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# Soil properties, tomato (*Solanum lycopersicum*) yield and monetary returns under different nutrient management practices

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ABSTRACT

The experiment was conducted during 2019 and 2020 at research farm of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu to study the effect of different manures proportion along with reduced fertilizers rate application on performance of tomato (*Solanum lycopersicum* L.) yield, produce quality and soil fertility indicators. Experiment was laid out in randomized block design (RBD) comprised of 6 treatments, viz. $T_1$, 100% organic; $T_2$, 75% organic + 3% *Panchagavya* spray + azophos @3 kg; $T_3$, 100% inorganic recommended dose of fertilizer (RDF) alone; $T_4$, State recommendation; $T_5$, 50% organic + 50% inorganic; and $T_6$, 75% organic + 25% inorganic. The results of two years mean showed that the soil quality indicators like SOC (8.12 g/kg), mineral N (266 kg/ha), available P (22.1 kg/ha), exchangeable K (482 kg/ha), microbial biomass carbon (256 mg/kg), dehydrogenase (35.8 µg TPF/g/day), alkaline phosphatase (475 µg PNP/g/soil/h), bacteria (38.4 CFU × $10^6$/g soil), fungi (15.0 CFU × $10^3$/g soil) and actinobacteria population (10.3 CFU × $10^5$/g soil) were better under 75% organic + 25% organic. Tomato yield was at par with 100% organic. On the basis of the above results, the tomato yield can be enhanced by about 99% and 150% in terms of production and monetary efficiency by the adoption of integrated nutrition management (INM) of organic (75%) and inorganic fertilizers (25%). Thus, the results suggest that the 75% organic + 25% inorganic could be adopted to get maximum benefits in terms of yield, fruit quality, soil fertility and fertilizer savings.

**Keywords**: Fertility, Manures, Production efficiency, Soil quality indicators, Tomato

Environmental concerns of chemical farming around the world have resulted in seeking for an alternative farming system which is associated with a major challenge of feeding the burgeoning population. Numerous research reports have highlighted that the productivity of all the crops is declining and the soil health is deteriorated under the enforcement of chemical fertilizers without replenishing the soil with organic matter. Hence, these concerns have been the drivers for developing an alternative nutrient management technique for sustaining the environment quality and yield as well. Of which, integrated nutrient management (INM) is an effective alternative method which relies on the maximum use of organic manures and less or as supplementary use of chemical fertilizers for ensuring the sustainable yield and in addition, INM enhances water infiltration, reduces soil erosion, improves aeration (Smaling 1993). On the other side, practicing of organic farming has exerted many ecological advantages compared to chemical amended farming (Patel *et al*. 2015).

Tomato (*Solanum lycopersicum* L.) is one of the most popular, widely consumed, staple and economically important vegetables in India. It is being an exhaustive crop, highly responsive to applied nutrients. Use of chemical fertilizer alone increase the crop yield in the initial year, but adversely affect the sustainability subsequently. The cost of chemical fertilizers is also increasing day by day. Therefore, to reduce dependence on chemical fertilizers along with sustainable production are vital issues in modern agriculture which can be achieved possible through integrated nutrient supply. Hence, a field study was carried out to evaluate the influence of organic, inorganic and integrated nutrient management practices on performance of tomato yield, produce quality and soil fertility indicators.

## MATERIALS AND METHODS

The experiment was conducted during 2019 and 2020 at the research farm of Tamil Nadu Agricultural University, Coimbatore (11.0168° N, 76.9558° E; at an altitude of 426 m msl), Tamil Nadu. The annual average rainfall of 950 mm was received in 42 rainy days. The mean maximum and minimum temperatures were 32.9 and 24.6ºC, respectively. The soil type at the site was predominantly sandy clay loam.

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The tomato crop was raised during September 2019 and 2020 in the same field which had been under cultivation of other crops for the past years. Experiment was laid out in randomized block design (RBD) comprised of 6 treatments, viz. $T_1$, 100% organic (organic manures equivalent to 100% N requirement of the system) [50% farmyard manure (FYM) + 50% vermicompost]; $T_2$, 75% organic (organic manures equivalent to 75% N requirement of the system) + innovative organic practice (3% *Panchagavya* + Azophos @2 kg/ha); $T_3$, 100% inorganic [No organic manures; recommended dose of fertilizer (RDF) alone]; $T_4$, State recommendation/ Farmer's practices (FYM @25 t/ha + Azophos @2 kg/ha + RDF); $T_5$, 50% organic (50% FYM + 50% vermicompost) + 50% inorganic; and $T_6$, 75% organic (50% FYM + 50% vermicompost) + 25% inorganic. Each treatment with 4 plots, each measuring 175 $m^2$ was randomly arranged in the fields. Before raising the tomato, the green manure, Dhaincha (*Sesbania bispinosa*) was raised and incorporated into the field at the time of 50% flowering. The tomato variety PKM 1 seedlings were transplanted at a spacing of 45 cm × 30 cm. The crop was irrigated as required depending on the moisture status of the soil and requirement of plants. Intercultural operations like regular weeding and plant protection measures were followed as per schedule in all the treatments.

*Nutrient management practices*: The different nutrient management adopted for the investigation were: $T_1$, FYM @10 t/ha as basal, vermicompost @5 t/ha as top-dressing [(30 days after transplanting (DAT)]; $T_2$, FYM @7.5 t/ha as basal, vermicompost @4 t/ha as top-dressing (30 DAT), Panchagavya foliar spray @3% + Azophos @2 kg/ha; $T_3$, RDF: 150:100:50 kg NPK/ha, Urea-325 kg/ha (50% as basal + 50% as top-dressing), Single superphosphate (SSP)-625 kg/ha and Muriate of Potash (MOP)-80 kg/ha as basal; $T_4$, RDF: 150:100:50 kg NPK/ha, Urea-325 kg/ha (50% as basal + 50% as top-dressing), SSP-625 kg/ha and MOP-80 kg/ha as basal + FYM @25 t/ha; $T_5$, FYM @5 t/ha as basal, vermicompost @2.25 t/ha as top-dressing (30 DAT), Urea-160 kg/ha (50% as basal + 50% as top-dressing), SSP-300 kg/ha and MOP-40 kg/ha as basal; $T_6$, FYM @7.5 t/ha as basal, vermicompost @4 t/ha as top-dressing (30 DAT), Urea-80 kg/ha (50% as basal + 50% as top-dressing), SSP-156 kg/ha and MOP-20 kg/ha as basal.

*Soil sampling and analysis*: Soils were collected from different treatments (0–30 cm depth) immediately after harvest of tomato adopting random sampling technique during both the years. Soil *p*H and EC were determined using a soil suspension of 1:2.5 ratio. The samples were oven dried at 105°C for 24 h and bulk density was calculated based on oven dry weight (Blake and Hartge 1986). Solid organic carbon (Walkley and Black 1934), Soil mineralizable or available N (Waring and Bremner 1964), available P (Olsen 1954), available K (Stanford and English 1949), soil microbial biomass carbon (Vance *et al*. 1987), dehydrogenase activity (Tabatabai 1994) and Alkaline phosphatase activity (Tabatabai and Bremner 1969) were also calculated. Collected soil samples were enumerated for total culturable aerobic bacteria (TCB), fungi (TCF), and actinobacteria (ACT) using the serial dilution technique in soil extract agar medium, potato dextrose agar medium, and Kenknight's agar medium, respectively, following dilution plating viable count method (Weaver *et al*. 1994). One gram of soil from each sample was aseptically weighed, transferred to 100 ml of sterile distilled water to get $10^{-2}$ dilution, after thorough shaking, 1 ml of dilution was transferred to 9 ml water blank to get $10^{-3}$ dilution. Likewise, the sample was diluted serially with 9 ml water blanks until the appropriate dilution was obtained.

*Assessment of productivity, quality and economic analysis*: Fruits were harvested manually 110 days after transplanting. The economic analysis was done using fruit yield, cost of cultivation incurred and prevailing market price of tomato grown organically and conventionally. The production efficiency (PE) (kg/ha/day) and monetary efficiency (ME) (₹/ha/day) of tomato were computed (Kumar *et al*. 2015).

*Statistical analyses*: Data were statistical analyzed using IBM SPSS Statistics 25 for Windows (IBM, Inc., Armonk, NY, USA) and results were expressed as mean values with standard error (SE) of four replicated analyses. A one-way ANOVA was employed for the analysis. Upon observing statistical significance, we calculated the critical difference (CD) at the 0.05 level of probability for comparison.

## RESULTS AND DISCUSSION

*Soil physio-chemical indicators*: It is important to note that the soil reaction under the studied area was alkaline in nature. Due to the continuous cropping, fertilizer and manure application, there was a fluctuation in the range of *p*H. From the result, it was observed that the soil *p*H ranges from 8.21–8.46 (Table 1).

Application FYM and vermicompost (VC) by the treatment $T_1$, have resulted in the compaction reduction of 20.5% bulk density. This might be due to the higher SOM content which improves the aggregate formation resulting in decreased bulk density. Judicious application of organic manure (75%) in combination with inorganic sources (25%) could have resulted in decreased bulk density (1.25 Mg/$m^3$) and was statistically equivalent to the treatment $T_1$ receiving 100 organics. These results are in line with the findings of Brar *et al.* (2013) who found the decreased bulk density by the application of balanced fertilizer treatments (inorganic with FYM).

Comparing all the treatments, higher availability of nutrients (N, P, K) was obtained under treatment $T_6$ (75% organic + 25% inorganic) than applying organic ($T_1$) and inorganic alone ($T_3$) (Table 1). The incorporation of FYM and vermicompost along with readily fertilizers might have reduced the loss of nitrogen and increases the microbial activity, thus increases the availability of N in the soil (Ge *et al.* 2018). Similarly, the highest available P was recorded for treatment comprising 75% organic + 25% inorganic ($T_6$) followed by $T_1$. Integration of organic and mineral nutrients might have helped in the solubilization of native P and

Table 1 Effect of different nutrient management practices of tomato on physical, chemical and biological indicators of soils (Pooled mean of two years)

| Indicator | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ |
|---|---|---|---|---|---|---|
| Soil reaction | $8.27 \pm 0.53^{ns}$ | $8.33 \pm 0.69^{ns}$ | $8.46 \pm 0.57^{ns}$ | $8.31 \pm 0.39^{ns}$ | $8.38 \pm 0.48^{ns}$ | $8.29 \pm 0.23^{ns}$ |
| Bulk density ($mg/m^3$) | $1.23 \pm 0.06^{b}$ | $1.34 \pm 0.11^{ab}$ | $1.56 \pm 0.10^{a}$ | $1.44 \pm 0.07^{ab}$ | $1.51 \pm 0.09^{a}$ | $1.25 \pm 0.03^{b}$ |
| Solid organic carbon (g/kg) | $8.56 \pm 0.56^{a}$ | $6.69 \pm 0.55^{b}$ | $5.30 \pm 0.35^{c}$ | $5.09 \pm 0.24^{c}$ | $6.19 \pm 0.36^{bc}$ | $8.12 \pm 0.22^{a}$ |
| Mineral N (kg/ha) | $219 \pm 10.1^{bc}$ | $245 \pm 20.2^{abc}$ | $213 \pm 10.0^{c}$ | $232 \pm 9.30^{abc}$ | $250 \pm 10.3^{ab}$ | $266 \pm 10.9^{a}$ |
| Available P (kg/ha) | $19.1 \pm 1.21^{b}$ | $22.4 \pm 1.85^{ab}$ | $20.0 \pm 1.34^{b}$ | $25.0 \pm 1.16^{a}$ | $20.0 \pm 1.15^{b}$ | $22.1 \pm 0.61^{ab}$ |
| Exchangeable K (kg/ha) | $463 \pm 15.7^{ab}$ | $439 \pm 36.3^{abc}$ | $383 \pm 21.0^{c}$ | $414 \pm 16.2^{bc}$ | $424 \pm 25.5^{abc}$ | $482 \pm 19.4^{a}$ |
| Microbial biomass carbon (mg/kg) | $263 \pm 13.9^{a}$ | $221 \pm 18.3^{b}$ | $211 \pm 9.63^{b}$ | $230 \pm 10.7^{ab}$ | $229 \pm 11.1^{ab}$ | $256 \pm 8.10^{a}$ |
| Dehydrogenase (µg TPF/g/day) | $38.5 \pm 2.45^{a}$ | $25.5 \pm 2.11^{d}$ | $23.6 \pm 1.59^{d}$ | $28.2 \pm 1.33^{cd}$ | $31.9 \pm 1.83^{bc}$ | $35.8 \pm 1.00^{ab}$ |
| Alkaline phosphatase (µg PNP/g soil/h) | $500 \pm 31.8^{a}$ | $451 \pm 37.3^{a}$ | $245 \pm 16.4^{b}$ | $320 \pm 14.9^{b}$ | $430 \pm 24.7^{a}$ | $475 \pm 13.2^{a}$ |
| Bacterial population (CFU × $10^6$/g soil) | $39.6 \pm 2.51^{a}$ | $35.7 \pm 2.95^{ab}$ | $24.9 \pm 1.67^{c}$ | $29.7 \pm 1.39^{bc}$ | $37.3 \pm 2.15^{a}$ | $38.4 \pm 1.07^{a}$ |
| Fungal population (CFU × $10^3$/g soil) | $15.8 \pm 1.00^{a}$ | $11.7 \pm 0.96^{c}$ | $9.2 \pm 0.62^{d}$ | $11.7 \pm 0.54^{c}$ | $12.8 \pm 0.74^{bc}$ | $15.0 \pm 0.42^{ab}$ |
| Actinobacteria population (CFU × $10^5$/g soil) | $10.2 \pm 0.65^{a}$ | $8.2 \pm 0.68^{bc}$ | $9.9 \pm 0.66^{a}$ | $9.7 \pm 0.45^{ab}$ | $7.9 \pm 0.46^{c}$ | $10.3 \pm 0.29^{a}$ |

Data are the mean values of four replicates with ± standard error. Means followed by the same letter within each row are not significantly different at 5% level. Ns, Non-significant.

Treatments details are given under Materials and Methods.

making it in an available form by the action of microbes or organic acids as reported by Azarmi *et al*. (2008).

In parallel to the P, available K was also higher in the plots receiving 75% organic + 25% inorganic compared to all other treatments. Organic colloidal complex released from FYM and vermicompost might have had a greater cation exchange sites, that could contribute to the attraction of the K from non-exchangeable pool and applied K, and make into readily available form (Singh *et al*. 2007).

*Biological indicators*: Plots received 100% of organic manures ($T_1$) were observed to have the highest organic carbon (8.5 g/kg) which was statistically equivalent to 75% organic + 25% inorganic ($T_6$) (Table 1). Applied manures and the previously cultivated crops could have added more organic matter to the soil, which showed higher SOC content and the same positive effect, was also highlighted by Bharani *et al*. (2018). The results showed that, continuous cultivation of 100% fertilizers enforced soil ($T_3$) can accelerate depletion of the soil organic carbon without the addition of carbon biomass in soil and reduced the SOC accumulation (Hamer *et al*. 2009).

Higher microbial biomass carbon (MBC) was obtained from the soil receiving 100% nutrients through organics, which was comparable to 75% organic + 25% inorganic ($T_6$). Higher MBC could be ascribed due to the source of carbon by the supply of FYM and vermicompost for microbial build up and in turn biomass carbon. In addition, it could be due to several factors, such as higher moisture content, greater soil aggregation and higher SOC content. 100% inorganically maintained soil $T_3$ recorded lower MBC might be due to no addition of organic biomass and manures and by the toxic effect of chemicals amended. This was supported by the findings of Kaur *et al.* (2005).

The microbial population in the treatment $T_1$ always maintained the highest level among all the other treatments, while the $T_6$ treatment was more frequently found to have similarity with $T_1$ (Table 2). Higher SOM available in the treatment $T_1$ (100% organic) and $T_6$ (75% organic + 25% inorganic) could have increased the soil carbohydrate, which provides the energy source for soil microbes thus increased microbial population. Additionally, the numbers of total bacteria were higher in the FYM applied soils which are in line with the report of Jarvan *et al.* (2014). The lowest count was observed in treatment $T_3$ (only NPK through fertilizers) might be due to the no addition of organic manures for the growth of microbes.

The soil dehydrogenase activity (DHA) across the treatments varied between 23.6–38.2 µg TPF/g soil/day (Table 1). Hence, application of balanced fertilizer and manure resulted in the higher soil organic matter which was in turn reflected in the higher enzymatic activity. In the present study, higher dehydrogenase activity was observed in soil receiving 75% organic + 25% inorganic ($T_6$) and lower dehydrogenase activity was observed in the treatment 100% inorganic through RDF ($T_3$). This might be due to the fact the dehydrogenase was highly sensitive to the inhibitory effects associated with large fertilizer additions and the increased activity by the influence of applied organic manure in treatment $T_6$ (75% organic + 25% inorganic). Kanchikerimath and Singh (2001) reported

Table 2 Effect of different nutrient management practices on tomato yield and profitability (Pooled mean of two years)

| Treatment | Fruit yield (t/ha) | Total cost of cultivation (₹/ha) | Gross return (₹/ha) | Net return (₹/ha) | Benefit cost ratio | Production efficiency (kg/ha/day) | Monetary efficiency (₹/ha/day) |
|---|---|---|---|---|---|---|---|
| $T_1$ | 8.7 ± 0.56$^{cd}$ | 77715 | 108413 | 30698 | 1.40 | 64.2 ± 4.46$^{bc}$ | 227 ± 13.6$^{c}$ |
| $T_2$ | 10.3 ± 1.05$^{bc}$ | 66564 | 129150 | 62586 | 1.94 | 76.5 ± 6.31$^{b}$ | 464 ± 38.2$^{b}$ |
| $T_3$ | 7.0 ± 0.69$^{d}$ | 36733 | 70410 | 33677 | 1.92 | 52.2 ± 3.59$^{c}$ | 250 ± 16.8$^{c}$ |
| $T_4$ | 7.6 ± 0.35$^{d}$ | 49333 | 76390 | 27057 | 1.55 | 56.6 ± 2.65$^{c}$ | 200 ± 9.42$^{c}$ |
| $T_5$ | 12.7 ± 1.32$^{ab}$ | 48891 | 130270 | 81379 | 2.66 | 96.5 ± 5.61$^{a}$ | 603 ± 35.1$^{a}$ |
| $T_6$ | 13.9 ± 0.01$^{a}$ | 54969 | 139140 | 84171 | 2.53 | 103.1 ± 3.05$^{a}$ | 624 ± 16.4$^{a}$ |

Data are the mean values of four replicates with ±standard error. Means followed by the same letter within each column are not significantly different at 5% level.

Treatments details are given under Materials and Methods.

that the greatest reduction of dehydrogenase activity was observed in the treatment receiving inorganic fertilization. Similarly, alkaline phoshphatase activity was followed the trend of DHA. On the other hand, the lowest activity of enzymes was observed in the treatment received 100% RDF fertilizers.

*Fruit yield*: The results of the study indicate that the fruit yield from treatment with 75% organic + 25% inorganic ($T_6$) was significantly higher (13.9 t/ha) and statistically equivalent to the yield obtained from the treatment 50% organic + 50% inorganic ($T_5$) ($P$<0.05) (Table 2). Enhancement in fruit yields could be due to partial to large increases in soil microbial biomass after application of vermicompost and FYM, leading to the availability of more nutrients, reduce the deficiency of trace elements, thus increased the sink development (Batabyal *et al.* 2016). There had been considerable reduction in yield under inorganic system ($T_4$). The major soil health parameters attributed to the lower yield in treatment $T_4$ were increased bulk density, decreased SOM content, low microbial and enzyme activity, and essentially the decreased availability of nutrients. Furthermore, the slow release of nutrients from FYM synchronizes crop nutrient demand at critical crop growth stages (Paramesh *et al*. 2014). It is well known that FYM improves soil microbial activity, thereby increasing soil nutrient availability and crop nutrient uptake (13,36). As like yield, production efficiency was also significantly higher in treatment $T_6$ which was statistically comparable with $T_5$. The soil properties improved under treatment $T_6$ have resulted in better production efficiency.

*Monetary benefits*: It is imperative to note that the cost of production was higher in the treatment receiving 100% organic and treatment $T_6$ (INM practice of 75% organic + 25% inorganic) obtained 41% reduction in cost of cultivation of tomato compared to 100% organic (Table 2). The net income of the INM practice 75% organic + 25% inorganic was ₹1, 39,140 followed by INM practice 50% organic + 50% inorganic. This might be due to lower cost of production and higher yield. The lowest benefit: cost ratio under 100% organic was mainly due to higher cost of cultivation and lowest gross return owing to the low yield of tomato. The high cost might be due to the purchase of FYM and VC externally and labour cost for weeding. The data on monetary efficiency indices clearly indicate that the INM practice 75% organic + 25% inorganic of tomato fetches about 103 ₹/ha/day where 100% organic fetched 64 ₹/ha/day. The results apparently indicated that the combined use of organic (75%) and inorganic (25%) increased the tomato yield and, thereby, resulted in high remuneration besides building up of soil health.

From the results, it is evident that in tomato about 99% and 150% in terms of production and monetary efficiency can be enhanced by the adoption of integrated nutrition management (INM) involving organic (75% equally through FYM and vermicompost) and inorganic NPK fertilizers (25%). However, INM practice 75% as organic + 25% as inorganic was at par with 100% organic in improving the soil organic matter, nutrients, improves soil physical and chemical properties, and stimulate soil biological and enzyme activities. From the results it is also evident that higher production cost exists under 100% organic sources of nutrient supply. Thus, INM is a viable option that can be practiced to achieve desired yield and sustaining the fertility and productivity of soil where 100% organic farming is not feasible.

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