International Journal of Plant & Soil Science

Volume 38, Issue 8, Page 1-11, 2026; Article no.IJPSS.162389
ISSN: 2320-7035

Influence of Integrated Nutrient Management on Soil Health Indicators and Nutrient Dynamics in Cantaloupe (*Cucumis melo* L.) Cultivation

Suryansh Marker [a++*], Saurabh Sharma [a#], Manpreet Singh [a#], Arshdeep Singh [a++] and Navneet Kaur [a++]

[a] *P.G. Department of Agriculture, Khalsa College, Amritsar (Punjab) 143002, India.*

Authors' contributions

This work was carried out in collaboration among all authors. Author SM did conduction of field experiment, data collection and manuscript drafting. Author SS did the conceiving the idea and manuscript editing. Author MS did data analysis and manuscript editing. Author AS did the assisted in data analysis and manuscript writing. Authors NK did the writing corrected draft and feedback. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2026/v38i86193

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/162389

Original Research Article

Received: 01/05/2026
Accepted: 11/07/2026
Published: 15/07/2026

Abstract

Integrated nutrient management is an important strategy for improving soil health and sustaining crop productivity through the combined use of organic and inorganic nutrient sources. A field experiment was conducted during 2024 and 2025 at the Students' Research Farm, Khalsa College, Amritsar, Punjab, India, to evaluate the effect of integrated nutrient management on soil health indicators, nutrient dynamics, fruit yield and quality of cantaloupe (*Cucumis melo* L.). The experiment was laid out in a Randomised Block Design

---

[++] *Research Scholar;* [#] *Assistant Professor;*
**Corresponding author: E-mail: markersuryansh@gmail.com;*

Cite as: *Marker, S., Sharma, S., Singh, M., Singh, A., & Kaur, N. (2026). Influence of Integrated Nutrient Management on Soil Health Indicators and Nutrient Dynamics in Cantaloupe (Cucumis melo L.) Cultivation. International Journal of Plant & Soil Science, 38(8), 1–11. https://doi.org/10.9734/ijpss/2026/v38i86193*

with eight nutrient management treatments and three replications. The results revealed that 100% of the recommended dose of fertilisers (RDF) (T_2) produced the highest fruit yield (69.04 q acre^{-1}). Among the integrated nutrient management treatments, 50% RDF + 50% recommended N through VC (T_7) recorded a fruit yield of 64.02 q acre^{-1}, which was comparable to T_2 while substantially improving soil fertility. The highest soil organic carbon (0.44 %) was recorded under 50 % recommended N through FYM + 50% recommended N through VC (T_3), whereas the maximum cation exchange capacity (8.93 cmol (+) kg^{-1} soil) and available nitrogen (233.85 kg ha^{-1}), phosphorus (23.73 kg ha^{-1}) and potassium (276.73 kg ha^{-1}) were obtained under T_7. Soil microbial biomass carbon and dehydrogenase activity were also significantly enhanced under integrated nutrient management treatments compared with the control. These findings indicate that integrating VC with inorganic fertilisers improves soil health while maintaining crop productivity. Therefore, 50 % RDF + 50 % recommended N through VC (T_7) may be considered a sustainable nutrient management strategy for cantaloupe cultivation, as it provides productivity comparable to the recommended fertiliser dose while enhancing soil quality and reducing dependence on chemical fertilisers. The study was conducted at a single location over two cropping seasons; therefore, further long-term and multi-location studies are required to validate these findings under diverse agro-climatic conditions.

Keywords: Cantaloupe; integrated nutrient management; farmyard manure; vermicompost; soil organic carbon; nutrient availability; microbial biomass carbon; dehydrogenase activity; fruit yield; soil health.

1. Introduction

The Cucurbitaceae family includes several economically important vegetable crops, among which cantaloupe (*Cucumis melo* L.) is widely cultivated due to its high yield potential, short crop duration and nutritional value. Cantaloupe is a warm-season crop adapted to arid and semi-arid environments and is grown under both irrigated and rainfed conditions. Although the geographic origin of melon remains debated, early studies suggested Africa as the centre of domestication (Kerje & Grum, 2000), whereas recent taxonomic and molecular evidence indicates Asia, particularly the Indian subcontinent, as the primary centre of origin and diversity (Schaefer *et al*., 2009; Sebastian *et al*., 2010). In India, cantaloupe cultivation is mainly concentrated in Uttar Pradesh, Punjab, Rajasthan and Madhya Pradesh, with increasing adoption in temperate regions.

Cantaloupe fruits are valued for their high moisture content, pleasant flavour and nutritional composition, including substantial amounts of vitamin C, β-carotene, potassium and other bioactive compounds (Lester & Hodges, 2008). Owing to these attributes and its adaptability to diverse production systems, cantaloupe has gained importance in commercial vegetable cultivation in recent years. However, despite its high genetic yield potential, productivity is often limited by declining soil fertility, nutrient imbalance and inefficient nutrient management practices.

Modern intensive agricultural systems, which rely predominantly on inorganic fertilisers, have contributed to the deterioration of soil physical structure, depletion of soil organic carbon and reduction in soil biological activity (Fageria, 2012). In cucurbit crops, inadequate nutrient availability during critical growth stages adversely affects source-sink relationships, resulting in reduced fruit size, yield and quality due to poor photoassimilate translocation (Singh & Sahare, 2019). These challenges emphasise the need for sustainable nutrient management strategies that enhance soil health while maintaining high crop productivity.

Integrated nutrient management (INM) is a holistic approach that involves the combined use of organic manures, inorganic fertilisers and biological inputs to maintain soil fertility and optimise nutrient availability for crops. Proper integration of nutrient sources improves nutrient use efficiency, reduces production costs and minimises environmental pollution associated with excessive fertiliser use (Soumya *et al*., 2013). Organic amendments play a critical role in improving soil physical, chemical and biological properties by increasing soil organic carbon, enhancing microbial activity and improving soil structure and moisture retention (Bhagat & Prajapati, 2021).

Recent syntheses of vegetable production systems indicate that partial substitution of mineral fertilisers with organic nutrient sources may maintain productivity while supporting soil biological activity and nutrient cycling (Himanshu *et al*., 2026). Field evidence in cucumber also shows that combinations of mineral nutrients, vermicompost and biofertiliser can improve growth and yield components relative to an unfertilised control (Malo *et al*., 2022). Long-term studies in other cropping systems have further associated combined organic and mineral fertilisation with improved soil organic carbon, nutrient transformations, enzymatic activity and yield sustainability (Walia *et al*., 2024; Wang *et al*., 2024). Despite these advances, the comparative effects of replacing recommended inorganic nitrogen with FYM and VC on the combined physical, chemical and biological indicators of sandy loam soil under cantaloupe cultivation remain insufficiently characterised under the agro-climatic conditions of Punjab. In particular, evidence is limited on whether partial organic substitution can maintain fruit yield while simultaneously improving post-harvest nutrient availability and microbial activity across consecutive seasons.

Therefore, the present study was undertaken to evaluate the effect of INM involving inorganic fertilisers, FYM and VC on soil health indicators, nutrient dynamics, fruit yield and fruit quality of cantaloupe (*Cucumis melo* L.). The specific objectives were to: (i) assess the influence of different integrated nutrient management practices on soil physical, chemical and biological properties; (ii) evaluate their impact on fruit yield; and (iii) identify a sustainable nutrient management strategy that enhances soil fertility while maintaining high crop productivity.

2. Materials and Methods

A field experiment was conducted during the spring seasons of 2024 and 2025 at the Students' Research Farm, Khalsa College, Amritsar, Punjab, India (31°38′15’’ N, 74°50′10’’ E; 229 m above mean sea level). The region has a subtropical semi-arid climate characterised by hot summers and cool winters. The experiment was laid out in a Randomised Block Design (RBD) with eight treatments and three replications.

The experimental soil was sandy loam in texture with an alkaline reaction (pH 8.29), low in available nitrogen (N) (179.38 kg ha^{-1}) and organic carbon (0.39 %), and medium in available phosphorus (P) (13.08 kg ha^{-1}) and potassium (K) (249.32 kg ha^{-1}).

The crop used was cantaloupe (*Cucumis melo* L.) cv. F_1 Punjab Hybrid. Seedlings were transplanted on 3 March 2024 and 6 March 2025 at a spacing of 60 × 60 cm. Each experimental plot measured 3 m × 5 m (15 m^2). Standard agronomic practices recommended by Punjab Agricultural University, Ludhiana, were followed uniformly for all treatments. Irrigation was applied at regular intervals according to crop requirements to avoid moisture stress.

The recommended fertiliser dose (RDF) for cantaloupe was 50:25:25 kg $N:P_2O_5:K_2O$ ha^{-1}. Fifty percent of the recommended N and the full doses of P and K were applied as a basal dose at transplanting, while the remaining N was applied in two equal splits at 30 and 45 days after transplanting.

The treatments consisted of: T_1: Absolute control; T_2: 100 % RDF; T_3: 50 % of the recommended N supplied through FYM + 50 % through VC; T_4: 75 % RDF+ 25% of the recommended N through FYM; T_5: 50 % RDF+ 50 % of the recommended N through FYM; T_6: 75 % RDF + 25 % of the recommended N through VC; T_7: 50 % RDF + 50 % of the recommended N through VC; and T_8: 50 % RDF + 25 % of the recommended N through VC + 25 % through FYM. In all integrated treatments, substitution was based only on the recommended N dose (RDFN), whereas P and K were applied through inorganic fertilisers to maintain uniform recommended levels across treatments.

Prior to field application, FYM and VC were analysed for their nutrient composition to determine the quantities required to substitute the recommended N dose. The nutrient contents of FYM were 1.5 % N, 0.2 % P and 0.5 % K, whereas VC contained 1.0 % N, 0.8 % P and 0.8 % K. The calculated quantities of FYM and VC were incorporated uniformly into the soil 15 days before transplanting.

After harvest, composite soil samples were collected from each plot and analysed for bulk density, porosity, water-holding capacity (WHC), pH, electrical conductivity (EC), organic carbon, cation exchange capacity (CEC), available N, P and K, soil microbial biomass carbon (SMBC) and dehydrogenase activity (DHA) using standard procedures. Available N was determined by the alkaline permanganate method (Subbiah & Asija, 1956), available P by the Olsen method (Olsen *et al*., 1954), available K by flame photometry (Merwin & Peech, 1951), pH and EC according to Jackson (1973), CEC by Chapman (1965), organic carbon by Walkley and Black (1934), bulk density by the core method (Prihar & Hundal, 1971), porosity by the PAU moisture gauge method (Prihar & Sandhu, 1968), WHC by the Keen box method (Keen & Raczkowski, 1921), SMBC by the chloroform fumigation-incubation method (Jenkinson & Powlson, 1976), and DHA by the method of Casida *et al*. (1964).

The data obtained from both years were subjected to analysis of variance (ANOVA) using OPSTAT software following the RBD. Treatment means were compared using the least significant difference (LSD) test at $p \leq 0.05$.

3. Results and Discussion

3.1 Physical Properties of Soil

The data presented in Table 1 illustrate that the application of various organic and inorganic nutrient sources significantly influenced the bulk density, soil porosity and WHC at the time of cantaloupe harvest. Across the pooled data, bulk density values ranged from 1.37 to 1.44 g cm^{-3}. The maximum pooled mean was recorded in T_1 (1.44 g cm^{-3}) followed closely by T_2 (1.43 g cm^{-3}). The lowest pooled bulk density was recorded in T_3 at 1.37 g cm^{-3}, which was significantly lower than that of most other treatments. Treatments with higher organic inputs (T_5, T_7 and T_8) also showed reduced bulk density (1.38, 1.39 and 1.39 g cm^{-3}) and were statistically comparable to T_3, highlighting the beneficial impact of organic amendments on soil physical properties. However, the marginal reduction in bulk density values in the integrated treatments compared with the control and the sole use of inorganic fertilisers may be ascribed to an increase in organic matter due to the addition of organic manures, which results in soil aggregation and more pore space (Zahoor *et al*., 2022).

Soil porosity ranged from 45.27 to 48.70 per cent, indicating consistent enhancement across treatments. The lowest pooled porosity was recorded in T_1 (45.27 %), followed by T_2 (45.67 %), demonstrating that inorganic fertilisers alone were less effective in improving pore space. The highest pooled porosity was found in T_3 at 48.70 per cent, which was significantly greater than other treatments. Similarly, treatments incorporating organic manure (T_5, T_7 and T_8) recorded higher porosity values than T_1 and T_2, confirming the beneficial influence of INM practices on soil physical health. Krishna *et al*. (2022) reported that higher organic carbon content improves the pore space in the soil. The incorporation of organic sources, i.e. FYM and VC, reduced soil bulk density and increased soil aggregate stability, thereby increasing soil porosity.

Table 1. Effect of integrated nutrient management on bulk density, soil porosity and water holding capacity of soil (Pooled analysis of two years)

Symbol	Treatments	Bulk density (g cm^{-3})	Soil porosity (%)	WHC (%)
T_1	Absolute control	1.44	45.27	34.34
T_2	100 % RDF	1.43	45.67	35.06
T_3	50 % of the recommended N supplied through FYM + 50 % through VC	1.37	48.70	43.44
T_4	75 % RDF+ 25% of the recommended N through FYM	1.40	47.16	40.26
T_5	50 **%** RDF + 50 % of the recommended N through FYM	1.38	47.74	42.44
T_6	75 % RDF + 25 % of the recommended N through VC	1.41	46.79	39.09
T_7	50 % RDF + 50 % of the recommended N through VC	1.39	47.55	42.31
T_8	50 % RDF + 25 % of the recommended N through VC + 25 % through FYM	1.39	47.54	42.24
SE(m)		0.005	0.33	0.39
LSD (p = 0.05)		0.01	0.99	1.20
Initial status		1.44	42.10	32.88

The WHC values ranged from 34.34 to 43.44 per cent. The lowest pooled WHC was recorded under T_1 (34.34 %), reflecting the limited moisture retention capacity in the absence of nutrient application. T_2 recorded 35.06 per cent, indicating only minor improvement with inorganic fertilisers alone. The highest pooled WHC was recorded in T_3 (43.44 %), significantly surpassing all other treatments. Other organic-based treatments such as T_5 (42.44 %), T_7 (42.31 %) and T_8 (42.24 %) also registered higher WHC and were statistically at par with each other and comparable to T_3. The enhanced WHC may be due to the hygroscopic nature of organic matter, which acts as a reservoir for water by absorbing and retaining moisture. This increases the availability of plant-accessible water, particularly in sandy loam soils (Bamboriya *et al*., 2022).

3.2 Chemical Properties of Soil

The data presented in Table 2 represent the effects of the combined application of organic and inorganic plant nutrient sources on soil pH, EC, organic carbon and CEC. The results revealed that different INM treatments did not exert a statistically significant influence on soil pH. This indicates that the inclusion of various combinations of organic and inorganic nutrient sources maintained the soil reaction within a relatively narrow and stable range. The recorded pH values across treatments varied only between 8.22 and 8.28, suggesting that the soil buffering capacity effectively resisted major shifts in acidity or alkalinity. Among the treatments, the highest pH (8.28) was observed in T_1. In contrast, the lowest pH of 8.22 was recorded under T_3, which involved the combined use of FYM and VC.

The pooled EC values ranged narrowly from 0.33 to 0.38 dS m^{-1} across treatments, suggesting that the applied nutrient management practices had a minimal impact on the soluble salt concentration of the soil. Among the treatments, the highest EC (0.38 dS m^{-1}) was recorded under T_2, where only chemical fertilisers were applied. The lowest EC (0.33 dS m^{-1}) was observed in T_1, where no fertilisers or organic amendments were applied, reflecting the natural ionic composition of the soil.

The pooled SOC values ranged from 0.36 to 0.44 per cent across the treatments. The lowest SOC content (0.36 %) was recorded in T_1. The highest SOC value (0.44 %) was observed under T_3, which was significantly higher than all other treatments. The increase in SOC content with the application of different manures may be attributed to the direct incorporation of these materials into the soil and their subsequent decomposition, resulting in an enhanced OC content of the soil (Jhaliwal *et al*., 2022).

Table 2. Effect of integrated nutrient management on chemical properties (Pooled analysis of two years)

Symbol	Treatment	pH	EC (dS m^{-1})	Soil organic carbon (%)	Cation exchange capacity [cmol (+) kg^{-1} soil]
T_1	Absolute control	8.28	0.33	0.36	6.62
T_2	100 % RDF	8.27	0.38	0.37	6.87
T_3	50 % of the recommended N supplied through FYM + 50 % through VC	8.22	0.35	0.44	7.21
T_4	75 % RDF+ 25% of the recommended N through FYM	8.24	0.35	0.41	7.89
T_5	50 % RDF + 50 % of the recommended N through FYM	8.23	0.36	0.43	8.63
T_6	75 % RDF + 25 % of the recommended N through VC	8.24	0.36	0.41	8.25
T_7	50 % RDF + 50 % of the recommended N through VC	8.23	0.37	0.42	8.93
T_8	50 % RDF + 25 % of the recommended N through VC + 25 % through FYM	8.23	0.36	0.42	8.47
SE(m)		0.004	0.002	0.007	0.05
LSD (p = 0.05)		NS	NS	0.02	0.17
Initial status		8.28	0.36	0.39	6.71

In the pooled analysis, the lowest pooled CEC was recorded in T_1 at 6.62 cmol (+) kg^{-1} soil. The highest pooled CEC was observed in T_7 with 8.93 cmol (+) kg^{-1} soil, significantly surpassing other treatments. Treatments incorporating organic amendments also recorded high CEC values, including T_5 [8.63 cmol (+) kg^{-1} soil], T_6 [8.25 cmol (+) kg^{-1} soil] and T_8 [8.47 cmol (+) kg^{-1} soil]. CEC was significantly better in treatments receiving organic manure than in those receiving fertiliser alone, which might be due to the porous structure of organic matter, a high specific surface area and an abundance of functional groups (-COOH and -OH) that provide additional exchange sites for cations (Pandit *et al*., 2020).

3.3 Macronutrient Availability in Soil

During the investigation period, the treatments exhibited significant variations in the available NPK content of the soil, as shown in Table 3. Post-harvest analysis of soil revealed that available N ranged from 176.08 to 233.85 kg ha^{-1}. The lowest N was recorded under T_1 with 176.08 kg ha^{-1}, indicating continuous nutrient depletion without any input. The highest pooled N was found in T_7, which recorded 233.85 kg ha^{-1}, significantly exceeding all other treatments. This was closely followed by T_5, which registered 231.47 kg ha^{-1}. Higher available N content was observed in treatments that received a combination of organic manure and inorganic fertilisers, which might be partly due to the release of native soil N and partly due to the mineralisation of nutrients from organic manure (Sande *et al*., 2024). This build-up in soil fertility indicates that chemical fertilisers in combination with organic manures have a marked effect on the availability of nutrients in the soil after crop harvest (Upadhyay *et al*., 2022).

The pooled available P values ranged from 12.08 to 23.73 kg ha^{-1}, showing consistent improvement across the INM treatments. The lowest pooled P was recorded under T_1 at 12.08 kg ha^{-1}, indicating nutrient mining in unfertilised soil. The highest pooled P availability was observed in T_7, which recorded 23.73 kg ha^{-1}, significantly surpassing all other treatments. Other treatments incorporating organic manure also recorded high values, particularly T_5 (22.48 kg ha^{-1}) and T_6 (20.01 kg ha^{-1}). These values indicate that even partial substitution of inorganic fertilisers with FYM or VC markedly improved soil P availability compared with T_2. This increase in P content is attributed to the direct addition and solvation of native P through organic acids (Varikuppala *et al*., 2021).

Table 3. Effect of integrated nutrient management on available macronutrient status of soil (Pooled analysis of two years)

Symbol	Treatment	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	Absolute control	176.08	12.08	246.08
T_2	100 % RDF	216.54	17.16	258.48
T_3	50 % of the recommended N supplied through FYM + 50 % through VC	205.66	15.94	251.04
T_4	75 % RDF+ 25% of the recommended N through FYM	223.17	17.91	262.29
T_5	50 % RDF + 50 % of the recommended N through FYM	231.47	22.48	271.21
T_6	75 % RDF + 25 % of the recommended N through VC	226.47	20.01	264.18
T_7	50 % RDF + 50 % of the recommended N through VC	233.85	23.73	276.73
T_8	50 % RDF + 25 % of the recommended N through VC + 25 % through FYM	229.49	20.93	269.20
SE(m)		0.99	0.74	0.87
LSD (p = 0.05)		3.04	2.26	2.67
Initial status		179.38	13.08	249.32

The pooled available K values ranged from 246.08 to 276.73 kg ha^{-1}, showing consistent improvement with INM. The lowest pooled K occurred in T_1 with 246.08 kg ha^{-1}, reiterating the loss of K in untreated soil. The highest pooled K was observed under T_7, recording 276.73 kg ha^{-1}, significantly exceeding other treatments. Other organic-based treatments also showed elevated K levels, including T_5 (271.21 kg ha^{-1}) and T_8 (269.20 kg ha^{-1}). The improvement in available K content under integrated treatments can be attributed to the synergistic effect of organic and inorganic nutrient sources, which collectively enhance soil nutrient retention and release mechanisms. Organic matter interacts with clay minerals, reducing the fixation of K by occupying adsorption sites on clay surfaces, thereby maintaining K in a more readily available form for plant uptake. The mineralisation of organic matter also releases organic acids and carbon dioxide, which help dissolve K-bearing minerals such as feldspars and micas, further enhancing the availability of K in the soil (Singh *et al*., 2020).

3.4 Biological Properties of Soil

The data presented in Table 4 demonstrate that the application of various organic and inorganic nutrient sources significantly influenced soil biological properties, including SMBC and DHA at the time of cantaloupe harvest. The pooled SMBC values reinforced the trends observed in individual years. The lowest SMBC was recorded in T_1 (82.84 µg g^{-1}). The highest SMBC was recorded in T_3 at 92.40 µg g^{-1}. Treatments with organic components also showed elevated pooled SMBC values, including T_5 (90.91 µg g^{-1}), T_7 (90.15 µg g^{-1}) and T_8 (89.42 µg g^{-1}). According to Zhang *et al*. (2022), the surface area, porous structure and mineral content of organic matter significantly affect soil microorganisms because they provide food and habitats for beneficial microorganisms, thereby increasing SMBC.

The pooled DHA values reflected consistent trends across both years. The lowest pooled DHA was found in T_1 with 21.55 µg TPF g^{-1} soil 24 h^{-1}, showing sustained reduction in microbial enzymatic activity without nutrient inputs. The highest pooled DHA was recorded in T_3 with 32.64 µg TPF g^{-1} soil 24 h^{-1}, demonstrating the superior effect of integrating FYM and VC. Other organic-enriched treatments also recorded high values, including T_5 (30.12 µg TPF g^{-1} soil 24 h^{-1}), T_7 (29.67 µg TPF g^{-1} soil 24 h^{-1}) and T_8 (28.92 µg TPF g^{-1} soil 24 h^{-1}). The increase in DHA with the application of organic manures may be due to improved soil aeration, moisture retention and labile carbon availability, which stimulate microbial respiration and enzyme synthesis (Brar *et al*., 2015).

Table 4. Effect of integrated nutrient management on soil microbial biomass carbon and dehydrogenase activity (Pooled analysis of two years)

Symbol	Treatments	SMBC (µg g^{-1} soil)	DHA (µg TPF g^{-1} soil 24 h^{-1})
T_1	Absolute control	82.84	21.55
T_2	100 % RDF	84.97	24.96
T_3	50 % of the recommended N supplied through FYM + 50 % through VC	92.40	32.64
T_4	75 % RDF+ 25% of the recommended N through FYM	88.28	27.90
T_5	50 % RDF + 50 % of the recommended N through FYM	90.91	30.12
T_6	75 % RDF + 25 % of the recommended N through VC	88.10	28.35
T_7	50 % RDF + 50 % of the recommended N through VC	90.15	29.67
T_8	50 % RDF + 25 % of the recommended N through VC + 25 % through FYM	89.42	28.92
SE(m)		0.80	0.73
LSD (p = 0.05)		2.47	2.23
Initial status		85.71	23.63

3.5 Yield Attributes

Integrated nutrient management significantly influenced the pooled fruit yield of cantaloupe (Table 5). Among the treatments, T_2 recorded the highest pooled fruit yield (69.04 q acre^{-1}), followed by T_7 with 64.02 q acre^{-1}. The T_5 and T_8 treatments produced comparable yields of 55.94 q acre^{-1} and 55.77 q acre^{-1}, respectively, whereas the lowest yield (21.25 q acre^{-1}) was recorded under T_1. The superior performance of T_2 and T_7 indicates that balanced nutrient supply through recommended fertilisers or partial substitution of inorganic N with VC effectively enhanced crop productivity.

The higher fruit yield under T_2 may be attributed to the continuous availability of essential nutrients, which promoted vigorous vegetative growth, efficient photosynthesis, flowering, fruit set and assimilate partitioning towards developing fruits. Likewise, the comparable yield recorded under T_7 demonstrates that replacing 50 % of the recommended N with VC maintained adequate nutrient availability while improving soil biological activity and nutrient-use efficiency. Paramesh *et al*. (2023) reported that INM significantly improves crop productivity, nutrient-use efficiency and soil fertility through the combined use of organic and inorganic nutrient sources. Similarly, Wu *et al*. (2023) observed that VC enhanced nutrient uptake, carbohydrate transport and fruit yield by improving plant physiological processes and nutrient availability.

Table 5. Effect of integrated nutrient management on fruit yield of cantaloupe (*Cucumis melo* L.) (pooled analysis of two years)

Symbol	Treatments	Pooled (q acre^{-1})
T_1	Absolute control	21.25
T_2	100 % RDF	69.04
T_3	50 % of the recommended N supplied through FYM + 50 % through VC	39.39
T_4	75 % RDF+ 25% of the recommended N through FYM	48.16
T_5	50 % RDF + 50 % of the recommended N through FYM	55.94
T_6	75 % RDF + 25 % of the recommended N through VC	50.67
T_7	50 % RDF + 50 % of the recommended N through VC	64.02
T_8	50 % RDF + 25 % of the recommended N through VC + 25 % through FYM	55.77
SE(m)		2.78
LSD (p = 0.05)		8.43

4. Conclusions

The study demonstrated that INM improved soil physical, chemical and biological properties under cantaloupe cultivation. Treatments involving organic amendments reduced soil bulk density and enhanced porosity and water-holding capacity compared with the control and sole inorganic fertiliser application. The combined use of FYM and VC substantially improved soil organic carbon, microbial biomass carbon and dehydrogenase activity, whereas 100% RDF produced the highest fruit yield and 50% RDF + 50% recommended N through VC achieved comparable productivity while improving soil health. Treatments combining inorganic fertilisers with VC also increased CEC and the post-harvest availability of N, P and K. Soil pH and EC remained within a narrow range, indicating that the integrated nutrient treatments did not adversely affect soil reaction or soluble salt status. The findings suggest that partial substitution of chemical fertilisers with organic manures can support soil fertility, nutrient availability and biological activity in cantaloupe cultivation. Integrated nutrient management may therefore be considered a useful strategy for sustaining soil health under intensive vegetable production systems.

5. Limitations

This study was conducted at a single experimental site over two consecutive growing seasons; therefore, the findings may not be directly applicable to other agro-climatic regions and soil types. The study evaluated the short-term effects of INM on soil health indicators and fruit yield, whereas the long-term residual effects of repeated applications of FYM and VC on soil fertility and productivity were not assessed. Further multi-location and long-term studies are required to validate the present findings and develop location-specific nutrient management recommendations for sustainable cantaloupe production.

Acknowledgements

The authors are highly thankful to P.G. Department of Agriculture, Khalsa College Amritsar for providing necessary research facilities.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references and interpretations, were carefully reviewed, revised, verified and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Bamboriya, J. S., Purohit, H. S., Jat, G., Bamboriya, S. D., Shekhawat, A. S., & Meena, A. K. (2022). Impact of integrated nutrient management in maize on physico-chemical properties of soil. *The Pharma Innovation Journal, 11*(2), 475–478.

Bhagat, S. R., & Prajapati, D. R. K. (2021). Effect of organic and sulphur along with chemical fertilizer (RDF) on oil yield of tulsi (*Ocimum basilicum* L.) under *Acacia mangium*-based multitier agroforestry system. *The Pharma Innovation Journal, 10*(10), 1035–1039.

Brar, B. S., Singh, J., Singh, G., & Kaur, G. (2015). Effects of long-term application of inorganic and organic fertilizers on soil organic carbon and physical properties in maize–wheat rotation. *Agronomy, 5*(2), 220–238. https://doi.org/10.3390/agronomy5020220

Casida, L. E., Jr., Klein, D. A., & Santoro, T. (1964). Soil dehydrogenase activity. *Soil Science, 98*(6), 371–376. https://doi.org/10.1097/00010694-196412000-00004

Chapman, H. D. (1965). Cation-exchange capacity. In C. A. Black (Ed.), *Methods of soil analysis: Part 2. Chemical and microbiological properties* (Agronomy Monograph No. 9, pp. 891–901). American Society of Agronomy. https://doi.org/10.2134/agronmonogr9.2.c6

Fageria, N. K. (2012). Role of soil organic matter in maintaining sustainability of cropping systems. *Communications in Soil Science and Plant Analysis, 43*(16), 2063–2113. https://doi.org/10.1080/00103624.2012.697234

Himanshu, Sagwal, V., & Kumar, S. (2026). Integrated nutrient management for sustainable vegetable production and soil health improvement. *International Journal of Environment and Climate Change, 16*(2), 209–226. https://doi.org/10.9734/ijecc/2026/v16i25276

Jackson, M. L. (1973). *Soil chemical analysis*. Prentice-Hall of India.

Jenkinson, D. S., & Powlson, D. S. (1976). The effects of biocidal treatments on metabolism in soil—V. A method for measuring soil biomass. *Soil Biology and Biochemistry, 8*, 209–213. https://doi.org/10.1016/0038-0717(76)90005-5

Jhaliwal, J., Hasan, A., Thomas, T., David, A. A., Kumar, A., & Serawat, R. (2022). Effect of integrated nutrient managements on physico-chemical properties of soil, growth and yield attributes of black gram (*Vigna mungo* L.) in an Inceptisol of Prayagraj. *The Pharma Innovation Journal, 11*(9), 2012–2015.

Keen, B. A., & Raczkowski, H. (1921). The relation between the clay content and certain physical properties of a soil. *The Journal of Agricultural Science, 11*(4), 441–449. https://doi.org/10.1017/S0021859600004469

Kerje, T., & Grum, M. (2000). The origin of melon, *Cucumis melo*: A review of the literature. *Acta Horticulturae, 510*, 37–44. https://doi.org/10.17660/ActaHortic.2000.510.5

Krishna, G. K. S., Rao, C. S., Subbaiah, P. V., Rekha, M. S., & Rao, V. S. (2022). Effect of integrated nutrient management practices on available nutrient status of soil under rice–sorghum cropping system in clay loamy soils. *International Journal of Environment and Climate Change, 12*(12), 387–404. https://doi.org/10.9734/ijecc/2022/v12i121474

Lester, G. E., & Hodges, D. M. (2008). Antioxidants associated with fruit senescence and human health: Novel orange-fleshed non-netted honey dew melon genotype comparisons following different seasonal productions and cold storage durations. *Postharvest Biology and Technology, 48*(3), 347–354. https://doi.org/10.1016/j.postharvbio.2007.11.008

Malo, K., Khatun, K., Mostarin, T., Samad, M. A., Tania, M. M., Habiba, M. U., & Touhidujjaman, M. (2022). Effect of integrated nutrient management on growth and yield of cucumber (*Cucumis sativus L.*) in winter season. *Journal of Global Agriculture and Ecology, 13*(3), 1–12. https://doi.org/10.56557/jogae/2022/v13i37466

Merwin, H. D., & Peech, M. (1951). Exchangeability of soil potassium in the sand, silt, and clay fractions as influenced by the nature of the complementary exchangeable cation. *Soil Science Society of America Proceedings, 15*, 125–128. https://doi.org/10.2136/sssaj1951.036159950015000c0026x

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate* (Circular No. 939). U.S. Department of Agriculture. https://searchworks.stanford.edu/view/10498019

Pandit, N. R., Schmidt, H. P., Mulder, J., Hale, S. E., Husson, O., & Cornelissen, G. (2020). Nutrient effect of various composting methods with and without biochar on soil fertility and maize growth. *Archives of Agronomy and Soil Science, 66*(2), 250–265. https://doi.org/10.1080/03650340.2019.1610168

Paramesh, V., Mohan Kumar, R., Rajanna, G. A., Gowda, S., Nath, A. J., Madival, Y., & Toraskar, S. (2023). Integrated nutrient management for improving crop yields, soil properties, and reducing greenhouse gas emissions. *Frontiers in Sustainable Food Systems, 7*, Article 1173258. https://doi.org/10.3389/fsufs.2023.1173258

Prihar, S. S., & Hundal, S. S. (1971). Determination of bulk density of soil clod by saturation. *Geoderma, 5*(4), 283–286.

Prihar, S. S., & Sandhu, B. S. (1968). A rapid method of soil moisture determination. *Soil Science, 105*(3), 142–144.

Sande, T. J., Tindwa, H. J., Alovisi, A. M. T., Shitindi, M. J., & Semoka, J. M. (2024). Enhancing sustainable crop production through integrated nutrient management: A focus on vermicompost, bio-enriched rock phosphate, and inorganic fertilizers—A systematic review. *Frontiers in Agronomy, 6*, Article 1422876. https://doi.org/10.3389/fagro.2024.1422876

Schaefer, H., Heibl, C., & Renner, S. S. (2009). Gourds afloat: A dated phylogeny reveals an Asian origin of the gourd family (Cucurbitaceae) and numerous oversea dispersal events. *Proceedings of the Royal Society B: Biological Sciences, 276*(1658), 843–851. https://doi.org/10.1098/rspb.2008.1447

Sebastian, P., Schaefer, H., Telford, I. R. H., & Renner, S. S. (2010). Cucumber (*Cucumis sativus*) and melon (*C. melo*) have numerous wild relatives in Asia and Australia, and the sister species of melon is from Australia. *Proceedings of the National Academy of Sciences of the United States of America, 107*(32), 14269–14273. https://doi.org/10.1073/pnas.1005338107

Singh, G., & Sahare, H. A. (2019). Response of different potassium fertilizers as foliar application on yield and quality of muskmelon (*Cucumis melo* L.) fruit. *Annals of Biology, 35*(2), 268–272.

Singh, N., Kushwaha, H. S., & Singh, A. (2020). Integrated nutrient management on growth, yield, nutrient uptake and fertility balance in soybean (*Glycine max* L.)–wheat (*Triticum aestivum* L.) cropping sequence. *International Journal of Bio-resource and Stress Management, 11*(4), 405–413. https://doi.org/10.23910/1.2020.2132

Soumya, D. V., Sreeramu, B. S., & Chandregowda, M. (2013). Plant nutrient content and uptake studies in stevia (*Stevia rebaudiana*) through integrated nutrient management approach. *Mysore Journal of Agricultural Sciences, 47*(3), 492–497.

Subbiah, B. V., & Asija, G. L. (1956). A rapid procedure for the estimation of available nitrogen in soils. *Current Science, 25*, 259–260. https://www.currentscience.ac.in/php/show_article.php?issue=08&page=0259&titleid=id_025_08_0259_0260_0&volume=025

Upadhyay, V. K., Hasan, A., David, A. A., Thomas, T., & Singh, A. K. (2022). Effect of integrated nutrient management on physico-chemical properties of soil in soybean (*Glycine max* L.) var. PK-1029. *The Pharma Innovation Journal, 11*(12), 3808–3814.

Varikuppala, M., David, A. A., Thomas, T., Swaroop, N., & Hasan, A. (2021). Effect of integrated nutrient management practices on soil health, quality and yield of spinach (*Beta vulgaris* L.) grown on alluvial soil. *The Pharma Innovation Journal, 10*(10), 2068–2071.

Walia, S. S., Dhaliwal, S. S., Gill, R. S., Kaur, T., Kaur, K., Randhawa, M. K., Obročník, O., Bárek, V., Brestic, M., Gaber, A., & Hossain, A. (2024). Improvement of soil health and nutrient transformations under balanced fertilization with integrated nutrient management in a rice–wheat system in Indo-Gangetic Plains—A 34-year Research outcomes. *Heliyon, 10*(4), Article e25113. https://doi.org/10.1016/j.heliyon.2024.e25113

Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science, 37*(1), 29–38. https://doi.org/10.1097/00010694-193401000-00003

Wang, N., Zhan, J., Feng, K., Qi, J., & Nan, H. (2024). Higher yield sustainability and soil quality by reducing chemical fertilizer with organic fertilizer application under a single-cotton cropping system. *Frontiers in Plant Science, 15*, Article 1494667. https://doi.org/10.3389/fpls.2024.1494667

Wu, D., Chen, C., Liu, Y., Zhang, G., & Yang, L. (2023). Vermicompost improves tomato yield and quality by promoting carbohydrate transport to fruit under salt stress. *Horticulturae, 9*(9), Article 1015. https://doi.org/10.3390/horticulturae9091015

Zahoor, S., Dutt, V., Mughal, A. H., Pala, N. A., Rashid, M., & Khan, P. A. (2022). Influence of intercropping on soil properties and nutrient status of fruit-based agroforestry systems in the north-western region of the Indian Himalaya. *Indian Journal of Agroforestry, 24*(1), 85–92. https://epubs.icar.org.in/index.php/IJA/article/view/121836

Zhang, C., Zhao, Z., Li, F., & Zhang, J. (2022). Effects of organic and inorganic fertilization on soil organic carbon and enzymatic activities. *Agronomy, 12*(12), Article 3125. https://doi.org/10.3390/agronomy12123125

Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/162389