Research Article

# Integrated Use of Simple Compost, Vermicompost, Vermi-Tea and Chemical Fertilizers NP on the Morpho-Physiological, Yield and Yield Related Traits of Tomato (*Solanum lycopersicum* L.)

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**Abstract** | Nutrient deficiency is a serious threat to tomato growth and productivity. Application of vermicompost, vermi-tea, simple compost and chemical fertilizers can help to minimize this threat. In order to combat nutrient deficiency, an experiment was carried out to optimize the best dose of fertilizers for tomato crop at Student Research Farm, Department of Agronomy, Faculty of Agriculture, University of Agriculture, Faisalabad in a tunnel under field conditions. The experiment had five treatments in which the mineral (NP) fertilizer, simple compost, earthworm's excreta-based vermicompost and vermi-tea were alone and combined in different proportions as ($T_0$: control (recommended fertilizers), $T_1$: 100% simple compost, $T_2$: 100% vermicompost, $T_3$: 100% vermi-tea, $T_4$: 33% simple compost + 33% vermicompost + 34% vermi-tea and $T_5$: 25% simple compost + 25% vermicompost + 25% vermi-tea+ 25% chemical fertilizers) were applied in tomato variety Aroma. The assessment was performed on the basis of morphological, yield and yield related traits (petiole length, no. of primary branches, stem diameter, time taken for flowering, time taken to fruit set, fruit diameter, fruit length, fruit weight $plant^{-1}$, $plant^{-1}$ no. of fruits, $plant^{-1}$ fruit yield, and yield $ha^{-1}$) and physiological traits (membrane stability index, relative water content of leaves, total carotenoids, chlorophyll *a*, chlorophyll *b*, total chlorophyll *(a+b)* contents, SPAD value of chlorophyll and photosynthetic rate). The obtained results indicated that treatment $T_5$ had significantly ($p<0.05$) higher fruit yield (1.50 kg/plant, 15.5 kg/plot and 13657 kg/ha) while treatment $T_0$ had significantly lower fruit yield (0.87 kg/plant, 8.33 kg/plot, and 7900 kg/ha) as compared to all other treatments.

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## 1. Introduction

Tomato (*Lycopersicum esculentum*) is a popularly grown vegetable belonging to Solanaceae family, and it ranks third in global production of vegetables (Sadaf *et al.*, 2012). The overall per anum worldwide tomato production is estimated to be more than 1.82 billion tons obtained from area of 4.8 million hectares with an average production of 38 tonnes/hectare (Soomro *et al*., 2020). The export of processed tomato in the world has reached up to US$ 13 billion and of fresh ripened tomato exports has reached to US$ 8.8 billion. China, India, the United States, Turkey and Italy are the countries with the highest tomato production, with Pakistan ranking 33th in the world (FAO, 2020). Tomato crop is grown on 61 thousand hectares in Pakistan, yielding a total of 569 thousand tons and with an average yield of 9.5 tons per hectare. In Punjab, tomatoes are raised on 18.29 thousand hectare, with a total yield of 94.60 thousands tones and an average yield of 9.2 tonnes per hectare (MINFAL, 2019-20). Khushab, Okara, Sahiwal, Sheikhupura, Faisalabad, Sargodha, Rahim Yar Khan, Khanewal, Muzaffargarh, Bahawalnagar, Bahawalpur are the important tomato growing areas of Punjab (Qasim *et al*., 2018).

Tomato is an important vegetable that can be used in a variety of recipes, sauces, salads, and beverages. Tomato fruits are high in nutritional value and cost less than other vegetables (Sadaf *et al*., 2012). Several studies have revealed that tomatoes are high in nutrient and antioxidant compounds like lycopene and vitamin C. Lycopene is the most effective antioxidant that has been effective to minimize the risks of prostate cancer as well as other heart diseases (Clinton, 1998; Kumar and Sharma, 2004). Tomato-based products are in high demand, and domestic consumption and demand are increasing as a result of the rapid growth in population. It is projected that if this pattern continues in the future, demand of tomato would rise even more. Since tomatoes are produced seasonally, they can be found in a variety of locations throughout Pakistan (Soomro *et al*., 2020).

Commercially, tomato is a heavy feeder crop so intensive fertilizer application involved in its production. Apart from variety, fertilization is a crucial component in the tomato yield (Cheuk *et al*., 2003; Mercado *et al*., 2010). Organic and inorganic nutrients have a major impact on tomato's growth and yield. It is an established fact that the use of inorganic fertilizers, as opposed to organic fertilizers, is harmful to environment and the human health, owing to their residual nature, and that the injudicious use of inorganic fertilizers may in fact intensify problems in the foreseeable future (Srivastava *et al*., 2012; Avasthe *et al*., 2014). The contamination of soil and water bodies caused by the over use of inorganic fertilizers poses a major threat nowadays. Hence, switching to organic fertilizers as a substitute for chemical fertilizers is the key step towards sustainable agriculture. There has been a movement toward using organic fertilizers more effectively and lowering the volume of mineral fertilizer used in soil (Srivastava *et al*., 2012). Organic fertilizers serve a dual purpose, enhancing soil productivity while also improving crop quality and production. As a result, proper management is required to produce a high economic return on production while simultaneously avoiding the risk of excessive fertilizer application to the environment (Mercado *et al*., 2010).

Vermicomposting from organic waste materials can reduce the environmental impacts of chemical fertilizers. During this process earthworms employ non-thermophilic transformations on organic waste which expedite microbial facilitated humification and breakdown (Atiyeh *et al*., 2001). Vermicompost contains lump sum of readily available plant nutrients viz, ammonium or nitrates of nitrogen, exchangeable phosphorus, solubilized magnesium, calcium, and potassium, all of which are extracted from wastes (Chanda *et al*., 2011; Ahmad *et al*., 2022). Multiple studies have shown that in comparison to traditional chemical fertilization, vermicompost supplements can directly enhance crop yield by increasing nutrients availability and indirectly through modifying soil structure and fostering bacteriological activities (Song *et al*., 2015; Kashem *et al*., 2015). Vermicompost affects crop growth, quality, and productivity in a positive way (Singh *et al*., 2008). When vermicompost's humic acid and commercial humic acids applied at same quantity, the farmer increased growth, yield and yield related traits of crops (Edwards *et al*., 2006). Vermicompost impacts on biomass production, seed germination, root growth, stem elongation, yield, and economic yield have been demonstrated in previous studies in medicinal and vegetable crops (Lim *et al*., 2016; Azarmi *et al*., 2008; Singh *et al*., 2008; Atiyeh *et al*., 2002). Similarly, Singh *et al*. (2008) described optimistic response of tomato cultivars to vermicompost application and proposed that growth enhancement was due to the stimulation of naphthalene acetic acid, an auxin plant growth regulator that is essential for flowering and fruit setting.

Brewed water extracts of earlier composted elements from vermicompost are known as vermi-tea or extract of vermicompost (Gomez-Brandon *et al*., 2015). Key components of vermicompost viz, bio-active metabolites, mineral nutrients, and beneficial microbiota are sifted in vermicompost tea during the brewing process (Mishra *et al*., 2017). Vermi-tea is usually sprayed on the leaves surface or drenched into the soil (Simsek-Ersahin, 2011). The primary benefit of using vermi-tea is that it delivers fine particulate organic matter, soluble compounds of vermicompost and microbial biomass on outer surface of plant and in top most soil in such a manner not feasible with raw vermicompost. As a result, several studies have shown that vermicompost tea can be used as a liquid fertilizer or a biocontrol agent. Crop health, yield, and nutritive quality were all improved when vermicompost tea was used (Pant *et al*., 2009). Furthermore, it has been propagated that inert elements, carbon-based substances and soluble plant growth regulator obtained from vermi-tea have a simulative effect on initial root development and crop growth when applied foliarly or in the soil (Ahmad et al., 2022). It also has substantially increased seed germination in various plant species like tomatoes (Zaller, 2006; Arancon *et al*., 2008), petunia (Atiyeh *et al*., 2002), and pines (Arancon *et al*., 2008). Renčo and Kováčik (2015) also reported similar findings while researching the vermi-tea effects on potato crop.

It is clear from above discussion that sole application of mineral fertilizers is unable to fulfil the nutritional requirements of crops and associated cropping system due to incurring high cost associated with them and environmental pollution attributed to their large-scale application, so sustainability of system's requires a proper blend of inorganic and organic amendments (Kumar and Surendran, 2002). However, there is limited research is conducted on the impact of combining the use of vermicompost, vermi-tea, and chemical fertilizer on tomato growth and production. Therefore, in lieu of aforementioned discussion the present research was undertaken with the following aims (a) to determine the impact, appropriateness, and efficacy of integrated application of vermicomposting, synthetic fertilizers and vermi-tea for morph-physiological characters of tomato (b) dose optimization of these amendments to get maximum yield under semi-arid conditions.

## 2. Materials and Methods

The current experiment was conducted in the winter of 2019-20 at the University of Agriculture Faisalabad (height 184 m, latitude 31.30° N, longitude 73.05° E). The Institute of Horticultural Sciences at the University of Agriculture in Faisalabad provided the nursery for the tomato variety Aroma. Four different fertilizers; Earth worm's excreta based vermicompost @ 5 ton/ha, vermi-tea @ 6%, simple compost @ 10 ton/ha and chemical fertilizers (NP) @ 150-110 kg/ha were applied. The Randomized Complete Block Design (RCBD) was employed. Simple compost and vermicompost was prepared from cow dung. 500g of solid vermicompost was mixed with 2.0 L of clean water to create vermi-tea, which was then left to steep for two days. After that by using perforated cloth, vermi-tea was extracted and applied foliarly.

### *2.1 Meteorological data*

Weather information was gathered from the Meteorological Observatory Department of Agronomy, University of Agriculture, Faisalabad, throughout the crop-growing season. The weather patterns that persisted throughout the tomato crop's growth season in 2019-20 are shown in Figure 1.

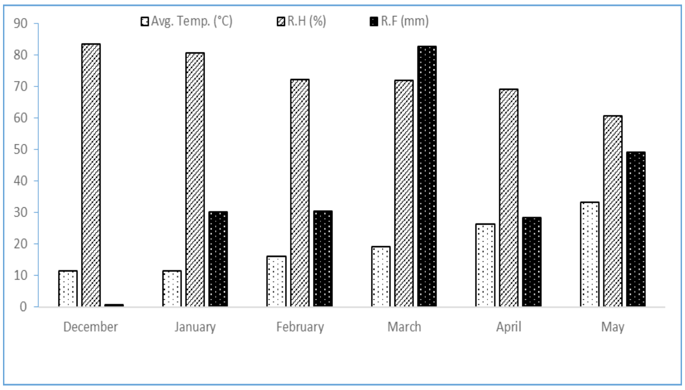


**Figure 1: Avg. Temp (Average temperature) (°C), R.H (Relative humidity) (%), R.F (Rainfall)(mm).**

### *2.2 Treatments*

Different types of chemical fertilizers used for vermicompost formation which were applying at following rates.

$T_0$: control (recommended fertilizers); $T_1$: 100% simple compost; $T_2$: 100% vermicompost; $T_3$: 100% vermi-tea; $T_4$: 33% simple compost + 33% vermicompost + 34% vermi-tea; $T_5$: 25% simple compost + 25% vermicompost + 25% vermi-tea + 25% chemical fertilizers.

The following parameters' data were recorded.
(i) Plant height (cm): Plant height was taken by using

a meter rod and selecting three plants randomly from each plot and computed their average. (ii) Number of leaves: The total number of leaves were calculated manually by selecting three plants, picking their leaves and computing their means. (iii) Leaf length (cm): Leaves of three random plants were selected for the measurement of leaf length by using a meter scale, and their average was computed. (iv) Leaf breadth (cm): Leaf breadth was measured by using a meter scale by calculating mean of the three randomly chosen plants. (v) Petiole length (cm): The petiole length was calculated through a scale meter and an average of three randomly selected plants was taken. (vi) Primary branches per plant: The primary branches of each plant were physically noted by calculating average of three random plants. (vii) Stem diameter (cm): The stem diameter was measured with a meter tape from three different plants and calculating their mean. (viii) Days taken for flowering: Days taken for flowering were counted from germination to inhiation of flowering. (ix) Fruit length (cm): The length of three fruits from randomly chosen plants was measured using a metre tape. (x) Days taken to fruit set: The total sum of days from transplanting to the setting of fruits were counted. (xi) Fruit diameter (cm): Three random fruits were selected from various plants, and their diameter were recorded. (xii) Fruit weight (g): The three fruits were taken from the selected plants and measured their weight with electrical balance. (xiii) Per plant number of fruits: The whole quantity of fruits was numbered from randomly chosen three plants in each plot and mean was counted. (xiv) Yield per plant (kg): From a plot of three randomly chosen plants, the fruits were collected, weighed using an electrical scale, and the average was taken. (xv) Yield per plot (kg): Fruits were collected, weighed on an electronic scale, and converted to kilogrammes (kg) per plot from an area of one $m^2$ from each plot. (xvi) Yield per hectare (kg): Fruits were harvested, weighed on an electronic scale, and translated to kilogrammes per hectare in a one-square-meter area from each subplot. (xvii) RWC (%): The Relative water contents were measured according to Schonfeld *et al*. (1988). RWC was determined by removing the second leaf on the stem of a tomato plant with the help of shrill razor blade. Leaves were put in purified water in airtight plastic bags for the measurement of turgid weight (TW). After that, the plastic bags were placed in a study environment with low light (about 20 m mol $m^2$ $s^{-1}$), naturally fluctuating temperature, and leaves that had been soaked for 24 hours. Following imbibition, the leaf sample weights were reweighed and the turgid weight (TW) was determined. After weighing the turgid samples, the leaf samples were put in the oven at 70°C for 72 hours. The samples' oven dry weight (DW) was then calculated. On an analytical scale with 0.0001 g accuracy, all measurements were done. The following equation was used to reflect the values of FW, TW, and DW to calculate RWC. RWC (%) = ((fresh weight - dry weight)/ (turgid weight - dry weight)) * 100. (xviii) Chlorophyll contents (mg $g^{-1}$fwt): Chlorophyll a and b were measured according to the Arnon (1949) method. With 80% acetone at 0-4°C new leaves (0.2 g) were cut and extracted during night. For five minutes the extracts were centrifuged at 10,000 x g. The absorbance of the supernatant was measured at 645 and 663 nm using a spectrophotometer (Hitachi-U2001, Tokyo, Japan).

The levels of chlorophylls *a* and *b* were calculated using the formulae below:

$$Chl\ a= (12.7\ (OD\ 663) -2.69\ (OD\ 645)) \times V/1000 \times W$$
$$Chl\ b= (22.9\ (OD\ 645) -4.68\ (OD\ 663)) \times V/1000 \times W$$

V= extract volume (mL); W= fresh leaf tissue weight (g).

(xix) Total Chlorophyll contents (*a+b*) (mg $g^{-1}$fwt): Chlorophyll *a* + Chlorophyll *b* make up the total amount of chlorophyll. (xx) Chlorophyll contents (SPAD value): By means of SPAD tool (model SPAD-502; Minolta Corp., Ramsey, N.J.) chlorophyll contents of the leaves were measured. (xxi) Total carotenoids (mg $g^{-1}$ fwt): Total carotenoids were calculated through the method of Yang *et al*. (1998). Procedure for the synthesis of extracts was alike as chlorophyll determination. A spectrophotometer (Hitachi-U 2001, Tokyo, Japan) was used to calculate the absorbance of the supernatant at 480 nm.

Contents of total carotenoids were computed by the given equations:

$$\text{Total Carotenoids} = \frac{A^{car}}{Em} \times 100$$

Where; Em = 2500; $A^{car}$ = O.D 480 + 0.114 (O.D 663) – 0.638 (O.D 645).

(xxii) Photosynthetic rate (An) (μmol $m^{-2}$ $s^{-1}$): Photosynthetic rate was measured by leaf attached to the plant by using IRGA, infrared gas analyzer (Singh *et al*., 2018; Rosolem *et al*., 2019). Five measurements were taken from five different plants from each treatment and then their average was taken. (xxiii) Membrane Stability Index (MSI) (%): MSI (Membrane stability index) was calculated using Premachandra *et al*. (1990) process, which was latter updated by Sairam (1994). Leaf samples (0.1 g) were put in 10 ml of double-distilled water in 2 sets. A conductivity meter was used to measure the conductivity of one set ($C_1$), which was held at 40 °C for 30 minutes. The conductivity of second set was also recorded ($C_2$) by placing it in a boiling water bath (100 ⁰C) for 15 minutes. The MSI was calculated as:

$$MSI = 1-(C_1/C_2) \times 100$$

*2.3 Statistical analysis*

Using Fisher's analysis of variance (ANOVA) approach, the obtained data was examined. To compare treatment means, Analytical Software's Statistics version 8.1 employed the Least Significant Difference (LSD) test (Steel *et al*., 1997).

## 3. Results and Discussion

*3.1 Morphological, yield and yield relating traits*

Table 1 displays information on morphological features, including plant height, number of main branches plant$^{-1}$, number of leaves plant$^{-1}$, leaf width, petiole length, leaf length, and stem diameter. As shown in Table 1, the combination delivery of inorganic and organic fertilizer had a substantial impact on all morphological features.

In case of height of plant, statistically maximum height (76.66 cm) of plant was recorded by applying 25% simple compost + 25% vermicompost + 25% vermi-tea + 25% chemical fertilizers followed by 33% simple compost + 33% vermicompost + 34% vermi-tea (73.66 cm). Conversely, the control treatment gave rise to lowest plant height (60 cm) which was at par with applying 100% simple compost. Similar outcomes were discovered in a cotton research study done by Ansari and Sukhraj (2010), where maximum yield characteristics were observed. Use of macronutrients and micronutrients by bio-fertilizers, such as vermicompost, enhanced the tomato plants' morphological parameters. As a result, the plant's auxins concentration, nitrogen cycle, chlorophyll synthesis and photosynthetic activity may increase. The findings of Musa *et al*. (2018) and Naidu *et al*. (2002) are in agreement with concurrent study.

The statistically highest number of leaves per plant and length of leaf (117.67 and 5.03 cm, respectively) were observed when 25 % simple compost was applied + 25% vermicompost + 25% vermi-tea + 25% chemical fertilizers which was at par by applying 33% simple compost + 33% vermicompost + 34% vermi-tea (116.00 and 4.63 cm, respectively). Whereas, lower leaf numbers on every plant and length of the leaves (99.67 and 2.43 cm, respectively) was recorded under control. In a research work similar results had been observed by Balasubramanian *et al*. (2009) and Musa *et al*. (2018), where highest number of leaves had been observed. Vermicompost and vermi-tea both are nutritious organic fertilizers with high Macro nutrient concentrations NPK (1.85-2.25% potassium (K), 2-3% nitrogen (N), and 1.55-2.25% Phosphorus (P)), micro-nutrients and useful soil microorganisms. The nitrogen-fixing bacteria and mycorhizal fungi present in vermi-tea and vermicompost are scientifically demonstrating as plant growth promoters.

**Table 1: Effects of organic and inorganic soil amendments on the morphological traits of tomato crop.**

| Treatments | Plant height (cm) | Number of leaves/ plant | Leaf length (cm) | Leaf breadth (cm) | Petiole length (cm) | Primary branches per plant | Stem diameter (cm) |
|---|---|---|---|---|---|---|---|
| $T_0$ | 60.00 E | 99.67 E | 2.43 D | 1.09 D | 0.97 D | 17.66 F | 8.83 E |
| $T_1$ | 66.00 E | 105.67 D | 3.00 C | 1.83 C | 1.18 C | 20.66 E | 10.66 D |
| $T_2$ | 68.66 D | 109.67 C | 3.500 BC | 2.06 C | 1.31 C | 23.66 D | 12.00 C |
| $T_3$ | 71.66 C | 113.67 B | 3.91 B | 2.48 B | 1.72 B | 25.66 C | 14.00 B |
| $T_4$ | 73.66 B | 116.00 A | 4.63 A | 2.76 AB | 1.78 AB | 28.00 B | 15.16 A |
| $T_5$ | 76.66 A | 117.67 A | 5.03 A | 2.91 A | 1.90 A | 30.33 A | 16.00 A |
| MS for treatment | 105.95** | 139.78** | 2.88** | 1.37** | 0.41** | 65.73** | 22.92** |
| LSD @ 0.05 | 2.22 | 2.22 | 0.54 | 0.33 | 0.17 | 1.72 | 1.04 |

Means sharing the same letters do not differ significantly ($P \leq 0.05$). **= Highly Significant; MS= Mean sum of square; LSD= Least significant differences test.

Data concerning leaf breadth and petiole length is shown in the Table 1. It is clear that leaf breadth and petiole length is affected significantly by applying combination of organic and inorganic fertilizers. Statistically maximum leaf breadth and petiole length (2.91 cm and 1.90 cm, respectively) was obtained by applying 25% simple compost + 25% vermicompost + 25% vermi-tea + 25% chemical fertilizers which was at par with applying 33% simple compost + 33% vermicompost + 34% vermi-tea (2.76 cm and 1.78 cm, respectively). Whereas, less leaf petiole and petiole length (1.09 cm and 0.97 cm, respectively) was observed under control. It is clear that an increase of 167 and 96 % in leaf breadth and petiole length was recorded by applying combination of both the organic and the inorganic fertilizer in comparison to control. Meghvansi *et al.* (2012) found almost identical results in another study in which maximum growth had been observed. Vermicompost have enzymes such as cellulases, amylases, chitinases and lipases that continue to degrade soil organic matter and release the bound nutrients, making them accessible to plant roots even after their draining.

Data describing primary branches per plant is given in Table 1 which showed that this attribute is affected significantly by applying combination of organic and inorganic fertilizer. Statistically maximum primary branches per plant (30.33) was recorded by applying 25% simple compost + 25% vermicompost + 25% vermi-tea + 25% chemical fertilizers followed by 33% simple compost + 33% vermicompost + 34% vermi-tea (28.00). On contrary, lower primary branches per plant (17.66) was obtain under control treatment. It is clear that an increase of 71.74% in number of primary twigs on each plant was attained by applying combination of inorganic and organic fertilizer as compared to control. Almost identical findings were reported by Parmar *et al.* (2019) in their research where most monopodial as well as sympodial branches were observed.

Many beneficial enzymes such as ureases, Phosphomonoesterase, Phosphodiesterases and Arlsulphatase etc. are found in soil when the vermicompost is added to soil annually in adequate amount. The vermicompost-emulated soil has an excellent electrical conductivity (EC) and a pH that is almost neutral.

Data concerning days taken for flowering and fruit setting is arranged in the Table 2. It is clear from the data that this attribute is affected significantly by applying combination of organic and inorganic fertilizer. Statistically maximum days for flowering and fruit setting (35.0 and 59.0 days, respectively) was recorded under control treatment. On the other hand, statistically minimum days for flowering and fruit setting (24.33 and 45.33 days) was observed by applying 25% simple compost + 25% vermicompost + 25% vermi-tea + 25% chemical fertilizers. Similar outcomes were discovered in a cotton research study done by Ansari and Sukhraj (2010), where maximum yield characteristics were observed. The use of bio-fertilizers like vermicompost as micro and macronutrients source improved the morphological parameters of the tomato plants. As a result, the plant's formation of chlorophyll, photosynthesis process, nitrogen metabolism, and also the auxin content may increase. The findings of concerned study are completely in syn with those of Musa *et al.* (2018) and Naidu *et al.* (2002).

**Table 2: Effects of organic and inorganic fertilizers on the morphological, yield and yield related traits of tomato crop.**

| Treatments | Days taken to flowering | Fruit length (cm) | Days taken to fruit set | Diameter of fruit (cm) | Weight of fruits (g) | Number of fruits per plant | Yield per plant (kg) |
|---|---|---|---|---|---|---|---|
| $T_0$ | 35.00 A | 4.16 E | 59.00 A | 3.23 E | 72.33 F | 17.33 F | 0.87 E |
| $T_1$ | 32.33 B | 5.166 D | 55.33 B | 3.840 D | 83.00 E | 20.33 E | 0.98 D |
| $T_2$ | 30.00 C | 6.03 C | 53.33 B | 4.33 C | 89.00 D | 22.33 D | 1.03 D |
| $T_3$ | 27.66 D | 6.83 B | 50.33 C | 4.80 B | 98.00 C | 25.66 C | 1.19 C |
| $T_4$ | 26.00 E | 7.66 A | 47.33 D | 5.50 A | 104.33 B | 27.33 B | 1.40 B |
| $T_5$ | 24.33 F | 8.26 A | 45.33 D | 5.75 A | 110.67 A | 29.33 A | 1.500 A |
| MS for treatment | 48.22** | 7.14** | 78.35** | 2.81** | 605.15** | 61.52** | 0.18** |
| LSD @ 0.05 | 1.54 | 0.61 | 2.60 | 0.40 | 3.89 | 0.85 | 0.08 |

Means sharing the same letters do not differ significantly ($P \leq 0.05$). **= Highly Significant; MS= Mean sum of square; LSD= Least significant differences test.

**Table 3: Effects of organic and inorganic fertilizers on the physiological and yield traits of tomato crop.**

| Treatments | Yield per plot (kg) | Yield per hectare (kg) | Relative water contents (RWC) (%) | Membrane stability index (MSI)(%) | Chlorophyll a (mg $g^{-1}$ fwt) | Chlorophyll b (mg $g^{-1}$ fwt) | Total chlorophyll contents (a+b) (mg $g^{-1}$ fwt) |
|---|---|---|---|---|---|---|---|
| $T_0$ | 8.33 F | 7900 E | 80.333F | 77.33 F | 3.26 F | 0.94 D | 4.21 F |
| $T_1$ | 10.66 E | 8733 E | 83.00 E | 80.00 E | 3.98 E | 1.08 D | 5.07 E |
| $T_2$ | 11.66 D | 966 D | 84.33 D | 81.00 D | 4.71 D | 1.33 C | 6.04 D |
| $T_3$ | 13.66 C | 11497 C | 86.33 C | 83.00 C | 5.11 C | 1.66 B | 6.77 C |
| $T_4$ | 14.66 B | 12466 B | 87.66 B | 84.33 B | 5.83 B | 1.89 A | 7.72 B |
| $T_5$ | 15.50 A | 13657 A | 89.00 A | 85.33 A | 6.20 A | 2.01 A | 8.22 A |
| MS for treatment | 21.85** | 1.51** | 30.62** | 26.50** | 3.69** | 0.57** | 7.13** |
| LSD@0.05 | 0.49 | 880.93 | 0.79 | 0.57 | 0.24 | 0.20 | 0.31 |

Means sharing the same letters do not differ significantly ($P \leq 0.05$). **=Highly Significant; MS= Mean sum of square; LSD= Least significant differences test.

Data regarding fruits length, diameter of fruits and fruit numbers on each plant described in Table 2 which showed that all of these attributes is affected significantly by applying combination of inorganic and organic fertilizers. Statistically maximum length of fruits, diameter of fruits and fruits number on every plant (8.26 cm, 5.75 cm and 29.33, respectively) was recorded by applying 25% simple compost + 25% vermicompost + 25% vermi-tea + 25% chemical fertilizers. On contrary the control treatment showed fruits length, diameter of fruits and fruit numbers on each plant (4.16 cm, 3.23 cm and 17.33 cm) was recorded under control treatment. It is clear from data that use of combined inorganic and organic fertilizers resulted in rise of 99, 78 and 69% respectively in length of fruits, diameter of fruits and fruits number on every plant. The same results had been perceived in a study on radish conducted by Domínguez and Edwards (2011), in which maximum yield had been observed. Vermicompost mixed with simple compost has very high-water holding capacity, drainage, aeration and porosity. They have a large surface area, which allows for good nutrient absorption and retention. They seem to hold more nutrients for extended period of time for plants.

Data regarding yield per plant is arranged in the Table 2. The literature clearly shows that yield/ plant is impacted significantly by applying combined application of inorganic and organic fertilizer. Statistically higher yield per plant (1.50 kg) was recorded after applying 25% simple compost + 25% vermicompost + 25% vermi-tea + 25% chemical fertilizers. However, minimum yield per plant (0.87 kg) was observed under control treatment. It is clear that an increase of 72% in yield per plant was observed by applying combination of organic and inorganic fertilizer. In a study the same results have been observed performed on tomato by Bansal and Kapoor (2000), in which maximum fruit yield per plant had been observed. It has been shown to have an effect on all yield parameters including increased seedling growth, improved seed germination, fruiting and flowering of all major crops like sugarcane, okra, potato, wheat, paddy, corn, brinjal, tomato, grape, strawberry, spinach and those of flowering crops such as chrysanthemums, marigolds, poinsettias, sunflowers and petunias.

*Physiological and yield traits*

Data regarding various physiological and yield traits like per plot yield (kg), per hectare yield (kg), membrane stability index (MSI %), relative water contents (RWC %), chlorophyll *a*, *b* and total chlorophyll contents (a+b) (mg $g^{-1}$fwt) of tomato crop is shown in Table 3.

It is clear from the data taken from this experiment that all the treatments included in the study significantly affected yield/ plot (kg) and yield per hectare (kg) of tomato. Recorded data showed that statistically maximum yield per pot (15.50 kg) and yield per hectare (13657 kg) achieved in $T_5$ (25% simple compost + 25% vermicompost + 25% vermi-tea + 25% chemical fertilizers) followed by $T_4$ (33% simple compost + 33% vermicompost + 34% vermi-tea) which produced tomato yield per pot (14.66 kg) and yield per hectare (12466 kg). On the other hand, minimum yield per pot and yield per hectare (8.33 and 7900 kg) was noted in $T_0$ (control/recommended fertilizers). The same results have been perceived in a study performed on tomato by Bansal and Kapoor (2000) in which maximum yield/plot and yield/ha respectively had been observed. The vermi-tea have 0.74% total $P_2O_5$, 0.92% total N and 0.85% total $K_2O$ (Alcantara and Gonzaga, 2019). Vermicompost tea, vermicompost and simple compost are impressive modifications for plant growth and yield, as well as disease and insect pest suppression (Arancon *et al*., 2012). It contains various micro and macronutrients including nitrogen, iron, potassium, magnesium, zinc, calcium, cooper, vitamins, amino acids, and plant growth regulators such as auxin and cytokinins (Sinha *et al*., 2010). Data regarding membrane stability index (MSI %) and relative water contents (RWC %) stated that all the treatments (organic and inorganic fertilizers) under study have substantial effect on these attributes of crop. It is very obvious from the recorded data that maximum values of membrane stability index (85.33%) and relative water contents (89.00%) were recorded in treatment where 25% simple compost + 25% vermicompost + 25% vermi-tea + 25% chemical fertilizers ($T_5$) were applied. In contrast statistically minimum RWC (80.33%) and MSI (77.33%) were recorded in treatment ($T_0$) where only recommended chemical fertilizer dose was used. Same results have been perceived in a study on radish done by Milind and Isha (2013), in which maximum the membrane stability index and relative water contents have been perceived. Test outcomes have shown the improved availability of beneficial microbes and necessary micronutrients in vermicompost, vermi-tea and simple compost deployed soil. The most striking finding was a significantly lower occurrence of pest and disease attacks in vermicompost., vermi-tea and compost applied crops.

Data regarding chlorophyll *a, b* and total chlorophyll contents (*a+b*) (mg $g^{-1}$ fwt) demonstrated that combined application of inorganic and organic sources significantly enhanced these vital attributes of crop as compared to rest of the treatments under study. Statistically higher chlorophyll *a*, *b* and total chlorophyll contents (6.20, 2.01 and 8.22 mg $g^{-1}$fwt) were observed in $T_5$ (25% simple compost + 25% vermicompost + 25% vermi-tea + 25% chemical fertilizers) followed by $T_4$ (33% simple compost + 33% vermicompost + 34% vermi-tea) which produced 5.83. 1.89 and 7.72 mg $g^{-1}$fwt (chlorophyll *a*, *b* and total chlorophyll contents), respectively. Conversely, the lowest values of chlorophyll, *a*, chlorophyll *b* and total chlorophyll contents (3.26. 0.94 and 4.21 mg $g^{-1}$ fwt) were noted in $T_0$ (recommended fertilizer) treated plots. The same results were seen in radish study by Domínguez and Edwards (2011), in which maximum chlorophyll contents had been observed where vermicompost, simple compost, vermi-tea and chemical fertilizers were applied.

Data regarding chlorophyll contents (SPAD value), total carotenoids (mg $g^{-1}$ fwt) and photosynthetic rate (µmol $m^{-2}$ $s^{-1}$) is shown in Table 4. The presented data of these parameters clearly indicated that all the treatments under study significantly affected these vital attributes of tomato.

From the data it is marked that combined application of inorganic and organic fertilizers ($T_5$: 25% simple compost + 25% vermicompost + 25% vermi-tea + 25% chemical fertilizers) gave maximum SPAD value (41.66) of chlorophyll contents of tomato which was statistically at par with $T_4$ (33% simple compost + 33% vermicompost + 34% vermi-tea) which gave SPAD value (39.33) of chlorophyll contents. Treatment $T_3$ (100% vermi-tea) gave SPAD value (37.00) of chlorophyll contents which was statistically equal to that of treatment $T_4$ (33% simple compost + 33% vermicompost + 34% vermi-tea). In contrast minimum SPAD value (27.66) of chlorophyll contents was observed in treatment $T_0$ (recommended fertilizers). Same results had been perceived in a study on radish done by Musa *et al*. (2018) and Naidu *et al*. (2002) where maximum chlorophyll contents were observed where organic and inorganic nutrients were applied. The all sources of nutrition i.e chemical fertilizers, vermicompost, simple compost and vermi-tea enhance soil organic matter content including humic elements that influence nutrient addition in soil, thus providing media for nutrients uptake by plant roots and encouraging growth by promoting chlorophyll contents.

Total carotenoids (mg $g^{-1}$ fwt) and photosynthetic rate (µmol $m^{-2}$ $s^{-1}$) figures given in Table 4 indicated that all the treatments improved these attributes over control. It is obvious from the data that $T_5$ (25% simple compost + 25% vermicompost + 25% vermi-tea + 25% chemical fertilizers) produced significantly maximum carotenoids (3.98 mg $g^{-1}$ fwt) and photosynthetic rate (23.66 µmol $m^{-2}$ $s^{-1}$) in tomato crop. These values are statistically at par with $T_4$ (33% simple compost + 33% vermicompost + 34% vermi-tea) which gave photosynthetic rate and carotenoid contents of 21.33 µmol $m^{-2}$ $s^{-1}$ and 3.77 mg $g^{-1}$ fwt, respectively. As far as photosynthetic rate was concerned $T_3$ (100% vermi-tea) gave 19.66 µmol $m^{-2}$ $s^{-1}$ that was statistically similar with $T_4$ (33% simple compost + 33% vermicompost + 34% vermi-tea). In comparison minimum photosynthetic rate and carotenoid contents (12.33 µmol $m^{-2}$ $s^{-1}$ and 2.17 mg $g^{-1}$ fwt) were noted in treatment $T_0$ (recommended fertilizer). Same results had been perceived in a study of Balasubramanian *et al*. (2009) in which the maximum total carotenoids and photosynthetic rate had been observed. Vermicomposts, vermi-tea and simple compost are rich in diversity and microbial population, especially bacteria such as actinomycetes and fungi. Plant growth promoting rhizobacteria (PGPB) increases productivity straightforwardly by nitrogen fixation (N), solubilizing nutrients, and producing growth hormones like 1-aminocyclopropane-1-carboxylate (ACC) deaminase, as well as periphrastically by promoting fungal growth by producing fluorescent pigments, siderophores, antibiotics, chitinase, ß-1, 3-glucanase and cyanide. These all-growth promoters, regulators and nutrients increase growth, development and physiological mechanism i.e carotenoids and photosynthetic activity enhanced.

**Table 4: Effects of inorganic and organic fertilizers on the physiological traits of tomato crop.**

| Treatments | Chlorophyll contents (Spade value) | Total carotenoids (mg $g^{-1}$fwt) | Photosyn-thetic rate (µmol $m^{-2}$ $s^{-1}$) |
|---|---|---|---|
| $T_0$ | 27.66 E | 2.17 E | 12.33 E |
| $T_1$ | 31.00 DE | 2.61 D | 14.66 DE |
| $T_2$ | 34.66 CD | 2.93 C | 17.33 CD |
| $T_3$ | 37.00 BC | 3.40 B | 19.66 BC |
| $T_4$ | 39.33 AB | 3.77 A | 21.33 AB |
| $T_5$ | 41.66 A | 3.98 A | 23.66 A |
| MS for treatment | 82.08** | 1.45** | 53.70** |
| LSD @ 0.05 | 3.69 | 0.31 | 2.67 |

Means sharing the same letters do not differ significantly ($P \leq 0.05$). **= Highly Significant; MS= Mean sum of square; LSD= Least significant differences test.

## Conclusions and Recommendations

According to the present research, the treatment combination which gave rise to maximum values of growth, yield, and quality traits was consisting of 25% simple compost + 25% vermicompost + 25% vermi-tea+ 25% chemical fertilizers ($T_5$). As a result of the current research, this treatment ($T_5$) was determined to be the best possible treatment combination to obtain maximum yield and quality of tomato. The growers might consider this combo of treatment if they can't afford the others. Overall, taking into account yield sustainability, economic feasibility, soil health enhancement, environmental safety and human wellbeing, it is advisable that tomato growers in the concurrent area should use 25% of the recommended amount of inorganic fertilizer with 25% simple compost, 25% vermicompost, and 25% vermicompost tea. Though it might be too early to draw any conclusions from the current study, further studies of this type are needed to generate more precise and accurate data by incorporating more integrated ratios of certain nutrient sources (vermicompost, NP fertilizers, vermi-tea, and simple compost) in a variety of soil and agro-climatological scenarios. It' is worth noting that, recycling of human waste via vermicomposting technique for crop production is relatively a novel idea in the study area, so farmers need to be trained and supported in issues such as proper waste collection, handling, composting/ vermicomposting, and their combined application inorganic fertilizer. Finally, the competent authorities must draft a proper policies by legislation, and institutional frameworks that take into account the social and cultural dynamics of the community in order to prevent the environmental and health associated problems with excreta use while also promoting its effective and sustainable use in agriculture.

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## Novelty Statement

The addition of nutrients is necessary for promoting plant development. Therefore, in this study, a novel integrated organic and inorganic fertilizers containing both macro and micro nutrients were applied on tomato crop. The main aim of this research was to integrate the use of natural and man-made soil nutrients to increase crop productivity and preserve soil productivity for future generations.

## Author's Contribution

Conceived and designed the experiments: Zubair Aslam and Ali Ahmad, Performed the experiments: Ali Ahmad, Analyzed the data: Ali Ahmad and Zubair Aslam, Contributed reagents/materials/analysis tools: Zubair Aslam, Ali Ahmad and Korkmaz Bellitürk, Wrote the paper: Zubair Aslam, Ali Ahmad, Korkmaz Bellitürk, Hira Kanwal, Muhammad Asif and Ehsan Ullah.

*Conflict of interests*

The authors have acknowledged that that they do not have any conflicts of interest.

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