



RESEARCH ARTICLE

Enhancement in growth, yield and quality of tomato (*Solanum lycopersicon* L.) fruits by application of integrated nutrient management in Agro-Teri region of West Bengal

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Abstract

The present investigation was conducted for two crop cycles during the Rabi season of 2018-19 and 2020-21 to elucidate the effect of integrated nutrient management on tomato growth, yield, quality and storage quality of fruits at field conditions under the Terai region of West Bengal at Departmental Instructional Farm, UBKV, Pundibari, Cooch Behar. It was laid out in randomized block design (RBD) with 14 treatments. The pooled analysis revealed that treatment viz., A₈ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM), A₁₀ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + 50 % NC) and A₁₄ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + 50 % NC+ PSB) was found most effective to enhance the yield, quality and economic return with 10.66, 8.31 and 10.51 % higher estimated yield from per hectare land, respectively than inorganic nutrient management. Poultry manure and vermicompost found to have positive effects on almost all the parameters. Integrated nutrient management and bio-stimulants both found equally effective for influencing quantitative and quality parameters in open pollinated and hybrid varieties of tomato. Second experiment revealed that characters viz., truss per plant, fruit per plant, lycopene, total sugar, ascorbic acid and shelf life equally influence by variety and bio-stimulants.

Keywords: integrated nutrient management; production; quality; rabi; tomato

Introduction

The cultivated tomato *Solanum lycopersicon* L., is a commercially annual crop, belongs to the family of Solanaceae, with diploid chromosome number (2n= 2X= 24) and grown throughout the world for local utilization or as an export crop. It was originated from Peru- Ecuador- Bolivia area of Andes (South America) including the Galapagos islands and was introduced to Europe in early 16th century. Tomato originated from a Spanish usage assigned to the Mexican word in Náhuatl “Xictomatl” (“Xictli”: navel and “Tomatl”: tomato), meaning the tomato with a navel. This refers to the scar left on the fruit by the peduncle. In Mexico the plant is frequently called “Jitomate” (1). Tomato called as “protective food”, “poor man’s orange” and in England it is called as “love of apple”. It is one of the most widely cultivated as well as used vegetable crops in the world. It is consumed as fresh and used for making processed products. As tomatoes are a rich source of vitamin A, vitamin C, potassium, folic acid and oxalic acid, it acts as a health-promoting agent for human beings (2). Tomato contains ascorbic acid ranges from 16 to 65 mg/100 g of fresh fruit

weight, total sugars of 2.5 %, protein 1.10 g and vitamin A 900 IU and total amino acid ranges from 100 to 350 mg/100 g of fruit weight. It is a well appetizer and excellent remedy for patients suffering from constipation (3, 4).

In current times, India is the 2nd most populous country in the world with a rapid rate of increasing population and shrinkage of cultivable land resource regularly have made evident that the food needed for the growing population could be meet only by increased agricultural production and productivity. After 1965, the introduction of high-yielding varieties, enhanced use of inorganic fertilizers and irrigation were mutually known as the green revolution, which needed to make India self-sufficient in production of food grains and thereby improved the agriculture system as a whole in India. A fertilizer is any material which is of natural or synthetic origin and is applied to soils to supply one or more essential plant nutrients to overcome the plant nutrient deficiency to support better growth coupled with higher return in the form of yield as output. The dangerous effect of synthetic fertilizers starts right from their manufacturing as they produce

hazard byproducts and poisonous gases such as CO₂, CH₄ and NH₄ etc., that are drastically degrading the quality of air and thereby creating alarming situation for the environment. In an extensive study it was reported that if the farmers exposed to chemical insecticides spray for 18 months, results in visual symptoms seen were stinging/ burning of eyes (18.42 %), dry sore throat (21.05 %), blurred vision (23.68 %), burning of nose (28.9 %), shortness of breath/ excessive sweating (34.2 %) and skin itching/ redness (50.0 %) (5). There was some evidence of widely used herbicides and insecticides like metolachlor, pendimethalin, chlorpyrifos and diazinon caused lung cancer (6). Some groups of chemicals pesticides like atrazine, simazine and ametryn are inducing endocrine-disrupting effects and reproductive toxicity (7). Pesticide residues and accumulated toxic chemicals can be found in a variety of everyday beverages and foods, including water, instant cooked meals, refreshments, wine, fruit juices and animal feeds (8, 9).

Materials and Methods

Raw materials

Hybrid seeds (Syngenta- Tomato Hybrid Rocky) of tomato (*Solanum lycopersicon L.*) purchased from seed market at pundibari, Cooch Behar, West Bengal, India.

Vermicompost contains nitrates, phosphates, soluble potassium and exchangeable calcium, enzymes namely proteases, amylases, lipase, cellulose and chitinase and immobilized microflora. Due to higher nutritional contents (2.40 % nitrogen, 0.80 % phosphorus and 1.20 % potassium) than other bulky organic manure, it is ideal to get improved growth and yield of many plants (10).

Poultry manure is identified as excellent organic manure to the agricultural cropping system. It is rich in nitrogen (2.19 %), phosphorus (2.59 %), potassium (1.64 %) and other essential nutrients and it supplies phosphorus readily to plants than other organic phosphorus sources (11). Poultry manure prevents nutrient imbalances, associated animal health risks and surface and ground water contamination.

The neem (*Azadirachta indica*) products such as bark, leaves and seeds are most useful for medicinal and agricultural needs (12). Neem cake is a byproduct after neem oil extraction and azadirachtin obtained from the neem seed kernels. Deoiled neem cake (NSC) is used as a fertilizer by Indian farmers because of its high nutritional value (5.20 % N, 1.00 % P and 1.40 % K) and it improves the soil structure as well as increases water holding capacity and it plays dual role as fertilizer and pest repellent (13).

Farmyard manure is the decomposed mixture of dung and urine of farm animals along with litter and left over material from roughages. Farmyard manure is ecofriendly and is desirable to use in tomato production due to lower price and is also available throughout the year (14). Well decomposed farmyard manure comprised of 0.5 % nitrogen, 0.2 % phosphorous and 0.5 % potassium.

Study site

Field experiment was conducted at Departmental Instructional Farm, UBKV, Pundibari, Cooch Behar. Present experimental field was geographically located at 26°19'86" N latitude and 89°23'53" E longitude, at an elevation of 43 m above MSL (mean sea level). The experimental area is characterized by a Terai-agro climatic zone of West Bengal. The climatic condition of terai zone of West Bengal is

sub-tropical humid in nature characterized by high rainfall, high relative humidity, moderate temperature, prolonged winter with high residual soil moisture. Usually, the temperature in this area ranges from minimum of 7-8 °C to maximum 24.0-33.2 °C with an average annual rainfall of 2100 to 3300 mm. The soil is sandy loam (Teesta alluvial plain group) with low pH (acidic-5.5), composed of sand, silt and clay content of 64.98 %, 19.81 % and 15.21 %, respectively and organic carbon of 0.72 %, total N of 156.87 kg/ha, available P of 16.25 kg/ha, exchangeable K of 75.39 kg/ha.

Field experiment and treatments

The current experimental study involved fourteen treatments such as A₁ (Recommended NPK), A₂ (100 % FYM), A₃ (100 % VC), A₄ = 100 % PM, A₅ (100 % NC), A₆ (100 % VC + 100 % FYM + 100 % PM + 100 % NC), A₇ (½ Recommended NPK + 50 % FYM + 50 % VC), A₈ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM), A₉ (½ Recommended NPK + 50 % FYM + 50 % VC + 50%NC), A₁₀ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + 50%NC), A₁₁ (½ Recommended NPK + 50 % FYM + 50 % VC + PSB), A₁₂ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + PSB), A₁₃ (½ Recommended NPK + 50 % FYM + 50 % VC + 50%NC + PSB) and A₁₄ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + 50 % NC + PSB), each replicated three times, using RBD. The study consisted of a total of 42 plots, each measuring 4.5 m by 3.0 m, with 50 cm bunds separating the plots. In this experiment healthy and uniform 25 days aged seedlings were uprooted during evening hours and transplanted in respective plots on the same day with spacing of row to row and plant to plant distances were kept at 90 cm and 90 cm. Transplanting was followed by irrigation with the help of watering cane for 5 days during morning hours till the plants established properly. The experimental site was kept free from weeds by periodical hand weeding. Irrigation was given at regular intervals of 10-12 days depending on the soil moisture conditions.

Data collection for diverse attributes

Plant height was measured from collar region to the emerging leaf from the main stem at the time of the final harvest and expressed in centimeter (cm). Stem girth (mm) was measured with the help of digital vernier calipers at the base of plant and above the ground level. The number of branches arising from the main stem, i.e., above the ground level at final harvest was counted and average was expressed as in number. The number of days taken for first flower opening in fifty percent population in each replication was recorded from the date of transplanting to the date of first flower opening on tagged plants for different treatments. In the tagged plants of different treatments, the number of days taken for attaining horticultural maturity in fifty percent population in each replication for harvest was recorded from date of transplanting.

Number of fully fertile truss per plant for selected plants in each treatment was counted in full blossom stage, the number of fruits harvested per plant for each treatment during the harvesting period was recorded and data was recorded and average was worked out. Five mature and healthy fruits were randomly taken from selected plants of each treatment and weighed individually and average was recorded in grams (g). Fruit polar diameter was measured from stalk end to blossom end; equatorial diameter was measured from fruit breadth at highest bulged portion of the fruit by using vernier calipers. Pericarp thickness was measured from the matured fruit and data was collected after cutting horizontally into half, measured the pericarp thickness with

vernier caliper and expressed in cm. The weight of fruits at each harvest from tagged plants were recorded and then added to the weight of fruits of all the pickings, the total yield for an individual plant of a treatment was calculated. The estimated average yield per ha was recorded throughout the harvesting period based on the yield and expressed in tonnes per hectare.

The estimation of total soluble solids was done by ERMA hand refractometer (0-32 °Brix) and the values were corrected at 20 °C; tomato juice was collected from red ripen fruits. Ascorbic acid content of the juice was determined by titrating freshly extracted juice against 2, 6-dichlorophenol indophenols dye (15). β -Carotene content of tomato fruit was determined using standard procedure with some modifications (16). Lycopene content of tomato fruit was determined by standard procedure with some modifications (17). Reducing and total sugar of tomato fruits was estimated (18). Leaf chlorophyll a, b and total content were estimated as per (19). The five tomatoes were selected randomly from each treatment and stored at room temperature and examined daily, shelf life of fruit was noticed and expressed in number of days to take it. Shelf life was determined by computing the average weight of 10 tomato fruits at every 3 days interval up to 12th day. The physiological loss in weight was calculated with the help of following formula.

Statistical data processing

The observations were recorded from different treatments in the field as well as in the laboratory were subjected to statistical analysis (20). The treatment variations were tested for significance by adopting F test (21). Statistical significance was tested by F table value at 5 % level of significance. The critical difference values were calculated at 5 % level of significance wherever the treatments mean difference was found significant. The treatment variations in experiment were tested by adopting LSD method (R software v 4.2.0).

Source of Variation

ANOVA is all about looking at different sources of variation, in ANOVA consists of two types of variability *i.e.*, between group variability (refers to variation between the distribution of individual treatments) and within group variability (variation caused by differences within individual treatment).

Test statistics

Under H_0 (null hypothesis):

$$F = \text{TrMS}/\text{EMS} \sim F(t-1, (r-1)(t-1)) \text{ df}$$

The calculated F value is compared with table F value for respective df (treatment df error df) given level of significance

If $F_{\text{cal}} \geq F_{\text{tab}} \Rightarrow \text{Reject } H_0$

If $F_{\text{cal}} < F_{\text{tab}} \Rightarrow \text{Accept } H_0$

Critical difference (C D)

It is used to know which of the treatment means are significantly different from each other.

$$CD = t_{\alpha, \text{error df}} * SE(d)$$

Where, $SE(d) = \sqrt{\frac{2EMS}{r}}$ r = number of replications

$t_{\alpha, \text{error df}} \rightarrow$ Table 't' value for error df at α level of significance.

Results

Growth attributes

The gained data regarding growth parameters such as plant height at the last harvest (cm), number of primary branches and stem girth at the last harvest (mm) are presented in Table 1 and depicted in Fig. 1 - 3. The data collected and analyzed for pooled data for all the sole organic and inorganic amendments and combined treatments under study. While 100 % recommended NPK led to a maximum plant height (93.54 cm) as compared to other sole and combined treatments, the minimum plant height (77.26 cm) was recorded in treatment A_3 (100 % VC). Considering the nutrient source group, as compared to the sole inorganic treatment, plant height decreased by 13.21 % in the organic group treatments and 6.54 % in the integrated group of treatments (Fig. 1). In tomatoes, a similar result of increased plant height by inorganic fertilizer treatment as compared to the sole organic or integrated nutrient management approach was also observed (22). Maximum stem girth (15.07 mm) was significantly higher with $\frac{1}{2}$ recommended NPK + 50 % FYM + 50 % VC, minimum stem girth (12.17 mm) was recorded in A_1 (recommended dose fertilizer). Considering nutrient source groups, as compared to the sole inorganic treatment, stem girth was increased by 4.25 % by the organic group and 14.14 % by the integrated group of nutrients (Fig. 2). A similar result of increased stem girth by integrated nutrient treatments was also observed in tomato (23). The maximum number of primary branches (6.13) was obtained in 100 % FYM and the minimum number of primary branches (4.75) was recorded in A_1 (recommended NPK). Considering the nutrient source group, as compared to the sole inorganic treatment numbers of primary branches increased 15.59 % by organic group of treatments and 8.48 % by integrated group of treatments. Similar results of enhanced number of primary branches in tomato recorded by the application of farmyard manure (24).

Yield and yield related attributes

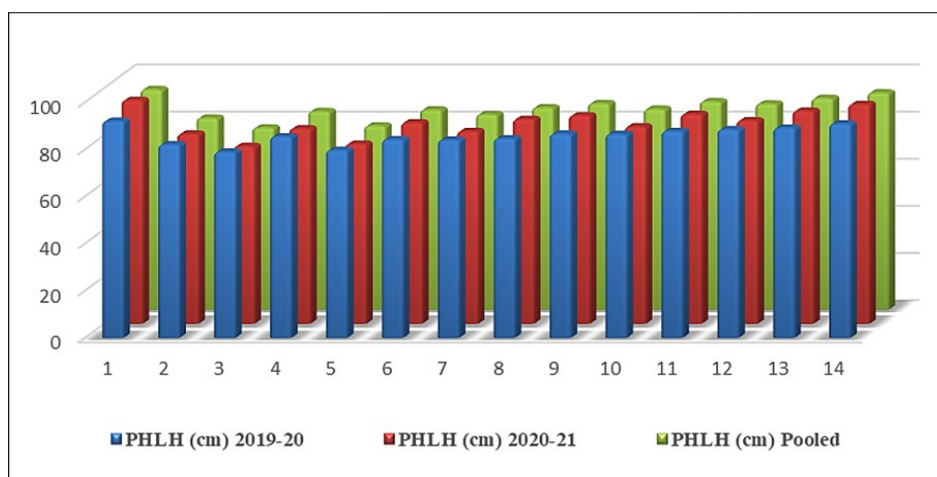
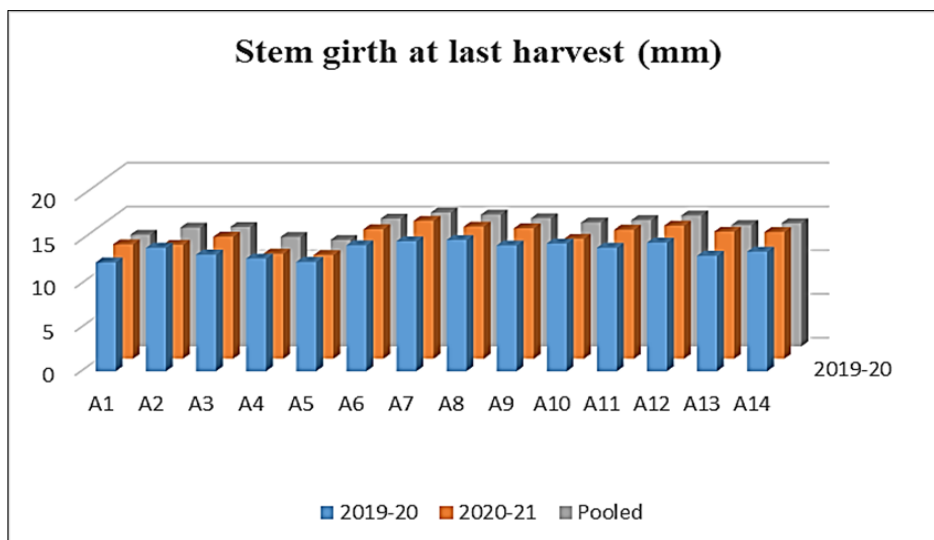
The gained data regarding yield parameters such as days to first flowering and maturity, numbers of truss per plant, number of fruits per truss, number of fruits per plant, average fruit weight (g), polar diameter (mm), equatorial diameter (mm), pericarp thickness (mm), fruit yield per plant (kg) and yield per ha (t) are presented in the Table 2 - 4 and depicted in Fig. 4 - 7. Days to first flowering and maturity were no statistically significant differences obtained among the treatments and minimum days to first flowering (27.47) was obtained in $\frac{1}{2}$ recommended NPK + 50 % FYM + 30 % VC + 20 % PM. Similar results were also found non-significant results in tomato (25). Minimum days to maturity (58.01) was obtained in A_{11} ($\frac{1}{2}$ recommended NPK + 50 % FYM + 50 % VC + PSB) and in tomato were also observed that non-significant results in days to 90 % fruit picking (25). The pooled data exhibited that maximum numbers of truss per plant (8.69) obtained in $\frac{1}{2}$ recommended NPK + 50 % FYM + 30 % VC + 20 % PM, minimum numbers of truss per plant (6.21) was recorded in A_5 (100 % NC). Considering the nutrient source group, as compared to the sole inorganic treatment truss per plant decreased 2.18 % in organic group of treatments, but increased 11.63 % in integrated group of treatments. A similar result was observed with application of organic manure along with inorganic fertilizers in tomato (25, 26). The maximum number of fruits per truss (4.49) obtained with $\frac{1}{2}$ recommended NPK + 50 % FYM + 50 % VC + 50 % NC,

Table 1. Effect of different sources of nutrients on plant height, stem girth at last harvest, number of primary branches and days to first flowering of tomato crop

S. No	Treatments	Plant height at last harvest (cm)			Stem girth at last harvest (mm)			Number of primary branches			Days to first flowering		
		2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
1.	A₁	92.13 ^a	94.96 ^a	93.54 ^a	12.44 ^e	13.08 ^{c-d}	12.76 ^{d-f}	4.69 ^b	4.81 ^b	4.75 ^b	28.35 ^a	29.09 ^a	28.72 ^a
2.	A₂	82.15 ^{d-f}	80.70 ^{e-g}	81.43 ^{e-f}	14.11 ^{a-d}	13.04 ^{c-d}	13.57 ^{c-e}	6.31 ^a	5.95 ^{a-b}	6.13 ^a	29.73 ^a	29.22 ^a	29.48 ^a
3.	A₃	79.06 ^f	75.47 ^g	77.26 ^f	13.33 ^{b-e}	13.96 ^{b-c}	13.65 ^{c-e}	5.29 ^b	6.49 ^a	5.89 ^{a-b}	28.69 ^a	29.13 ^a	28.91 ^a
4.	A₄	85.53 ^{b-e}	82.93 ^{d-f}	84.23 ^{c-e}	12.88 ^{d-e}	12.01 ^d	12.51 ^{e-f}	4.83 ^b	4.79 ^b	4.81 ^b	29.38 ^a	28.07 ^a	28.73 ^a
5.	A₅	79.78 ^{e-f}	76.43 ^{f-g}	78.11 ^f	12.49 ^e	11.86 ^d	12.17 ^f	5.53 ^{a-b}	4.91 ^b	5.22 ^{a-b}	29.58 ^a	28.86 ^a	29.22 ^a
6.	A₆	84.33 ^{c-f}	85.51 ^{c-e}	84.92 ^{c-e}	14.39 ^{a-c}	14.82 ^{a-b}	14.61 ^{a-c}	5.11 ^b	5.69 ^{a-b}	5.40 ^{a-b}	29.39 ^a	27.97 ^a	28.68 ^a
7.	A₇	84.09 ^{c-f}	81.80 ^{d-g}	82.94 ^{d-f}	14.85 ^a	15.78 ^a	15.31 ^a	5.38 ^b	5.72 ^{a-b}	5.55 ^{a-b}	29.11 ^a	28.11 ^a	28.61 ^a
8.	A₈	84.73 ^{c-f}	86.95 ^{b-e}	85.84 ^{c-e}	15.01 ^a	15.12 ^{a-b}	15.07 ^{a-b}	5.35 ^b	5.70 ^{a-b}	5.52 ^{a-b}	27.46 ^a	27.48 ^a	27.47 ^a
9.	A₉	86.71 ^{a-d}	88.45 ^{a-d}	87.58 ^{a-e}	14.38 ^{a-c}	14.92 ^{a-b}	14.65 ^{a-c}	4.96 ^b	5.39 ^{a-b}	5.18 ^{a-b}	28.10 ^a	27.93 ^a	28.02 ^a
10.	A₁₀	86.62 ^{a-d}	83.82 ^{c-e}	85.22 ^{c-e}	14.60 ^{a-c}	13.72 ^{b-c}	14.16 ^{a-c}	4.88 ^b	5.01 ^b	4.94 ^{a-b}	29.34 ^a	28.82 ^a	29.08 ^a
11.	A₁₁	87.80 ^{a-d}	89.06 ^{a-d}	88.43 ^{a-d}	14.11 ^{a-d}	14.75 ^{a-b}	14.43 ^{a-c}	4.92 ^b	5.13 ^{a-b}	5.02 ^{a-b}	27.28 ^a	28.36 ^a	27.82 ^a
12.	A₁₂	88.53 ^{b-c}	86.33 ^{b-e}	87.43 ^{b-e}	14.70 ^{a-b}	15.23 ^{a-b}	14.96 ^{a-b}	4.86 ^b	5.06 ^{a-b}	4.96 ^{a-b}	27.74 ^a	28.12 ^a	27.93 ^a
13.	A₁₃	89.21 ^{a-c}	90.38 ^{a-c}	89.80 ^{a-c}	13.19 ^{c-e}	14.54 ^{a-c}	13.87 ^{b-d}	4.98 ^b	5.11 ^{a-b}	5.05 ^{a-b}	29.24 ^a	28.58 ^a	28.91 ^a
14.	A₁₄	90.96 ^{a-b}	93.29 ^{a-b}	92.13 ^{a-b}	13.67 ^{a-e}	14.49 ^{a-c}	14.08 ^{a-c}	4.79 ^b	5.23 ^{a-b}	5.01 ^{a-b}	28.63 ^a	29.35 ^a	28.99 ^a
	S.Em(±)	1.78	2.25	1.88	0.44	0.51	0.39	0.17	0.18	0.18	0.91	0.78	0.73
	CD 0.05 %	5.17	6.53	5.48	1.27	1.47	1.12	0.50	0.52	0.51	N.S.	N.S.	N.S.

*Means followed by the same superscript are not significantly different using DMRT at $P < 0.05$

A₁ (Recommended NPK), **A₂** (100 % Farmyard manure), **A₃** (100 % Vermicompost), **A₄** (100 % Poultry manure), **A₅** (100 % Neem cake), **A₆** (100 % Vermicompost + 100 % Farmyard manure + 100 % Poultry manure + 100 % Neem cake), **A₇** (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost), **A₈** (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure), **A₉** (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem Cake), **A₁₀** (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Neem cake), **A₁₁** (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Phosphate solubilizing bacteria), **A₁₂** (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Phosphate solubilizing bacteria), **A₁₃** (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake + Phosphate solubilizing bacteria) and **A₁₄** (½ recommended NPK + 50 % Farmyard Manure + 30 % Vermicompost + 20 % Poultry manure + Neem cake + Phosphate solubilizing bacteria)

**Fig. 1.** Comparative performance of treatments in 2019-20, 2020-21 and pooled for plant height.**Fig. 2.** Comparative performance of treatments in 2019-20, 2020-21 and pooled for Stem girth at last harvest.

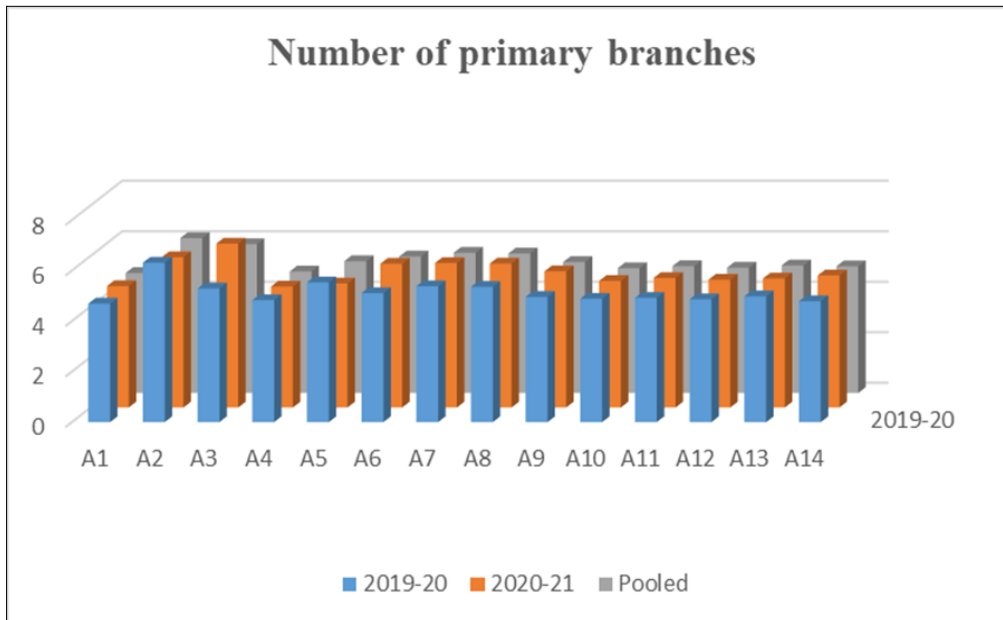


Fig. 3. Comparative performance of treatments in 2019-20, 2020-21 and pooled for number of primary branches.

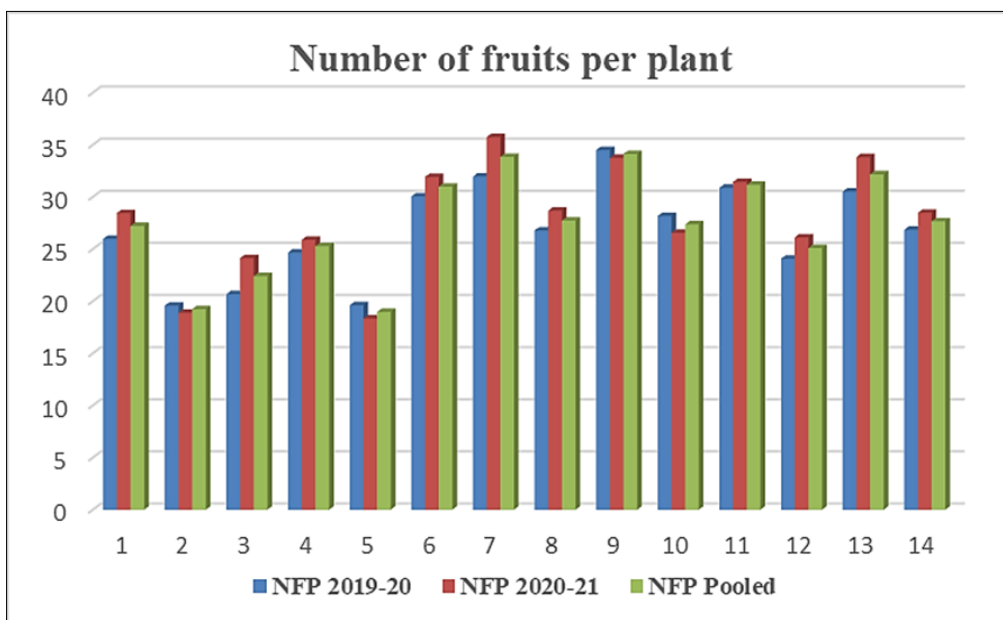


Fig. 4. Comparative performance of treatments in 2019-20, 2020-21 and pooled for number of fruits per plant.

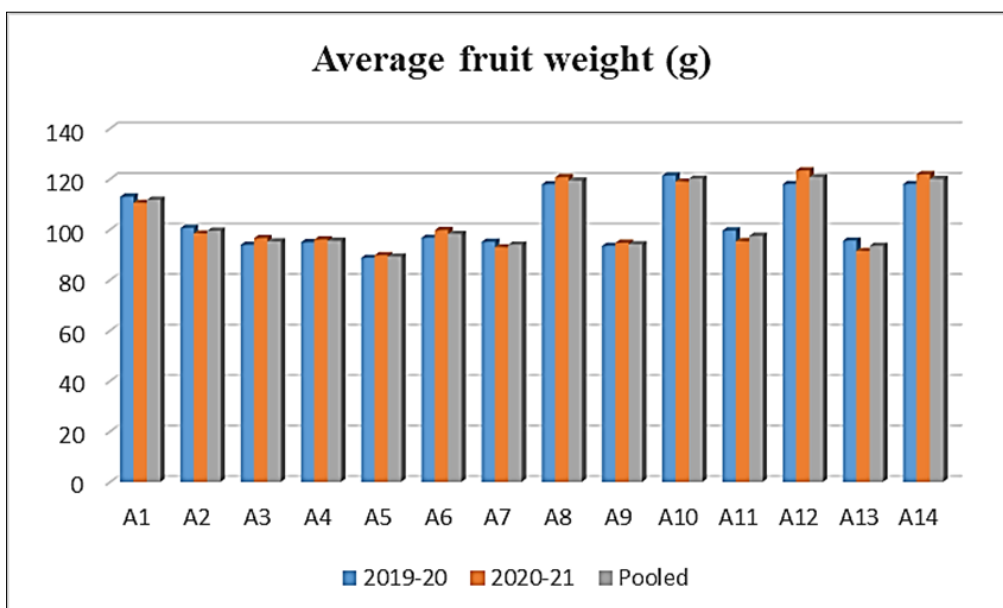


Fig. 5. Comparative performance of treatments in 2019-20, 2020-21 and pooled for Average fruit weight (g).

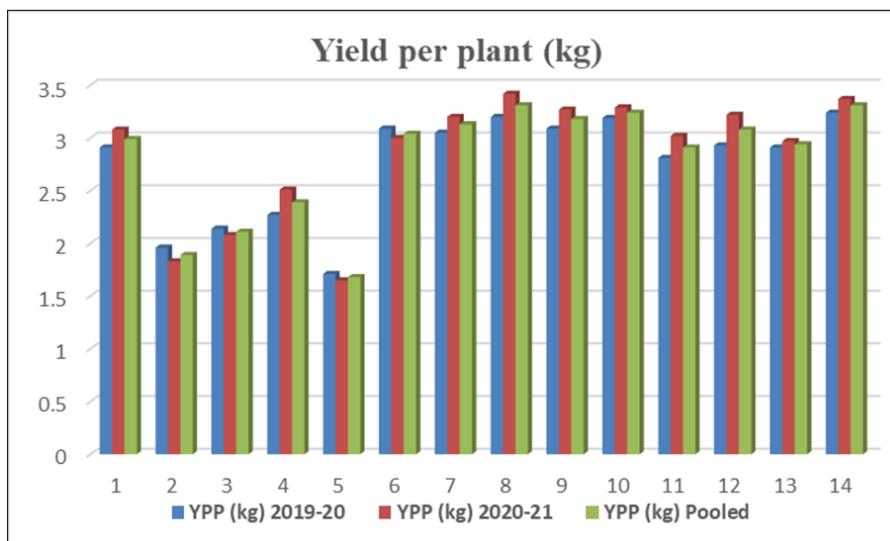


Fig. 6. Comparative performance of treatments in 2019-20, 2020-21 and pooled for yield per plant (kg).

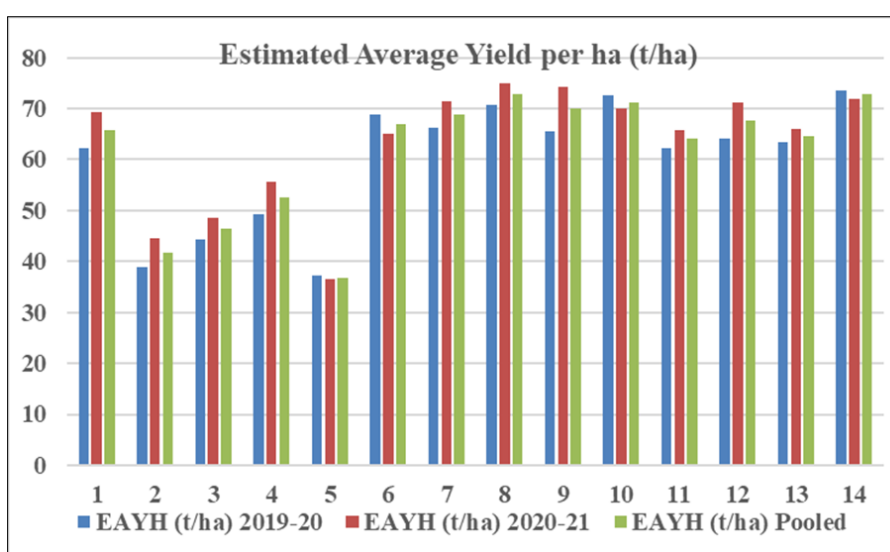


Fig. 7. Comparative performance of treatments in 2019-20, 2020-21 and pooled for estimated average yield per ha (t/ha).

Table 2. Effect of different sources of nutrients on days to maturity of fruits, number of trusses per plant, number of primary branches, number of fruits per truss and number of fruits per plant of tomato crop

S. No	Treatments	Days to maturity of fruits			Number of trusses per plant			Number of fruits per truss			Number of fruits per plant		
		2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
1.	A ₁	60.26 ^a	58.66 ^{a-b}	59.46 ^a	6.92 ^{d-f}	7.46 ^{d-f}	7.19 ^{d-e}	3.86	4.03	3.95 ^{b-d}	25.97 ^{b-e}	28.45 ^{b-d}	27.21 ^d
2.	A ₂	58.63 ^a	59.33 ^{a-b}	58.98 ^a	6.32 ^{e-f}	6.78 ^{e-g}	6.55 ^f	3.18	2.98	3.08 ^f	19.57 ^f	18.88 ^e	19.23 ^f
3.	A ₃	59.03 ^a	57.83 ^{a-b}	58.43 ^a	6.46 ^{e-f}	7.17 ^{e-f}	6.81 ^{e-f}	3.34	3.46	3.40 ^{e-f}	20.67 ^{e-f}	24.13 ^d	22.40 ^{e-f}
4.	A ₄	59.94 ^a	60.64 ^a	60.29 ^a	7.10 ^{c-f}	7.71 ^{c-e}	7.40 ^{c-e}	3.73	3.60	3.67 ^{d-e}	24.66 ^{c-f}	25.88 ^d	25.27 ^{d-e}
5.	A ₅	58.39 ^a	57.78 ^{a-b}	58.09 ^a	6.18 ^f	6.25 ^g	6.21 ^f	3.36	3.19	3.27 ^{e-f}	19.60 ^f	18.33 ^e	18.96 ^f
6.	A ₆	58.83 ^a	59.22 ^{a-b}	59.03 ^a	8.00 ^{a-c}	8.33 ^{a-d}	8.16 ^{a-b}	3.93	3.97	3.95 ^{b-d}	30.04 ^{a-d}	31.91 ^{a-b}	30.98 ^{a-c}
7.	A ₇	59.29 ^a	58.06 ^{a-b}	58.68 ^a	7.65 ^{a-d}	8.66 ^{a-b}	8.16 ^{a-b}	4.50	4.25	4.37 ^{a-b}	31.95 ^{a-b}	35.73 ^a	33.84 ^a
8.	A ₈	59.32 ^a	57.75 ^{a-b}	58.53 ^a	8.22 ^{a-b}	9.16 ^a	8.69 ^a	3.36	3.21	3.29 ^{e-f}	26.77 ^{b-e}	28.68 ^{b-d}	27.72 ^{b-d}
9.	A ₉	58.58 ^a	58.69 ^{a-b}	58.64 ^a	8.47 ^a	7.96 ^{b-e}	8.22 ^{a-b}	4.35	4.62	4.49 ^a	34.49 ^a	33.74 ^a	34.12 ^a
10.	A ₁₀	59.35 ^a	58.79 ^{a-b}	59.07 ^a	7.45 ^{b-d}	7.83 ^{b-e}	7.64 ^{b-d}	3.90	3.49	3.70 ^{c-e}	28.17 ^{b-d}	26.55 ^{c-d}	27.36 ^{c-d}
11.	A ₁₁	58.64 ^a	57.38 ^b	58.01 ^a	7.75 ^{a-d}	8.27 ^{b-d}	8.01 ^{b-c}	4.06	3.89	3.97 ^{b-d}	30.87 ^{a-c}	31.43 ^{a-c}	31.15 ^{a-b}
12.	A ₁₂	58.80 ^a	58.50 ^{a-b}	58.65 ^a	7.22 ^{b-e}	7.89 ^{b-e}	7.55 ^{b-d}	3.44	3.41	3.42 ^{e-f}	24.07 ^{d-f}	26.11 ^d	25.09 ^{d-e}
13.	A ₁₃	59.44 ^a	58.52 ^{a-b}	58.98 ^a	7.72 ^{a-d}	8.41 ^{a-c}	8.07 ^{a-c}	4.08	4.14	4.11 ^{a-c}	30.51 ^{a-c}	33.81 ^a	32.16 ^a
14.	A ₁₄	59.45 ^a	60.51 ^a	59.98 ^a	7.52 ^{a-d}	8.17 ^{b-d}	7.84 ^{b-d}	3.71	3.58	3.64 ^{d-e}	26.84 ^{b-e}	28.48 ^{b-d}	27.66 ^{b-d}
	S.Em(±)	0.81	0.83	0.72	0.68	0.31	0.21	0.17	0.19	0.14	1.84	1.59	1.16
	CD5%	N.S.	N.S.	N.S.	0.90	0.74	0.59	0.51	0.55	0.41	5.36	4.62	3.38

*Means followed by the same superscript are not significantly different using DMRT at P<0.05

A₁ (recommended NPK), A₂ (100 % Farmyard manure), A₃ (100 % Vermicompost), A₄ (100 % Poultry manure), A₅ (100 % Neem cake), A₆ (100 % Vermicompost + 100 % Farmyard manure + 100 % Poultry manure + 100 % Neem cake), A₇ (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost), A₈ (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure), A₉ (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake), A₁₀ (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Neem cake), A₁₁ (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Phosphate solubilizing bacteria), A₁₂ (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Phosphate solubilizing bacteria), A₁₃ (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake + Phosphate solubilizing bacteria) and A₁₄ (½ recommended NPK + 50 % Farmyard Manure + 30 % Vermicompost + 20% Poultry manure + Neem cake + Phosphate solubilizing bacteria)

Table 3. Effect of different sources of nutrients on fruit weight, equatorial diameter and polar diameter of tomato fruits

S. No	Treatments	Average fruit weight (g)			Equatorial diameter (mm)			Polar diameter (mm)		
		2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
1.	A₁	112.97 ^a	110.55 ^b	111.76 ^b	60.02 ^b	58.83 ^c	59.43 ^c	57.31 ^c	56.68 ^c	56.99 ^c
2.	A₂	100.60 ^b	98.40 ^{c-d}	99.50 ^c	54.91 ^c	55.76 ^d	55.34 ^d	51.94 ^e	52.63 ^e	52.29 ^e
3.	A₃	93.91 ^{b-c}	96.57 ^{c-d}	95.24 ^{c-d}	51.69 ^{e-g}	53.62 ^{d-e}	52.66 ^e	49.79 ^g	50.37 ^{f-g}	50.08 ^{g-h}
4.	A₄	94.89 ^{b-c}	96.02 ^{c-d}	95.45 ^{c-d}	53.55 ^{c-e}	52.37 ^{e-f}	52.96 ^e	50.70 ^{f-g}	51.00 ^f	50.85 ^{f-g}
5.	A₅	88.77 ^c	89.80 ^d	89.28 ^d	49.86 ^g	50.53 ^f	50.20 ^g	48.58 ^h	48.19 ^h	48.38 ⁱ
6.	A₆	96.69 ^{b-c}	99.73 ^c	98.21 ^c	54.44 ^{c-d}	55.34 ^d	54.89 ^d	54.17 ^d	53.98 ^d	54.08 ^d
7.	A₇	95.10 ^{b-c}	92.93 ^{c-d}	94.02 ^{c-d}	51.90 ^{e-g}	52.00 ^{e-f}	51.95 ^{e-f}	50.23 ^{f-g}	50.49 ^{f-g}	50.36 ^{f-h}
8.	A₈	117.91 ^a	120.72 ^a	119.31 ^a	64.22 ^a	63.02 ^b	63.62 ^{a-b}	62.87 ^a	62.72 ^{a-b}	62.80 ^a
9.	A₉	93.51 ^{b-c}	94.69 ^{c-d}	94.10 ^{c-d}	52.52 ^{d-f}	52.98 ^e	52.75 ^e	50.02 ^g	50.71 ^f	50.37 ^{f-h}
10.	A₁₀	121.35 ^a	118.92 ^a	120.14 ^a	62.99 ^a	61.78 ^b	62.39 ^b	61.47 ^b	61.95 ^b	61.71 ^b
11.	A₁₁	99.59 ^b	95.30 ^{c-d}	97.45 ^c	52.84 ^{c-f}	53.13 ^e	52.98 ^e	51.24 ^{e-f}	50.95 ^f	51.10 ^f
12.	A₁₂	117.97 ^a	123.39 ^a	120.68 ^a	64.06 ^a	65.64 ^a	64.85 ^a	63.43 ^a	63.70 ^a	63.56 ^a
13.	A₁₃	95.61 ^{b-c}	91.44 ^{c-d}	93.53 ^{c-d}	51.09 ^{f-g}	50.65 ^f	50.87 ^{f-g}	49.99 ^g	49.52 ^g	49.76 ^h
14.	A₁₄	117.98 ^a	121.84 ^a	119.91 ^a	62.92 ^a	63.74 ^{a-b}	63.33 ^b	63.03 ^a	62.69 ^{a-b}	62.86 ^a
	S.Em(±)	2.86	2.53	1.96	0.71	0.73	0.51	0.36	0.39	0.27
	CD5%	8.31	7.36	5.71	2.06	2.13	1.46	1.04	1.13	0.79

*Means followed by the same superscript are not significantly different using DMRT at P<0.05

A₁ (recommended NPK), **A₂** (100 % Farmyard manure), **A₃** (100 % Vermicompost), **A₄** (100 % Poultry manure), **A₅** (100 % Neem cake), **A₆** (100 % Vermicompost + 100 % Farmyard manure + 100 % Poultry manure + 100 % Neem cake), **A₇** (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost), **A₈** (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure), **A₉** (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake), **A₁₀** (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Neem cake), **A₁₁** (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Phosphate solubilizing bacteria), **A₁₂** (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Phosphate solubilizing bacteria), **A₁₃** (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake + Phosphate solubilizing bacteria) and **A₁₄** (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Neem cake + Phosphate solubilizing bacteria)

Table 4. Effect of different sources of nutrients on pericarp thickness, yield per plant and estimated average yield per hectare of land

S. No	Treatments	Pericarp thickness (mm)			Yield per plant (kg)			Estimated average yield per ha (t/ha)		
		2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
1.	A₁	7.18 ^{c-d}	7.12 ^e	7.15 ^e	2.91 ^{b-c}	3.08 ^{b-c}	2.99 ^{c-e}	62.33 ^c	69.34 ^{a-c}	65.83 ^{b-c}
2.	A₂	8.83 ^{a-b}	7.99 ^d	8.41 ^{c-d}	1.96 ^{e-f}	1.83 ^f	1.89 ^h	38.81 ^e	44.52 ^e	41.66 ^{e-f}
3.	A₃	8.72 ^{a-b}	9.58 ^{a-b}	9.15 ^{a-c}	2.14 ^{d-e}	2.08 ^e	2.11 ^g	44.28 ^{d-e}	48.65 ^{d-e}	46.47 ^e
4.	A₄	8.89 ^{a-b}	9.13 ^{b-c}	9.01 ^{b-d}	2.27 ^d	2.51 ^d	2.39 ^f	49.33 ^d	55.73 ^d	52.53 ^d
5.	A₅	9.67 ^a	10.19 ^a	9.93 ^a	1.71 ^f	1.65 ^f	1.68 ⁱ	37.13 ^e	36.62 ^f	36.88 ^f
6.	A₆	7.96 ^{b-c}	8.38 ^{c-d}	8.17 ^d	3.09 ^{a-c}	3.00 ^c	3.04 ^{b-e}	68.91 ^{a-c}	64.97 ^c	66.94 ^{a-c}
7.	A₇	9.15 ^a	9.43 ^{a-b}	9.29 ^{a-b}	3.05 ^{a-c}	3.20 ^{a-c}	3.13 ^{a-d}	66.14 ^{a-c}	71.46 ^{a-c}	68.80 ^{a-c}
8.	A₈	6.10 ^e	6.00 ^f	6.05 ^f	3.20 ^{a-b}	3.42 ^a	3.31 ^a	70.69 ^{a-c}	75.00 ^a	72.85 ^a
9.	A₉	8.96 ^{a-b}	9.30 ^b	9.13 ^{a-c}	3.09 ^{a-c}	3.27 ^{a-b}	3.18 ^{a-c}	65.57 ^{a-c}	74.26 ^{a-b}	69.92 ^{a-c}
10.	A₁₀	6.47 ^{d-e}	6.09 ^f	6.28 ^f	3.19 ^{a-b}	3.29 ^{a-b}	3.24 ^{a-b}	72.54 ^{a-b}	70.05 ^{a-c}	71.30 ^{a-b}
11.	A₁₁	8.86 ^{a-b}	9.04 ^{b-c}	8.95 ^{b-d}	2.81 ^c	3.02 ^{b-c}	2.91 ^e	62.30 ^c	65.85 ^c	64.08 ^c
12.	A₁₂	5.92 ^e	5.90 ^f	5.91 ^f	2.93 ^{b-c}	3.22 ^{a-c}	3.08 ^{b-e}	64.10 ^{b-c}	71.27 ^{a-c}	67.68 ^{a-c}
13.	A₁₃	9.34 ^a	9.73 ^{a-b}	9.54 ^{a-b}	2.91 ^{b-c}	2.97 ^c	2.94 ^{d-e}	63.35 ^c	66.03 ^{b-c}	64.69 ^{b-c}
14.	A₁₄	5.98 ^e	6.06 ^f	6.02 ^f	3.24 ^a	3.37 ^a	3.31 ^a	73.60 ^a	71.90 ^{a-c}	72.75 ^a
	S.Em(±)	0.33	0.27	0.26	0.09	0.08	0.06	2.82	2.54	2.09
	CD5 %	0.97	0.81	0.78	0.27	0.24	0.18	8.20	7.41	6.08

*Means followed by the same superscript are not significantly different using DMRT at P<0.05

A₁ (recommended NPK), **A₂** (100 % Farmyard manure), **A₃** (100 % Vermicompost), **A₄** (100 % Poultry manure), **A₅** (100 % Neem cake), **A₆** (100 % Vermicompost + 100 % Farmyard manure + 100 % Poultry manure + 100 % Neem cake), **A₇** (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost), **A₈** (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure), **A₉** (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake), **A₁₀** (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Neem cake), **A₁₁** (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Phosphate solubilizing bacteria), **A₁₂** (½ Recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Phosphate solubilizing bacteria), **A₁₃** (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake + Phosphate solubilizing bacteria) and **A₁₄** (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Neem cake + Phosphate solubilizing bacteria)

minimum number of fruits per truss (3.18) were recorded in A₁ (100 % FYM). Considering the nutrient source group, as compared to the sole inorganic treatment fruits per truss were decreased 12.01 % by group organic group of treatments and 1.86 % by integrated group of treatments. Similar results were reported in tomatoes with organic manures in combination with the inorganic fertilizers (25). The maximum number of fruits per plant (34.12) obtained in A₉ (½ recommended NPK + 50 % FYM + 50 % VC + 50 % NC), minimum number of fruits per plant (18.96) was recorded in A₅ (100 % NC) (Fig. 4). Considering the nutrient source group, as compared to the sole inorganic treatment number of fruits per plant decreased 14.12 % by group organic of treatments and increased by 9.85 % in integrated group of treatments (Fig. 4). However, alike findings observed with application of different integrated treatment by (23), (26) and (25) in tomato. Maximum average fruit weight (120.68 g) obtained in A₁₂ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + PSB), minimum average fruit weight (89.28 g) was recorded in A₅ (100 % NC) (Fig. 5). Considering the nutrient source group, as compared to the sole inorganic treatment weight of the fruit decreased by 14.51 % in the group of organic treatments and 3.91 % in the group of integrated treatments (Fig. 5). However, similar results of increased average fruit weight were reported with different nutrient sources combination treatments in tomato (26, 27). A₈ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM) showed maximum equatorial diameter of fruit (64.85 mm), minimum equatorial diameter of fruit (50.20 mm) was recorded in A₅ (100 % NC). The sole inorganic treatment equatorial diameter of fruit decreased 10.46 % by group of organic treatments and 2.66 % by group of integrated treatments. Organic manures in combination with the inorganic fertilizers increase equatorial diameter in tomato and brinjal (26, 28). The maximum polar diameter of fruit (63.70 mm) obtained in A₁₂ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + PSB), minimum polar diameter of fruit (48.38 mm) was recorded in A₅ (100 % NC). As compared to the sole inorganic treatment polar diameter decreased 10.28 % by group of organic treatments and 0.75 % by group of integrated treatments. Similar findings were also reported by organic manures in combination with the inorganic fertilizers in tomato (26). The maximum pericarp thickness of fruit (9.93 mm) obtained in A₅ (100 % NC); minimum pericarp thickness of fruit (5.91 mm) was recorded in A₁₂ (½ recommended NPK + 50 % FYM + 30 % VC + 20 % PM + PSB). Considering the nutrient source group, as compared to the sole inorganic treatment pericarp thickness increased 24.92 % by group of organic treatments and 6.90 % by group of integrated treatments. However, a similar result recorded by the combined treatment of organic manures with inorganic nutrient source in bell pepper (29). The maximum fruit yield per plant (3.31 kg) obtained in A₈ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM) and A₁₄ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + 50 % NC + PSB) (Fig. 6). However, minimum fruit yield per plant (1.68 kg) was recorded in A₅ (100 % NC). Considering the nutrient source group, as compared to the sole inorganic treatment yield decreased 25.75 % in group of organic treatments and increased 4.84 % by group of integrated treatments (Fig. 6). Similar result of enhanced yield per plant by organic manures in combination with the inorganic fertilizers was reported (26). The maximum estimated average fruit yield per hectare (72.85 t/ha) obtained in A₈ (½ recommended NPK + 50 % FYM + 30 % VC + 20 % PM) (Fig. 7). However, minimum estimated average fruit yield per

hectare (36.88 t/ha) was recorded in A₅ (100 % NC). As compared to the sole inorganic treatment yield per hectare decreased 25.73 % by group of organic treatments and increased 4.82 % by group of integrated treatments (Fig. 7b). However, alike results were also reported with organic manures in combination with the inorganic fertilizers in tomato (23, 25).

Quality parameters

The gained data regarding quality parameters such as leaf chlorophyll a content (mg/100 g), leaf chlorophyll b content (mg/100 g) and total leaf chlorophyll content (mg/100 g), TSS (°brix), β- carotene content (mg/100 g), lycopene content (mg/100 g), ascorbic acid (mg/100 g), reducing sugar (%) and total sugar (%) are presented in the Table 5 - 7 and depicted in Fig. 8 - 11.

A perusal of pooled data (Table 5) explicated that maximum chlorophyll a content in leaf (273.19 mg/100 g) was obtained in A₁₃ (½ Recommended NPK + 50 % FYM + 50 % VC + NC + PSB). However, minimum chlorophyll a content (250.76 mg/100 g) was recorded in A₁ (Recommended NPK). Considering the nutrient source group, the sole inorganic treatment increased by 4.72 % by the group of organic treatments and 6.60 % by the group of integrated treatments. The present findings confirmed the investigation on integrated nutrient management of tomatoes (30). Maximum chlorophyll b content (72.38 mg/100 g) obtained in A₁₃ (½ recommended NPK + 50 % FYM + 50 % VC + 50 % NC + PSB). However, minimum chlorophyll b content (64.20 mg/100 g) was recorded in A₄ (100 % PM). Considering the nutrient source group, as compared to the sole inorganic treatment, leaf chlorophyll b decreased by 2.02 % by the group of organic treatments and increased by 1.58 % by the group of integrated treatments. The total chlorophyll content (345.57 mg/100 g) was obtained in A₁₃ (½ recommended NPK + 50 % FYM + 50 % VC + 50 % NC + PSB) (Fig. 8). However, minimum leaf total chlorophyll content (318.50 mg/100 g) was recorded in A₁ (Recommended NPK). Considering the nutrient source group, as compared to the sole inorganic treatment increased by 3.29 % by a group of organic treatments and 5.54 % by a group of integrated treatments (Fig. 8). Total soluble solids (TSS) are the main components that give flavor to the tomato (sugars and acids) and influence the industrial yield (30). Among the various treatments in the pooled data exhibited that maximum total soluble solids (4.81 °brix) obtained in A₈ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM) and A₁₀ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + 50 % NC). However, minimum total soluble solids (4.35 °brix) were recorded in A₅ (100 % 50 % NC) and considering the nutrient source group, as compared to the sole inorganic treatment total soluble solid increased 2.27 % by group of organic treatments and 5.43 % by group of integrated treatments. Present findings were in accordance with the earlier research work (25, 26). Maximum lycopene content of fruits (2.84 mg/100 g) was obtained in A₁₄ (½ recommended NPK + 50 % FYM + 30 % VC + 20 % PM + 50 % NC + PSB) (Fig. 9). Considering the nutrient source group, as compared to the sole inorganic treatment lycopene content in ripe tomato fruit increased 1.70 % by groups of organic treatments and 6.45 % by group of integrated treatments (Fig. 9). However, minimum lycopene content of fruits (2.11 mg/100 g) was recorded in A₅ (50 % NC). The data on mean β-carotene content (Table 6 and Fig. 10) revealed that maximum beta-carotene content of fruits (0.86 mg/100 g) was obtained in A₁₄ (½ Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + 50 % NC + PSB). However, minimum β-carotene content of fruits (2.11 mg/100 g) was recorded in A₅ (50 %

Table 5. Effect of different sources of nutrients on chlorophyll a content of leaf, chlorophyll b content of leaf, total chlorophyll content of leaf and TSS of tomato fruits

S. No	Treatments	Chlorophyll a content of leaf (mg/100 g)			Chlorophyll b content of leaf (mg/100 g)			Total chlorophyll content of leaf (mg/100 g)			TSS (°Brix)		
		2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
1.	A ₁	247.62 ^f	253.90 ^c	250.76 ^e	64.38 ^{c-e}	71.09 ^{a-c}	67.74 ^{b-d}	312.00 ^e	325.00 ^{c-d}	318.50 ^g	4.43 ^{d-e}	4.39 ^{e-f}	4.41 ^d
2.	A ₂	258.27 ^{c-f}	261.55 ^{a-c}	259.91 ^{c-d}	69.73 ^{a-c}	65.39 ^{c-d}	67.56 ^{b-d}	328.00 ^{b-d}	326.94 ^{c-d}	327.47 ^{d-g}	4.45 ^{c-e}	4.50 ^{d-e}	4.48 ^{c-d}
3.	A ₃	262.30 ^{b-e}	266.55 ^{a-b}	264.42 ^{a-c}	65.58 ^{b-e}	63.64 ^d	64.61 ^d	327.88 ^{b-d}	330.19 ^{b-d}	329.03 ^{d-f}	4.44 ^{c-e}	4.38 ^{e-f}	4.41 ^d
4.	A ₄	270.98 ^{a-b}	263.35 ^{a-c}	267.17 ^{a-c}	70.46 ^{a-b}	57.94 ^e	64.20 ^d	341.44 ^{a-b}	321.28 ^d	331.36 ^{c-f}	4.64 ^{a-d}	4.59 ^{c-d}	4.62 ^{b-c}
5.	A ₅	261.12 ^{b-e}	258.67 ^{b-c}	259.89 ^{c-d}	62.49 ^e	67.25 ^{b-d}	64.87 ^d	323.61 ^{c-e}	325.92 ^{c-d}	324.77 ^{e-g}	4.37 ^e	4.34 ^f	4.35 ^d
6.	A ₆	257.75 ^{c-f}	265.44 ^{a-b}	261.59 ^{b-d}	72.17 ^a	69.01 ^{b-d}	70.59 ^{a-c}	329.91 ^{b-d}	334.45 ^{a-d}	332.18 ^{b-e}	4.69 ^{a-c}	4.71 ^{a-c}	4.70 ^{a-b}
7.	A ₇	255.86 ^{d-f}	267.78 ^{a-b}	261.82 ^{b-d}	69.08 ^{a-d}	66.94 ^{b-d}	68.01 ^{b-d}	324.94 ^{c-e}	334.72 ^{a-d}	329.83 ^{d-f}	4.46 ^{c-e}	4.49 ^{d-e}	4.48 ^{c-d}
8.	A ₈	267.50 ^{a-d}	268.01 ^{a-b}	267.76 ^{a-c}	64.20 ^{c-e}	64.32 ^d	64.26 ^d	331.70 ^{b-d}	332.33 ^{a-d}	332.02 ^{b-f}	4.76 ^{a-b}	4.86 ^a	4.81 ^a
9.	A ₉	255.05 ^{e-f}	254.41 ^c	254.73 ^{d-e}	63.76 ^{d-e}	71.23 ^{a-c}	67.50 ^{b-d}	318.82 ^{d-e}	325.65 ^{c-d}	322.23 ^{f-g}	4.46 ^{c-e}	4.44 ^{e-f}	4.45 ^{c-d}
10.	A ₁₀	268.29 ^{a-c}	270.02 ^a	269.15 ^{a-b}	67.07 ^{a-e}	67.51 ^{b-d}	67.29 ^{c-d}	335.36 ^{b-c}	337.53 ^{a-c}	336.44 ^{a-d}	4.79 ^a	4.83 ^a	4.81 ^a
11.	A ₁₁	276.71 ^a	263.27 ^{a-c}	269.99 ^{a-b}	71.95 ^a	71.08 ^{a-c}	71.51 ^{a-b}	348.66 ^a	334.36 ^{a-d}	341.51 ^{a-b}	4.54 ^{b-e}	4.48 ^{d-f}	4.51 ^{c-d}
12.	A ₁₂	271.55 ^{a-b}	272.55 ^a	272.05 ^a	68.22 ^{a-e}	70.86 ^{a-c}	69.54 ^{a-c}	339.76 ^{a-b}	343.41 ^{a-b}	341.59 ^{a-b}	4.79 ^a	4.72 ^{a-c}	4.76 ^{a-b}
13.	A ₁₃	276.88 ^a	269.50 ^{a-b}	273.19 ^a	71.99 ^a	72.77 ^{a-b}	72.38 ^a	348.87 ^a	342.27 ^{a-b}	345.57 ^a	4.57 ^{a-e}	4.65 ^{b-c}	4.61 ^{b-c}
14.	A ₁₄	270.54 ^{a-b}	269.21 ^{a-b}	269.88 ^{a-b}	64.60 ^{c-e}	75.38 ^a	69.99 ^{a-c}	335.14 ^{b-c}	344.59 ^a	339.87 ^{a-c}	4.81 ^a	4.76 ^{a-b}	4.78 ^{a-b}
	S.Em(±)	3.52	3.41	2.69	1.69	1.67	1.13	4.29	4.22	3.09	0.08	0.05	0.06
	CD5 %	10.23	9.91	7.81	4.91	4.86	3.28	12.46	12.28	8.98	0.22	0.13	0.16

*Means followed by the same superscript are not significantly different using DMRT at P<0.05

A₁(recommended NPK), A₂ (100 % Farmyard manure), A₃ (100 % Vermicompost), A₄ (100 % Poultry manure), A₅ (100 % Neem cake), A₆ (100 % Vermicompost + 100 % Farmyard manure + 100 % Poultry manure + 100 % Neem Cake), A₇ (½ Recommended NPK + 50 % Farmyard manure + 50 % Vermicompost), A₈ (½ Recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure), A₉(½ Recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake), A₁₀ (½ Recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Neem cake), A₁₁ (½ Recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Phosphate solubilizing bacteria), A₁₂ (½ Recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Phosphate solubilizing bacteria), A₁₃ (½ Recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake + Phosphate solubilizing bacteria) and A₁₄ (½ Recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20 % Poultry manure + Neem cake + Phosphate solubilizing bacteria)

Table 6. Effect of different sources of nutrients on ascorbic acid, β- carotene content and lycopene content of tomato fruits

S. No	Treatments	Lycopene content (mg/100 g)			β- carotene content (mg/100 g)			Ascorbic acid (mg/100 g)		
		2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
1.	A ₁	2.26 ^{b-c}	2.21 ^{b-c}	2.24 ^{b-c}	0.72 ^a	0.75 ^{a-c}	0.73 ^{a-b}	20.58 ^d	19.64 ^d	20.11 ^d
2.	A ₂	2.25 ^{b-c}	2.31 ^{a-c}	2.28 ^{a-c}	0.72 ^a	0.76 ^{a-c}	0.74 ^{a-b}	20.88 ^{c-d}	20.53 ^d	20.71 ^{c-d}
3.	A ₃	2.25 ^{b-c}	2.28 ^{a-c}	2.26 ^{a-c}	0.74 ^a	0.74 ^{a-c}	0.74 ^{a-b}	21.20 ^{b-d}	21.67 ^{b-d}	21.44 ^{a-d}
4.	A ₄	2.34 ^{a-c}	2.31 ^{a-c}	2.32 ^{a-c}	0.82 ^a	0.87 ^a	0.85 ^a	22.25 ^{a-d}	21.34 ^{b-d}	21.79 ^{a-d}
5.	A ₅	2.16 ^c	2.07 ^c	2.11 ^c	0.71 ^a	0.67 ^c	0.69 ^b	20.87 ^{c-d}	18.16 ^e	19.52 ^d
6.	A ₆	2.44 ^{a-b}	2.36 ^{a-b}	2.40 ^{a-b}	0.83 ^a	0.85 ^{a-b}	0.84 ^a	22.96 ^{a-d}	23.63 ^{a-b}	23.29 ^{a-b}
7.	A ₇	2.25 ^{b-c}	2.31 ^{a-c}	2.28 ^{a-c}	0.74 ^a	0.74 ^{a-c}	0.74 ^{a-b}	21.31 ^{b-d}	20.74 ^{c-d}	21.03 ^{b-d}
8.	A ₈	2.40 ^{a-b}	2.46 ^{a-b}	2.43 ^{a-b}	0.85 ^a	0.81 ^{a-c}	0.83 ^a	23.16 ^{a-c}	23.01 ^{a-c}	23.08 ^{a-c}
9.	A ₉	2.29 ^{a-c}	2.31 ^{a-c}	2.30 ^{a-c}	0.75 ^a	0.69 ^{b-c}	0.72 ^{a-b}	21.44 ^{b-d}	21.32 ^{b-d}	21.38 ^{a-d}
10.	A ₁₀	2.37 ^{a-b}	2.42 ^{a-b}	2.39 ^{a-b}	0.84 ^a	0.85 ^{a-b}	0.85 ^a	23.22 ^{a-c}	24.10 ^a	23.66 ^a
11.	A ₁₁	2.38 ^{a-b}	2.46 ^{a-b}	2.42 ^{a-b}	0.75 ^a	0.79 ^{a-c}	0.77 ^{a-b}	21.77 ^{a-d}	21.32 ^{b-d}	21.54 ^{a-d}
12.	A ₁₂	2.37 ^{a-b}	2.33 ^{a-c}	2.35 ^{a-b}	0.85 ^a	0.82 ^{a-c}	0.83 ^a	24.21 ^a	23.10 ^{a-c}	23.66 ^a
13.	A ₁₃	2.36 ^{a-b}	2.44 ^{a-b}	2.40 ^{a-b}	0.75 ^a	0.78 ^{a-c}	0.77 ^{a-b}	21.80 ^{a-d}	20.71 ^{c-d}	21.26 ^{a-d}
14.	A ₁₄	2.46 ^a	2.51 ^a	2.49 ^a	0.84 ^a	0.87 ^a	0.86 ^a	23.57 ^{a-b}	23.33 ^{a-b}	23.45 ^{a-b}
	S.Em(±)	0.06	0.08	0.07	0.05	0.04	0.04	0.47	0.37	0.26
	CD5 %	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	1.36	1.06	0.77

*Means followed by the same superscript are not significantly different using DMRT at P<0.05

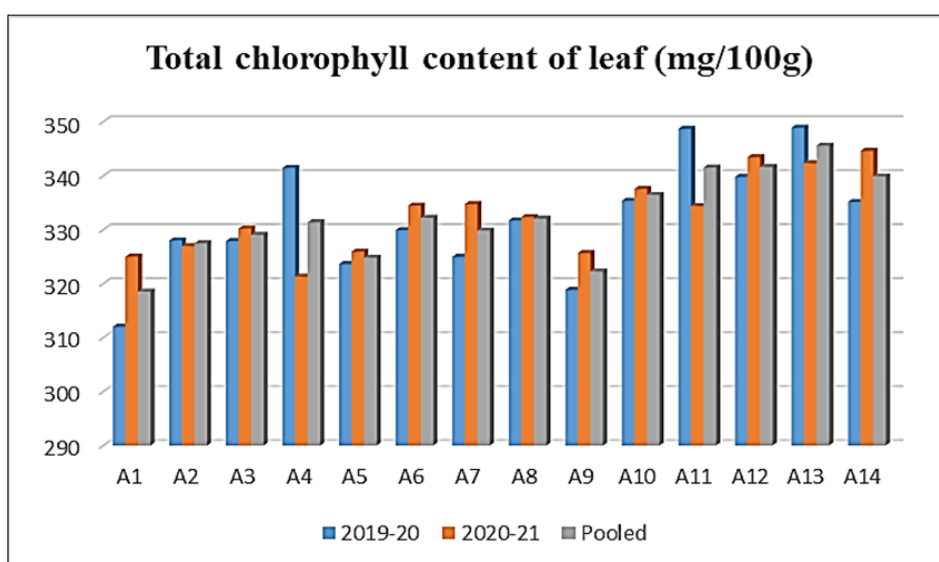
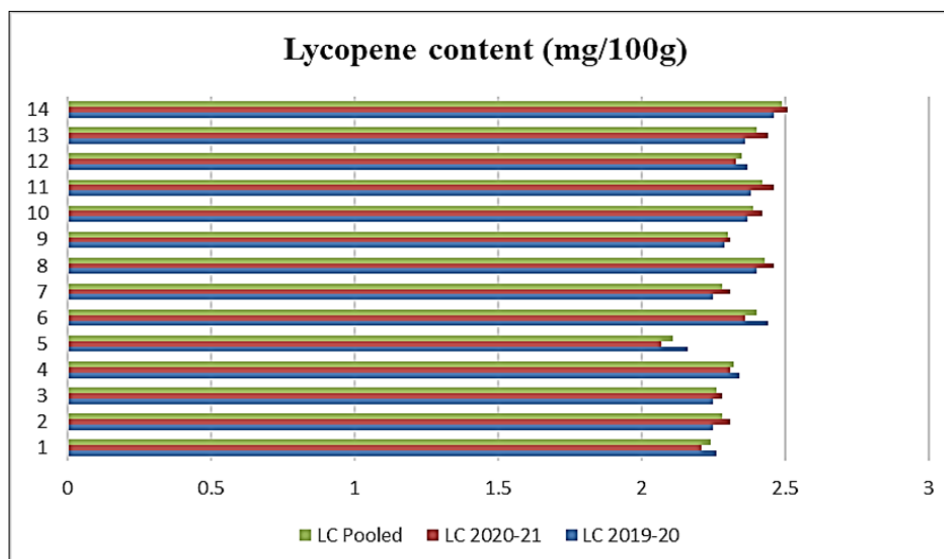
A₁ (Recommended NPK), A₂ (100 % Farmyard manure), A₃ (100 % Vermicompost), A₄ (100 % Poultry manure), A₅ (100 % Neem cake), A₆ (100 % Vermicompost + 100 % Farmyard manure + 100 % Poultry manure + 100 % Neem cake), A₇ (½ Recommended NPK + 50 % Farmyard manure + 50 % Vermicompost), A₈ (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure), A₉(½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake), A₁₀ (½ Recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Neem cake), A₁₁ (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Phosphate solubilizing bacteria), A₁₂ (½ Recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20 % Poultry manure + Phosphate solubilizing bacteria), A₁₃ (½ Recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake + Phosphate solubilizing bacteria) and A₁₄ (½ recommended NPK + 50 % Farmyard Manure + 30 % Vermicompost + 20 % Poultry manure + Neem cake + Phosphate solubilizing bacteria)

Table 7. Effect of different sources of nutrients on reducing sugar, total Sugar and shelf life of tomato fruits

S. No	Treatments	Reducing sugar (%)			Total sugar (%)			Shelf life (days)		
		2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
1.	A ₁	2.77 ^a	2.67 ^{a-b}	2.72 ^{b-c}	3.74 ^{a-b}	3.62 ^e	3.68 ^{d-f}	12.97 ^g	12.44 ^g	12.70 ^g
2.	A ₂	2.51 ^c	2.56 ^{b-c}	2.53 ^d	3.60 ^{b-c}	3.47 ^f	3.54 ^g	13.35 ^{f-g}	13.38 ^{e-f}	13.36 ^e
3.	A ₃	2.67 ^{a-c}	2.68 ^{a-b}	2.68 ^c	3.53 ^{c-d}	3.64 ^{d-e}	3.59 ^{f-g}	13.34 ^{f-g}	13.95 ^{b-e}	13.64 ^{b-e}
4.	A ₄	2.71 ^{a-b}	2.82 ^a	2.77 ^{a-c}	3.67 ^{a-c}	3.79 ^{b-d}	3.73 ^{c-e}	14.24 ^{b-d}	13.94 ^{b-e}	14.09 ^{b-d}
5.	A ₅	2.55 ^{b-c}	2.48 ^c	2.52 ^d	3.42 ^d	3.28 ^g	3.35 ^h	12.98 ^g	13.38 ^{e-f}	13.18 ^g
6.	A ₆	2.71 ^{a-b}	2.79 ^a	2.75 ^{a-c}	3.77 ^a	3.70 ^{c-e}	3.74 ^{c-e}	14.25 ^{b-d}	14.46 ^{a-b}	14.35 ^{a-b}
7.	A ₇	2.82 ^a	2.69 ^{a-b}	2.75 ^{a-c}	3.71 ^{a-b}	3.79 ^{b-c}	3.75 ^{b-d}	13.56 ^{f-g}	13.75 ^{c-e}	13.66 ^{c-e}
8.	A ₈	2.84 ^a	2.78 ^a	2.81 ^{a-b}	3.74 ^{a-b}	3.98 ^a	3.86 ^{a-b}	14.69 ^{a-c}	13.99 ^{b-e}	14.34 ^{a-c}
9.	A ₉	2.71 ^{a-b}	2.76 ^a	2.73 ^{a-c}	3.60 ^{b-c}	3.84 ^{a-c}	3.72 ^{c-e}	13.59 ^{f-g}	13.84 ^{b-e}	13.71 ^{b-e}
10.	A ₁₀	2.75 ^a	2.81 ^a	2.78 ^{a-c}	3.78 ^a	3.85 ^{a-c}	3.81 ^{a-c}	14.79 ^{a-b}	14.87 ^a	14.83 ^a
11.	A ₁₁	2.76 ^a	2.71 ^{a-b}	2.74 ^{a-c}	3.67 ^{a-c}	3.60 ^e	3.64 ^{e-g}	13.77 ^{d-f}	13.83 ^{c-e}	13.80 ^{c-e}
12.	A ₁₂	2.76 ^a	2.85 ^a	2.81 ^{a-b}	3.72 ^{a-b}	3.87 ^{a-b}	3.80 ^{a-c}	14.89 ^a	14.08 ^{b-d}	14.49 ^{a-d}
13.	A ₁₃	2.79 ^a	2.73 ^{a-b}	2.76 ^{a-c}	3.72 ^{a-b}	3.77 ^{b-d}	3.74 ^{c-e}	14.17 ^{c-e}	13.64 ^{d-f}	13.91 ^{d-e}
14.	A ₁₄	2.83 ^a	2.85 ^a	2.84 ^a	3.81 ^a	3.96 ^a	3.88 ^a	14.86 ^{a-b}	14.30 ^{a-b}	14.58 ^{a-b}
	S.Em(±)	0.06	0.05	0.04	0.05	0.04	0.04	0.18	0.19	0.12
	CD5 %	0.16	0.16	0.10	0.14	0.13	0.10	0.52	0.55	0.35

*Means followed by the same superscript are not significantly different using DMRT at P<0.05

A₁ (Recommended NPK), A₂ (100 % Farmyard manure), A₃ (100 % Vermicompost), A₄ (100 % Poultry manure), A₅ (100 % Neem cake), A₆ (100 % Vermicompost + 100 % Farmyard manure + 100 % Poultry manure + 100 % Neem cake), A₇ (½ Recommended NPK + 50 % Farmyard manure + 50 % Vermicompost), A₈ (½ Recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure), A₉ (½ Recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake), A₁₀ (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Neem Cake), A₁₁ (½ Recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Phosphate solubilizing bacteria), A₁₂ (½ Recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Phosphate solubilizing bacteria), A₁₃ (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake + Phosphate solubilizing bacteria) and A₁₄ (½ Recommended NPK + 50 % Farmyard Manure + 30 % Vermicompost + 20% Poultry manure + Neem cake + Phosphate solubilizing bacteria)

**Fig. 8.** Comparative performance of treatments in 2019-20, 2020-21 and pooled for total chlorophyll content of leaf (mg/100 g).**Fig. 9.** Comparative performance of treatments in 2019-20, 2020-21 and pooled for lycopene content (mg/100 g).

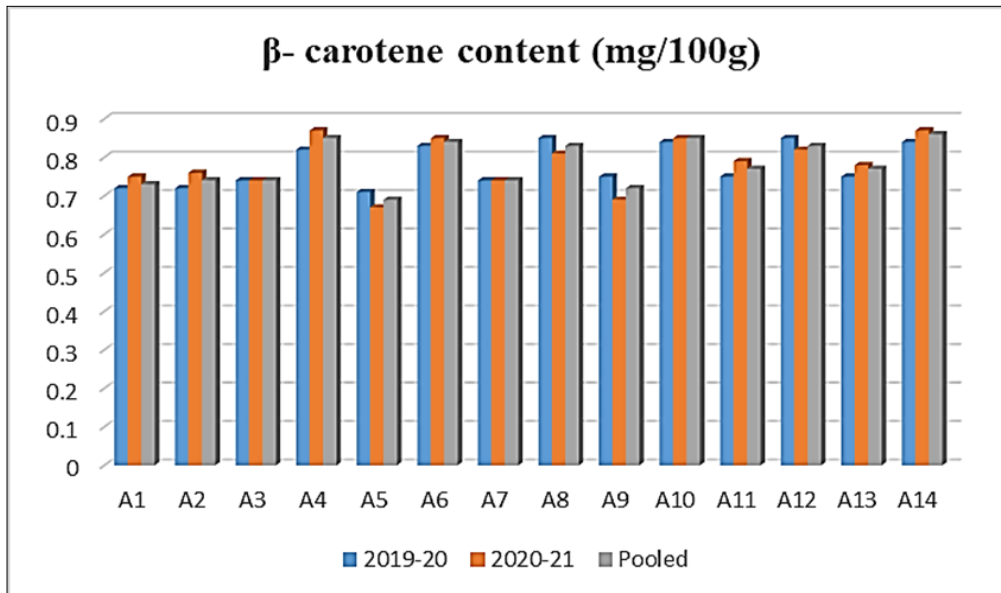


Fig. 10. Comparative performance of treatments in 2019-20, 2020-21 and pooled for β -carotene content.

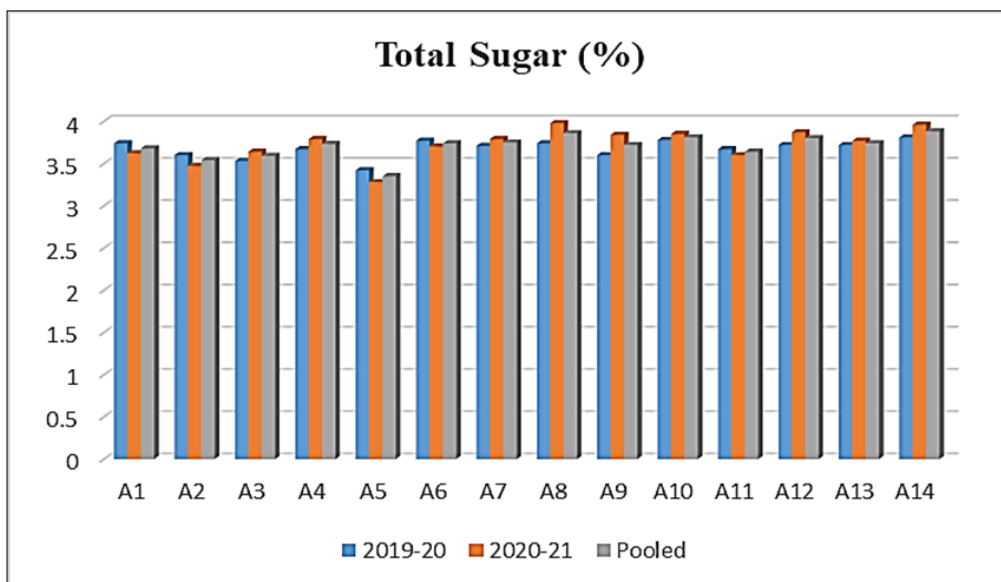


Fig. 11. Comparative performance of treatments in 2019-20, 2020-21 and pooled for total sugar (%).

NC) (Fig. 10). Considering the nutrient source group, as compared to the sole inorganic treatment β -carotene content in ripe tomato fruit increased 5.17 % by group of organic treatments and 8.62 % by group of integrated (Fig. 10). Maximum ascorbic acid content of fruits (23.66 mg/100 g) was obtained in A₁₀ (1/2 Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + 50 % NC) and A₁₂ (1/2 Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + PSB) and these treatment performances were similar. However, fruits' minimum ascorbic acid content (19.52 mg/100 g) was recorded in A₅ (100 % 50 % NC). Considering the nutrient source group, as compared to the sole inorganic treatment, the ascorbic acid content of fruit increased by 6.17 % by the group of organic treatments and 11.31 % by the group of integrated treatments. However, similar results obtained with application of organic manure combined with inorganic fertilizers in tomato (26, 31). Maximum reducing sugar (2.84 %) in A₁₄ (12 recommended NPK + 50 % FYM + 30 % VC + 20 % PM + 50 % NC + PSB). However, minimum reducing sugar (2.52 %) was recorded in A₅ (100 % 50 % NC) (Table 7). Considering the nutrient source group, as compared to the sole inorganic treatment, reducing sugar decreased 2.62 % by group of organic treatments and increased 2.09 % by group of

integrated treatments. Maximum total sugar (3.88 %) in A₁₄ (1/2 Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + 50 % NC + PSB) (Fig. 11). However, minimum total sugar (3.35 %) was recorded in A₅ (100 % NC). Considering the nutrient source group, as compared to the sole inorganic treatment, total sugar content in ripe fruit juice decreased 2.48 % by group of organic treatments and increased 2.62 % by group of integrated treatments (Fig. 11). Maximum shelf life (14.83 days) in A₁₀ (1/2 Recommended NPK + 50 % FYM + 30 % VC + 20 % PM + 50 % NC). However, the minimum shelf life (12.70 days) was recorded in A₁ (Recommended NPK) (Fig. 12). Considering the nutrient source group, as compared to the sole inorganic treatment increased by 8.07 % by organic group treatments and 11.51 % by a group of integrated treatments (Fig. 12). Overall minimum physiological weight loss *i.e.*, 9.95 % at 12 days, reported in treatment A₁₀ (1/2 recommended NPK + 50 % FYM + 30 % VC + 20 % PM + 50 % NC) in pooled respectively on 12 days of storage and maximum physiological weight loss percentage was recorded in treatment A₁ (recommended NPK) *i.e.*, 13.35 % at 12 days storage (Table 8, Fig. 13). These reductions in physiological weight loss percentage with the advancement of the storage period were also reported in cauliflower (32).

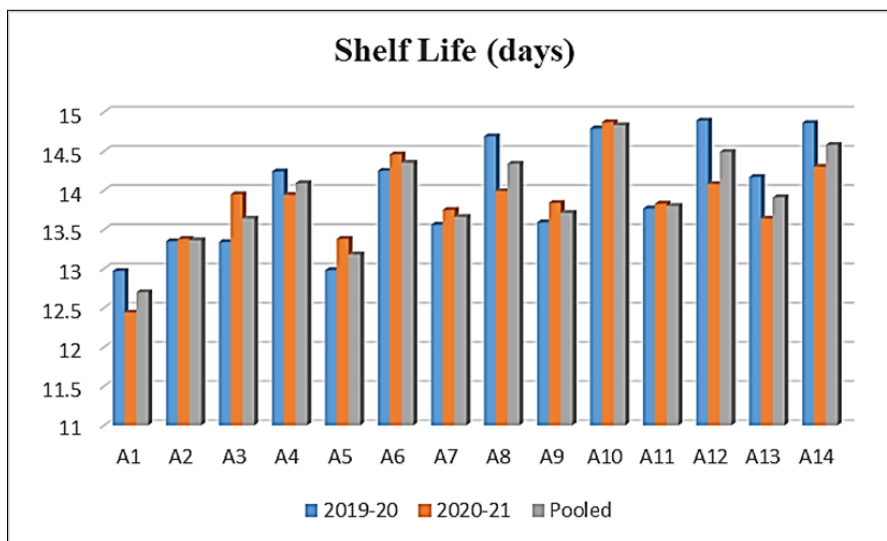


Fig. 12. Comparative performance of treatments in 2019-20, 2020-21 and pooled for shelf life (days).

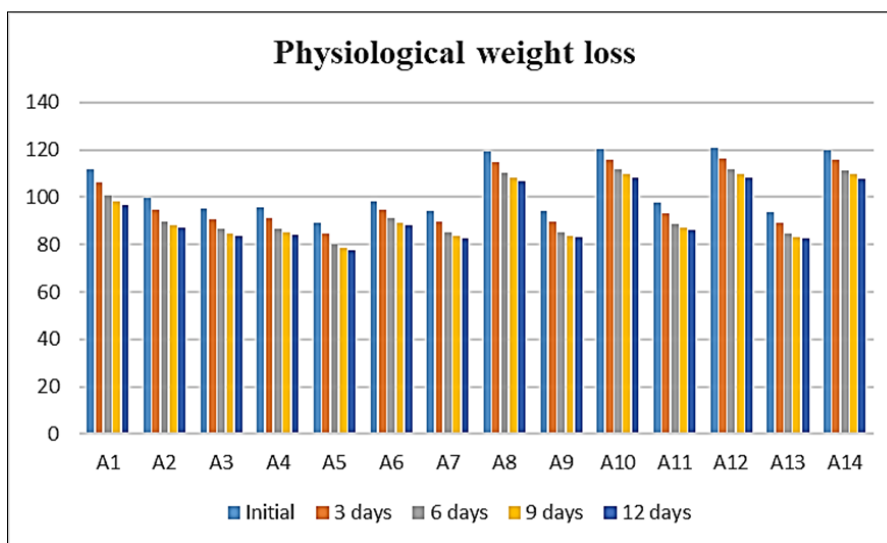


Fig. 13. Comparative performance of treatments in 2019-20, 2020-21 and pooled for physiological weight loss percentage.

Table 8. Effect of different sources of nutrients on postharvest physiological weight loss in ripe fruits along with percentage of change in magnitude for the pooled estimate

S. No	Treatments	Initial	3 days	6 days	9 days	12 days
1.	A ₁	111.76	106.03 (5.13)	100.50 (10.08)	98.19 (12.15)	96.85 (13.35)
2.	A ₂	99.50	94.72 (4.8)	89.84 (9.71)	87.97 (11.6)	87 (12.57)
3.	A ₃	95.24	90.8 (4.66)	86.38 (9.3)	84.74 (11.03)	83.67 (12.15)
4.	A ₄	95.45	91.11 (4.55)	86.71 (9.16)	85 (10.95)	84.28 (11.7)
5.	A ₅	89.28	84.71 (5.12)	80.33 (10.02)	78.66 (11.89)	77.39 (13.32)
6.	A ₆	98.21	94.58 (3.7)	90.89 (7.46)	89.1 (9.29)	88.02 (10.39)
7.	A ₇	94.02	89.6 (4.7)	85.06 (9.53)	83.49 (11.21)	82.61 (12.14)
8.	A ₈	119.31	114.67 (3.89)	110.18 (7.65)	108 (9.48)	106.63 (10.63)
9.	A ₉	94.10	89.82 (4.54)	85.31 (9.34)	83.6 (11.16)	82.93 (11.86)
10.	A ₁₀	120.14	115.93 (3.5)	111.74 (6.98)	109.82 (8.58)	108.18 (9.95)
11.	A ₁₁	97.45	93 (4.57)	88.38 (9.31)	86.87 (10.87)	85.9 (11.87)
12.	A ₁₂	120.68	116.49 (3.46)	111.96 (7.21)	109.94 (8.89)	108.45 (10.12)
13.	A ₁₃	93.53	89.14 (4.7)	84.63 (9.52)	83.16 (11.1)	82.36 (11.96)
14.	A ₁₄	119.91	115.69 (3.52)	111.43 (7.07)	109.47 (8.7)	107.57 (10.29)
	S.Em (±)	3.42	3.30	3.11	3.11	3.03
	CD5r%	10.00	9.66	9.08	9.09	8.84

*Average value of 10 fruits data and beside mean values in parentheses is showing the percentage of increase/decrease from the initial values A₁ (Recommended NPK), A₂ (100 % Farmyard manure), A₃ (100 % Vermicompost), A₄ (100 % Poultry manure), A₅ (100 % Neem cake), A₆ (100 % Vermicompost + 100 % Farmyard manure + 100 % Poultry manure + 100 % Neem Cake), A₇ (½ Recommended NPK + 50 % Farmyard manure + 50 % Vermicompost), A₈ (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure), A₉ (½ Recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake), A₁₀ (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20% Poultry manure + Neem cake), A₁₁ (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Phosphate solubilizing bacteria), A₁₂ (½ Recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20 % Poultry manure + Phosphate solubilizing bacteria), A₁₃ (½ recommended NPK + 50 % Farmyard manure + 50 % Vermicompost + Neem cake + Phosphate solubilizing bacteria) and A₁₄ (½ recommended NPK + 50 % Farmyard manure + 30 % Vermicompost + 20 % Poultry manure + Neem cake + Phosphate solubilizing bacteria)

Discussion

The current study implied that the INM treatments and in particular A₈ (½ recommended NPK + 50 % FYM + 30 % VC + 20 % PM), A₁₀ (same as A₈ + 50 % NC) and A₁₄ (same as A₁₀ + PSB) significantly enhanced growth, yield and quality of tomato hybrid compared with the sole organic and the chemical nutrient resources.

With respect to crop growth, the recommended dose of NPK used in these treatments supplemented the availability of essential macronutrients for cells at the early vegetative stage and relatively fast cell division multiplication, cell elongation and dry matter buildup owing to efficient carbohydrate metabolism. The increased root activity observed in integrated treatments might have enhanced the nutrient uptake (33). The application of organic manures, especially the poultry manure (which had low C:N ratio), vermicompost (high in nitrate-nitrogen) and FYM (as a source of potassium) was responsible for promoting microbial activity and water-holding capacity, which might have resulted in subsequent mineralization (dehydrogenase β-glucosidase and e-fluorescein diacetate (FDA) activity) and release of nutrients (34, 35). These circumstances resulted in an increased plant vigor and biomass. The treatments which combinations of organic and inorganic prepared increased activities of nitrate reductase and glutamine synthetase and thus increased nitrogen assimilation. The enhanced root TTC-reducing activity with treatments A₁₀ and A₁₄ showed that the roots were more metabolically active and had stronger metabolic capacity which may have been accompanied by higher nutrient absorption, especially regarding N and P essential in vegetative and reproductive growth (36).

In terms of fruit quality, integrated treatments significantly increased TSS, total sugars and ascorbic acid contents. Potassium derived from organic and inorganic sources had a crucial role in carbohydrate translocation and sugar-accumulation by activating the enzyme, sucrose synthase and starch-hydrolysis pathways. Furthermore, potassium reduced the enzymatic activity of oxidase, thus preventing the damage of the ascorbic acid and resulted in a higher concentration of vitamin C found in these treatments. As previously mentioned, biosynthesis of ascorbic acid in plants is primarily done through the L-galactose pathway aided by L-galactose dehydrogenase enzymes. Considering optimal levels of nitrogen, phosphorus and potassium, ascorbic acid enzymes work most efficiently (37). Previous studies have shown that integrated treatments improve nutrient uptake. Either way, this directly translates to greater ascorbate synthesis and accumulation in fruits. Moreover, the presence of humic substances in manures may have also supplemented hormonal activity and enhanced transport of nutrients and therefore metabolism efficiency leading to improvements in fruit quality (38, 39). Chlorophylls, which are sensitive to oxidation and proportional to the carotenoid content, did not show remarkable variation with the treatment combinations, which might have led to a non-significant effect of treatments on pigment contents in ripe fruit in the present investigation (40). Due to addition of different organic manure and amendments in to soil under integrated nutrient management might have enhanced availability of nitrogen which is essential element for many bio-synthetic processes, resulted into enhanced the translocation and biosynthesis of carbohydrates in fruit (41 - 44). On the other hand, greater retention of firmness and shelf life in A₁₂ and A₁₄ treatments might be associated with increased sugar

concentrations and antioxidants that limit deterioration.

As stated above, treatments A₈, A₁₀, A₁₂ and A₁₄ not only provided effective balanced integrated nutrient management but also were found to support vigorous growth coupled with high yield besides considerable enhancement of fruit biochemical quality and shelf life resulting in increased sustainability. The described approaches appeared to alter nutrient supply parameters by greatly influencing nutrient acquisition as well as physiological efficiency coupled with microbial processes while sustaining soil health forwarding a sustainable means for enhanced tomato productivity enabling sustained assurance towards quality.

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Authors' contributions

SS gave guidance throughout the research, from the initial setup to data collection, analysis, writing and organization. SD, JCJ, RC, MPD and GS contributed to all manuscript revisions and provided guidance in the writing process. All authors read and approved the final manuscript.

Compliance with ethical standards

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

Ethical issues: None

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