



RESEARCH ARTICLE

Nutritional quality of lettuce cultivars as affected by organic and conventional fertilization

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Abstract

Lettuce (*Lactuca sativa* L.) is widely consumed as a fresh salad vegetable and valued for its nutritional quality; however, increasing concern over excessive chemical fertilizer use has intensified interest in organic production systems. Comparative information on how organic and conventional fertilization influence lettuce quality, particularly across different cultivars under Bangladeshi conditions, remains limited. Therefore, this study evaluated the effects of organic and conventional fertilization on the quality attributes of three lettuce cultivars (Green Wave, Grand Rapid and Iceberg). A randomized complete block design with three replications was used for the experiment. Quality parameters including water and dry matter content, chlorophyll, ascorbic acid, β -carotene, iron, calcium and magnesium were analyzed. Regardless of cultivar, the highest dry matter content (7.46 %) was observed in plants receiving organic fertilization. In contrast, conventional fertilization resulted in the highest water content (92.95 %), chlorophyll a and b, ascorbic acid (26 mg/100 g), β -carotene, iron (106.48 ppm) and calcium. Among cultivars, 'Green Wave' exhibited the highest chlorophyll and magnesium contents, while 'Grand Rapid' showed the highest water content and iron accumulation (105.63 ppm). 'Iceberg' performed best in dry matter content, ascorbic acid (21.9 mg/100 g), β -carotene (470 IU/100 g) and calcium. Notably, the combination of 'Iceberg' with organic fertilization produced superior results in dry matter, ascorbic acid and magnesium contents. The findings suggest that appropriate integration of fertilization method and cultivar selection can enhance lettuce quality while supporting sustainable production systems.

Keywords

ascorbic acid; β -carotene; conventional fertilizer; lettuce; minerals; organic fertilizer

Introduction

One of the most popular salad vegetables in the world, lettuce (*Lactuca sativa* L.) is primarily consumed for its fresh, raw leaves. It belongs to the family Compositae and is valued for its palatability, nutritional quality and health-promoting properties (1, 2). Because lettuce is generally eaten raw, its vitamins, minerals and bioactive compounds enter the human diet without thermal degradation, making its quality particularly important (3). In recent years, growing concerns over soil health, environmental pollution and potential health risks associated with excessive use of chemical fertilizers have increased interest in organic vegetable production (4–6). Organic farming is increasingly preferred by consumers due to its perceived benefits for food safety and nutritional quality (7, 8). However, conventional fertilization systems are still widely practiced because of their ability to supply readily available nutrients and support rapid plant growth. The comparative effects of organic and

conventional fertilization systems on vegetable quality, particularly in leafy vegetables such as lettuce, remain variable and cultivar dependent (9–12).

Lettuce's antioxidant capacity and nutritional worth are enhanced by its abundance of vitamins and minerals, such as calcium, iron, magnesium, vitamin A, vitamin C, β -carotene and chlorophyll (13, 14). The nutrient composition of lettuce is influenced by cultivar, fertilization method, soil condition and environmental factors during growth (13). Differences in head structure among lettuce types can also affect light interception and carotenoid accumulation (15). Several studies have reported inconsistent responses of quality parameters to organic and conventional fertilization, highlighting the need for location-specific and cultivar-based evaluation (16, 17). In Bangladesh, lettuce cultivation is confined to a limited area and its average yield remains low compared to major lettuce-producing countries (18). The low productivity is mainly attributed to inadequate information on suitable cultivars, fertilization practices and improved production technologies. Despite the increasing demand for safe and nutritious vegetables, scientific information comparing the quality attributes of lettuce grown under organic and conventional fertilization systems in Bangladesh is scarce.

Therefore, the present study was undertaken to evaluate the effects of organic and conventional fertilization on the quality attributes of selected lettuce cultivars under Bangladeshi agro-climatic conditions. The study focused on water and dry matter content, chlorophyll, ascorbic acid, β -carotene and mineral composition. The findings are expected to provide valuable information for improving lettuce quality through appropriate cultivar selection and fertilization management, while promoting sustainable vegetable production practices.

Materials and Methods

Experimental site, design and materials

Lettuce was grown both conventionally and organically at the Horticulture Research Farm and Laboratory of Gazipur Agricultural University in Salna, Gazipur. The study site was situated at coordinates 24.036829° N and 90.397706° E in Gazipur, Bangladesh. The site is located on the elevated Pleistocene terraces of the Madhupur Tract, about 35 km north of Dhaka which was under the agro ecological zone (AEZ) 28. The site serves as a transition between the agricultural research zones of the north and the intense urban expansion of the south due to its westward location on the N3 national highway. The soil at the experimental site was virtually neutral, had a clay loam texture and belonged to the Shallow Red Brown Terrace soil series in the Madhupur tract. Its pH was 6.3. The subtropical climate zone where the experimental site is located has heavy rainfall for the remainder of the year and minimal rainfall from November to

April. Between 24.2 to 33.6 °C was the temperature range. The air temperature throughout the rabi season is between 12 and 31 °C and the relative humidity ranges from 30 to 70 % at the lowest point to over 90 % at the highest. Winter is short and cold, while the hottest months are March through May. The average annual rainfall of 210 cm comes mostly between June and October (19). Soil types and key nutrient properties of the study site in AEZ-28 (Madhupur Tract) is mentioned in Table 1. The Department of Horticulture's analytical laboratory performed the quality examination.

Three replications of the field experiment were carried out using randomized complete block design (RCBD). The experimental plot was 108 m² in total, measuring 13.5 m in length and 8 m in breadth. Three equal blocks were created from the entire region. Each block was divided into six plots, each with a random distribution of six treatment combinations. The experiment included a total of eighteen-unit plots. Each plot was 2 m by 1.5 m. Two blocks and two plots were kept 70 cm and 50 cm apart, respectively. Plots were elevated to a height of 10 cm. Row to row and plant to plant spacing in the plot was maintained at 25 cm and 40 cm, respectively. In the organic fertilization approach, only well-decomposed cow dung at 50 t/ha was used, while in the conventional fertilization method, Urea at 250 kg/ha, TSP at 150 kg/ha, MOP at 200 kg/ha and 15 t/ha well decomposed cow dung were used (21), which represents one of the earliest standardized recommendations for lettuce production under Gazipur agro-ecological conditions. Although fertilizer recommendations have evolved, these rates remain widely adopted by growers in central Bangladesh due to similar soil texture (clay loam), pH (6.3) and nutrient status of AEZ-28. Therefore, their use in the present study ensures comparability with prevailing farmer practices while allowing evaluation of quality responses under realistic production systems. The heads of lettuce were put in a lab to be analyzed for nutritional quality. The head samples were dried for mineral analysis using a drying oven (Sanyo, Japan) and the experiment's laboratory portion was set up in a complete randomized design with three replications. There were two components to the experiment:

Factor-A (cultivars)	Factor-B (fertilization methods)
a. C ₁ = Green Wave	a. G ₀ = Organic
b. C ₂ = Grand Rapid	b. G ₁ = Conventional
c. C ₃ = Iceberg	

The cultivar of lettuce used in this experiment was the Green Wave, Grand Rapid and Ice-berg were collected (certified seeds) from the market of Siddique Bazar of Dhaka. After being soaked in water for a whole day (24 hr), lettuce seeds were combined with powdered soil and planted in rows. The seeds were planted two centimeters deep, covered with a thin layer of soil and then lightly irrigated using a watering can. The beds were then covered with dry straw to keep the proper moisture and

Table 1. The study site's soil types and important nutritional characteristics in AEZ-28 (Madhupur Tract)

Major land type	Soil pH	Soil OM	Nutrient status							
			N	P	K	S	Ca	Mg	Zn	B
Highland (56 %)	3.7-6.7	L-M	VL-L	VL-L	L-M	VL-L	L-M	L-M	L-M	VL-L
Medium highland (18 %)	3.9-6.8	L-M	VL-L	VL-L	L-M	VL-L	L-M	L-M	L-M	VL-L

L-M: Low to medium, VL-L: Very low to low, L-M: Low to medium. Source: BARC (20)

temperature. The crop was collected when it reached maturity after healthy, uniformly sized seedlings were moved into the experimental plots. Biochemical analysis was performed on the harvested lettuce. During the nutrition analysis, data on water content (%), dry matter content (%), ascorbic acid (mg/100 g), β -carotene (IU/100 g), iron (ppm), calcium (%), magnesium (%) were recorded. Water and dry matter content (%) was determined by using the following formula:

$$\% \text{ Water} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

$$\% \text{ Dry matter} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

Determination of chlorophyll content

At harvest, it was measured using a chlorophyll meter (made by Konica Minolta Sensing, INC., Japan) with the SPAD-502 unit. From each plot, nine randomly chosen plants were used and readings from different parts of the head were averaged (22).

Determination of ascorbic acid

A sample weighing 50 g was placed in a warring blender. 50 mL of distilled water was added to the warring blender to homogenize the material. After the homogenized solution was put into a 250 mL volumetric flask and filled to the appropriate level with distilled water, it was centrifuged at 4 °C for 20 min at 4000 rpm. The 250 mL volumetric flask was once more filled with supernatant liquid. This was the extract solution used to measure ascorbic acid. The method outlined earlier was used to determine the ascorbic acid content (23).

Determination of β -carotene

After crushing and thoroughly mixing 1 g of the sample with 10 mL of acetone: hexane (4:6) solution, the sample was centrifuged and the optical density of the supernatant was measured using a spectrophotometer (Model no. 200-20, Hitachi, Japan) at 663 nm, 645 nm, 505 nm and 453 nm using the formula outlined previously (24).

Determination of minerals

To determine the total iron, calcium and magnesium content, dried plant materials were digested using a concentrated HNO_3 and HClO_4 mixture as outlined formerly (25).

Statistical analysis

The "Statistix 10" program was used to statistically evaluate the gathered data. The Least Significant Test (LSD at 5 %) was used to examine the mean differences between the treatments after the mean values for each treatment were determined and each character's analysis of variance was completed (26, 27).

Results and Discussion

Water and dry matter percentage

Fertilization methods showed insignificant influence on water and dry matter of lettuce (Fig. 1A). Higher water (92.95 %) was obtained from conventional methods. The lowest water content (92.54 %) was found in organic method. On the other hand, significant higher dry matter content (7.46 %) was obtained from organic methods. The lowest dry matter (7.16 %) was found in conventional method. Previously it was reported that the higher dry matter was achieved by organic lettuce (17).

Lettuce's water and dry matter percentages varied slightly between Green Wave and Grand Rapid (C_1 and C_2), but dramatically in Ice-berg (C_3) (Fig. 1B). C_2 had the significantly greatest water content (93.45 %), while C_3 had the lowest (91.69 %). However, C_3 had the significantly greatest dry matter content (8.31 %). C_2 had the lowest percentage (6.72 %).

The combination of cultivars and fertilization techniques had a substantial impact on the percentage of water and dry matter in lettuce (Table 2). The current study's results show that the C_2G_0 treatment combination produced the significantly largest water content (93.47 %), which was statistically identical to all other treatments except for the C_3G_0 treatment. On the other hand, the C_3G_0 treatment had the noticeably lowest water content (91.02 %). The C_3G_0 treatment had noticeably greatest dry matter content (8.98 %) and C_2G_0 treatment had the significantly lowest

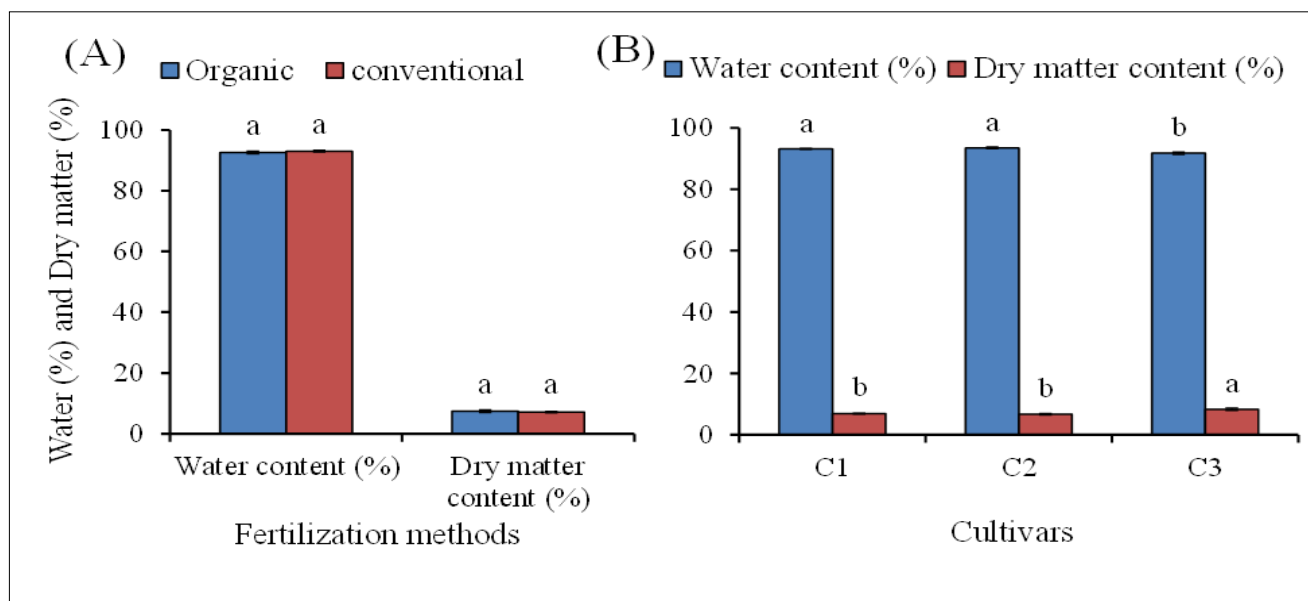


Fig. 1. Water and dry matter content of lettuce as affected by fertilization methods (A) and cultivars (B). C_1 : Green Wave; C_2 : Grand Rapid; C_3 : Ice-berg cultivars of lettuce. $n=3$, $p < 0.05$ by LSD

Table 2. Interaction effect of lettuce on water and dry matter percentage

Treatments	Water content (%)	Dry matter content (%)
T ₁ (C ₁ G ₀)	93.12 ab	6.88 bc
T ₂ (C ₂ G ₀)	93.47 a	6.53 c
T ₃ (C ₃ G ₀)	91.02 c	8.98 a
T ₄ (C ₁ G ₁)	93.07 ab	6.93 bc
T ₅ (C ₂ G ₁)	93.43 a	6.90 bc
T ₆ (C ₃ G ₁)	92.35 b	7.65b
LSD _{0.05}	0.89	0.74
SE (±)	0.32	0.26
CV (%)	0.59	6.20

G₀, Organic fertilizer; G₁, Conventional fertilizer; C₁, Green wave; C₂, Grand rapid; C₃, Ice-berg; G₀, Organic; G₁, Conventional. Means in a column bearing different letter(s) are significantly different by LSD at 5 % level of significance.

dry matter content (6.53 %), which was statistically similar to all other treatments except for the C₃G₀ treatment. Leaf dry matter was highest in organic cultivation and lowest in conventional cultivation. Vegetables cultivated using organic fertilization had a higher dry matter content than those grown using conventional methods (12). Furthermore, different cultivars have different percentages of dry matter and water (28).

The higher dry matter content under organic fertilization may be attributed to slower nitrogen mineralization and gradual nutrient release, which reduces excessive leaf succulence and promotes accumulation of structural carbohydrates (29, 30). In contrast, readily available mineral nitrogen in the conventional system likely enhanced rapid cell expansion and vacuolar water accumulation, leading to slightly higher leaf water content. This pattern is consistent with the nutrient dilution effect, whereby accelerated biomass production under high nitrogen supply can dilute mineral and phytochemical concentrations on a fresh weight basis due to increased tissue water content (31). Similar dilution phenomena have been reported in leafy vegetables under intensive fertilization regimes (30). Therefore, the results suggest a trade-off between vegetative growth and nutrient density, particularly for dry matter-associated minerals and bioactive compounds (32).

Effect of fertilization method, lettuce cultivars and their interaction on chlorophyll and vitamin content

No big difference in SPAD value (total chlorophyll content) was observed with the influence of fertilization method, cultivars and their interaction effect (Table 3). This contrasts with Chatterjee (2015), who reported higher chlorophyll content under organic lettuce production. Among cultivars, only Grand Rapid with organic fertilizer (C₂G₀) showed significantly lower SPAD. Although differences were not statistically significant, the slightly higher SPAD values under conventional fertilization are physiologically consistent with greater nitrogen availability, since nitrogen is an essential component of chlorophyll molecules and key photosynthetic enzymes such as Rubisco (33). Increased nitrogen supply enhances chloroplast development and leaf greenness, which may explain the marginal trend observed.

Ascorbic acid content was not significantly affected by fertilization method but differed among cultivars. Iceberg (C₃) recorded the highest ascorbic acid content (21.90 mg/100 g), followed by C₂ (20.10 mg/100 g), while C₁ showed the lowest value (19.10 mg/100 g). Interaction effects revealed the highest ascorbic acid content in C₃G₀ (22.10 mg/100 g), which was statistically similar to C₃G₁ and C₂G₁. The lowest values were observed in C₁G₁ and C₂G₀ (Table 3). Higher ascorbic acid levels in Iceberg, particularly under organic fertilization (C₃G₀), may be associated with moderate nutrient stress or balanced nutrient availability that stimulates antioxidant biosynthesis pathways (32). Organic systems often enhance soil microbial activity and improve micronutrient dynamics, which can promote synthesis of secondary metabolites including vitamin C (34, 35). Ascorbic acid plays a protective role against oxidative stress in plant tissues; therefore, slight variations in nutrient availability between fertilization systems may trigger adaptive antioxidant responses (33).

β-carotene content was significantly influenced by fertilization method, with higher levels under conventional fertilization (403.33 IU/100 g) than organic fertilization (343.33 IU/100 g). Cultivar effects were also significant, with Iceberg (C₃) showing the highest β-carotene content (470.00 IU/100 g) and

Table 3. Influence of lettuce cultivars and different fertilization levels on chlorophyll and vitamin content

Fertilization methods	SPAD	Ascorbic acid (mg/100g)	β-carotene (IU/100g)
Organic (G ₀)	19 a	21 a	343.33 b
Conventional (G ₁)	20 a	26 a	403.33 a
LSD _{0.05}	1.77	2.40	35.34
SE (±)	0.61	0.83	12.18
CV (%)	5.42	6.15	5.65
Cultivars			
Green wave (C ₁)	19 b	19.10 b	353.33 b
Grand rapid (C ₂)	18 b	20.10 ab	296.67 b
Ice-berg (C ₃)	20 a	21.90 a	470.00 a
LSD _{0.05}	1.48	2.57	32.88
SE (±)	0.52	0.89	11.51
CV (%)	4.71	7.59	5.34
Combined effect (Growing methods × Cultivars)			
C ₁ G ₀	19 a	19.30 bc	183.33 c
C ₂ G ₀	18 b	18.80 c	380.00 b
C ₃ G ₀	20 a	22.10 a	466.67 ab
C ₁ G ₁	19 a	18.80 c	523.33 a
C ₂ G ₁	19 a	21.40 ab	213.33 c
C ₃ G ₁	20 a	21.70 ab	473.33 ab
LSD _{0.05}	1.44	2.32	45.92
SE (±)	0.51	0.82	16.23
CV (%)	4.61	6.98	7.52

G₀, Organic fertilizer; G₁, Conventional fertilizer; C₁, Green wave; C₂, Grand rapid; C₃, Ice-berg; G₀, Organic; G₁, Conventional. Means in a column bearing different letter(s) are significantly different by LSD at 5 % level of significance.

Green Wave (C₁) the lowest. These differences may be related to head structure and light penetration, as reported in the past (14, 15). Interaction effects showed the highest b-carotene content in C₁G₁, while the lowest was recorded in C₁G₀ (Table 3). Enhanced vitamin A content under combined nutrient sources may be associated with improved translocation of photosynthates and stimulation of carotenoid biosynthesis in lettuce heads.

The greater β -carotene content observed under conventional fertilization in certain cultivars may be explained by enhanced nitrogen-driven chloroplast development. Carotenoids are synthesized within plastids and are closely linked to photosynthetic metabolism; thus, increased nitrogen availability can stimulate carotenoid biosynthesis through improved photosynthetic capacity (14, 30). However, genotype-dependent differences in plastid density and head structure influence light interception and carotenoid accumulation, which likely explains the superior performance of Iceberg (15). Similar nitrogen-mediated increases in carotenoid concentration have been reported in leafy vegetables under optimized fertilization regimes (30, 34).

Variation in mineral content of lettuce under different fertilization systems

Fertilization method had a significant effect on iron content in lettuce (Fig. 2A). Conventional fertilization resulted in higher iron content (106.48 ppm) than organic fertilization (95.30 ppm). Iron content also varied significantly among cultivars (Fig. 2B), with C₂ recording the highest value (105.63 ppm), statistically similar to C₃ (102.13 ppm), while C₁ showed the lowest iron content (94.90 ppm). A significant interaction between fertilization method and

cultivar was observed (Table 4). The highest iron content was recorded in C₂G₁ (111.07 ppm), whereas the lowest occurred in C₁G₀ (87.80 ppm). Several treatment combinations were statistically similar. These findings are generally consistent with former reported higher nutrient accumulation under organic fertilization (36).

Higher iron accumulation under conventional fertilization may reflect improved nutrient solubility and enhanced root uptake efficiency facilitated by balanced NPK supply. Nitrogen-induced root proliferation can increase rhizosphere exploration and micronutrient absorption (29). However, organic amendments improve soil structure, microbial activity and cation exchange capacity, which can enhance gradual micronutrient availability over time (35). The differential iron accumulation observed among cultivars further suggests genotype-specific nutrient uptake efficiency, as previously reported in lettuce and other leafy crops (30).

Calcium content was not significantly affected by fertilization method (Fig. 3A), though slightly higher values were observed under conventional fertilization (0.23 %) compared to organic fertilization (0.22 %). In contrast, magnesium content differed significantly between fertilization methods, with higher magnesium under organic fertilization (0.24 %) than conventional fertilization (0.23 %), which agreed with the previous findings (11, 19). Cultivar effects were significant for calcium content (Fig. 3B), with C₃ showing the highest value (0.25 %), while C₁ and C₂ recorded lower and statistically similar values (0.22 %). Magnesium content did not differ significantly among cultivars.

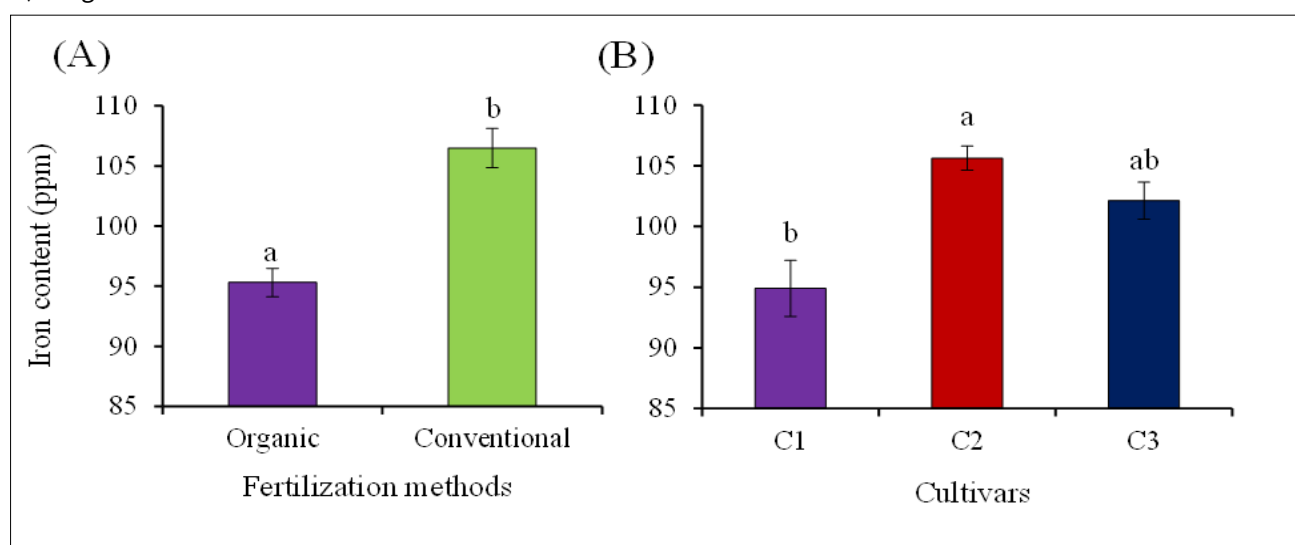


Fig. 2. Effects of fertilization methods (A) and cultivars (B) on iron content in lettuce. C₁: Green Wave; C₂: Grand Rapid; C₃: Ice-berg cultivars of lettuce. n=3, p < 0.05 by LSD

Table 4. Interaction effects of fertilization method and cultivar on lettuce mineral content

Treatment	Iron (ppm)	Calcium (%)	Magnesium (%)
T ₁ (C ₁ G ₀)	87.80 b	0.21 d	0.23 bc
T ₂ (C ₂ G ₀)	100.20 ab	0.22 cd	0.24 ab
T ₃ (C ₃ G ₀)	97.90 ab	0.24 ab	0.25 a
T ₄ (C ₁ G ₁)	102.00 ab	0.23bc	0.24 ab
T ₅ (C ₂ G ₁)	111.07 a	0.21 d	0.22 c
T ₆ (C ₃ G ₁)	106.36 ab	0.25 a	0.23 bc
LSD _{0.05}	7.47	0.02	0.02
SE (±)	2.64	0.01	0.01
CV (%)	4.53	4.38	3.93

G₀, Organic fertilizer; G₁, Conventional fertilizer; C₁, Green wave; C₂, Grand rapid; C₃, Ice-berg; G₀, Organic; G₁, Conventional. Means in a column bearing different letter(s) are significantly different by LSD

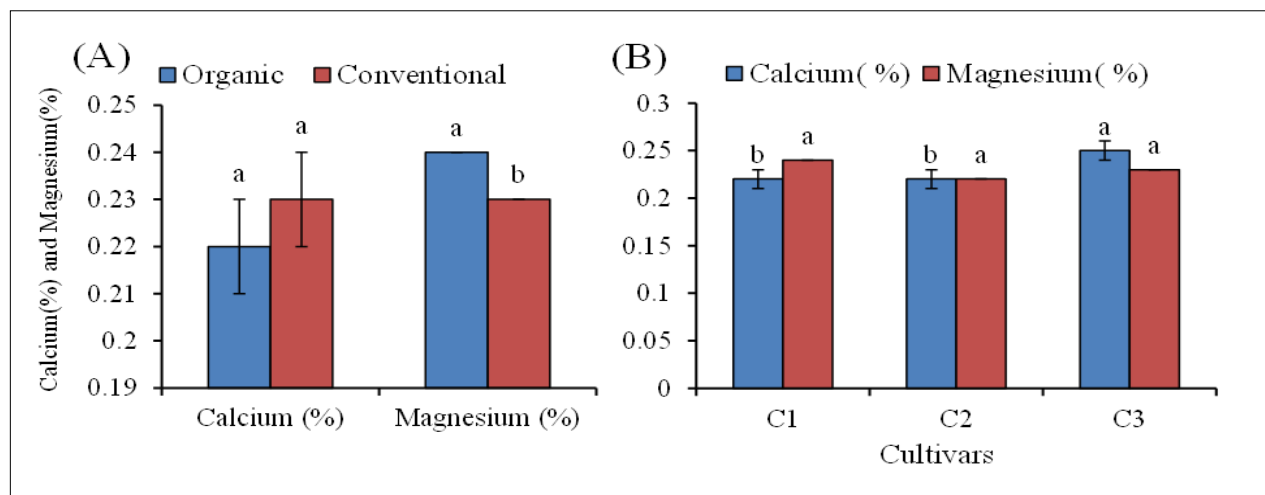


Fig. 3. Calcium and magnesium content of lettuce as affected by fertilization methods (A) and cultivars (B). C₁: Green Wave; C₂: Grand Rapids; C₃: Ice-berg cultivars of lettuce. n=3, p < 0.05 by LSD

Interaction effects were significant for both calcium and magnesium (Table 4). The highest calcium content was observed in C₃G₁ (0.25 %), statistically like C₃G₀ (0.24 %), while the lowest values occurred in C₁G₀ and C₂G₁ (0.21 %). Magnesium content was highest in C₃G₀ (0.25 %) and lowest in C₂G₁ (0.22 %), with several treatment combinations showing no significant differences.

The slightly higher magnesium content under organic fertilization may be attributed to improved soil cation exchange capacity and gradual mineralization of organic matter, enhancing magnesium retention in the root zone (32). Magnesium is a central atom in the chlorophyll molecule and plays a crucial role in photosynthesis and enzyme activation (33). These mineral patterns reinforce the concept that conventional systems promote rapid nutrient uptake, whereas organic systems support sustained nutrient availability and potentially improved nutrient balance (35).

Conclusion

This investigation shows that through different physiological processes, cultivar selection and fertilization technique work together to affect the nutritional composition of lettuce. Conventional fertilization increased water content, iron accumulation and β -carotene, perhaps through nitrogen-driven chlorophyll and plastid development, while organic fertilizer increased dry matter and magnesium content, probably because of delayed nutrient release and less tissue dilution. These results highlight the necessity of matching fertilization tactics with production goals and market demand by exposing a trade-off between nutrient density and quick vegetative development. Future studies should measure the link between yield and nutrient density, assess integrated organic-mineral fertilization techniques and look into the molecular processes that underlie the manufacture of antioxidants and carotenoid pigments under various nitrogen regimes. It is also advised to do long-term field research evaluating environmental sustainability, economic returns and soil health in Bangladesh. Overall, there is a great deal of promise to enhance the nutritional content of lettuce while promoting sustainable horticulture production in Bangladesh and other subtropical agro-ecosystems through the strategic integration of cultivar selection and nutrient management.

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Authors' contributions

MSR, SC and NA jointly conceptualised the study and conducted the experiments and data collection. EK and MSA supervised the research and critically revised the manuscript. SA performed the statistical analyses. MSR and SC prepared the initial draft. All authors reviewed and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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