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RESEARCH ARTICLE

Effects of biostimulants on growth, yield and quality of Tomato (*Solanum lycopersicum* L) intercropped with palmyrah (*Borrassus flabellifer* L)

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Abstract

The present study aimed to investigate the impact of bio-stimulants on the growth and yield of Tomato (var. PKM-1) as an intercrop under Palmyrah plantation at the College Orchard of the Department of Horticulture, VOC Agricultural College and Research Institute, Killikulam, Thoothukudi district of Tamil Nadu during 2023-24. The maximum plant height at 30 (52.80 cm), 60 (73.40 cm) and 90 days after transplanting (86.47 cm), number of branches at 30 days after transplanting (3.20), 60 days after transplanting (7.60) and 90 days after transplanting (8.40), early flowering (26.2 days), 50 % flowering (39.8 days), individual fruit weight (30.29 g), number of fruits per plant (28.6), yield of fruits per plant (0.87 kg), yield per ha (31.97 ton per ha), chlorophyll a (0.89 mg per g), chlorophyll b (1.28 mg per g), total chlorophyll (1.65 mg per g), TSS (5.54° Brix), ascorbic acid content (23.87 mg per 100g), titrable acidity (0.65 %), lycopene content (2.47 mg per 100g) was recorded in (the 3 %) Panchagavya spray treatment. The salient findings revealed that among the different treatments, a 3 % Panchagavya spray demonstrated superiority in promoting the growth and yield of Tomato as an intercrop under Palmyrah in the dry land conditions of the Thoothukudi district. These findings highlight the potential of incorporating organic practices into intercropping systems suitable for arid and semi-arid regions.

Keywords

intercrop; KCl; lycopene; Palmyrah; Panchagavya; PPFM; Tomato

Introduction

Palmyrah (*Borrassus flabellifer* L.) belongs to the Arecaceae family. It is a versatile and resilient palm species, long esteemed for its diverse uses, including food, medicinal applications and construction materials. It is a hardy tree native to tropical Africa in the drier parts of India, Sri Lanka, Thailand, Malaysia, Vietnam and Indonesia. Palmyrah is often referred to as Karpagathara (Tree of Life), highlighting its importance to humankind, with over 800 reported uses from crown to root of the tree (1). It has been designated as the state tree of Tamil Nadu since 1978. Around 103 million palms are estimated to exit India, with Tamil Nadu retaining half of the total (2). More than half of the 51.6 million palm trees in Tamil Nadu are located in the southern districts of Virudhunagar, Thoothukudi, Tirunelveli and Ramnad. Thoothukudi district alone has approximately 10 million palm trees (3). The Palmyrah tree can grow up to a height of 13-14 meters, sometimes even reaching 90 meters in height. It is a slow-growing plant and takes approximately five months to produce its first frond (4). The species offers significant opportunities for intercropping by providing both horizontal and vertical space for additional income generation (1). Restoring diversity in agricultural ecosystems and effectively managing it are two crucial aspects of sustainable agriculture (5). This approach can be utilized to optimize the utilization of available resources, boost yield and enhance profitability per unit area (6). Vegetable crops, renowned for their shorter life cycles and high market value, demonstrate superior performance as intercrops.

The tomato (*Solanum lycopersicum* L.) belongs to the Solanaceae family. It is a significant vegetable crop with a chromosome number of 2n=2x=24. It first grew in the wild in the Peru-Ecuador-Bolivia region of the Andes in South America (7). Now, people grow it in almost every part of the world. It is a self-pollinated crop that belongs to the nightshade family. It is an herbaceous, annual to perennial, propagated by seeds and day-neutral plant. Tomatoes are the second most important vegetable after potatoes. They are in high demand as a cash crop worldwide (8). It is an excellent source of organic acids, minerals and other bioactive compounds such as carotenoids (lycopene and beta-carotene), phenolic compounds, flavonoids and vitamins (mainly vitamins C, A and E). This compound makes tomatoes a valuable protective food.

Stress impacts crops at morphophysiological, biochemical and molecular levels, leading to growth inhibition, accumulation of compatible organic solutes and alterations in endogenous phytohormone levels. In agricultural practices, fertilizer is a crucial input for increasing crop yields. Meanwhile, the foliar application of organic and inorganic fertilizers at appropriate intervals facilitates quick and efficient absorption, enhancing crop growth and increasing yield by 15 to 25 % (9). Foliar applied fertilizers (Nitrogenous fertilizer, Phosphatic fertilizer, Potassic fertilizer, Humic acid, Panchagavya, Salicylic acid, Jeevamirutham, Azospirillum, PPFM, Phosphobacteria etc.) are more effective than soil applied fertilizers.

During drought, the lack of water significantly affects crop production. External application of potassium (K) has been shown to mitigate the adverse effects of water stress. Under mild or severe water stress, K uptake by crops can be reduced by 67 % and 82 %, respectively. Lower K concentration in the plants leads to decreased resistance to drought stress and reduced size, yield, quality and photosynthetic pigments (10). Spraying K under drought conditions enhances crop tolerance to various abiotic stresses, improves growth and yield and regulates physiological processes such as turgor pressure, photosynthesis and enzyme activation (11). Methylobacterium, a pink-pigmented facultative methylotroph (PPFM), is well-studied for its ability to enhance plant growth and induce defence mechanisms. In addition, PPFM treatment enhanced antioxidant enzyme activity, particularly catalase, suggesting its role in mitigating oxidative stress under drought conditions (12).Panchagavya serves as a nutrient source that enhances crop growth. Plants treated with Panchagavya exhibit accelerated growth, increased yield, higher production of secondary metabolites and enhanced chlorophyll content under drought conditions. This beneficial effect is attributed to increased stomatal count, sponge parenchyma development and enhanced thylakoid development (13).

The study investigated the intercropping of groundnut with Palmyrah trees at various tree densities. The results revealed that intercropping significantly improved the post-harvest soil nutrient status, remarkably increasing nitrogen (N), phosphorus pentoxide (P_2O_5) and potassium oxide (K_2O) levels (1). Intercropping with vegetables under Palmyrah plantations is a relatively understudied area. This research aims to establish optimal Palmyrah-vegetable intercropping systems to enhance income generation while also examining crop performance, economic viability, environmental sustainability and the associated challenges. Thothukudi district is a dry land tract of the southern part of Tamil Nadu. Palmyrah farmers were often traditionally reported to be intercropping under Palmyrah with crops like grains and pulses alone, which met less income per unit area. Vegetable farming has recently introduced a form of intensive cultivation for the farming community, offering higher income per unit area. The present study aimed to investigate the impact of various bio-stimulants on the growth and yield of tomatoes under the Palmyrah plantation as intercrop.

Materials and Methods

The field experiment was conducted during the *Kharif* season at College Orchard, Department of Horticultural, VOC Agricultural College and Research Institute, Killikulam, Thoothukudi district of Tamil Nadu during the period (October to February) of 2023-24. The experimental site was at 8°70'N latitude and 77°86'E longitude at 41.73 m above mean sea level. The experimental plot had uniform topography and was divided into small plots, ridges and furrows were formed. The irrigation was provided through the furrow irrigation method.

Under open field conditions, the maximum temperature varies between 32°C to 38°C with an average of 35°C and the minimum temperature varies between 22°C to 28°C with an average of 25.4°C. The annual rainfall was 668mm and relative humidity varied between 60 and 91 percent, averaging 76 percent. The experimental plot consisted of red soil with a pH value of 7.40. Soil profiling revealed available NPK at 253:23:110 kg/ha. The field consisted of a Palmyrah plantation with 25 years of old trees planted at 3x3 m spacing.

The tomato variety PKM-1 was raised in the nursery after 25 days and the seedlings were transplanted into the main field as intercrops. The plot size was 3.75 m^2 with a plant spacing of 60X45 cm. In this experiment, randomized block design with four treatments (KCl (1 %) (1g in 100 ml of water), PPFM (1 %) (1 ml in 100 ml of water), Panchagavya (3 %) (3ml in 100 ml of water) and plain water as control) and five replications. The foliar spray was given 25 days after planting in a frequent interval of 15 days (4 sprays). The recommended amount of fertilizer (NPK: 75:100:50 kg per ha) was applied as a basal dose to the field using uniform cultural practices.

Observations recorded were plant height, no. of branches per plant recorded at 30, 60 and 90 days after transplanting, chlorophyll a, b and total chlorophyll, 1 %

flowering and 50 % of flowering calculated by counting the days taken for flowering after transplanting the crop and individual fruit weight, no. of fruits, yield per plant and yield per ha (tonnes), TSS (°Brix), ascorbic acid content (mg per 100g), titratable acidity (%), lycopene content (mg per 100g) were recorded.

Chlorophyll content

Chlorophyll content in the fresh leaves was measured using the standard method (14). Macerate 0.25 g of leaf tissue with 10 ml of acetone. Centrifuge the mixture at 3000 rpm for 10 minutes and collect the supernatant. Adjust the final volume to 25 ml using 80 % acetone. Measure the optical density (OD) at 663 nm, 645 nm and 652 nm using a spectrophotometer as per Equation 1-3.

Chlorohylla =

$$(12.7 \times 0Dat663) - (2.69 * 0Dat645) \times \frac{V}{1000 \times W} \quad \text{(Eqn.1)}$$

Chlorohyllb =

$$(22.9 \times 0Dat645) - (4.68 \times 0Dat663) \times V/(1000 \times W) \quad \text{(Eqn.2)}$$

$$\text{Total Chlorohyll} = (0Dat652 \times V) / (34.5 \times W) \quad \text{(Eqn.3)}$$

OD- Optical Density measured at a respective wavelength

V- Final volume of extract

W- Weight of the leaf sample

Quality parameters

Tomato quality parameters (TSS, Ascorbic acid content, Titratable acidity and lycopene content were analyzed in fully ripened fruits.

TSS

TSS of fruit was measured by a Digital Refractometer (0-32 ° Brix). Juice extracted from the cut fruits was used to determine the value of TSS at room temperature and the value was noted at °Brix.

Ascorbic acid content

Aground sample (1g) was taken, dissolved in four per cent oxalic acid, added to a 100 ml volume and centrifuged at 5000 rpm for thirty minutes. After that, 100 ml of 4 % oxalic acid was mixed with 5 ml of the supernatant that had been extracted. After that, this mixture was titrated against a dye solution that was prepared up to 200 ml and comprised42 mg of sodium bicarbonate and 52 mg of 2, 6 dichlorophenolindophenol. The achieved titre value was identified as V_2. After the standard was created using the specified procedure, the titre value was recorded as V_1 ml (14, 15), the ascorbic acid content (mg 100 g^{-1}) was calculated by using the Equation 4 formula:

$$\text{Ascorbic acid (mg } 100g^{-1}) = (0.5 \times V_2 \times 100) / (V_1 \times 5 \times \text{Weight of the sample}) \times 100 \quad \text{(Eqn.4)}$$

Titratable acidity

Titratable acidity was determined by using the standard method and expressed in terms of percent (16).

Lycopene content

Lycopene content was seen in fully ripened fruit. It was extracted using petroleum ether and OD of the extract was measured at 503 nm in a UV-VIS spectrophotometer using petroleum ether as a blank (17). The Lycopene content of the sample was calculated using the Equation 5 formula and expressed in mg per 100g.

Lycopene =

$$\frac{3.1206 \times \text{OD of sample} \times \text{volume made up} \times \text{dilution}}{\text{weight of sample} \times 1000} \times 100 \quad \text{(Eqn.5)}$$

Statistical analysis

The days after transplanting and various observed parameters were analyzed statistically. Mean, standard error and critical difference were computed and significance was estimated at a five percent probability level using SPSS software version 16.0.

Standard error

It is calculated by dividing the standard deviation by the square root of the number of observations.

Results

Statistical analysis was done for the yield attributing parameter of Tomato under Palmyrah plantation with the effect of foliar application and the difference among the treatments was found to be significant at a 5 %significance level.

Morphological parameters

Regarding morphological characters, plant height and number of branches were recorded at 30, 60 and 90 days after transplanting (Table 1). The maximum plant height was seen in Panchagavya (3 %) with 86.47 followed by PPFM (1 %) with 82.32 cm at 90 days after transplanting and minimum plant height was seen control with 45.74 cm at 30 days after transplanting. The number of branches showed significant variations among the different treatments. The maximum number of branches was observed in Panchagavya (3 %) with

Table 1. Influence of biostimulants on plant height and no. of branches of tomato at 30 DAT, 60 DAT and 90 DAT under Palmyrah. Columns show mean values of five replicates with standard error of means

Treatments	Plant height (cm)			No. of branches per plant		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T_1	47.47	65.45	78.41	1.80	5.2	6.6
T_2	50.48	69.55	82.32	2.20	6.8	7.8
T_3	52.80	73.40	86.47	3.20	7.6	8.4
T_4	45.74	62.98	76.12	1.59	4.8	6.2
S.E m (±)	0.61	0.45	0.54	0.28	0.20	0.26
S.E(d)	0.86	0.64	0.77	0.40	0.28	0.37
C.D (5 %)	1.88	1.40	1.68	0.88	0.60	0.80
C.V (%)	2.78	1.50	1.51	28.94	7.18	7.96

8.4 at 90 days after transplanting, followed by PPFM (1 %) with 7.8 at 90 days after transplanting and the minimum number of branches was seen in control with 1.59, followed by KCl (%) with 1.80 was on par with PPFM (1 %).

The application of different biostimulants significantly affected the biochemical characteristics of Tomato plants, particularly in terms of chlorophyll level. Significant variations were observed among the various treatments.The Panchagavya (3 %) spray recorded the highest chlorophyll a, chlorophyll b and total chlorophyll with 0.89 mg per g, 1.28 mg per g and 1.65 mg per g respectively followed by PPFM (1 %) spray with chlorophyll a (0.75mg per g), chlorophyll b (1.16 mg per g) and total chlorophyll (1.48 mg per g) and control recorded the lowest amount of chlorophyll a, chlorophyll b and total chlorophyll with 0.62 mg per g, 0.74 mg per g and 1.36 mg per g respectively (Fig.1).

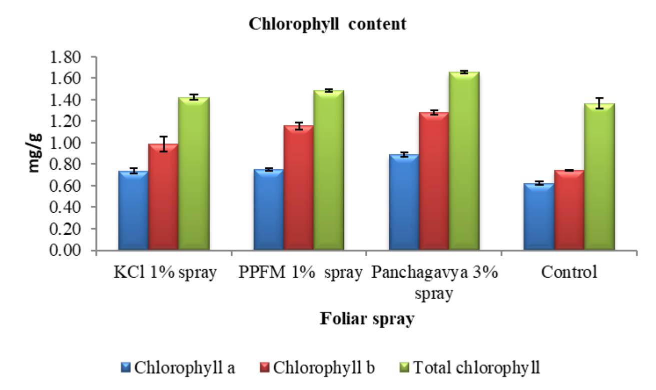

Fig. 1. Influence of biostimulants on Tomatos' chlorophyll a, b and total chlorophyll content under Palmyrah. Columns show mean values of five replicates with standard error of means.

The impact of various treatments on tomatoes as an intercrop was significant, with the days ranging from 26.2 to 30.2 days. Early flowering was seen in Panchagavya (3 %) at 26.2 days, which was followed by PPFM (1 %) at 27.8 days and flowering was delayed in control at30.2 days, followed by KCl (1 %) at 28.8 days (Table 2.). The days to 50 % flowering ranged from 39.8 to 45.20 days, with the shortest time in Panchagavya (3 %) spray at 39.8 days, followed by PPFM (1 %) at 43.20 days. More days to 50 % flowering was registered in control at 45.20 days, followed by KCl (1 %) at 44.2 days (Table 2).

Yield character

The number of fruits per plant also varied significantly, ranging from 23.4 to 28.6. The maximum number of fruits was recorded in Panchagavya (3 %) at28.6, which was followed by PPFM (1 %) at25.2 and, whereas a minimum number of fruits was obtained in control with 23.4 which was followed by KCl (1 %) with 24.2 (Table 2). Individual fruit weight of tomato as intercrop varied significantly among the different treatments, ranging from 28.63 g to 30.29 g. The highest weight was registered in Panchagavya (3 %) at30.29 g, followed by PPFM (1 %) at29.44 g. The minimum weight was seen in the control group, which was28.63 g (Table 2). Yield per plant varied significantly among the treatments, ranging from 0.66 kg to 0.87 kg. Maximum yield per plant was registered in Panchagavya (3 %) with 0.87 kg per plant, which was followed by PPFM (1 %) with 0.74 kg per plant, whereas minimum yield was recorded in control with 0.66 kg per plant, which was followed by KCl, (1 %) 0.69 kg per plant (Table.2)

Quality characters

The days after transplanting, pertaining to the TSS content of tomato as an intercrop, significantly varied across different treatments, ranging from 4.65 to 5.54 °Brix. The plant administered with Panchagavya (3 %) recorded the highest TSS content with 5.54, followed by PPFM (1 %) with 5.46 °Brix. In contrast, lower TSS content was seen in control with 4.65 ° Brix which was followed by KCl (1 %) with 5.21°Brix (Fig. 2). Applying bio-stimulants significantly affected ascorbic acid content, varying from 15.55 mg per 100g to 23.69 mg per 100g. The maximum value of ascorbic concentration was estimated in Panchagavya (3 %) at23.69 mg per 100g, which was followed by PPFM (1 %) with 21.91 mg per 100g and lowest ascorbic acid concentration was obtained in control with 15.55 mg per 100g followed by KCl (1 %) with 17.31 mg per 100g (Fig. 3)

The titrable acidity was one of the critical quality parameters in tomatoes. The value of titrable acidity in tomato as intercrop significantly varied from 0.57 % to 0.65 % among the different treatments. Maximum titrable acidity was recorded in Panchagavya (3 %) with 0.65 %, which was followed by PPFM (1 %) with 0.61 % when minimum titrable acidity (0.57 %) was found in control, which was followed by

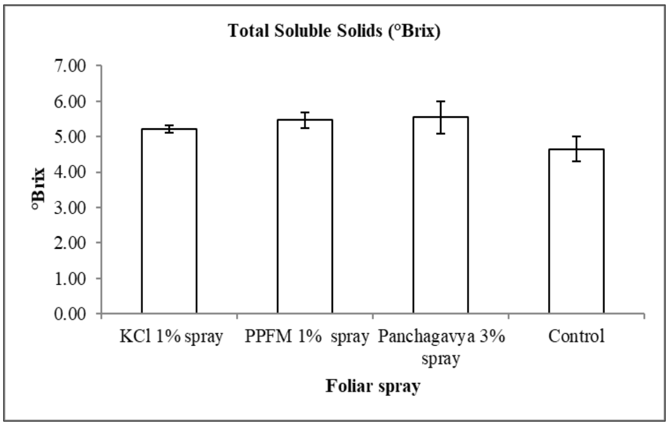

Fig. 2. Influence of biostimulants on TSS of tomato under palmyrah. Columns show mean values of five replicates with standard error of means.

Table 2. Influence of biostimulants on days to 1st flowering, 50 % of flowering, individual fruit weight, individual fruit weight, no. of fruits per plant, yield per plant and yield per ha under Palmyrah. Columns show mean values of five replicates with standard error of means

Treatments	Days to 1st flowering	Days to 50 % of flowering	Individual fruit weight (g)	No. of fruits per plant	Yield per plant (kg)	Yield per ha (t/ha)
T_1	28.8	44.2	28.85	24.2	0.69	26.32
T_2	27.8	43.2	29.44	25.2	0.74	27.31
T_3	26.2	39.8	30.29	28.6	0.87	31.97
T_4	30.2	45.2	28.63	23.4	0.66	24.57
S.E m (±)	0.28	0.20	0.30	0.28	0.01	0.34
S.E(d)	0.40	0.28	0.43	0.40	0.01	0.49
C.D (5 %)	0.86	0.62	0.93	0.86	0.02	1.06
C.V (%)	2.22	1.04	2.30	2.47	1.80	2.79

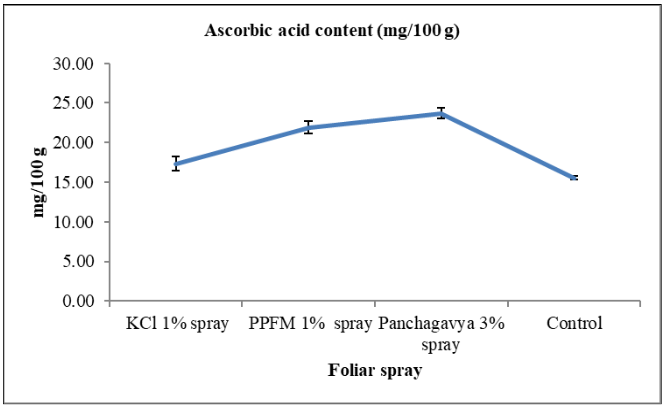

Fig. 3. Influence of biostimulants on ascorbic acid content of tomato under palmyrah. Columns show mean values of five replicates with standard error of means.

KCl (1 %) with 0.59 % (Fig. 4). Among the various treatments, the lycopene content in tomato as an intercrop varied significantly from 1.91 to 2.45 mg per 100g. Maximum lycopene content was recorded in the Panchagavya (3 %) with 2.45 mg per 100g, which was followed by PPFM (1 %) with 2.25 mg per 100g and minimum lycopene content was obtained in the control with 1.91 mg per 100g which was followed by 1.97 mg per 100g (Fig. 5)

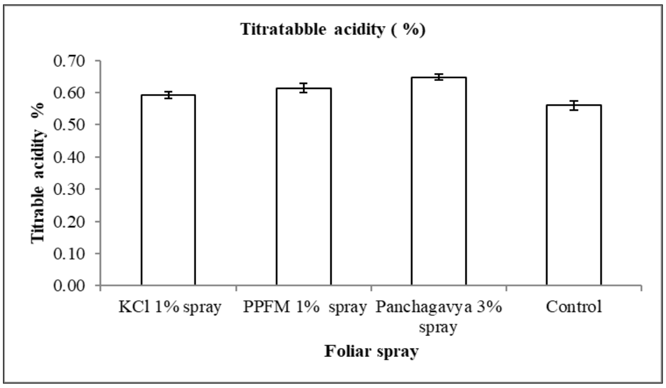

Fig. 4. Influence of biostimulants on titratable acidity of tomato under palmyrah. Columns show mean values of five replicates with standard error of means.

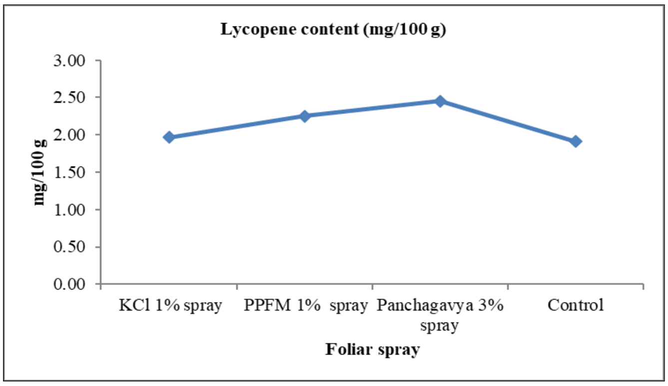

Fig. 5. Influence of biostimulants on lycopene content of tomato under palmyrah. Columns show mean values of five replicates with standard error of means.

Discussion

In upland cultivation, intercropping vegetables in tree-based systems is a popular vegetable agroforestry system (VAF) practice. This integrated approach replaces monoculture with a sustainable and lucrative income source. The primary goal is to minimize negative interactions between trees and vegetables, thereby enhancing productivity, profitability, nutrient use efficiency and environmental benefits (18). Some refer to this technique as Silvo-Olericulture, where vegetables are grown alongside legumes, timber, oil-producing trees and other tree species (19). Trees' shade helps regulate the local microclimate by keeping temperatures low, retaining water in the soil and preserving soil humidity. VAF systems are interconnected and strong, able to withstand severe weather events with minimal damage. Around a third of the population lives under the poverty line. Vegetable-based agroforestry systems with Palmyrah as the main crop had a high potential for carbon sequestration compared to either sole Palmyrah trees or vegetable crop cultures. Vegetable-based agroforestry systems could potentially generate food energy cum balanced nutrition and, thus, potential enough to change the diet of the farming community and potentially support the health of community members as a whole by assuring global food security. This way, the horticulture-based agroforestry systems offer a multipurpose way to address environmental preservation, climate change adaptation and global food security.

Palmyrah, known as 'Kalpagathara' or Tree of Life, not only signifies 800 uses for humankind but also offers scope to the farming community by integrated approach through intercropping with vegetables with a sustainable and lucrative additional income source. Palmyrah trees, as the main crop, provide optimal photosynthetic photon flux density, which is crucial for developing vegetables in intercropping systems. Intercropping of vegetables in Palmyrah significantly enhances post-harvest soil nutrient status. (20) Studied taro as an intercrop with Palmyrah and found that plant density correlated positively with leaf yield, achieving a benefit-cost ratio of 1:6.56 for Colocasia. The highest Colocasia yield occurred with 41 Palmyrah trees/plot. (1) Using various tree densities, They investigated intercropping groundnut with Palmyra trees. They determined that Palmyrah trees at a density of up to 567 trees/ha provided optimal photosynthetic photon flux density for groundnut growth and development in intercropping systems.

The highest increase in plant height and number of branches are the results of the interaction between the various treatments in tomato under Palmyrah as foliar spray of 3 % Panchagavya obtained intercrop because it might be linked to enhanced cell development, protein synthesis and absorption of easily obtained nutrients, particularly nitrogen. Furthermore, the presence of helpful micronutrients in Panchagavya combined with critical macronutrients like potassium (K), phosphorus (P) and nitrogen (N) may improve the production of growth-enhancing hormones and chlorophyll production will result in better photosynthesis and increased plant height (15). The tallest plants were achieved by assimilating nutrients at the right time. This resulted from applying the required nutrients, leading to taller plants compared to all other treatments. Panchagavya (3 %) is followed by PPFM (1 %) for all tomato growth, yield and quality parameters. The enhanced plant growth is due to the ability of the strains to produce spores, colonizing the rhizosphere of tomato crops, thereby improving their resilience under stressful conditions. It also demonstrated its opportunistic nature and survival under challenging environmental conditions. Applying the recommended dose of fertilizer along with Panchagavya (3 %) foliar spray increases plant height due to increased protein synthesis and all growth in baby corn (21).

Research indicates that the number of branches per plant increases when auxin (IAA) is present in Panchagavya (22). This phenomenon is explained by stimulating cell division and elongation in the auxillary buds, encouraging okra development. Gibberellin and IAA in Panchagavya cause leaves to expand, potentially altering the leaf area index and producing larger leaves, as shown in legumes and vegetables (23). Panchagavya comprises a high microbial load of fermented organic manure and beneficial microorganisms that boost auxin and gibberellins synthesis. Additionally, it found that a 3 %Panchagavya spray led to a corresponding rise in plant height in tomato cultivar cv. Arka Rahshak (24). Similarly, the 3 %Panchagavya spray on brinjal increased plant height and the number of branches(25). *Abelmoschus esculentus* cv. Arka Anamika showed a comparable outcome (26, 27).

Florigen hormone and auxin are present in Panchagavya, which promotes early flowering, helps produce more flowers, reduces flower drop and increases fruit set, which results in a higher number of fruits per plant (28). Higher production and movement of photosynthates may have resulted in increased plant height and number of branches, directly affecting the increased photosynthetic area and the formation of more fruits with better yield (25). A comparable result was noted in tomato (29). It was reported that the growth and yield properties of chilli cv. Kuchinda was enhanced by 3 % Panchagavya spray (24, 26, 30).There was a significant increase in the concentration of chlorophyll a, b and total chlorophyll content in the plants treated with 3 % Panchagavya in tomatoes. This could be because fermented Panchagavya contains high micronutrients and is readily available to plants such as N, P, K and S, which helps produce chlorophyll in leaves.

Additionally, it contains silica (1.5 %) and calcium (0.4 %), which increase protein content and photosynthetic activity and are essential for chlorophyll synthesis. Similar results were observed in brinjal as well (25, 31). Applying RDF along with Panchagavya (3 %) increases photosynthetic pigments such as chlorophyll a, b and total chlorophyll. This, in turn, produces larger leaves and a denser canopy, enhancing photosynthetic activity (26). This finding is consistent with the results reported in (32, 33).

The foliar spray of Panchagavya (3 %) combined with the recommended dose of fertilizer resulted in a significant increase in yield. This is attributed to coconut water in Panchagavya, which contains kinetin, which enhances biomass and yield. The foliar spray of Panchgavya improved all yield and quality parameters, possibly due to the quicker absorption of nutrients like urea present in Panchagavya through the leaf cuticle. This may be due to an adequate supply of nutrients at all stages of crop growth and the presence of growth regulators in Panchagavya. When Panchagavya (3 %) is used along with RDF, it has been reported to lead to better photosynthetic activity and a more extensive root system. This allows for better extraction of nutrients from the soil, which was readily available to the crop, leading to an increase in yield and its components (34).

Research indicates panchagavya (3 %) spray, which led to increased production, weight of a single fruit and number of fruits per plant in bitter gourd(35). Along with the recommended dosage of fertilizer for baby corn, the yield components like the number of cobs per plant, cob length and cob width were increased in Panchagavya (3 %) spray (36). The weight of a single fruit, the number of fruits and the yield were increased in Panchagavya (3 %) along with the recommended dose of fertilizer (37). These organic sources also have a high concentration of macro and micronutrients, including nitrogen, which boosts microbial activity and produces a high yield (38, 39).The age of rubber trees and cultivation practices significantly impact various parameters of Birds' eye chilli (BEC) production. They calculated the capsaicin content, oleoresin content and fresh and dry weight of 100 fruits. BEC plants can be intercropped under rubber plantations for up to three years after establishment without compromising yield or quality (40).

Conclusion

The present research was carried out to study the effect of biostimulants on growth, yield and quality parameters in Tomato (PKM -1) as intercrop under Palmyrah. The growth, yield and quality parameters were increased by the foliar spray of Panchagavya (3 %) followed by PPFM (1 %). It might be concluded that the assimilation of nutrients by applying required nutrients at the right time has major nutrients like N, P and K and minor nutrients along with growth hormones like auxin and gibberellins, which enhances cell division and elongation. This also increases the photosynthesis activity, increasing the crops' source and sink activity. It was an eco-friendly method that was less expensive and had no side effects. It increases the yield and gives additional income to the farmers who utilize the interspaces. It is concluded that Tomato (PKM-1), when grown as an intercrop under Palmyrah plantation along with a foliar spray of 3 % Panchagavya, increases the growth, yield and quality characters. It generates additional income for the farmers of Thoothukudi districts by utilising the interspaces between the Palmyrah planting.

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Authors' contributions

All the authors contributed equally to executing the research idea, designing the experiment, providing laboratory facilities for analysis, supervising the study and interpreting the data. They also revised and corrected the final manuscript.

Compliance with ethical standards

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References

1. Immanuel RR, Rao GB. Production potential of groundnut under palmyra (*Borassus flabellifer*) based agroforestry system in coastal red soils of Tamil Nadu. Crop Res. 2021;56(3and4):105–10.DOI: 10.31830/2454-1761.2021.017
2. Vengaiah PC, Kaleemullah S, Madhava M, Mani A, Sreekanth B. Some physical properties of palmyrah palm (*Borassus flabellifer* L.) fruits. CurrJ App Sci Technol. 2021 18;40(24):18-25. https://doi.org/10.9734/cjast/2021/v40i2431498
3. Krishnaveni TR, Arunachalam R, Chandrakumar M, Parthasarathi G, Nisha R. Potential review on palmyra (*Borassus flabellifer* L.). Adv in Res. 2020 Aug 4;21(9):29–40. https://doi.org/10.9734/air/2020/v21i930229
4. Aman A, Sengupta S, Prasad M, Sinha S, Kumari S. Evaluation of the fruit characteristics of some accession of palmyrah palm grown in Bhagalpur district of Bihar. J of Pharma and Phytochem. 2018;7(3):459–61.
5. Nandhini U, Somasundaram E. Intercropping-A substantial component in sustainable organic agriculture. Ind J Pure App Biosci. 2020;8(2):133–43. https://doi.org/10.18782/2582-2845.8007
6. Babar MA, Arif M, Kashif M, Hanif M, Hayat M, Daud M. Effects of intercropping on growth and yield of radish inter cropped with turnip and spinach under clmatic conditions of quetta. Pak J of Biotech. 2021 Dec 29;18(3-4):57–61. https://doi.org/10.34016/pjbt.2021.18.2-3.57
7. Rick CM. Controlled introgression of chromosomes of *Solanum pennellii* into *Lycopersicon esculentum*: segregation and recombination. Genetics. 1969 Aug;62(4):753. https://doi.org/10.1093/genetics/62.4.753
8. Purushothaman J, Saraswathi T, Kalaimagal T, Swarnapriya R, Karthikeyan M, Anitha A. Selection of tomato (*Solanum lycopersicum* L.) lines for fresh and processing market through multivariate analysis. Electronic J of Plant Breed. 2022 Sep 30;13(3):940–46. https://doi.org/10.37992/2022.1303.123
9. Latha MR, Nadanassababady T. Foliar nutrition in crops–A review. Agri Rev. 2003;24(3):229–34.
10. Farzane A, Nemati H, Shoor M, Ansari H. Antioxidant enzyme and plant productivity changes in field-grown tomato under drought stress conditions using exogenous putrescine. J of Plant Physio and Breed. 2020 Jun 1;10(1):29–40.
11. Ashraf MA, Rasheed R, Rizwan M, Hussain I, Aslam R, Qureshi FF, et al. Effect of exogenous taurine on pea (*Pisum sativum* L.) plants under salinity and iron deficiency stress. Environ Res. 2023 Apr 15;223:115448. https://doi.org/10.1016/j.envres.2023.115448
12. Sivakumar R, Chandrasekaran P, Nithila S. Effect of PPFM and PGRs on root characters, TDMP, yield and quality of tomato (*Solanum lycopersicum)* under drought. Int J Curr Microbiol Appl Sci. 2018;7 (3):2046–54. https://doi.org/10.20546/ijcmas.2018.703.240
13. Shanthi N, Al-Huqail AA, Perveen K, Vaidya G, Bhaskar K, Khan F, Alfagham A. Drought stress alleviation through nutrient management in *Cyamopsis tetrogonoloba* L. J of King Saud University Sci. 2023 Oct 1;35(7):102842. https://doi.org/10.1016/j.jksus.2023.102842
14. Arnon DI. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. Plant Physio. 1949 Jan;24 (1):1. https://doi.org/10.1104pp.24.1.1
15. Vignesh S, Somasundaram E, Sangeetha SP, Manoranjitham SK. Influence of organic nutrient sources on growth and yield of green chilli (*Capsicum annuum* L.).The Pharma innov J. 2022; 11 (8);707–10. https://doi.org/10.22271/tpi.2022.v11.i8i.14748
16. Cunniff P, Washington D. Official methods of analysis of AOAC International. J AOAC Int. 1997;80(6):127A. https://doi.org/10.1093/jaoac/80.6.127A
17. Ranganna S. Handbook of analysis and quality control for fruit and vegetable products. New Delhi: Tata McGraw-Hill Education; 1986.
18. Mercado Jr AR, Arcinal GA, Duque C, Palada MC, Reyes MR. Vegetable-agroforestry (VAF) system: Understanding vegetable-tree interaction is a key to successful farming enterprise. World Moscat: Agroforestry Centre Claveria Research Site; 2008. http://hdl.handle.net/10919/68514
19. Colmenares OM, Brindis RC, Verduzco CV, Grajales MP, Gómez MU. Horticultural agroforestry systems recommended for climate change adaptation: a review. Agri Rev. 2020;41(1):14–24. https://doi.org/10.18805/ag.R-133
20. Kazi AA, Tandel MB, Pathak JG, Prajapati DH. Potentiality of colocasia intercrop under naturally occurring palmyra palm (*Borassus flabellifer* L.). J of Tree Sci. 2017;36(1):58–61. https://doi.org/10.5958/2455-7129.2017.00008.5
21. Loganathan V. Influence of Panchagavya foliar spray on the growth attributes and yield of baby corn (*Zea mays*) cv. COBC 1. J of App and Nat Sci. 2014 Dec 1;6(2):397–401. https://doi.org/10.31018/jans.v6i2.434
22. Prathima K, Singh D. Effect of panchagavya on growth, yield and quality of tomato (*Lycopersicon esculentum* L.). Inter J of Plant and Soil Sci. 2022 Aug 6;34(22):410–15. https://doi.org/10.9734/IJPSS/2022/v34i2231405
23. Natarajan K. Panchagavya- a manual. Mapusa, Goa: Other India Press; 2002.
24. Panda DE, Padhiary AK, Mondal SA. Effect of panchagavya and jeevamrit on growth and yield of tomato (*Solanum lycopersicum* L). Annal of Plant and Soil Res. 2020;22(1):80–85.
25. Swarnam TP, Velmurugan A, Jaisankar I, Roy N. Effect of foliar application of panchagavya on yield and quality characteristics of eggplant (*Solanum melongena* L.). Adv in life Sci. 2016;5 (7):2636–39.
26. Rakesh S, Poonguzhali S, Saranya B, Suguna S, Jothibasu K. Effect of panchagavya on growth and yield of *Abelmoschus esculentus* cv. Arka Anamika. Inter J of Curr Microbio and App Sci. 2017;6 (9):3090–97. https://doi.org/10.20546/ijcmas.2017.609.380
27. Arivazhagan E, Kandasamy R, Maniram S. Influence of organic inputs on the growth, yield and quality of tomato (*Solanum lycopersicum* L.) cv. SIVAM. Annal of Plant and Soil Res. 2019;4:367–70.
28. Behera SR, Pandey R, Golui K, Sahoo S, Jakhwal R, Pal R. Application of panchagavya, a cow-based liquid formulation, as a lever for sustainable and enhanced vegetable crop production: A review. Inter J of Environ and Climate Change. 2024 May 18;14 (5):214–32. https://doi.org/10.9734/ijecc/2024/v14i54183
29. Parmar MN, Patel SY, Pandey AK. Effect of organic spray on growth parameters of tomato (*Solanum lycopersicum* L.) cv. GT 2 under south Gujarat condition. Inter J of Creative Res Thoughts. 2020;8(5):3970–74.
30. Swain SS, Sachu SG, Mishra N. Effect of panchagavya on growth and yield of chilli (*Capsicum annum* L.) cv Kuchinda local. The Green Farm. 2015;6(2):338–40.
31. Kumawat N, Kumar R, Sharma OP. Nutrient uptake and yield of mungbean [*Vigna radiata* (L.) Wilczek] as influenced by organic manures, PSB and phosphorus fertilization. Environ Ecol. 2009;27(4B):2002–05.
32. Somasundram E, Sankaran N, Meena S, Thiyagarajan T, Chandaragiri K, Panneerselvam. response of greengram to varied levels of panchagavya (organic nutrition) foliar spray. Mad AgricJ.2007;90:169–72.
33. Tharmaraj K, Ganesh P, Kumar RS, Anandan A, Kolanjinathan K. A Critical review on panchagavya - A boon plant growth. Int J Pharm Biol Arch. 2011;2(6):1611–14. http://www.ijpba.info/ijpba/index.php/ijpba/article/view/471

34. Vimalendran L, Wahab K. Effect of foliar spray of panchagavya on yield attributes, yield and economics of baby corn. J of Agrono. 2013 Apr 1;12(2):109–12. http://doi.org/10.3923/ja.2013.109.112

35. Gajjela S, Chatterjee R. Effect of foliar application of panchagavya and vermiwash on yield and quality of bitter gourd (*Momordica charantia* L.). Inter J of Chem Stud. 2019;7 (3):218–24.

36. Rohith MS, Sharma R, Singh SK. Integration of panchagavya, neemcake and vermicompost improves the quality of chilli production. J of App Horti. 2021 May 1;23(2):212–18. https://doi.org/10.37855/jah.2021.v23i02.39

37. Lallawmkima I, Singh SK, Sharma M. Application of azotobacter, vesicular arbuscular mycorrhiza and phosphate solubilizing bacteria for potato cultivation in Central Plain Zone (Pb-3) of Punjab. J of Environ Biol. 2018 Nov 1;39(6):985–89. http://doi.org/10.22438/jeb/39/6/mrn-463

38. Madhukumar V, Seenappa C, Lalitha BS, Sharanappa, Sanjay MT. Effect of organic farming practices on productivity, quality and economics of chilli hybrids in central dry zone of Karnataka, India. Inter J of Curr Microbio and App Sci. 2018;7(2):2877–85. https://doi.org/10.20546/ijcmas.2018.702.351

39. Kannur S, Patil SJ, Inamati SS. Influence of age and practices on rubber and nutrient management of intercrop on bird's eye chilli under agroforestry system. Ind J of Agroforestry. 2022;24 (1). https://epubs.icar.org.in/index.php/IJA/article/view/125569

40. Noman MA, Sahel MO, Ahmed F, Wadud MA. Performance of drumstick-chilli based agroforestry practice in charland ecosystem. J Agrofor Environ. 2018;12(1):73–76.