balance in the soil, along with appropriate environmental conditions like heat, light, and moisture, are essential for normal plant growth and organic matter production. The lack of any factors, including nutrients in the soil, causes changes in the plant body, metabolic disorders, which very quickly affects the appearance of the plants.

4. Utilization of Organic Fertilizers in Agriculture

It is commonly recognized that the nutritional value of various organic fertilizers is different. Manure is the most commonly utilized. Manure contains all the nutrients necessary for plants - nitrogen, phosphorus, potassium, calcium,

magnesium, sulfur, as well as microelements - boron, molybdenum, etc. Manure has a good effect on the growth and development of cabbage. According to the experience of studies using manure (40t/ha) on cabbage, in soddy-podzolic light loamy soil , developing on loess-like loam, with an average humus content (2.5–2.7%) showed an increase in yield from 13.11 to 14.5 (1.4 t/ha or 10.7%) when, as when using manure (20 t/ha ha) in carbonate, mountain chernozem (post-forest), with a gross humus content of 4.15% -0.65% (in Turin) increased from 23.93 t/ha to 29.77 t/ha, yield increase - 5.84 t/ha or 24.0%. However, in two cases, manure in small quantities affected the content of dry matter, sugars, and ascarbic acid [14, 15]. The amount of manure has recently dropped as a result of the decline in livestock populations in many countries; as a result, the agricultural sectors are turning toward alternative forms of organic fertilizers.

Poultry manure is also widely utilized as an organic fertilizer in agriculture. According to some reports, chicken manure outperforms manure as a fertilizer. Its value is mostly derived from the presence of nitrogen, phosphorus, and potassium. A variety of trace elements are also present in the litter, including calcium (0.5%), magnesium (0.2%), copper (0.008%), manganese (0.004%), zinc (0.0026%), cobalt (0.08%), sulfur (0.14%), and boron (0.0045%). Fresh bird droppings, on the other hand, contain a significant quantity of nitrogen in the form of ammonium. Increased ammonium nitrogen content inhibits plant growth and development, particularly sprouts. Granular fertilizers that have undergone fermentation and are derived from composted manure have been created in response to these individual characteristics. In a study employing fermented manure in soddy-podzolic medium loamy soil, the application of granular organic fertilizer at a dose of 300 kg/ha resulted in an increase of 5.68 t/ha, and at a dose of 500 kg/ha, an increase of 13.93 t/ha. It is also significant to note that fertilizer based on wasp droppings improved cabbage morphological traits, sugar content, and dry matter [16]. In addition, in a scientific trial comparing the impact of three distinct organic fertilizers (chicken dung, kraal manure, and compost) on cabbage quality and yield, poultry manure (chicken manure) outperformed all other factors [17].

Compost is a complete organic fertilizer containing decomposed remains of plant and animal origin. Compost is made from a variety of plant and animal wastes as source ingredients, and Beneficial bacteria, which penetrate the soil alongside the compost, improving the condition of the roots and enhancing plant stability. Composting by the rich components, enhances soil structure, as well as the water and air regimes, enhances soil aeration in heavy soils while increasing water-holding capacity in light soils. Research on growing cabbage with compost has yielded positive outcomes. Based on the data [18], it is evident that compost (made from food waste) improved the amount of fresh mass of cabbage and the content of N, K, P, and K in the shoots of white cabbage. Applying compost increased yield by 44% at 15 t ha and 64% at 30 t/ha.

One of the main sources of organic fertilizers is green manure. Green manure is a green fertilizer developed specifically to restore soil conditions. Following the growing season, these plants flood the soil with nitrogen and nutrients, aiding in the fight against weeds. Every green manure has a unique role and can be applied for the certain type of crop (Figure 3) Experiences with green manure in cabbage growth are limited; in some studies, the author reports that cultivation of green velvet resulted in a 15-22% increase in the size of cabbage heads [19]. Based on the data presented [20], we can conclude that cabbage respond favorably to the use of green manure leaves from acacia (Albizia saman (Jacq.) Merr.), ipil-ipila (Leucaena leucocephala (Lam.) de Wit), and madre de cacao (Gliricidia sepium) (Jacq.) Walp.).

Fig. 3. Green manure plants

5. Challenges and Future Directions

Although organic fertilizers offer many benefits, their extensive application in the cultivation of white cabbage is hindered by several challenges. These challenges encompass the gradual release of nutrients, potential presence of contaminants such as pathogens, weed seeds, and heavy metals if not appropriately handled, which can jeopardize plant health and environmental integrity. Furthermore, issues related to transportation and storage arise when utilizing various organic fertilizers. Organic fertilizers are typically bulkier and heavier in comparison to synthetic fertilizers. While organic fertilizers have a positive impact on soil, they contain lower concentrations of nutrients than synthetic fertilizers. As a result, larger quantities may be needed to achieve the same nutrient level, leading to higher application costs. Additionally, in certain cases, organic fertilizers may be more costly than synthetic alternatives due to factors such as production methods, supply sources, and certification requirements, making them less economically feasible for large-scale agriculture. To address these challenges, numerous studies within the field of agronomy recommend the use of organic fertilizers in conjunction with mineral fertilizers. This combined approach can help reduce the environmental impact associated with fertilizer usage. By adopting this comprehensive strategy for soil management, soil health and productivity can be sustained for future crops.

6. Conclusion

In conclusion, organic fertilizers offer promising solutions for increasing the yield and quality of white cabbage while promoting sustainable agriculture. One of the noteworthy findings highlighted in this review is the significant role of organic fertilizers in promoting soil health and fertility. By replenishing essential nutrients, improving soil structure and stimulating microbial activity, organic fertilizers create an environment that promotes sustainable plant growth. In addition, organic fertilizers have a significant impact on the quality of white cabbage, improving its nutritional profile and phytochemical composition. The increased levels of vitamin C, total phenolic content, and antioxidant activity observed in cabbage treated with organic fertilizers not only increase its nutritional value, but also provide potential health benefits to consumers. These results highlight the importance of considering not only yield but also nutrient quality in agricultural production systems. Despite the encouraging results reported in the literature, there are some operational and calculation difficulties when using organic fertilizers. To overcome these difficulties, some studies support the idea of combining mineral and organic fertilizers, and their results have shown positive results. Perhaps in future work we will consider methods for standardizing the compositions of organic fertilizers, optimizing application rates and timing, and integrating with other agricultural practices.

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