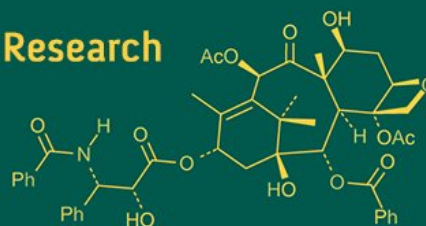


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Impact of integrated nutrient management on nutritional composition, antioxidant activity, and growth in red cabbage

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Abstract

Organic manures are beneficial for soil in the form of compost and used as an alternative to inorganic fertilizers (IFs). A field experiment was conducted to evaluate the effects of organic and inorganic nutrient sources on red cabbage growth, anthocyanin content and nutritional quality traits. The study was executed in vegetable research farm at Horticulture Department, Naini Agriculture Institute, SHUATS, Prayagraj, U.P. A Randomized Block Design (RBD) was laid out in the experiment with three replications. Ten treatments were used, including various combinations of inorganic and organic fertilizers. Among different treatments, T5 {50% N (inorganic) + 50% N (vermicompost)} recorded significantly the greatest plant height (35.30cm), head diameter (26.38cm), anthocyanin content (92.76 mg/100 g), total soluble solids (5.49 °Brix) and ascorbic acid (59.8 mg/100 g) whereas treatment T4 recorded the next highest value. {50% N (inorganic) + 50% N (FYM)}. T0 (100% Nitrogen through inorganic fertilizer) recorded the lowest results across all parameters. Results indicated that combining inorganic fertilizer with vermicompost enhanced growth parameters, anthocyanin content, and nutritional quality in red cabbage. Thus, the study highlights the potential for integrated nutrient management to enhance crop growth, antioxidant properties and nutritional quality in red cabbage and can be considered best for long term sustainable red cabbage production.

Keywords: Red cabbage, FYM, vermicompost, organic manures, inorganic, integrated, fertilizer, nutrient uptake

Introduction

Red cabbage (*Brassica oleracea* var. *capitata rubra*) belongs to the Brassicaceae family, is a modern dietary vegetable which is valued for its multifunctional health benefits and antioxidant properties. Originating in Europe, it is widely cultivated in India, China and the Americas due to its broad adaptability and high productivity (Ticha *et al.*, 2016) [16].

Red cabbage is naturally enriched with amino acids, organic acids, minerals and dietary fibers (Zayed *et al.*, 2022) [20]. It also contains many nutrients viz., P, K, Mg, Mn, chlorine and vitamins like B, C and K. Red cabbage has several bioactive compounds such as polyphenols and glucosinolates, which are secondary plant metabolites that break down into compounds like indole-3-carbinol, which contains anti-cancerous properties (Verkerk and Dekker, 2004) [18]. Regular intake of red cabbage has been reported to reduce the risk of several chronic ailments, cardiovascular diseases, metabolic disorders, cancer and Alzheimer's disease (Manchali *et al.*, 2012) [15]. Due to its low calorie, high fiber, and rich nutrients, red cabbage is highly recommended in our daily human diet. Increasing the production of red cabbage can play a vital role in addressing the nutritional demand of the country. To achieve better quality, a novel but sustainable technology should be adopted for red cabbage cultivation.

Anthocyanins are antioxidants responsible for red, purple, blue, and orange color in many fruits, flowers, leaves and vegetables, which are natural glycoside compounds. Red cabbage is an excellent source of water-soluble anthocyanin pigments, which it produces and accumulates throughout its growth cycle (Yuan *et al.* 2009) [19]. They are potent antioxidants with effective antiradical activity. Anthocyanin's in red cabbage is greater than in most other food sources and it highly depends on the variety, cultivation methods, and harvest time of red cabbage (Podszędek *et al.*, 2017) [12].

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The uses of chemical fertilizers have been increased with time advancement and nutrient balance has become more negative. Therefore, to minimize the nutrient depletion, it is important to apply the organic sources viz., Farm Yard Manure (FYM), vermicompost, poultry manure along with chemical fertilizers, because these manures can reduce the negative balance of nutrients applied to the soil. Integrated nutrient management plays a crucial role in the quality and anthocyanin production in red cabbage. The organic soil amendments improve soil properties, including higher water holding capacity, cation exchange capacity, and lower bulk density (Gupta *et al.*, 2022) [7]. They are also beneficial for microorganisms. Thus, an integrated approach involving organic fertilizers combined with chemical fertilizers can go a long way to improve crop quality and productivity (Shaowu *et al.*, 2023) [14].

Materials and Methods

Experimental site and soil

The experiment was carried out in the Department of Horticulture, Naini Agricultural Institute, and Prayagraj (U.P.) during the Rabi season of 2019-2020. Prayagraj is a city in southeast U.P. characterized by its sub-tropical climate, which features seasonal extremes. It is situated at 25.87° N, 81.15° E, and 98 meters above sea level. The average annual rainfall is between 850 and 1100 mm. The soil of the experimental plot was sandy loam soil with low clay and high sand content having 6.9 pH, 0.35% soil organic carbon, 212 kg N/ha, 14.59 kg P/ha and 225 kg K/ha available respectively. Soil pH was measured by digital pH meter and organic matter was determined by wet method. The content of total N was measured by Alkaline permanganate method and available P was determined by Calorimetric method. The exchangeable K was determined by flame photometric method.

Experimental Details

"The experiment and data collection were part of the trial conducted in 2019-2020; growth and yield results were reported earlier (Sadanand & Fatmi, 2022) [21]. Here we present anthocyanin analyses and the relationship between anthocyanin and selected growth parameters." The experiments were laid out in a Randomized Block Design (RBD) with three replications with combination of 10 treatments. The treatment details are presented in Table 1. The sources of inorganic fertilizers were urea, Diamonium Phosphate (DAP) and muriate of potash (MOP), while FYM, vermicompost, and poultry manure were used for organic sources. Nitrogen, through both organic and inorganic sources, was applied at four intervals (20, 40, 60, and 80 DAT). A normal sizes nursery bed (1.0mx1.0m) was prepared and raised 15cm above the soil surface, in the month of October 2019. For the efficient drainage a slope of 2.0 cm was maintained from the centre to all sides. Then the 5.0 cm thick layer of bedding mixture was evenly spread over the nursery. Rows size was made 1.5 to 2.0 cm deep and 10.0 cm apart from each other. At last seeds were sown in nursery, covered and watered.

The experimental field was prepared for transplanting 15 days in advance through repeated ploughing. A total of 30 plots were used, each measuring 1 meter by 1.5 meters, for a total area of 1.5 square meters per plot. A 0.2-meter bund was used to separate the plots. The test crop was the 'Red Jewel' variety of red cabbage. Seedlings selected for

transplanting were 30 days old, 10 to 15 centimeters tall, and had two pairs of leaves. The seedlings were transplanted between November 26 and November 30 in the evening, with a spacing of 45 by 60 centimeters. The plots were irrigated immediately after transplanting.

Various intercultural operations including gap filling, weeding, irrigation, and organic pesticides application were done as and when required. Manures and fertilizers were applied according to the recommended doses, i.e. 15-20 tonnes of FYM/ha, 1.5kg of vermin-compost/ha, 2kg of poultry manure/ha along with 150kg N/ha, and 80kg P₂O₅/ha and 80 kg K₂O/ha. FYM was well incorporated in the experimental field 25 days before transplanting the seedlings. Half of the dose of N, total P₂O₅ and K₂O were well incorporated as the basal dose in the soil before transplanting. Balance quantity of Nitrogen was applied in two equal splits doses of one-fourth each at 30 DAT and 45 DAT. Nutritional composition and moisture content of the manures under study are presented in Table 1.

Table 1: Treatment details

S. No.	Treatment	Treatment Combination
1	T ₀	100% N through inorganic fertilizer (control)
2	T ₁	25% N inorganic + 75% FYM
3	T ₂	25% N inorganic + 75% vermicompost
4	T ₃	25% N inorganic + 75% poultry manure
5	T ₄	50% N inorganic + 50% FYM
6	T ₅	50% N inorganic + 50% vermicompost
7	T ₆	50% N inorganic + 50% poultry manure
8	T ₇	75% N inorganic + 25% FYM
9	T ₈	75% N inorganic + 25% vermicompost
10	T ₉	75% N inorganic + 25% poultry manure

Table 2: Nutrient Composition of Organic Manures

Nutrient (%)	Farmyard Manure	Vermicompost	Poultry Manure
Nitrogen (N)	0.50	1.90	3.03
Phosphorus (P)	0.20	2.00	2.63
Potassium (K)	0.50	0.80	1.40

The data on growth, such as plant height (cm), head diameter (cm), and quality components, anthocyanin (mg/100g), ascorbic acid (mg/100g), and TSS (°Brix), were subjected to the statistical analysis.

Quality Parameters Measured

After harvesting the head, to assess the quality of the head, tests were performed at the laboratory of the department of Horticulture, to find out the following:

1. Anthocyanin content (mg/100 g)

For anthocyanin estimation, a 10g sample was macerated with 10mL of acidified ethanol (ethanolic HCl). The extract was transferred to a 100mL volumetric flask, made up to volume with the same solvent, and left in the refrigerator at 4 °C to facilitate complete pigment extraction. The mixture was then filtered through Whatman No. 1 filter paper. The Optical Density (OD) of the filtrate was recorded at 535 nm.

2. Ascorbic acid content (mg/100 g)

Ascorbic content of samples was measured by using the AOAC (1968) method. Ascorbic acid reduces oxidation-reduction indicator dye, 2, 6-dichloroindophenol, to a colorless solution. At end point, excess unreduced dye is rose pink in acid solution.

3. TSS content (°Brix)

A total solid of the plant samples were measured using a hand refractometer and expressed in °Brix.

Statistical analysis: All data were subjected to statistical analysis using ANOVA, and treatment means were compared using the Critical Difference (CD) at a 5% level of significance.

Results and Discussion

Growth parameters

Plant Height (cm) and Head Diameter (cm)

Across all treatments, T5 showed the best results in plant growth, viz., height (35.30cm) and head diameter (26.38cm), followed by T4 and T2. The the smallest growth, anthocyanin and quality parameters were found in Treatment T0. This finding suggests that solely relying on chemical fertilizers may not favor optimal plant development and nutrient uptake, and lowers plant development and quality (Gupta and Khandelwal, 2024; Chaudhary *et al.*, 2024) ^[2, 8].

Anthocyanin content

Micronutrients such as magnesium, manganese, and iron play a pivotal role as cofactors in enzymatic activities. They promote pigment formation in plants, thereby increasing anthocyanin biosynthesis. (Podsędek, 2007; Yuan *et al.*, 2009) ^[11, 19]. The increased anthocyanin accumulation found in T5 (92.76 mg/100 g) is due to availability of nutrients required for anthocyanin formation and the micronutrients in vermicompost. The organic nitrogen present in vermicompost provides sustained supply of nutrients, which supports secondary metabolite synthesis. Thereby, the combination has likely contributed to the increased production of anthocyanin in red cabbage. Nitrogen from inorganic fertilizer from Treatment T0 may have not provided the essential nutrients for sugar accumulation which may have limited the secondary metabolic activities in plant tissues (Gupta *et al.*, 2022) ^[7] and led to the the smallest anthocyanin production and other quality traits.

Ascorbic acid

The the greatest ascorbic acid content was observed in T5 (59.8 mg/100 g), followed by T4 (31.85 mg/100 g), indicating that humic substances present in organic fertilizers have positive effects on plant physiology by improving soil texture and fertility. They affect nutrient uptake and root structure (Trevisan *et al.* 2010) ^[17]. Organic amendment also promotes microbial biomass and enzymatic activity in the rhizosphere. This promotes greater availability of boron and other elements essential for ascorbic acid synthesis. These results were supported by Dalal *et al.* (2010) ^[4], who reported that combined fertilizer application improves vitamin C content in cabbage. The lowest performance found in T0 might be the result of sole supply of Nitrogen from chemical fertilizer, which lacks the buffering effect and microbial stimulation in soil (Gupta *et al.*, 2022) ^[7].

Total Soluble Solids (TSS)

TSS reflects sugar accumulation and influences fruit taste. Improved soil enzymatic activity and nutrient uptake in red cabbage have led to better carbohydrate translocation and sugar accumulation, which have developed maximum heads

(Rai *et al.*, 2013). Maximum head size contributed to increased TSS (5.49 °Brix) in treatment T5.

Overall, the findings are in accord with past investigations emphasizing the advantage of integrated nutrient management over sole organic or inorganic approaches (Dalal *et al.*, 2010; Gupta and Khandelwal, 2024; Chaudhary *et al.*, 2024) ^[2, 4, 8]. The results also confirm that improved vegetative growth and biochemical enhancement correlates with each other. The results of the organic and inorganic fertilizers on red cabbage are presented in Table 2.

Table 2: Impact of Integrated Nutrient Management on Nutritional Composition, Antioxidant Activity, and Growth in Red Cabbage

Treatment	Plant Height (cm)	Head Diameter (cm)	Anthocyanin (mg/100g)	Ascorbic Acid (mg/100g)	TSS (°Brix)
T0	33.75	24.15	53.68	43.8	3.29
T1	31.60	24.27	86.06	55.3	4.96
T2	31.10	24.48	82.69	57.3	5.42
T3	29.80	18.29	75.22	52.3	4.35
T4	31.85	24.60	90.51	57.7	5.19
T5	35.30	26.38	92.76	59.8	5.49
T6	30.40	23.32	87.37	55.6	4.19
T7	30.10	22.97	62.42	48.6	4.52
T8	30.50	24.06	61.56	50.0	3.97
T9	28.00	17.36	61.34	47.1	4.44

Conclusion

The study shows that the combination of 50% N inorganic + 50% vermicompost (T5), significantly improves the growth, anthocyanin content, and nutritional quality of red cabbage. The maximum plant height, head diameter, and biochemical constituents such as anthocyanin, ascorbic acid and TSS under treatment T5 indicates that vermicompost not only supplies essential nutrients but also improves soil health, microbial activity, and nutrient uptake efficiency. These results emphasize the importance of adopting organic and inorganic sources together for sustainable vegetable production. The organic sources such as vermicomposting integrated properly, can improve crop quality while reducing dependence on chemical fertilizers. Therefore, the adoption of integrated nutrient strategies could be a successful approach for boost the nutritional composition, antioxidant activity and growth in red cabbage.

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