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**Bijaylakhmi Goswami**
Co-Founder and Head,
Research and Development,
Agrithink Services LLP,
Guwahati, Assam, India

**Naseema Rahman**
Jr. Scientist (Horticulture),
AAU – HRS, Kahikuchi,
Guwahati, Assam, India

**Corresponding Author:**
**Bijaylakhmi Goswami**
Co-Founder and Head,
Research and Development,
Agrithink Services LLP,
Guwahati, Assam, India

# Field application of precise IoT based soil testing and fertilizer recommendation system in tomato

## Bijaylakhmi Goswami and Naseema Rahman

### Abstract
Soil fertility management has remained a static affair consisting of a blanket application of plant nutrients irrespective of soil fertility status and specific crop requirements. More often farmers apply the fertilizer of their choice in their own way without considering the importance of soil tests or any scientific basis before deciding upon the quantity and quality of fertilizer. Realizing the huge gap between a Farmer's Fertilizer Practice and the actual requirement of fertilizer based on crop requirement and nutrient status of the farm, an experiment was carried out to test the potential yield and quality enhancement by application of a required amount of nutrients taking tomato as test crop. For this purpose, a precise IoT-based instant and in-situ soil testing system with crop-specific fertilizer requirement decision was used. The present-day concern for hazards due to the use of chemicals was also taken into account. Therefore, the experiment was set up completely under an organic system. The precision of the IoT-based system in recommending crop and site-specific nutrients was reflected in the highly significant yield and quality aspects of tomato grown as per its recommendation.

**Keywords:** Soil fertility, farmer's fertilizer practice, fertilizer recommendation, organic farming, soil testing, tomato

### Introduction
Soil testing is one of the most effective tools for optimum as well as balanced fertilization (Kumar *et al.*, 2013) [18]. To determine the optimum requirement of nutrients, the most dependable approach would be to apply fertilizer doses based on soil test crop response studies (Singh *et al*. 2012) [29]. Soil testing is an indispensable tool for applying the optimum dose of plant nutrients for ensuring sustained fertility of the soil. Adoption of Good Agricultural Practices (GAP) guided with soil test-based crop-specific nutrient operations helps the grower by suggesting meaningful fertilizer practices for crop yield and quality (Satyanarayana *et al*., 2011) [28]. Currently, the shift from chemical to organic sources of nutrients is gaining momentum across the globe. However, the scientific nutrient management of organically cultivated crops may not be as simple as it is sometimes assumed. It may be noted that, unlike inorganic fertilizers, there are no universal norms for the accuracy and uniformity of nutrient contents of organic manures. The different types of manure differ in their nutrient content based on several biotic and abiotic factors (Goswami & Pariyar 2022) [6]. Therefore, employing reliable technology to determine nutrients from organic sources available at hand is imperative for the optimization of crop yield.

Tomato (*Solanum lycopersicon* Mill) is a high-value vegetable crop which is in great demand across the world. While the insufficient amount of nutrients can show deficiency symptoms and influence the yield and quality of tomatoes, a high dose of nutrients such as N can also reduce tomato yield by producing excessive biomass which at times leads to the lodging of the plants. Because tomatoes are unable to recover 100 per cent of applied N, the residual N in the soil can strain through the soil profile and contaminate groundwater, thereby deteriorating water quality and wasting the quantum and cost of fertilizers applied. Also, the excess availability of some nutrients can create a toxic effect (Sainju *et al*. 2003) [27]. Thus, the rate and type of nutrients applied in the form of fertilizers should be determined after assaying the nutrient contents of the soil and the requirement of the crop.

This experiment was laid out by recognising the significance of real-time soil-test values for crop-specific application of plant nutrients for the successful production of tomatoes. The assessment of the results of nutrient application guided by soil test value in real-time over Farmer's Fertilizer Practice was the specific aim of the study.

## Materials and Method

A farmers' participatory field experiment was carried out at 10 different farmers' fields during 2020- 21 in the Central Brahmaputra Valley Zone of Assam. The hypothesis of the study was set as yield and quality of products can be enhanced by the application of need-based crop-based manures and fertilizers instantly recommended by the Soilcare System. Tomato (*Solanum lycopersicon Mill*, var. Pusa Ruby) was taken as the test crop. The study was carried out with two treatments. In the first treatment (T1) Farmer's followed their usual fertilizer Practice (FFP) and in treatment 2 (T2) crop specific need-based fertilizer was applied based on soil test value.

**Determination of soil nutrient status and Dolomite and NPK requirement:** In both the treatments initial soil available N, P, K, pH, E.C., Organic Carbon were analyzed. Agrithink's Smart Soil Fertility Management System (Soilcare) was used to analyse the nutrient status of soil as well as the required amounts of liming material and NPK. Soilcare is an IoT based system designed for instant in-situ soil testing. When the sensor-based system is inserted in the soil sample, it instantly gives the status of different nutrients viz., N, P, K, S, Fe, Mn, Zn, Cu, B available for crop use as well as the measures of OC, pH and EC. The system also instantaneously calculates nutrient required in the sample for the crop of choice.

The soil samples in the experiment were found to be acidic, where pH ranged from 4.6 - 5.6. Organic carbon was also lower (0.32-0.51) in the tested samples. The available Nitrogen was 90 kg ha-1 to 270 kg ha-1, available phosphorus was between 26 – 64 kg ha-1 and available potassium ranged from 180 – 320 kg ha-1 (Table 1). Based on the soil test value and requirement of the test crop, a precise amount of liming material and NPK was calculated by the system (Table 3). In T2, the calculated nutrients were applied using FYM, Neem cake, Dolomite, Rich Fertiplus and Rich Delfan which were again calculated by the instant facility of Soilcare. In FFP (T1) farmers followed their own fertilizer choice and their preferred doses. They applied FYM @ 10 t ha-1, 12.5 t ha-1 and 5 t ha-1 randomly. As per design of the experiment, farmers under T1 also grew their crops using organic inputs.

**Table 1:** Soil physico-chemical properties

| Sl.NO | Av. N (kg/ha) | Av. $P_2O_5$ (kg/ha) | Av. $K_2O$ ( kg/ha) | pH | EC (dS/m) | OC |
|---|---|---|---|---|---|---|
| 1 | 95.00 | 47.00 | 224.00 | 4.60 | 0.04 | 0.33 |
| 2 | 110.00 | 26.00 | 274.00 | 4.90 | 0.03 | 0.34 |
| 3 | 180.00 | 53.00 | 180.00 | 5.10 | 0.05 | 0.37 |
| 4 | 90.00 | 49.00 | 229.00 | 4.70 | 0.05 | 0.33 |
| 5 | 94.00 | 50.00 | 243.00 | 5.40 | 0.04 | 0.51 |
| 6 | 210.00 | 59.00 | 256.00 | 5.20 | 0.08 | 0.44 |
| 7 | 110.00 | 60.00 | 200.00 | 4.90 | 0.03 | 0.40 |
| 8 | 270.00 | 64.00 | 320.00 | 5.40 | 0.02 | 0.42 |
| 9 | 200.00 | 51.00 | 275.00 | 5.50 | 0.03 | 0.32 |
| 10 | 198.00 | 45.00 | 300.00 | 5.60 | 0.04 | 0.46 |

**Table 2:** NPK content of manures (Dry wt. basis) and organic fertilizer applied

| Name | N (%) | P (%) | K (%) |
|---|---|---|---|
| FYM | 0.50 | 0.30 | 0.20 |
| Neem Cake | 4.00 | 1.00 | 1.00 |
| Rich Fertiplus | 4.00 | 3.00 | 3.00 |
| Rich Delfan | 10.80 | 0.00 | 0.00 |

**Table 3:** Application rates of NPK and dolomite.

| Sl. | Farmer's No | N(kg/ha) | | $P_2O_5$(kg/ha) | | $K_2O$(kg/ha) | | Dolomite t/ha |
|---|---|---|---|---|---|---|---|---|
| | | T1 | T2 | T1 | T2 | T1 | T2 | T2 |
| 1 | F1 | 40.00 | 92.50 | 30.00 | 10.10 | 20.00 | 19.60 | 4.58 |
| 2 | F2 | 40.00 | 85.00 | 30.00 | 20.60 | 20.00 | 8.00 | 3.86 |
| 3 | F3 | 20.00 | 50.00 | 15.00 | 7.10 | 10.00 | 41.60 | 3.38 |
| 4 | F4 | 20.00 | 95.00 | 15.00 | 9.10 | 10.00 | 17.10 | 4.34 |
| 5 | F5 | 40.00 | 93.00 | 30.00 | 8.60 | 20.00 | 10.10 | 2.66 |
| 6 | F6 | 20.00 | 35.00 | 15.00 | 4.10 | 10.00 | 3.60 | 3.14 |
| 7 | F7 | 50.00 | 85.00 | 37.50 | 3.60 | 25.00 | 31.60 | 3.86 |
| 8 | F8 | 50.00 | 5.00 | 37.50 | 1.60 | 25.00 | 6.10 | 2.66 |
| 9 | F9 | 40.00 | 40.00 | 30.00 | 8.10 | 20.00 | 8.08 | 2.42 |
| 10 | F10 | 20.00 | 41.00 | 15.00 | 11.10 | 10.00 | 6.04 | 2.18 |

### Determination of quality parameters

Healthy tomatoes having size and weight in a range of 60-70 g were harvested manually at the required ripening stage. For ripening stages description as given by United Fresh Fruit and Vegetable Association (UFFVA, 1975) [33] was followed. Ripe fruits were first oven dried (65°C constant weights) and grounded. The samples were then digested with a mixture of $H_2SO_4$, $H_2O_2$ and lithium sulfate for the determination of mineral nutrients N, P, K, Ca and Mg (Allen, S. *et al.* 1986). The determination of nitrogen by the Micro-Kjeldahl method and Phosphorous by the vanado molybdo phosphoric method was done by procedures given by Jackson (1973) [12].

K was determined flamephotometrically while Ca and Mg determination was done by versene titration given by Jackson (1973) [12]. TSS was determined by a refractometer (Model ERMA Inc) with a range of 0 to 32 °Brix and a resolution of 0.2° Brix by placing 1 to 2 drops of clear juice on the prism. Between samples, the prism of the refractometer was cleaned with distilled water and dried before use. The refractometer was standardized against distilled water (Tigist *et al.*, 2013 [31]. The titratable acidity (TTA), expressed as a percentage of citric acid, was determined according to the method described by Tigist *et al.* (2013) [31]. 10 ml of Tomato juice was manually titrated using 0.1 N NaOH to an endpoint of pH 8.2 using Agrithink's IoT based pH meter( a plug and play component of Agrithink's Smart Micro-climate Monitoring and Control System, a patented system) to monitor the pH. The result was expressed by gms of citric acid per 100 gms of tomato juice. Vitamin C was determined following the method given by Bailley (1974) [4].

### Data Collection

Interactions with farmers were carried out at different phases of the experiment and the data was recorded for various parameters.

### Statistical analysis and other operations

All other operations were carried out following the standard Package of Practices for tomatoes and were uniform in both treatments. The data were analysed for significance by Fischer's t-test using the software Graph Pad Prism.

### Results

A perusal of data from Table 4 reveals that vegetative characters viz. plant height (116.22cm) and the number of leaves (20.28) were significantly higher in T2, where soil test and crop-based fertilizer were applied. The number of branches per plant was not significantly different (P value=0.6231). The reproductive parameters viz. (Table 5.1

and 5.2) recorded from T2 showed that the appearance of the flower was significantly higher (P value<0.0001). Flowering started at 22.42 DAT which is the mean value in T2 as compared to a mean of 26.05 DAT in T1. Highly significant difference (P value <0.0001) was recorded in the case of number of flowers in cluster (Table 5.1). T2 recorded 5.54 flowers per cluster while 4.65 nos. of flowers per cluster was recorded in farmer's own practice (T1).

**Table 4:** Vegetative Character of Tomato

| Sl. | Farmer's No | Pl. Ht(cm) | Pl. Ht (cm) | No of leaves/Plant | No of leaves/plant | No. of branches/pl | No. of branches/pl |
|---|---|---|---|---|---|---|---|
| | | T1 | T2 | T1 | T2 | T1 | T2 |
| 1 | F1 | 110.10 | 118.20 | 8.89 | 19.90 | 12.60 | 14.01 |
| 2 | F2 | 106.80 | 115.40 | 10.12 | 22.60 | 12.70 | 13.00 |
| 3 | F3 | 105.40 | 119.30 | 10.80 | 22.16 | 13.20 | 14.30 |
| 4 | F4 | 103.60 | 107.80 | 10.87 | 19.75 | 13.60 | 13.70 |
| 5 | F5 | 110.20 | 111.00 | 11.23 | 19.78 | 13.30 | 13.60 |
| 6 | F6 | 115.81 | 121.90 | 11.22 | 19.75 | 13.10 | 13.80 |
| 7 | F7 | 112.45 | 118.56 | 11.60 | 19.56 | 13.70 | 13.56 |
| 8 | F8 | 108.56 | 120.25 | 10.55 | 19.30 | 13.20 | 13.45 |
| 9 | F9 | 102.35 | 113.45 | 10.23 | 19.50 | 13.56 | 13.70 |
| 10 | F10 | 110.32 | 116.3 | 11.80 | 20.45 | 12.34 | 13.00 |
| Mean | | 108.56 | 116.22 | 10.73 | 20.28 | 13.13 | 12.61 |
| SD | | 4.11 | 4.40 | 0.85 | 1.15 | 00.45 | 3.24 |
| SEM | | 1.3 | 1.39 | 0.27 | 0.37 | 0.14 | 1.03 |
| | | $p$<0.0001 | | $p$<0.0001 | | P=0.6231 | |

**Table 5.1:** Reproductive characters of Flower

| Sl. No | Farmer's No | Days to first flowering | Days to first flowering | No. of flowers/ cluster | No. of flowers/ cluster | No. of cluster /Plant | No. of cluster/ plant |
|---|---|---|---|---|---|---|---|
| | | T1 | T2 | T1 | T2 | T1 | T2 |
| 1 | F1 | 26.61 | 22.30 | 4.81 | 5.80 | 15.61 | 13.60 |
| 2 | F2 | 27.00 | 23.34 | 4.91 | 5.61 | 16.22 | 14.10 |
| 3 | F3 | 26.51 | 22.06 | 4.64 | 5.76 | 15.85 | 14.50 |
| 4 | F4 | 25.82 | 21.91 | 4.70 | 5.70 | 16.01 | 14.80 |
| 5 | F5 | 26.00 | 22.50 | 4.62 | 5.51 | 15.90 | 13.90 |
| 6 | F6 | 25.61 | 23.00 | 4.78 | 5.26 | 15.00 | 13.30 |
| 7 | F7 | 25.10 | 22.12 | 4.79 | 5.75 | 15.55 | 13.54 |
| 8 | F8 | 26.50 | 23.05 | 4.45 | 5.33 | 15.20 | 13.20 |
| 9 | F9 | 25.20 | 22.35 | 4.30 | 5.40 | 15.45 | 13.42 |
| 10 | F10 | 26.10 | 21.60 | 4.50 | 5.25 | 15.38 | 13.20 |
| | Mean | 26.05 | 22.42 | 4.65 | 5.54 | 15.63 | 13.76 |
| | SD | 0.62 | 0.55 | 0.19 | 0.21 | 0.38 | 0.56 |
| | SEM | 0.20 | 0.18 | 0.06 | 0.07 | 0.12 | 0.18 |
| | | $p$<0.0001 | | $p$<0.0001 | | $p$<0.0001 | |

**Table 5.2:** Reproductive characters of fruit

| Sl. No | Farmer's No | Days to fruit set | Days to fruit set | Fruits/ cluster | Fruits/ cluster | No. of fruits/ plant | No. of fruits/ plant |
|---|---|---|---|---|---|---|---|
| | | T1 | T2 | T1 | T2 | T1 | T2 |
| 1 | F1 | 68.2 | 65.20 | 4.20 | 5.00 | 57.12 | 78.05 |
| 2 | F2 | 69.00 | 64.38 | 4.00 | 5.10 | 56.40 | 82.72 |
| 3 | F3 | 68.66 | 65.66 | 4.60 | 5.21 | 66.70 | 82.58 |
| 4 | F4 | 69.00 | 64.82 | 4.80 | 5.07 | 71.04 | 81.17 |
| 5 | F5 | 67.80 | 66.01 | 4.50 | 5.01 | 62.55 | 79.66 |
| 6 | F6 | 68.00 | 65.00 | 4.50 | 4.90 | 59.85 | 73.50 |
| 7 | F7 | 67.10 | 64.07 | 4.60 | 5.10 | 62.28 | 79.31 |
| 8 | F8 | 67.42 | 65.20 | 4.55 | 5.77 | 60.06 | 87.70 |
| 9 | F9 | 67.31 | 65.57 | 4.06 | 5.23 | 54.49 | 80.80 |
| 10 | F10 | 68.02 | 65.10 | 4.22 | 5.90 | 55.70 | 90.74 |
| | Mean | 68.05 | 65.10 | 4.40 | 5.23 | 60.62 | 81.62 |
| | SD | 0.68 | 0.58 | 0.26 | 0.34 | 5.22 | 4.84 |
| | SEM | 0.21 | 0.18 | 0.08 | 0.11 | 1.65 | 1.53 |
| | | $p$<0.0001 | | $p$<0.0001 | | $p$<0.0001 | |

A highly significant difference ($p$<0.0001) was found in the number of flower clusters per plant, showing a mean of 15.63 in T2 while a mean of 13.76 was shown in plants under FFP(T1). The fruit set was observed in 68.05 DAT in T1 (FFP) while a significantly faster fruit set in 65.10 DAT was observed in T2 (soil test and crop-based fertilizer application). A significantly higher average of 5.23 fruits per cluster was recorded in T2 while T1 recorded a lower number of fruits per cluster (4.40). T2 recorded a very significantly higher nos. of fruits per plant with a mean of 81.62 fruits per plant while only 60.62 fruits were recorded in T1 ($p$<0.0001)

The superior quality of tomato resulted under T2 plots which received the right quantity of nutrients which were applied based upon the crop need (Table. no.6). Per cent mean contents of nitrogen (3.01%), phosphorous (0.72%), potassium (1.07%), calcium (0.07%) and magnesium (0.15%) were significantly higher in the plots under this treatment.

**Table 1:** Nutritional Quality of Tomato

| Sl. | N (%) | | P (%) | | K (%) | | Ca (%) | | Mg (%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T1 | T2 | T1 | T2 | T1 | T2 | T1 | T2 |
| F1 | 2.12 | 2.9 | 0.63 | 0.70 | 1.01 | 1.09 | 0.04 | 0.07 | 0.12 | 0.15 |
| F2 | 2.10 | 3.01 | 0.62 | 0.69 | 1.01 | 1.07 | 0.02 | 0.08 | 0.13 | 0.14 |
| F3 | 2.10 | 3.03 | 0.66 | 0.72 | 1.02 | 1.08 | 0.05 | 0.06 | 0.12 | 0.16 |
| F4 | 2.13 | 3.10 | 0.67 | 0.77 | 1.03 | 1.07 | 0.04 | 0.07 | 0.13 | 0.15 |
| F5 | 2.12 | 3.00 | 0.65 | 0.71 | 1.02 | 1.08 | 0.03 | 0.09 | 0.12 | 0.14 |
| F6 | 2.16 | 3.06 | 0.60 | 0.75 | 1.01 | 1.09 | 0.05 | 0.06 | 0.13 | 0.16 |
| F7 | 2.15 | 3.05 | 0.62 | 0.70 | 1.04 | 1.06 | 0.03 | 0.07 | 0.12 | 0.15 |
| F8 | 2.18 | 3.07 | 0.64 | 0.74 | 1.01 | 1.08 | 0.02 | 0.09 | 0.11 | 0.14 |
| F9 | 2.17 | 2.90 | 0.66 | 0.75 | 1.03 | 1.09 | 0.03 | 0.06 | 0.13 | 0.17 |
| F10 | 2.19 | 3.04 | 0.59 | 0.76 | 1.04 | 1.06 | 0.04 | 0.07 | 0.12 | 0.16 |
| Mean | 2.14 | 3.01 | 0.63 | 0.72 | 1.02 | 1.07 | 0.03 | 0.07 | 0.12 | 0.15 |
| SD | 0.032 | 0.067 | 0.026 | 0.028 | 0.012 | 0.011 | 0.011 | 0.011 | 0.007 | 0.010 |
| SEM | 0.010 | 0.021 | 0.008 | 0.009 | 0.004 | 0.004 | 0.003 | 0.004 | 0.002 | 0.003 |
| | $p$<0.0001 | | $p$<0.0001 | | $p$<0.0001 | | $p$<0.0001 | | $p$<0.0001 | |

Table.7 revealed that all the quality parameters in T2 where soil test and crop-based fertilizer were applied resulted in highly significant values as compared to the Farmer's Fertilizer Practice (T1). The average vitamin C content, Total Soluble Solid and titrable acidity were found to be 22.43 mg/100gm, 4.55Brix%, 6.53 mg/ 100gm and 0.33% respectively, showing very significantly superior results over T1.

**Table 2:** Quality of Parameter of Tomato

| Sl. | Farmer's Name | T1 Vitamin C (mg/100 gm) | T2 Vitamin C (mg/100 gm) | T1 Total Soluble Solids ($^0$Brix) | T2 Total soluble solids ($^0$Brix) | T1 Titrable Acidity (%) | T2 Titrable Acidity (%) |
|---|---|---|---|---|---|---|---|
| 1 | F1 | 20.01 | 22.08 | 3.10 | 4.50 | 0.27 | 0.35 |
| 2 | F2 | 19.05 | 21.12 | 3.40 | 4.80 | 0.23 | 0.32 |
| 3 | F3 | 18.23 | 23.00 | 3.10 | 4.80 | 0.26 | 0.34 |
| 4 | F4 | 18.86 | 22.55 | 3.50 | 4.60 | 0.26 | 0.32 |
| 5 | F5 | 19.10 | 21.17 | 3.30 | 4.50 | 0.25 | 0.34 |
| 6 | F6 | 19.00 | 22.62 | 3.50 | 4.20 | 0.22 | 0.32 |
| 7 | F7 | 18.90 | 23.10 | 3.10 | 4.60 | 0.24 | 0.31 |
| 8 | F8 | 20.00 | 21.80 | 3.40 | 4.60 | 0.23 | 0.33 |
| 9 | F9 | 18.67 | 23.34 | 3.50 | 4.40 | 0.25 | 0.33 |
| 10 | F10 | 17.78 | 23.52 | 3.30 | 4.50 | 0.22 | 0.32 |
| Mean | | 18.96 | 22.43 | 3.32 | 4.55 | 0.24 | 0.33 |
| SD | | 0.686 | 0.169 | 0.169 | 0.178 | 0.017 | 0.012 |
| SEM | | 0.217 | 0.053 | 0.053 | 0.056 | 0.006 | 0.004 |
| | | $p$<0.0001 | | $p$<0.0001 | | $p$<0.0001 | |

## Discussion

In the present study all the yield attributing characters were significantly higher and so were the yield and quality in T2 where NPK was applied based on soil test value and NPK requirement of crop grown. The significant increase in fruit yield was explained as a combination of factors, including an overall increase in vegetative and reproductive growth by Mzibra *et al*. (2021) [1]. Over the other site-specific common factors, the higher vegetative and reproductive growth of tomato plants in T2 could be attributed to the application of need-based fertilizer and the favourable pH achieved by applying an adequate quantity of dolomite for soil amelioration. The soil under tomato treatments was acidic ranging from 4.6 to 5.6 (Table 1). In acidic soil, most of the essential nutrients become unavailable while some elements like Aluminium and Iron become toxic (Das and Avasthe, 2018) [9]. Application of need-based liming material, reliant upon the recommendations made by Soilcare concerning proper time and method of application led to the availability of optimum level of essential nutrients which enhanced yield and quality of tomato in T2.

It has been known that the mineral nutrition of tomatoes from the application of the right quantity of fertilizers and manures can increase tomato yield and nutrient uptake by several folds compared with no fertilization or inadequate fertilization (Sainju *et al*, 2003) [27]. The same study by Sainju *et al* (2003) [27] suggested that as the amount of fertilizer requirement for tomatoes varies with soil type and environmental conditions, analysis of soil and plant samples need to be conducted every year before applying fertilizers to determine their proper rate. In the organic system of cultivation, there is a constant but slow release of available nutrients. Since the plants require a ready supply of available nutrients, it is necessary to determine nutrient requirements based on the current soil test value (Goswami and Pariyar, 2022) [6].

Mahajan *et.al* (2013) [22] emphasized need-based fertilizer application of crops for sustainable crop production as well as for economized use of costly fertilizer inputs. Suresh and Shanthi (2018) also found that Farmer's practice gave a relatively lower yield and response ratio as compared to treatments where a measured amount of crop-based NPK was applied.

The superior tomato fruit quality was evident in T2 with an expression of higher total soluble solid, titrable acidity and vitamin C contents. Similarly nutrient contents viz. N, P, K, Ca and Mg were also higher in the same treatment. Need-based nutrition treatment was found to have a significant positive impact on the quality of tomatoes (Kibria *et al.* 2016) [19]. It was found by the same research that the nutrient contents of tomato fruit were superior upon fertilization by biogas plant residues and the required dose of NPK. The increase in TSS, vitamin C and titrable acidity by the application of need-based manuring can be explained by the improvement of metabolic activities leading to the synthesis of significant amounts of acids, metabolites, and glucose. Farm management skills combined with site-specific effects contribute to high vitamin C levels (Zoran, 2014) [11]. In the current study, nutrient management at its best with instant soil test results and application of manures and fertilizer as per system-induced recommendation in T2 resulted in abundant vitamin C in tomatoes grown under T2.

It is evident from Table 3 that in T1 farmers applied blanket doses of single manure (FYM) which failed to fulfil the exact need of the plants. In most cases, they applied fewer nutrients where it was required in high amounts and vice versa. The quantity and quality of manures applied by the farmers in this case, could not supply the adequate NPK that the plants yearned for. Whereas in few cases, blanket application led to over-application of NPK. The excess nutrients can reduce tomato yield, decrease fertilizer-use efficiency, increase the cost of nutrient management, and degrade the water body ecosystem due to the leaching and runoff of nutrients, such as N and P from agricultural lands. The excessive application of animal manures causes the eutrophication of lakes and rivers, thereby increasing health hazards to aquatic animals (Sainju *et al*. 2003) [27]. A need-based application of NPK always results in better assimilation of photosynthates (Madhavi *et al.*, 2020) [20], resulting proper growth and development. Ray *et al.* (2000) [24], Meena *et. Al* (2001) [21], Jayprakash *et al* (2006) [13], Kumar *et al*. (2007) [16], Umesh (2008) [32], Vikram *et al.* (2015) [34], Kumar *et al.* (2018) [7] and Reddy *et al*. (2018) [26] also revealed similar outcomes in their respective experiments. Usually, blanket fertilizer recommendations to farmers do not consider spatial variability in the localised nutrient-supplying capacity of different farms and the nutrient requirement of the crop based on soil test value. So this kind of recommendation can rarely supply the actual amount of nutrients required by the crop for optimum yield, thereby leading to a loss in both yield and quality (Bhuiya *et al*. 2020) [10].

One of the key aspects of an organically managed farm is that there is a slow and constant release of nutrients from the applied organic sources. So it is necessary to determine the nutrient requirement based on the current soil test value as plants require a ready supply of available nutrients. A luxuriant vegetative growth with the required quantity of manure was also reported by Atiyeh *et al*. (2000) [3], Cooperband *et al*. (2002) [5, 8] in different experiments of organic farming.

## Conclusion

The present experiment re-established the importance of soil test-based nutrient management specific to crops. Farmers following their own practice often fail to harness the optimum potential of the crop they grow. The unavailability of a precise system of fertilizer recommendation under a purely organic system was a major cause of farmers opting for a blanket dose based on availability, purchasing capacity and experience which often lead to manurial application much lower than the optimum. The need for a convenient system for in-situ soil testing could be fulfilled by Soil care. The use of the real-time, accurate, economical and user-friendly system to decide site and crop-specific nutrient requirements enhanced the yield and quality of tomatoes.

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