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K Sudheer
Department of Agricultural
Microbiology and Bioenergy,
Professor Jaya Shankar Telangana
Agricultural University,
Rajendranagar, Hyderabad,
Telangana, India

Yama Santhoshi Lavanya
Department of Agricultural
Microbiology and Bioenergy,
Professor Jaya Shankar Telangana
Agricultural University,
Rajendranagar, Hyderabad,
Telangana, India

S Triveni
Department of Agricultural
Microbiology and Bioenergy,
Professor Jaya Shankar Telangana
Agricultural University,
Rajendranagar, Hyderabad,
Telangana, India

PC Latha
Principal Scientist, ICAR-IIRR,
Rajendranagar, Hyderabad,
Telangana, India

T Uma Maheswari
Department of Entomology,
Professor Jaya Shankar Telangana
Agricultural University,
Rajendranagar, Hyderabad,
Telangana, India

Corresponding Author:

K Sudheer
Department of Agricultural
Microbiology and Bioenergy,
Professor Jaya Shankar Telangana
Agricultural University,
Rajendranagar, Hyderabad,
Telangana, India

Impact of jeevamrutham and panchagavya on plant growth, nutrient content, and yield of tomato crop (*Solanum lycopersicum* L.)

K Sudheer, Yama Santhoshi Lavanya, S Triveni, PC Latha and T Uma Maheswari

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Abstract

This research examined the impact of Jeevamrutham and Panchagavya, traditional organic preparations, on the growth, nutrient composition, and fruit quality of tomato (*Solanum lycopersicum* L.) through a pot culture experiment. Seven treatments were assessed: absolute control (T₁), 100% of the recommended fertilizer dose (RDF) (T₂), 50% Jeevamrutham (T₃), 100% Jeevamrutham (T₄), 50% Panchagavya (T₅), 100% Panchagavya (T₆), and 100% Jeevamrutham combined with 100% Panchagavya (T₇). The combined treatment (T₇) displayed outstanding outcomes, matching or surpassing the effectiveness of chemical fertilizers for various parameters. Plant growth assessments indicated notable enhancements in root length (29.98 cm), plant height (130.78 cm), and number of leaves per plant (80) at harvest. Nutrient analysis revealed increased uptake of N (54.45 kg/ha), P (6.85 kg/ha), and K (37.59 kg/ha) in T₇, similar to the RDF treatment. Significantly, fruit quality parameters such as ascorbic acid (39.8 mg/100 g), lycopene (9.2 mg/100 g), and β -carotene (1.5 mg/100 g) were highest in T₇, greatly exceeding those of the other treatments. Principal Component Analysis showed that the initial two components accounted for 96.4% of the overall variance, with T₇ exhibiting significant positive correlations with both growth and quality metrics. Multivariate correlation analysis revealed significant connections between nutrient absorption patterns and plant performance metrics, implying the synergistic impacts of blended organic formulations.

Keywords: Panchagavya, Jeevamrutham, Nutrient uptake, Lycopene, β -Carotene

Introduction

Tomato (*Solanum lycopersicum* L.) is a key fruit vegetable in India, classified within the Solanaceae family ^[1]. Tomatoes rank highest among all fruits and vegetables as a provider of vitamins and minerals. It holds significant importance in human nutrition and is recognized for both its flavor and its nutrient richness, which is abundant in phosphorus, iron, vitamin A, vitamin B complex, and vitamin C, along with a rich source of lycopene and β -carotene ^[2]. It spans 789 thousand hectares and generates 19759 thousand metric tonnes annually, achieving a productivity of 25.0 metric tonnes per hectare ^[3]. The worldwide tomato output as of 2020 stands at 41.52 million tonnes and is predicted to rise to approximately 51.93 million tonnes by 2026 based on the global scenario ^[4]. Tomatoes, sometimes known as the poor man's orange, are produced in large quantities and consumed at high levels in our nation. Most often, tomatoes are used in processed form to make chutney, pickles, soup, and ketchup, but they can also be eaten fresh in salads. Nonetheless, the majority of commercial farmers employ various agrochemicals as sources of plant nutrients and as safeguards for their plants ^[5].

Indiscriminate use of chemical fertilizers and pesticides has adversely affected the soil quality and beneficial microbial load leading to decreased productivity in intensive agriculture. Organic farming mainly relies on locally available inputs especially on-farm inputs like livestock wastes which can be effectively recycled for sustainable crop production. In order to sustain crop productivity, combined use of organic manures along with liquid organic formulation is a viable alternative ^[6]. This will ensure higher yield by enhancing the availability of nutrients through faster decomposition of bulky organic manures indirectly boosting microbial activity in the soil. Presently, the demand for eco-friendly fermented liquid organic formulations prepared from on-

farm wastes such as Jeevamrutham, and Panchagavya has increased. Many of these formulations are rich in beneficial microflora and can act as efficient plant growth promoters [7] which are mainly preferred by resource poor farmers.

The Jeevamrutham, and Panchagavya are cheaper eco-friendly organic preparations made by cow products namely dung, urine, milk, curd and ghee. The Panchagavya is an efficient plant growth stimulant that enhances the biological efficiency of crops. It is used to activate soil and to protect the plants from pests and diseases and also increase the nutritional quality of fruits and vegetables. It is used as for foliar spray or soil application along with irrigation water, seed or seedling treatment *etc.* Three per cent *Panchagavya* is an ideal concentration for the foliar spray. *Jeevamrutham* promotes immense biological activity in soil and makes the nutrients available to crop [7, 8].

Due to the several positive effects of foliar or soil applied liquid organic formulations on plant growth and productivity of crops, it has become a major thrust area of research in the field of organic agriculture. Moreover, early maturing crops like vegetables will be much benefited with the foliar application of these formulations.

The organically produced fruits, vegetables, spices and condiments, crops, medicinal and aromatic plants *etc* have good keeping quality than that of conventionally grown products. The sustainable agriculture practices can effectively prevent the entry of pesticides and toxicants in the food chain and prevent soil and water pollution. It is adopted with a blend of ecologically safe modern technologies. The organic agriculture, though not in its orthodox version, has the potential to be accepted by the farmers [9, 10].

Many experts in the field of agriculture have voiced concern that any more efforts to persist with this model of chemical agriculture will only prove counterproductive in the long run and cause irreparable damage to soil health. Reverting to non - chemical agriculture, it has assumed great importance to attain sustainability in production. Use of organic manure in crop production and beneficial effect of its integration with inorganic fertilizer is often regarded as panacea to sustain higher levels of productivity coupled with environmental safety [11, 12, 13].

In the context of Zero Budget Natural Farming (ZBNF), farmers are advised to use traditional organic fertilizers as a part of Pradhan Manthri Krishi Vikas Yojana to promote plant growth and make sustainable agriculture.

Our approach combines traditional agricultural wisdom with modern scientific methods and employs advanced analytical techniques to elucidate the complex interactions between organic preparations, soil microbiota, and plant physiology. By examining multiple plant parameters simultaneously, we sought to provide a holistic understanding of the effects of these organic preparations on agricultural ecosystems.

Materials and Methods

Experimental Design

A pot culture study was carried out at the Department of Agricultural Microbiology & Bioenergy, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana Agricultural University (PJTUA), Hyderabad, India (17.3924° N, 78.3237° E) in the Rabi season, utilizing seven treatments and three replications to explore the impact of organic preparation application on soil and plant traits. Each pot (30 cm in diameter and 30 cm in height) filled with 15 kg of sterilized red soil. Red soil was gathered from the Student Farm at the College of Agriculture, Rajendranagar, PJTUA, in Hyderabad. The soil was

allowed to air dry, passed through a 2 mm mesh, and sterilized in an autoclave at 121 °C for 1 hour over three successive days. This sterilization procedure guarantees the removal of indigenous microorganisms, facilitating a regulated evaluation of the applied treatments.

Treatment details and their application rate

The experiment comprised seven treatments to assess the impacts of organic preparations in relation to conventional fertilizers. These included: T₁ (Absolute Control) with no inputs; T₂ (100% Recommended Dose of Fertilizer, RDF), serving as the standard chemical fertilizer treatment; T₃ (50% Jeevamrutham), representing a partial use of the organic formulation; T₄ (100% Jeevamrutham) for full application of the organic formulation; T₅ (50% Panchagavya), a partial use of the traditional organic composition derived from cow by-products; T₆ (100% Panchagavya) for its complete application; and T₇, a combined application of 100% Jeevamrutham + 100% Panchagavya to evaluate possible synergistic effects on soil and crop performance.

Three-week-old tomato (*Solanum lycopersicum* L.) hybrid SWEAKAR-448 seedlings were transplanted into individual pots, with three seedlings initially placed in each pot. After the seedlings were established, they were thinned to retain only one plant per pot. 1.15 g of nitrogen (N), 0.77 g of phosphorus (P), and 0.46 g of potassium (K) were added to each pot following the application of the recommended fertilizer dosage (RDF) at a rate of 150:100:60 kg ha⁻¹ N: P₂O₅: K₂O, modified according to soil volume. Phosphate and potassium were fully applied as baseline amounts, whereas nitrogen was divided into two applications: 50% given as a basal treatment and 50% as a top dressing four weeks post-transplanting (WAT). Jeevamrutham was applied at rates of 500 L ha⁻¹ (equivalent to 3.85 mL per pot) for the 100% treatment and 250 L ha⁻¹ (or 1.93 mL per pot) for the 50% treatment. Panchagavya and Jeevamrutham were given every 15 days until the crop reached the harvesting stage.

Preparation of Organic formulations

Preparation of Jeevamrutham: Jeevamrutham was made using the technique outlined by Palekar (2006) [14]. Initially, 10 kg of fresh cow dung, 10 liters of cow urine, 2 kg of jaggery, 2 kg of pulse flour, and a tiny quantity of soil gathered from the field's bund were combined thoroughly. This mixture was subsequently fermented in 200 liters of water for 12 days, ensuring it remained in the shade to promote adequate fermentation. The blend was mixed two times a day to foster even fermentation and guarantee the growth of advantageous microbial activity.

Preparation of Panchagavya: The preparation of Panchagavya followed the procedure outlined by Natarajan (2002) [9]. Seven kilograms of fresh cow dung, ten liters of cow urine, three liters of cow milk, two liters of curd, three liters of tender coconut water, three kilograms of jaggery, and twelve bananas were combined to start the preparation process. After that, the nutrient-rich mixture was swirled twice a day for 24 days while it fermented. to promote the growth of beneficial microbes and the decomposition of organic materials into a state that plants can easily utilize.

Plant Growth and Yield Measurements

Plant growth parameters were measured at 30 DAT, 60 DAT, and at harvest. The plant height was measured from the soil surface to the tip of the main shoot. The number of fully expanded leaves was counted. The root length was measured

after the plants were carefully uprooted. Total dry weight was determined by oven-drying samples at 70°C to a constant weight, and yield parameters were recorded, including average fruit yield per plant, and harvest index was calculated.

Plant Nutrient Analysis and Fruit qualitative parameters

Plant samples were collected at the harvest stage for nutrient analysis. Total nitrogen was determined using the Micro-Kjeldahl method ^[15], phosphorus using the vanadomolybdophosphoric yellow color method ^[16], and potassium using flame photometry ^[16]. Nutrient uptake was calculated by multiplying nutrient concentration by dry matter yield. Qualitative traits of fruit, including ascorbic acid, lycopene, and β -carotene, were estimated following standard methods. Lycopene and β -carotene were measured using the methods described by Sadasivam (1996) ^[17], and ascorbic acid was measured using the dye titration method.

Statistical analysis

To determine if treatment effects were significant at $p < 0.05$, Origin Lab's one-way ANOVA and R version 4.1.0 (R Core Team, 2025) were used to analyse all data. Using Tukey's HSD test, significant differences between treatment means were identified ($p < 0.05$). Relationships between plant growth characteristics, nutritional content, and fruit quality parameters were investigated using Pearson's correlation coefficients. In order to find patterns in plant characteristics across treatments and reduce the dimensionality of the dataset, PCA was used ^[18].

Results and Discussion

Plant growth parameters and yield attributes

Number of Leaves per Plant

The number of leaves per plant was measured at 30 DAT (Days After Transplanting), 60 DAT, and at the harvesting stage (Table 1). At 30 DAT, T₂ (RDF) showed the highest number of leaves (48.21 ± 1.16), followed closely by T₇ (Jeevamrutham + Panchagavya) with 47.56 ± 1.39 leaves. The lowest leaf count was observed in T₁ (Absolute Control) with 38.08 ± 2.07 leaves. At 60 DAT, T₂ maintained the highest leaf count (119.45 ± 7.35), while T₄ (100% Jeevamrutham) showed the lowest (67.89 ± 5.36). At the harvesting stage, T₂ again had the highest leaf count (91.00 ± 6.00), while T₁ had the lowest (62.67 ± 3.06). These results suggest that while chemical fertilizers (T₂) consistently promoted leaf production, the combination of organic treatments (T₇) was also effective, particularly in the early stages of growth ^[19, 20].

Root Length

The root length data across different developmental stages highlights the profound influence of treatment composition on root development (Table 1). At 30 DAT, the combination treatment T₇ (Jeevamrutham + Panchagavya) demonstrated a remarkable advantage in fostering root elongation (11.21 ± 0.30 cm), achieving significantly longer roots compared to all other treatments. The results underline the synergistic effect of the two organic amendments, which likely provided a balanced supply of nutrients and microbial activity conducive to root development and may attributed to presence of growth promoters like auxin and gibberellin in it ^[19]. T₂ (RDF) also showed commendable root growth (9.56 ± 0.35 cm), emphasizing the efficacy of chemical fertilizers in supporting early-stage development. Conversely, the limited root growth observed in T₁ (5.67 ± 0.16 cm) underscores the importance of nutrient inputs in enhancing root architecture. Moreover, organic

formulations help decrease the bulk density and increase the porosity of the soil, which facilitates the attainment of the full size of tomato roots ^[21].

By 60 DAT, the trend continued, with T₇ maintaining its superiority in promoting root length. This consistent performance indicates that the organic amendments in T₇ provide a sustained nutrient release and a conducive rhizosphere environment that supports prolonged root elongation. The incremental growth in T₂ (93.56 ± 6.17 cm) also suggests that chemical fertilizers offer substantial support during mid-stage development but lack the holistic benefits observed in T₇. At the harvesting stage, the significant difference in root length persisted, with T₇ recording the highest values (29.98 ± 4.63 cm), followed by T₂ (26.27 ± 1.92 cm) and T₆ (100% Panchagavya, 26.67 ± 3.70 cm). The close performance of T₆ to T₂ suggests that Panchagavya alone can rival the effects of chemical fertilizers, further emphasizing the potential of organic treatments as a sustainable alternative.

Plant Height

Plant height varied significantly across the treatments and developmental stages (Table 1). At 30 DAT, T₂ (RDF) produced the tallest plants (33.93 ± 2.80 cm), closely followed by T₇ (Jeevamrutham + Panchagavya) at 33.61 ± 0.61 cm, while T₁ (Absolute Control) had the shortest plants (23.33 ± 0.89 cm). At 60 DAT, T₂ continued to lead with the tallest plants (93.56 ± 6.17 cm) due to eagerly available to plants, whereas T₁ remained the shortest (74.56 ± 4.35 cm). At the harvesting stage, T₂ maintained its lead (134.44 ± 5.92 cm), with T₇ (130.78 ± 5.12 cm) and T₆ (100% Panchagavya, 128.89 ± 3.43 cm) showing similar growth, demonstrating the competitive performance of organic treatments. The rise in plant height and width could result from enhanced processes, including cell elongation, cell division, rapid reproduction, and the production of additional food substances in the plant. Organic fertilizers and bio-stimulants offer not just NPK but also deliver various micronutrients like Fe, Zn, and Mg to plants, aiding in the acceleration of metabolic functions like cell division and nutrition ^[21] and also presence of growth promoters like auxin and gibberellin in organic formulations may increases the plant height ^[19].

Dry matter production per plant (g)

The production of dry matter in tomatoes showed considerable variation across the treatments (Figure 1.a). During the harvest phase, the greatest dry matter yield was noted in T₂ (100% RDF) at $65.30 \text{ g plant}^{-1}$, with T₇ (Jeevamrutham + Panchagavya) following closely at $62.73 \text{ g plant}^{-1}$. The least production was noted in T₁ (Absolute Control) at $31.76 \text{ g plant}^{-1}$. Significantly, T₂ demonstrated a 105.6% rise in dry matter production relative to T₁, while T₇ displayed a 97.51% increase. The findings indicate that RDF supplied crucial nutrients for initial plant development, while organic methods aided in maintaining nutrient availability, especially during the later phases. While organic products like Jeevamrutham and Panchagavya enhance plant growth, their nutrient availability might be inadequate for early crop development, rendering chemical fertilizers more effective at first. Nonetheless, at harvest time, the combined organic treatment (T₇) performed comparably to the RDF, showcasing its potential as a sustainable option ^[22, 23].

Harvest index (%)

Apart from the yield, harvest index was influenced by traditional organic preparations (Figure 1.b), where significantly highest

harvest index (77.72%) was recorded in the treatment T₂ (100% RDF) followed by combination of Jeevamrutham and Panchagavya (76.09%) compared to rest of the treatments and minimum harvest index was recorded in absolute control (64.81%). The treatments 100% Panchagavya, 100% Jeevamrutham, 50% Panchagavya and 50% Jeevamrutham were at par with each other indicating good response well to the chemical fertilizers. Higher harvest index 19.9% in T₂ (100% RDF) as compared to organic preparations and T₁ (Absolute control) [24, 25].

Average yield per plant (g)

Average yield per plant is a critical parameter for evaluating crop productivity. The results (Figure 1.c) show that T₂ (100% RDF) achieved the highest fruit yield (1967.65 g plant⁻¹), significantly outperforming other treatments, followed by T₇ (Jeevamrutham + Panchagavya) at 1812.33 g plant⁻¹. The lowest yield was recorded in T₁ (Absolute Control) at 1059.66 g plant⁻¹. Treatments involving 100% Panchagavya, 100% Jeevamrutham, 50% Panchagavya, and 50% Jeevamrutham were statistically at par, indicating similar impacts on yield. The yield increase in T₂ (100% RDF) was 85.6% higher than the untreated control, while T₇ (Jeevamrutham + Panchagavya) exhibited a 71.02% increase. These findings highlight that while organic liquid manures supply nutrients and growth-promoting substances, they may be insufficient for early crop development. RDF application provides essential NPK for early growth, resulting in better yields compared to standalone organic treatments. However, the combination of Jeevamrutham and Panchagavya (T₇) performed comparably to RDF, showcasing its potential as a sustainable alternative [22, 26, 27, 28].

Plant nutrient content and uptake of N, P, K

Nitrogen content and uptake

The results regarding concentration of nitrogen in tomato by applying organic formulations determined at harvest stage is presented in the table 2. Application of traditional organic preparations influenced the concentration of N in the plant at harvest stage. Results revealed that significantly highest nitrogen content (2.93 ± 0.11) in T₇, followed by T₂ (2.84 ± 0.06), T₆ (2.75 ± 0.06), and T₅ (2.64 ± 0.09) when compared to all other treatments and lowest nitrogen content was recorded in absolute control as (1.72 ± 0.12) at harvest stage which might be due to constant availability and better uptake of nutrients throughout the crop growth through organic fertilizers and release of native soil nutrient at later stages mediated by soil microflora that helped in increased uptake of nutrients [29].

The results pertaining to uptake of nitrogen estimated at harvest stage is presented in the table 2. Where, N uptake by tomato crop was influenced by application of traditional organic preparations. Whereas, significantly higher N uptake was recorded with the treatment T₇ (54.45 ± 9.45), T₂ (54.99 ± 5.50) compared to all other treatments followed by T₆ (48.23 ± 3.91). The treatment absolute control has recorded significantly lower N uptake (16.22 ± 2.78) than rest of the treatments at harvest stage which might be due to more nutrient availability in soil by chemical fertilizers application and these organic formulations could be attributed to steady accessibility and improved absorption of nutrients during the crop development [25, 29].

Phosphorus content and uptake

The data presented in the table 2, revealed that, the content and uptake of phosphorus by tomato was significantly influenced by different treatments. Maximum phosphorous content was

observed with the treatment of T₇ (0.37 ± 0.04) at harvest stage of tomato followed by the treatment T₆ (0.35 ± 0.04) and T₂ (0.32 ± 0.06). Lowest P content was recorded with the treatment T₁ (0.15 ± 0.04) at harvest stage. The treatment T₇ was at par with different treatments viz., 100% Panchagavya, 100% RDF, 50% Panchagavya and 100% Jeevamrutham at harvest stage of tomato. Uptake of P by tomato crop was significantly influenced by different treatments at harvest stage and the data is presented in the table 4.12. Significantly higher P uptake was observed with the treatment T₇ (6.85 ± 0.85) and minimum uptake of P at harvest stage (1.36 ± 0.33) was recorded in Absolute control.

Potassium content and uptake

The highest potassium level in the plant with treatment T₇ (2.03 ± 0.06), followed closely by treatment T₆ (1.94 ± 0.08). In contrast, the treatment T₁ (Absolute control) exhibited the minimum potassium content of 1.01 ± 0.10 . The treatments Jeevamrutham + Panchagavya (T₇) were comparable to the treatments 100% Panchagavya, 100% RDF, 50% Panchagavya, and 100% Jeevamrutham at the crop's harvest stage. The absorption of K in tomatoes was steadily elevated, significantly affected by the use of conventional organic preparations at the harvest stage shown in table 2. A notably increased K uptake was noted with treatment T₇ (37.59 ± 4.85), while treatment T₁ (9.44 ± 0.84) exhibited the lowest uptake. The rise in potassium content and absorption in tomatoes may be attributed to the use of Jeevamrutham and Panchagavya, which led to higher K availability through the leaves [30]. Nutrient build-up in plants is caused by both nutrient levels and the accumulation of dry matter. The greater availability of plant nutrients through foliar application in a plant-accessible form may have enhanced dry matter accumulation by positively influencing root branching. The rise in dry matter in the aboveground sections promotes the movement of additional carbohydrates to growing roots. The greater distribution of food substances to the roots subsequently improved the root volume, which in turn led to a higher absorption of additional plant nutrients [31, 32].

Fruit qualitative parameters

The application of organic formulations had a significant influence on fruit quality parameters, including ascorbic acid, lycopene, and β -carotene contents (Figure 2). Among the treatments, T₇ (100% Jeevamrutham + 100% Panchagavya) consistently recorded the highest levels of all quality parameters, indicating its superior efficacy in enhancing the nutritional profile of fruits. Specifically, T₇ resulted in an ascorbic acid content of 39.8 mg/100 g, lycopene content of 9.2 mg/100 g, and β -carotene content of 1.5 mg/100 g, significantly surpassing other treatments. Treatments involving 100% applications (T₆ and T₄) also performed better than reduced applications (50%) (T₃ and T₅), underscoring the importance adequate nutrient availability for optimal fruit quality; while, the control (T₁) and 100% RDF (T₂) were less impact of fruit quality. The integration of Jeevamrutham and Panchagavya (T₇) likely contributed to a synergistic effect, enhancing bioavailability of nutrients and promoting secondary metabolite production, which are critical for improving ascorbic acid and carotenoid concentrations [19, 33, 34].

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) elucidated significant distinct patterns in the associations between treatments and measured variables, with the initial two principal components accounting for 96.4% of the overall variance (PC1: 83.2%, PC2:

13.2%) from figure 3. The biplot topology demonstrated clear differentiation among treatments, where T₁ (Absolute Control) exhibited negative correlation with PC1, indicating suboptimal performance across all measured parameters. In contrast, organic treatments (T₃-T₇) clustered along the positive axis of PC1, with T₇ (100% Jeevamrutham + 100% Panchagavya) demonstrating the strongest positive correlation. This spatial distribution suggests synergistic effects of combined organic preparations, enhanced agronomic performance under integrated organic management. PC1 exhibited robust positive loadings for nutritional quality indicators (ascorbic acid, β -carotene, and lycopene levels), suggesting these variables were closely linked and responded similarly to treatments. Treatment T₇ (100% Jeevamrutham + 100% Panchagavya) was situated positively on PC1, demonstrating its exceptional ability to enhance crop nutritional quality. Growth and yield parameters (plant height, root length, harvest index, and dry matter production) were grouped together with moderate positive loadings on PC1, indicating coordinated responses to management practices. Nutrient uptake variables (nitrogen, phosphorus, and potassium) displayed similar vector orientations, suggesting a synergistic relationship with plant nutrition. Notably, T₂ (100% RDF) was positioned on PC2, implying that conventional fertilization, while supporting basic growth parameters, may not optimize nutritional quality compared to organic preparations. The number of leaves per plant exhibited a unique loading pattern, indicating partial independence from other growth parameters. The clear separation of treatments along PC1 and the clustering of quality parameters versus growth parameters offer compelling evidence that integrated organic preparations (particularly T₇) can effectively balance both productivity and nutritional quality objectives in crop production systems.

Multivariate correlation analysis of Plant growth, nutrient content and fruit quality parameters influenced by Jeevamrutham and Panchagavya

Multivariate correlation revealed intricate relationships between nutrient absorption patterns and plant performance indicators across various experimental conditions (Figure 4). Robust positive associations ($r > 0.90$) were noted between the uptake of total nitrogen and phosphorus ($r = 0.93$), indicating cooperative nutrient assimilation processes possibly augmented by organic formulations. Growth metrics exhibited significant interconnectedness, with plant height showing positive correlations with root length ($r = 0.69$) and harvest index ($r = 0.81$), suggesting that treatments promoting strong vegetative development also enhanced yield components. The biochemical quality indicators, specifically lycopene and β -carotene levels, exhibited a strong positive relationship ($r = 0.98$), implying that treatments boosting one carotenoid typically increased others, possibly because of common biosynthetic routes. Interestingly, the total potassium absorption demonstrated moderate to strong positive correlations with yield parameters ($r = 0.87$) and ascorbic acid content ($r = 0.87$), underscoring the vital role of potassium in both productivity and nutritional value. The incorporation of organic preparations, particularly in T₇ (100% Jeevamrutham + 100% Panchagavya), seems to have established a beneficial soil-plant interaction system, as evidenced by the positive correlations between nutrient uptake and both growth and quality indicators. This implies that the combined application of organic formulations may present a feasible strategy for sustaining crop productivity, while potentially improving nutritional quality, although additional research is necessary to clarify the specific mechanisms driving these associations.

Table 1: Impact of organic formulations on plant growth parameter (No. of Leaves, Root length, Plant height) at different growth stages.

Treatments	Number of leaves plant ⁻¹			Root Length (cm)			Plant Height (cm)		
	30 DAT	60 DAT	Harvesting stage	30 DAT	60 DAT	Harvesting stage	30 DAT	60 DAT	Harvesting stage
T ₁	38.08 $\pm$ 2.07 ^d	84.45 $\pm$ 8.45 ^b	62.67 $\pm$ 3.06 ^c	5.67 $\pm$ 0.16 ^f	9.95 $\pm$ 1.51 ^b	20.10 $\pm$ 1.12 ^b	23.33 $\pm$ 0.89 ^a	74.56 $\pm$ 4.35 ^b	108.45 $\pm$ 2.18 ^c
T ₂	48.21 $\pm$ 1.16 ^a	119.45 $\pm$ 7.35 ^a	91.00 $\pm$ 6.00 ^a	9.56 $\pm$ 0.35 ^b	15.03 $\pm$ 1.53 ^{ab}	26.27 $\pm$ 1.92 ^{ab}	33.93 $\pm$ 2.80 ^b	93.56 $\pm$ 6.17 ^a	134.44 $\pm$ 5.92 ^a
T ₃	40.23 $\pm$ 1.78 ^{cd}	81.11 $\pm$ 3.10 ^b	65.00 $\pm$ 3.61 ^c	6.87 $\pm$ 0.19 ^e	10.44 $\pm$ 0.76 ^b	22.02 $\pm$ 1.79 ^b	31.85 $\pm$ 1.15 ^b	78.33 $\pm$ 5.21 ^{ab}	113.55 $\pm$ 7.96 ^{bc}
T ₄	42.67 $\pm$ 1.16 ^{bcd}	67.89 $\pm$ 5.36 ^b	75.00 $\pm$ 5.30 ^{bc}	7.54 $\pm$ 0.20 ^{cd}	11.21 $\pm$ 1.40 ^b	26.78 $\pm$ 1.79 ^{ab}	32.80 $\pm$ 2.06 ^b	81.45 $\pm$ 6.48 ^b	124.65 $\pm$ 4.97 ^{ab}
T ₅	44.00 $\pm$ 2.00 ^{abc}	80.45 $\pm$ 6.94 ^b	69.00 $\pm$ 5.00 ^{bc}	7.02 $\pm$ 0.19 ^{de}	12.07 $\pm$ 1.87 ^{ab}	22.10 $\pm$ 2.84 ^b	32.49 $\pm$ 4.21 ^b	80.67 $\pm$ 7.13 ^b	121.78 $\pm$ 3.70 ^{bc}
T ₆	45.08 $\pm$ 2.25 ^{ab}	89.67 $\pm$ 19.14 ^b	77.34 $\pm$ 8.63 ^{abc}	7.89 $\pm$ 0.16 ^c	13.16 $\pm$ 1.81 ^{ab}	26.67 $\pm$ 3.70 ^{ab}	33.20 $\pm$ 3.19 ^b	84.17 $\pm$ 4.01 ^b	128.89 $\pm$ 3.43 ^a
T ₇	47.56 $\pm$ 1.39 ^a	91.61 $\pm$ 1.95 ^b	80.00 $\pm$ 3.61 ^{ab}	11.21 $\pm$ 0.30 ^a	16.83 $\pm$ 3.56 ^a	29.98 $\pm$ 4.63 ^a	33.61 $\pm$ 0.61 ^b	86.20 $\pm$ 7.88 ^b	130.78 $\pm$ 5.12 ^a

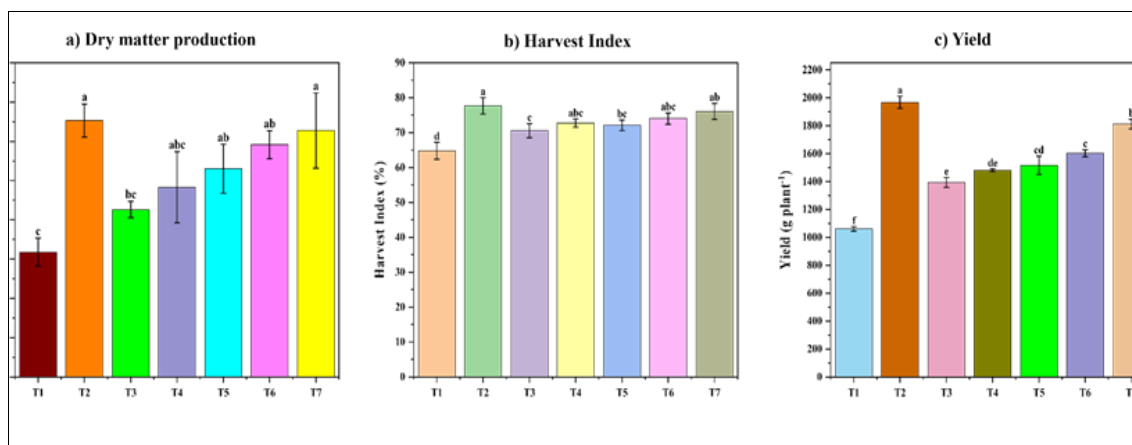
Values in each column are mean of three replications ($\pm$ standard error). Mean values in each column followed by same letter(s) are significantly different at 5% level.

T₁: Absolute Control; T₂: 100% RDF; T₃: 50% Jeevamrutham; T₄: 100% Jeevamrutham; T₅: 50% Panchagavya; T₆: 100% Panchagavya; T₇: 100% Jeevamrutham + 100% Panchagavya.

Table 2: Plant nutrient content and their uptakes during harvesting stage of crop as influenced by organic formulations

Treatments	Plant Nutrient content (%)			Nutrient Uptake (Kg ha ⁻¹)		
	N	P	K	N	P	K
T ₁	1.72 $\pm$ 0.12 ^d	0.15 $\pm$ 0.04 ^d	1.01 $\pm$ 0.10 ^d	16.22 $\pm$ 2.78 ^d	1.36 $\pm$ 0.33 ^e	9.44 $\pm$ 0.84 ^d
T ₂	2.84 $\pm$ 0.06 ^{ab}	0.32 $\pm$ 0.06 ^{ab}	1.93 $\pm$ 0.13 ^{ab}	54.99 $\pm$ 4.50 ^a	6.17 $\pm$ 0.93 ^{ab}	37.23 $\pm$ 3.63 ^a
T ₃	2.30 $\pm$ 0.18 ^c	0.20 $\pm$ 0.03 ^{cd}	1.54 $\pm$ 0.14 ^c	29.03 $\pm$ 2.10 ^{cd}	2.53 $\pm$ 0.38 ^{de}	19.41 $\pm$ 0.73 ^c
T ₄	2.55 $\pm$ 0.10 ^{bc}	0.26 $\pm$ 0.04 ^{bc}	1.67 $\pm$ 0.13 ^{bc}	36.60 $\pm$ 7.88 ^{bc}	3.67 $\pm$ 0.17 ^{cd}	23.64 $\pm$ 2.68 ^c
T ₅	2.64 $\pm$ 0.09 ^{ab}	0.29 $\pm$ 0.03 ^{abc}	1.76 $\pm$ 0.07 ^{abc}	41.40 $\pm$ 4.90 ^{abc}	4.57 $\pm$ 0.78 ^{bc}	27.70 $\pm$ 4.03 ^{bc}
T ₆	2.75 $\pm$ 0.06 ^{ab}	0.35 $\pm$ 0.04 ^{ab}	1.94 $\pm$ 0.08 ^{ab}	48.23 $\pm$ 3.91 ^{ab}	6.12 $\pm$ 0.44 ^{ab}	33.87 $\pm$ 2.18 ^{ab}
T ₇	2.93 $\pm$ 0.11 ^a	0.37 $\pm$ 0.04 ^a	2.03 $\pm$ 0.06 ^a	54.45 $\pm$ 9.45 ^a	6.85 $\pm$ 0.85 ^a	37.59 $\pm$ 4.85 ^a

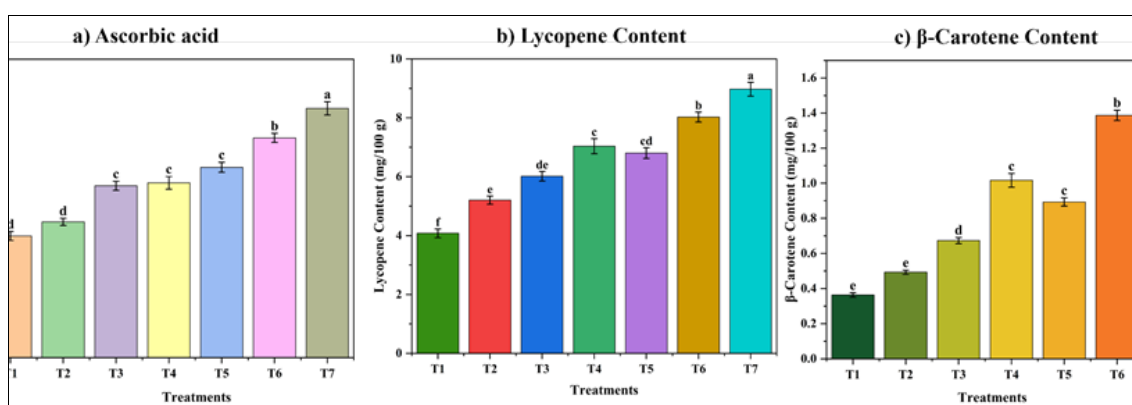
Values in each column are mean of three replications ($\pm$ standard error). Mean values in each column followed by same letter(s) are significantly different at 5% level. T₁: Absolute Control; T₂: 100% RDF; T₃: 50% Jeevamrutham; T₄: 100% Jeevamrutham; T₅: 50% Panchagavya; T₆: 100% Panchagavya; T₇: 100% Jeevamrutham + 100% Panchagavya.



Values in each axis represents mean of three replications, Error bars represent the standard error ± 0.05 , and Significant letters showed at 5% for individual variables.

T₁: Absolute Control; T₂: 100% RDF; T₃: 50% Jeevamrutham; T₄: 100% Jeevamrutham; T₅: 50% Panchagavya; T₆: 100% Panchagavya; T₇: 100% Jeevamrutham + 100% Panchagavya.

Fig 1: Bar Graphs represents yield parameters 1.a) Dry matter production; 1.b) Harvest Index; 1.c) Yield



Values in each axis represents mean of three replications, Error bars represent the standard error ± 0.05 , and Significant letters showed at 5% for individual variables.

T₁: Absolute Control; T₂: 100% RDF; T₃: 50% Jeevamrutham; T₄: 100% Jeevamrutham; T₅: 50% Panchagavya; T₆: 100% Panchagavya; T₇: 100% Jeevamrutham + 100% Panchagavya.

Fig 2: Bar graphs represent fruit qualitative parameters 2.a) Ascorbic acid content; 2.b) Lycopene content; 2.c) β -Carotene content

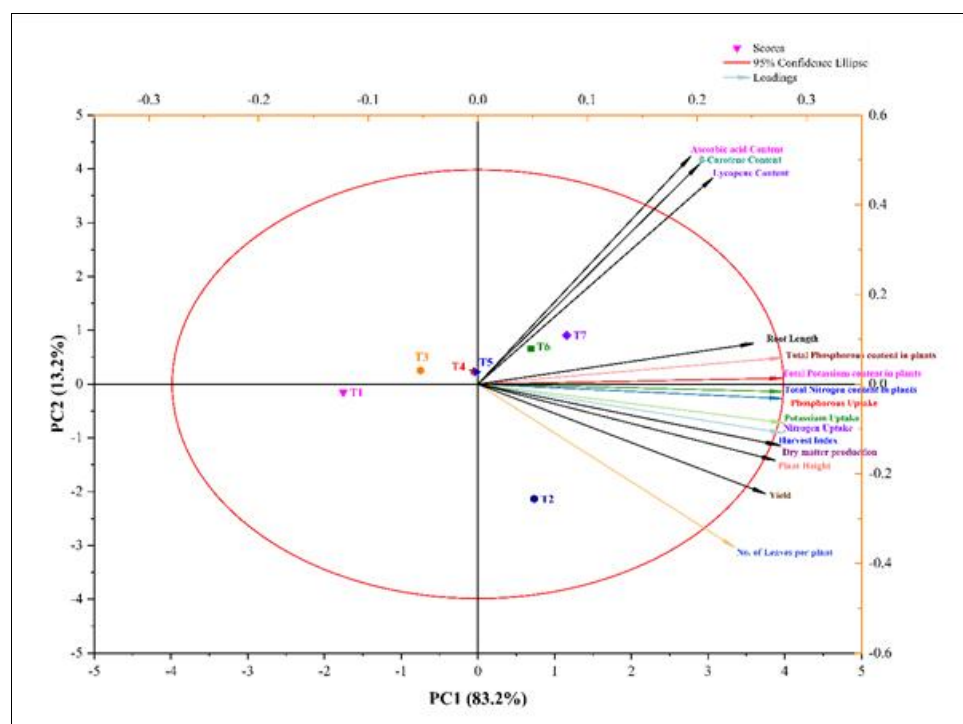
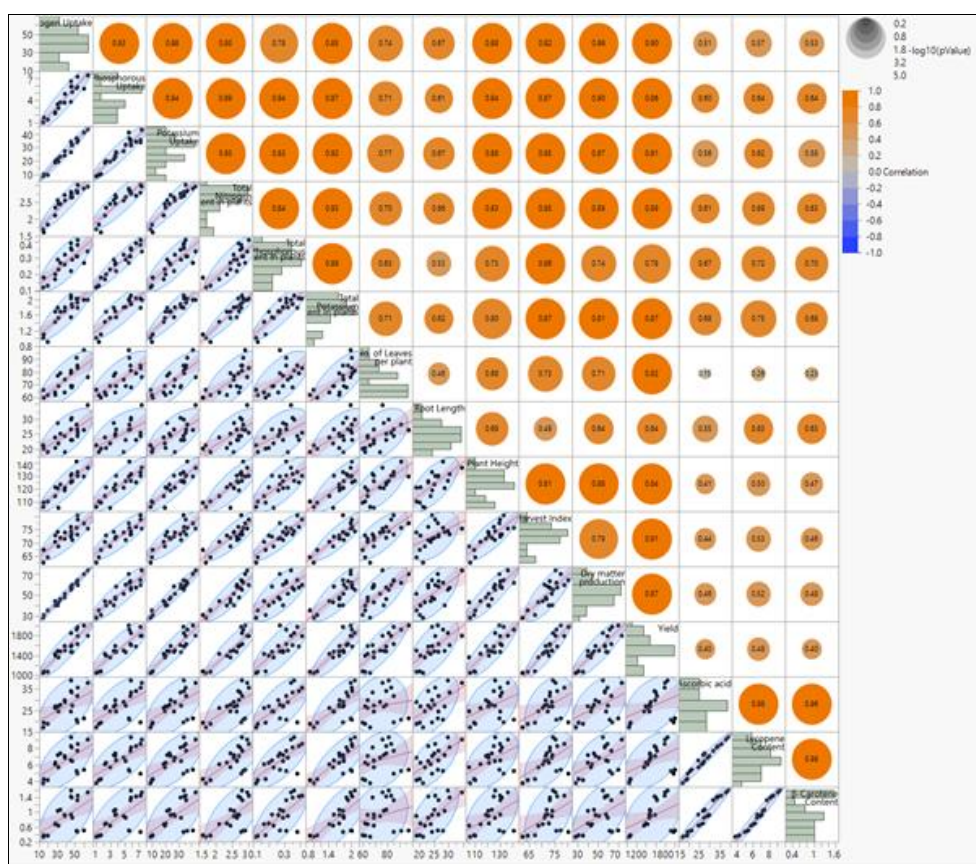


Fig 3: Principal Component Analysis of Plant growth, nutrient content and fruit quality parameters influenced by Organic Formulations



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