RESEARCH ARTICLE

Effect of Different Sources of Nutrients on Productivity, Profitability and Quality of Tomato (*Solanum lycopersicum* L.)

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ABSTRACT

The present study aimed to evaluate the efficacy of various sources of nutrients on the growth, quality, yield and economics of tomato (*Solanum lycopersicum* L). There were six nutrient management practices consisting of organic, inorganic, and combined sources of nutrients evaluated in randomized block design with five replications. Among the practices, the state recommended nutrient management practice (Farm yard manure (FYM) @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + Recommended dose of fertilizers (RDF)) showed maximum plant height (88.7), number of primary and secondary branches per plant (49.8), number of fruits per plant (11.6) and yield per hectare (25,794 kg). Whereas, the organic nutrient management (50 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + seedling treatment with Beejamrit + Ghanajeevamrit @ 250 kg ha^{-1}, Jeevamrit @ 500 litres ha^{-1} $time^{-1}$ twice a month with irrigation water) resulted in a gross return of Rs. 299288 ha^{-1}, net return of Rs. 183844 ha^{-1} and benefit-cost ratio of 2.59. The quality parameters like ascorbic acid content, total soluble solids (TSS), and titrable acidity were higher under the organic source of nutrients than chemical only or integrated nutrient sources. It can be concluded that the productivity of tomatoes was higher under state-recommended nutrient management practice (FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF). However, , the organic package – 50 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + seedling treatment with Beejamrit + application of Ghanajeevamrit @ 250 kg ha^{-1}, Jeevamrit @ 500 litres ha^{-1} $time^{-1}$ twice a month with irrigation water can be recommended toproduce highly profitable and quality tomato.

Keywords: *Tomato; Organic; Integrated; Nutrient management; Jeevamrith*

INTRODUCTION

Tomato (*Solanum lycopersicum L.)* is one of the most common, widely consumed, and economically important solanaceous vegetable crops. It is third most grown and produced vegetable in India (2nd Adv. Est. 2019-20), next to onion and potato. In Tamil Nadu, it is cultivated over 52,898 ha with an annual production of 15,92,230 metric tons (tnhorticulture.tn.gov.in). Tomatoes are rich in vitamins, minerals, carotenoids, antioxidants, and phenolic compounds. These bioactive compounds have many health benefits, including anti-inflammatory,anti-allergenic, antimicrobial, antithrombotic, and cardio-protective effects (Raiola *et al.,* 2014). The yield and quality of tomatoes have been influenced by various interacting factors. Among them, nutrient management is the most crucial as well as basic factor (Usha *et al*., 2019). Farmers generally use imbalanced inorganic fertilizers and pesticides injudiciously to harvest good yields. Almost all farmers rely on commercial fertilizers for profitable yields thus, less or no build-up of organic matter occurs in the soil (Khan *et al.,* 2017). Continuous use of chemical fertilizers affects the physical properties (Zia *et al*., 2000) and increases the concentration of heavy metals in the soil (Arya and Roy, 2011), which reduces the production potential of soil in the long-term. To maintain sustainability in the production and quality of produce, proper use of nutrient sources, which is easily available, contains adequate level of nutrients, maintains soil fertility and provides favourable environment for higher yield is essential. Judicious use of organic manures facilitates good quality fruits along with maintaining soil fertility (Singh and Sinsinwar, 2006). Soil organic carbon is a crucial factor for realizing higher yield of vegetables; the addition of organic manures like FYM can play a vital role in the sustenance of soil fertility and crop production (Singh *et al.,* 2013). Vermicompost provides excellent soil structure, porosity, aeration, drainage, water retention capacity besides nutrients (Pal *et al.,* 2015). Jeevamrit, a fermented liquid product, contains enormous microbial load (Palekar, 2006), which promotes immense biological activity in the soil and enhances nutrient availability to the crop (Gore and Sreenivasa, 2011). Beejamrit, a source of beneficial microorganisms (Sreenivasa *et al.,* 2009) helpful in plant growth and protects the crop from harmful soil-borne and seed-borne pathogens. Before transplanting, smearing the seeds or dipping the seedlings with Beejamrit controls many diseases that attack the plant from its seedling stage.

Therefore, the present study was undertaken to study the response of tomato to different sources of nutrients in terms of growth, yield, and quality and to identify economically effective nutrient management practices in tomato.

MATERIAL AND METHODS

The present investigation was carried out at Eastern Block Farm, TNAU, Coimbatore, during *Kharif* season of 2020. The experimental site is geographically located at 11°N latitude, 77°E longitude and at an elevation of 427 m above mean sea level, which falls under the western agro-climatic zone of Tamil Nadu. The soil of the experimental field was clay loam in texture having pH of 7.7, EC of 0.82 dSm^{-1} and organic carbon (OC) of 0.8 %. The soil was low in available nitrogen (180 kg ha^{-1}), medium in available phosphorus (18.0 kg ha^{-1}) and high in available potassium (875 kg ha^{-1}). The experiment was laid out in a randomized block design with six treatments (Table 1) and five replications. 25 days old tomato seedlings (variety PKM 1) were transplanted at the spacing of 60 x 45 cm with gross plot size of 5m x 4m. Seedling root dip treatment with beejamrit was given for MP_1-II and MP_3-II treatments. FYM, Vermicompost, Jeevamrit, Ganajeevamrit and urea, single super phosphate, muriate of potash were used as a source of nutrients for organic and inorganic treatments, respectively. The nitrogen content of the manures used were tested in the laboratory and according to the results, the doses of manures were set in such a way that it contains required amount of nitrogen. Jeevamrit was prepared by using following ingredients for 1 hectare; 25 kg desi cow dung + 25 litre desi cow urine + 5 kg jaggery + 5 kg pulse flour + 500 g rhizosphere soil + 500 litre water. The ingredients were mixed in a plastic drum, poured 500 litres of water, and kept under shade by covering with a wet jute bag. The mixture was stirred thrice a day and it was used on 3rd day after preparation. Beejamrit was prepared by using 5 kg desi cow dung + 5 litres desi cow urine + 50 g calcium chloride + 20 litres of water. Cow dung tied in a cloth was dipped in a bucket containing 20 liters of water and kept overnight. Next day, the tied dung was squeezed and dipped in the water. Five litres of cow urine, 500 g of soil and 50 g of calcium chloride were added to this extract and used for seedling treatment. FYM and Ganajeevamrit were applied as basal, vermicompost was applied as top dress (30 DAT), Jeevamrit was given through irrigation, inorganic fertilizers were applied as split in the respective treatments. Azadirachtin (10000 ppm), pheromone traps and yellow sticky traps @ 12 ha^{-1}, *Bacillus* buttermilk solution (10 %) and chemicals recommended in TNAU Crop Production Guide, 2020 were used to manage pests and diseases in the organic and inorganic plots, respectively. Other cultural practices were followed as per the standard recommendations for tomato crops.

Five plants per replication were selected randomly, tagged and biometric observations like plant height, and number of branches per plant were recorded. The total numbers of fruits from five tagged plants were counted in all the pickings and the mean total numbers of fruits plant^{-1} in each treatment were worked out. Ten numbers of fruits from each replication were selected from the third harvest onwards and used for measuring single fruit weight and fruit diameter. Fruit diameter was measured by using carbon fiber composites digital Vernier caliper. The fresh fruit yield from the net plot area was taken to calculate the fruit yield per hectare. Quality parameter like ascorbic acid content was determined by the titration method (Sadasivam and Manickam, 1996), and titrable acidity is estimated by the procedure established by Horwitz (1975). Total soluble solids content (TSS) was measured using the Erma hand refractometer (0-32 °Brix). The economics of the system was worked out considering the overall cost of inputs and price of output. All the results were then analyzed by analysis of variance using Agres software. The level of significance was kept at 5 % (P=0.05).

RESULTS AND DISCUSSION

Growth characters

Plant height

The plants grown under state-recommended management practice (MP_2-II) produced significantly taller plants (88.7 cm) at harvest compared to all other management practices (Figure 1). It was followed by plants grown under 50 % N through organic manures + seedling treatment with Beejamrit + application of Ghanajeevamrith & Jeevamrith (MP_1-II) (80.5 cm) and 25 % N through organic manures + seedling treatment with Beejamrit + 25 % N through inorganic fertilizers + application of Ghanajeevamrith & Jeevamrith (MP_3-I) (77.9 cm) applied management practice. Presence of readily available nutrients from inorganic fertilizers (RDF), growth-enhancing factors from FYM, nitrogen fixers and phosphorus solubilizers from biofertilizers might have helped the plants attain more vigour in MP_2-II. Suriya *et al*., 2020 reported that the conjunctive use of bioinoculants and inorganic fertilizers had resulted in higher plant height at all the stages of tomato plant. Dwivedi *et al.* (2014) reported a significant increase in plant height with the application of Jeevamrit @ 5 % besides positive impacts on physico-chemical properties of soil.

Number of branches

The numbers of branches contribute to yield as they bear leaves, which fix carbon dioxide. The present study revealed that the number of primary and secondary branches per plant was maximum (49.8) in plots applied with state recommended management practice (FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF) (MP_2-II). However, it was statistically on par with plots applied with 50 % N through organic manures + seedling treatment with Beejamrit + application of Ghanajeevamrith & Jeevamrith (47.2 cm), 25 % N through organic manures + 25 % N through inorganic fertilizers + seedling treatment with Beejamrit + Ghanajeevamrit & Jeevamrit (46.8) and 100 % N through organic manures (44.0) (Figure 1). Patil *et al. (2014) reported that the number of branches per plant in pigeon pea increased by applying* FYM @ 20.5 t ha^{-1} + Jeevamrit @ 500 l ha^{-1}. Reddy *et al*., 2018 noted that the integrated application of 100 % NPK + FYM + biofertilizers resulted in a higher number of branches in tomato.

Yield attributing characters

Number of fruits per plant

The number of fruits per plant chiefly determines the yield of any crop under different management practices. In the present study, the highest number of fruits per plant (11.6) was observed in plots treated with FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF (MP_2-II). However, it was on par with plots applied with 50 % of N through organic manures + seedling treatment with Beejamrit + application of Ghanajeevamrith and Jeevamrith (10.8) (Figure 1). Better performance of MP_1-II may be attributed to the application of jeevamrit, which acts as an immense source of beneficial microbes in addition to nutrients required by the plant. Chandrakal *et al.* (2007) reported that FYM + Beejamrit + Jeevamrit applied soils showed higher available NPK and *dehydrogenase* activity. Gore and Sreenivasa, 2011 noticed that the application of Beejamrit and Jeevamrit had resulted in higher root growth and dry matter accumulation in tomatoes.

Fruit weight

The average fruit weight had ranged from 48.4 g to 57.7 g with state recommended management practice (FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF) obtaining higher fruit weight (Table 2). However, it was on par with 50 % N through organic manures + seedling treatment with Beejamrit + application of Ghanajeevamrith & Jeevamrith applied plots. The lowest fruit weight of 48.4 g was recorded in RDF alone applied plots (MP_2-I). The findings show that the supply of nutrients from a wide range of sources had improved the partitioning of photo-assimilates from source to sink (leaf to fruit) and thereby increases fruit weight.

Fruit girth

Statistical data analysis revealed that the fruit girth was significantly influenced by different management practices (Table 2). State recommended management practice (FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF) showed maximum fruit girth with 50.5 mm. However, it was on par with 50 % N through organic manures + seedling treatment with Beejamrit + application of Ghanajeevamrith & Jeevamrith (MP_2-II) and 25 % N through organic manures + 25 % N through inorganic fertilizers + seedling treatment with Beejamrit + application of Ghanajeevamrit & Jeevamrit applied plots (MP_3-I) with fruit girth of 49.1 mm and 48.7 mm respectively. Fruit girth was minimum (45.3 mm) in the recommended dose of fertilizers alone applied plots. The results were in line with Adil Rehman *et al.* (2015), who reported that the growing regimes significantly influenced the fruit diameter of brinjal cultivars.

Quality characters

Titrable acidity

Titrable acidity of tomato varied significantly among the nutrient management practices (Table 2). Fruits received from 50 % N through organic manures + 50% N through ghanajeevamrit and jeevamrit (MP_1-II) applied plots have registered higher titrable acidity (1.32 %) compared to all other practices. It was followed by fruits received from 100 % N through organic manures applied plots (MP_1-I) (1.24 %). The state recommended management practice applied plots registered slightly lower titrable acidity of 0.82 %. Prabakaran and Pichai (2003) reported that application of organic sources of nutrients have resulted in higher titrable acidity in tomato than inorganic sources. Oliveira *et al*. (2013) reported that the tomato fruits from organic farming showed 29 % increased titrable acidity as compared to fruits from conventional farming.

Ascorbic acid

Ascorbic acid plays a major role in determining the flavor of tomatoes. Among the treatments, the fruits received from 100 % organic nutrient management practices (MP_1-I and MP_1-II) have shown significantly higher ascorbic acid content (25.82 mg & 25.56 mg) compared to inorganic or integrated practices (Table 2). It was followed by 75 % organic + 25 % inorganic nutrient management practice (MP_3-II) with 23.46 mg per 100 grams of fruit. A significantly lower ascorbic acid content of 21.85 mg per 100 grams of fruit was noted in fruits received from inorganic nutrient management practice (MP_2-I). Higher ascorbic acid in organics can be hypothesized to higher C uptake from the soil, maintaining more C: N ratio in the plant, which would eventually favor the synthesis of more C-based compounds like ascorbic acid. Sreenivasa *et al.* (2010) observed that seedling root dip with Beejamrit, soil application of jeevamrit (500 l ha^{-1}) and foliar application of panchagavya @ 3 % recorded higher ascorbic acid and capsaicin content in chilli fruits. Muthukumar *et al*. (2019) reported that the tomato variety ‘Sivam’ grown under 100 % organic management have shown higher ascorbic acid content (31.08 mg $100g^{-1}$) than inorganic management (28.27 mg $100g^{-1}$).

Total Soluble Solids

Total soluble solids (TSS) had ranged from 3.88 to 4.23 ^{o}Brix as furnished in Table 2. Higher TSS of 4.23 and 4.16 ^{o}Brix was recorded in fruits obtained from MP_1-I (50 % N through FYM + 50 % N through Vermicompost) & MP_1-II (50 % N through organic manures + seedling treatment with Beejamrit + application of Ghanajeevamrit + Jeevamrit) management practice respectively. The Lowest TSS of 3.88 ^{o}Brix was recorded in MP_2-I (RDF alone) management practice. The results are in line with Sharpe *et al.,*(2020), who observed an 18.9 % higher TSS in organically grown tomatoes thantheir conventional counterparts.

Yield and Economics

Yield

The results indicated that MP_2-II (FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF) is the best management practice in terms of yield (25794 kg ha^{-1}), which was 8, 28, 38, 39 and 46 % higher than MP_1-II, MP_3-II, MP_3-I, MP_1-I, MP_2-I management practice (Table 2). The increase in yield was obvious as it produced a higher number of fruits per plant, higher fruit weight, and girth. Kumar and Sharma (2004) recorded the highest values for yield and soil available nutrients with the application of farmyard manure @ 25 t ha^{-1} + NPK 150:112.5:82.5 kg ha^{-1} in tomatoes. Chumyani *et al.* (2010) reported that the growth and yield parameters of tomatoes were found to be maximum with the application of FYM + RDF + biofertilizers as compared to other treatments. The combinations of FYM + inorganic fertilizers + biofertilizers were also exerted salutary effects in the studies of Patel *et al.* (2010); Yeptho *et al.* (2010); Neerja *et al.* (2010).

The next best management practice in terms of yield was found to be MP_1-II (50 % N through organic manures + seedling treatment with Beejamrit + application of Ghanajeevamrit & Jeevamrit) and MP_3-II (25 % N through organic manures + 25 % N through inorganic fertilizers + seedling treatment with Beejamrit + application of Ghanajeevamrit & Jeevamrit) with tomato yield of 23943 kg and 19896 kg ha^{-1} respectively. The superiority of MP_1-II and MP_3-II could be ascribed to macro and micro nutrients present in the organic manures which gets released during mineralization, stimulated by the microorganisms present in the Jeevamrit as reported by Gore and Sreenivasa (2011) in tomato; Boraiah (2013) in chilli; Patil *et al.* (2014) in pigeon pea.

Economics

Cost of cultivation

The management practices have shown larger variationin the cost of cultivation due to the use of a wider range of inputs. The cost of cultivation (Rs. 1, 45,004 ha^{-1}) was higher in plots treated with 100 % N through organic manures (MP_1-I) as the cost incurred for the production and application of vermicompost and farmyard manure was higher compared to all other inputs. A lower cost of cultivation (Rs. 94,782 ha^{-1}) was observed in the recommended dose of fertilizers alone applied plots (Table 3).

Gross return

Gross return was worked out based on the prevailing market prices. Fruits harvested from 100 % organic management practices (MP_1-I and MP_1-II) were sold at a premium price (25 % higher). The higher gross return (Rs. 2, 99,288 ha^{-1}) was fetched from management practice MP_1-II (50 % N through organic manures + seedling treatment with Beejamrit + application of Ghanajeevamrit & Jeevamrit) which was followed by MP_2-II (state recommended management practice) (Rs. 2,57,939). A lower gross return of Rs. 1, 77,078 was recorded in the recommended dose of fertilizers alone applied plots (Table 3).

Net Return

The management practice MP_1-II (50 % N through organic manures + seedling treatment with Beejamrit + application of Ghanajeevamrit & Jeevamrit) had fetched a higher net return per ha (Rs. 1,83,844) as it produced higher tomato yield and also sold with a premium price. It was followed by plots applied with state recommended management practice (MP_2-II) with a net return of Rs. 1, 45,517 ha^{-1}. A lower net return of Rs. 73,777 ha^{-1} was recorded in MP_3-I (50 % N through organic manures + 50 % N through inorganic fertilizers) management practice (Table 3).

Benefit-Cost Ratio (BCR)

The benefit cost ratio computed from the study revealed that the maximum BCR of 2.59 was associated with the management practice MP_1-II (50 % through organic manures + seedling treatment with Beejamrit + application of Ghanajeevamrit & Jeevamrit). It was followed by MP_2-II (FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF) (2.70). Lower BCR (1.87) was registered in the management practice MP_2-I (RDF alone) (Table 3).

CONCLUSION

Despite the fact that the growth and yield of tomato were higher under state-recommended practice (FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF), the nutrient management - 50% N requirement through organic manures (50 % FYM + 50 % vermicompost) + seedling treatment with Beejamrit + application of Ghanajeevamrit @ 250 kg ha^{-1}, Jeevamrit @ 500 litres $ha^{-1}time^{-1}$ twice a month with irrigation water was recorded to be highly cost-effective as it fetched higher net return in addition to better quality fruits.

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Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Consent for publication

All the authors agreed to publish the content.

Competing interests

There were no conflict of interest in the publication of this content.

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Table 1. Treatments details

MP_1-I	:	50 % N requirement through FYM + 50 % N requirement through Vermicompost
MP_1-II	:	50 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + seedling treatment with Beejamrit + application of Ghanajeevamrit @ 250 kg ha^{-1}, Jeevamrit @ 500 $litres^{-1}$ ha^{-1} time $^{-1}$ twice a month with irrigation water
MP_2-I	:	Recommended Dose of Fertilizers (RDF) alone
MP_2-II	:	State recommendation / Farmer's practice (FYM @ 25 t ha^{-1} + Azophos @ 2kg ha^{-1} + RDF)
MP_3-I	:	50 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + 50% N requirement through inorganic fertilizers
MP_3-II	:	25 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + 25 % N requirement through inorganic fertilizers + seedling treatment with Beejamrit + application of Ghanajeevamrit @ 250 kg ha^{-1}, Jeevamrit @ 500 $litres^{-1}$ ha^{-1} time $^{-1}$ twice a month with irrigation water

MP - Management Practice, RDF - 150:100:50 kg of NPK ha^{-1}

Table 2. Effect of different nutrient management practices on yield and quality characters of brinjal

Treatments	Fruit weight (grams)	Fruit girth (mm)	Fruit yield (Kg ha^{-1})	Titrable acidity (%)	Ascorbic acid (mg 100 g^{-1})	Total Soluble Solids (°Brix)
MP_1-I	51.6	47.1	18611	1.24	25.82	4.23
MP_1-II	56.0	49.1	23943	1.32	25.56	4.16
MP_2-I	45.3	45.3	17708	0.65	21.85	3.44
MP_2-II	57.7	50.5	25794	0.82	22.50	3.92
MP_3-I	48.4	45.9	18534	0.90	22.75	3.88
MP_3-II	52.5	48.7	19896	1.16	23.46	4.08
S Ed	2.28	1.50	391.05	0.03	0.30	0.04
CD (P=0.05)	4.76	3.14	815.72	0.07	0.63	0.08

Table 3. Effect of different nutrient management practices on economics of tomato

Treatments	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
MP1-I: 50 % N requirement through FYM + 50 % N requirement through Vermicompost	145004	232635	87631	1.60
MP_1-II: 50 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + seedling treatment with Beejamrit + application of Ghanajeevamrit @ 250 kg ha^{-1}, Jeevamrit @ 500 $litres^{-1}$ ha^{-1} time $^{-1}$ twice a month with irrigation water	115443	299288	183844	2.59
MP2-II: Recommended Dose of Fertilizers (RDF) alone	94782	177078	82296	1.87
MP2-II: State recommendation / Farmer's practices (FYM @ 25 t ha^{-1} + Azophos @ 2 kg ha^{-1} + RDF)	112422	257939	145517	2.29
MP_3-II: 50 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + 50 % N requirement through inorganic fertilizers	111560	185336	73777	1.66
MP_3-II: 25 % N requirement through organic manures (50 % FYM + 50 % Vermicompost) + 25 % N requirement through inorganic fertilizers + seedling treatment with Beejamrit + application of Ghanajeevamrit @ 250 kg ha^{-1}, Jeevamrit @ 500 $litres^{-1}$ ha^{-1} time $^{-1}$ twice a month with irrigation water	103097	198965	95867	1.93

Data not statistically analysed

Figure 1. Effect of different nutrient management practices on growth and yield characters of tomato