# MICROBIAL POPULATION ECOLOGY UNDER TEAK (*TECTONA GRANDIS* LINN. F.) FERTIGATION RESEARCH TRIAL IN FARM CONDITIONS OF WESTERN TAMIL NADU

ANJALI, K. S.[1*] – BALASUBRAMANIAN, A.[1*] – RADHAKRISHNAN, S.[1] – RAMAH, K.[2] – BOOMINATHAN, P.[3] – HARI PRASATH, C. N.[1]

[1]*Department of Silviculture & Natural Resource Management, Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam - 641 301, Tamil Nadu, India*

[2]*Agricultural Research Station, Tamil Nadu Agricultural University, Bhavanisagar - 638 451, Tamil Nadu, India*

[3]*Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore - 641 003, Tamil Nadu, India*

[*]*Corresponding author*
*e-mail: balasubramanian.a@tnau.ac.in, anjalisudhaks123@gmail.com*

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**Abstract.** A field study was established in farmer's field at Coimbatore district of Tamil Nadu to study the impact of fertigation on growth and productivity of teak (*Tectona grandis* Linn. f.). The irrigation treatments were scheduled according to the crop water requirement based on climatological approach and the fertigation treatments are imposed as per the reference fertilizer dosage of 150:100:100 kg NPK/ha. The chemical fertilizers applied may have an impact of the physiobiochemical properties on the soil. Based on these assumptions the current study deals with the comparison of microbial populations under different fertigation regimes recorded terms of Total Bacterial Count (TBC), Total Fungal Count (TFC) and Total Actinoimycetes Count (TAC) in two-year-old teak plantations. The maximum value for TBC (6.69 cfu $g^{-1}$), TFC (3.60 cfu $g^{-1}$) and TAC (5.19 cfu $g^{-1}$) is observed in $I_1F_2$ (50% PE 100% RDF). The karl Pearsons correlation analysis and canonical correlation analysis conducted infers correlation between soil physiochemical factors such as pH, electrical conductivity, organic carbon, total nitrogen and carbon:nitrogen(C:N) with soil microbial populations. The current study regsitered a decrease in microbial count at higher fertilizer levels with altered soil parameters corresponding to the microbial population.
**Keywords:** *teak, growth, productivity, computed water requirement, Total Bacterial Count, Total Fungal Count, Total Actinoimycetes Count*

## Introduction

A growing demand for timber is one of the main challenges in the wood-based industries in the 21st century. The market demand of Indian timber is mainly met from state forest departments, forest development corporations, Trees outside Forests (TOF), and imports from other countries (ITTO, 2010). Owing to its superlative properties, *Tectona grandis* is traditionally the most preferred timber species in India. In India, mostly teak-distributed forest areas are found in Madhya Pradesh, Maharashtra, Tamil Nadu, Karnataka, Kerala, Uttar Pradesh, etc. (Troup, 1921). The total area of teak plantations is about 1.7 million hectares. Despite, the imports of teak roundwood have doubled from about half a million $m^3$ in 2009 to slightly more than a million $m^3$ in 2019 (ITTO, 2010). India alone consumes 70 to 100 percent of teak logs from Africa and Latin America and 90,000 $m^3$ of teak is imported annually (Shrivastava and Saxena, 2017). Thus, the demand emphasises pressure on the plantation forestry sectors to


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supply the wood based raw materials within short rotation period. Hence, in order to overcome this situation we are in need to promote inefficacious silvicultural practices in irrigation and fertilization management.

The need of high productivity with long-term sustainability and optimum resource use efficiency in the restricted land available for farming, has impacted in the evolution of various management practices (He et al., 2018). The basic fundamental factors which play a vital role for the growth and development of plants are water and nutrients. They are widely accepted and used in intensive agriculture, horticulture, plantation forestry, and agroforestry, where they work in tandem and complement each other (Morgan, 1984; Stanturf et al., 2001; Rajput and Patel, 2006; Li and Liu, 2011). Controlled application of water and fertilization is a basic farming practice in which chemical or organic fertilizers with a certain amount of water are used primarily to improve soil nutrients and hence crop productivity (Mayer et al., 2015). Drip irrigation is one such novel approach with high water and fertilizer use-efficiency enhancing sustainable crop production.

The anthropological innovations have obligated changes in farming practices which leads to shift in soil microbial population altering physicobiochemical properties of soil (Goverts et al., 2007). The soil functioning and sustenance of soil fertility is predominantly governed by the activities of soil microflora, as an indicator of soil health and productivity (Anderson, 2003; Alberton and Hungria, 2010; Mbuthia et al., 2015). Therefore, the shift in the soil microbial population owing to different farming practices may influence the overall productivity and stability of the system (Francioli et al., 2016; Schloter et al., 2018). The importance of the soil microflora in forest ecosystems are well known, despite there are few studies in understanding the impacts of long-term fertilization and other farming management practices on soil microbial population (Wang et al., 2019). Thus, the current study focused on "Microbial population dynamics in teak (*Tectona grandis* Linn. f.) under different fertigation regimes in farm conditions".

## Materials and method

The current research trial on teak was established in farmer's field at Pachapalayam village, Perur, Coimbatore district of Tamil Nadu, India (11º14" N and 77º03" E) in August 2021. The experiment was laid out with a spacing of 3 m x 3 m for an area of about 7.5 acres. The treatments were imposed on the selected homogenous sampling plot of 5508 $m^2$ (108 m x 51 m) following split plot design with irrigation regimes as main plot and fertilizer regimes as subplot. The average weather parameters of the study area are presented in *Figure 1* and *Figure 2*.

### *Treatment and observations*

The experiment consists of four irrigation levels viz., $I_1$ – 50%, $I_2$ – 75%, $I_3$ – 100%, $I_4$ – 125% of calculated water requirement of tree (WRt) as a main plot and Four fertigation levels viz., $F_1$ – 75%, $F_2$ – 100%, $F_3$ – 125%, $F_4$ – 150% of recommended dose of fertilizer (RDF) as sub plots (*Table 1*). The recommended dose of fertilizer (RDF) for teak is 150:100:100 Kg NPK $ha^{-1}$ (Geetha and Balagopalan, 2009) has taken as a baseline for the study. One control treatment with conventional method of irrigation (surface) and fertigation (soil application of 100% of recommended dose of fertilizer) is


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added for comparison. The experiment was laid out by the following split plot design with three replications.

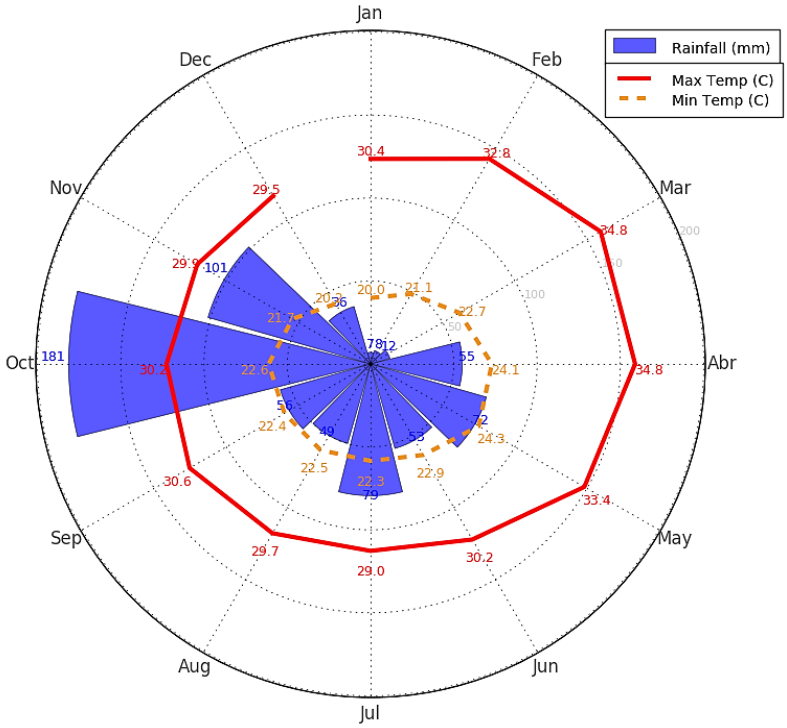


***Figure 1.*** *Average weather data of the study area (Model- NoeESM1-M, 2021)*

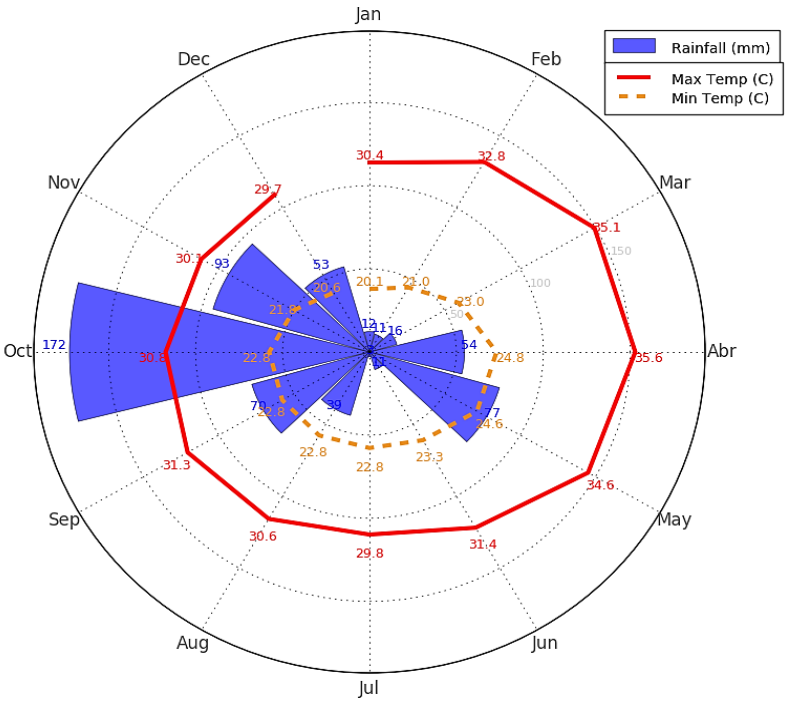


***Figure 2.*** *Average weather data of the study area (Model- NoeESM1-M, 2022)*


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***Table 1.*** *Layout of the irrigation (main plot) and fertilizer (sub plot) treatments*

| **Treatments** | | **Sub plot (Fertigation levels)** | | | |
|---|---|---|---|---|---|
| | | $F_1$ | $F_2$ | $F_3$ | $F_4$ |
| Main Plot (Irrigation levels) | $I_1$ | 50% PE 75% RDF | 50% PE 100 % RDF | 50% PE 125% RDF | 50% PE 150% RDF |
| | $I_2$ | 75% PE 75% RDF | 75% PE 100% RDF | 75% PE 125% RDF | 75% PE 150% RDF |
| | $I_3$ | 100% PE 75% RDF | 100% PE 100% RDF | 100% PE 125% RDF | 100% PE 150% RDF |
| | $I_4$ | 125% PE 75% RDF | 125% PE 100% RDF | 125% PE 125% RDF | 125% PE 150 % RDF |
| Control | | Conventional method of irrigation (surface) and fertigation (soil application of 100 % of recommended dose of fertilizer) | | | |

PE – Potential Evapotranspiration, RDF- Recommended Dose of Fertilizers

The fertilizers used for Nitrogen (N), Phosphorus (P) and Potassium (K) are Urea (46% N), Mono-ammonium phosphate (MAP) (61% $P_2O_5$), White potash (60% $K_2O$) for drip fertigation and conventional method of application. The entire dosage of 150:100:100 Kg NPK $ha^{-1}$ was supplied once in 30 days as per the fertilizer schedule through drip irrigation. The irrigation was carried out through drip system once in three days based on the climatological approach i.e., daily pan evaporation value (PE) taken from meteorology observatory of Tamil Nadu Agricultural University, Coimbatore.

The water requirement of the tree is computed as

$$\mathbf{WRc} = \mathrm{CPE} \times \mathrm{Kp} \times \mathrm{Kc} \times \mathrm{Wp} \times \mathrm{A} - \mathrm{ER} \qquad \text{(Eq.1)}$$

where,
**$WR_C$** = Computed water requirement for tree (lit / plant)
**CPE** = Cumulative pan evaporation (mm)
**$K_p$** = Pan factor**, $K_c$** = Crop factor/plant factor (Allen et al. (FAO), 1988)
**$W_p$** = Wetted percentage, **ER** = Effective rainfall
**A** = Spacing of the crop.

The derived plant factor (**$K_c$**) used in the present study was developed by Allen et al. (FAO, 1988), which is regarded as 0.85 for medium size actively growing trees. The wetted percentage is calculated as the ratio of radius of the wetted area in the field to the lateral spacing (Keller and Bliesner, 1990; Yıldırım, 2003).

The derived plant factors by FAO are reevaluated by the formula,

$$\boldsymbol{Plant\ factor} = \frac{\boldsymbol{Canopy\ area}}{\boldsymbol{Land\ area}} \qquad \text{(Eq.2)}$$

### *Soil parameters*

*Soil pH and electrical conductivity*

For pH estimation 1:25 ratio of soil: water suspension was prepared. The pH was measured by using pH meter as described by Jackson (1973). The electrical conductivity of soil samples collected from different depths were determined from the supernatant liquid of the water suspension (1:2.5) with the help of a conductivity meter (Jackson, 1958).


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*Organic carbon*

Determination of organic carbon was done by wet digestion method (Walkley and Black, 1934). The soil samples collected near the tree root zone were air dried and passed through 0.2 mm sieve. The soil organic carbon was estimated using equation:

$$\textbf{Soil organic carbon}\ (\%) = \frac{(\textbf{Blank value} - \textbf{Titre value}) \times 10 \times 0.003 \times 100}{\textbf{Weight of soil sample}\ (g) \times \textbf{blank value}} \quad \text{(Eq.3)}$$

*Nitrogen content*

Nitrogen content of the soil samples collected near the tree root zone were determined by alkaline permanganate method (Subbaih and Asija, 1956).

***Total Microbial Count***

Estimation of Total Microbial Count (TMC) was done by "Serial dilution plate technique (Johnson and Curl, 1972) using Nutrient agar medium for bacteria, Potato Dextrose agar medium for fungi and Ken Knight's Agar medium for actinomycetes."

***Statistical analysis***

The design of the experiment used is split plot design with three replications. For treatment significance, the critical differences (CD) were worked out by means of Tuckey's HSD for the post-hoc test under R environment (R Core Team, 2012).

## Results

***Total Microbial Count***

The comparison of microbial population taken under 2-year-old teak under different fertigation regimes is estimated in terms of Total Bacterial Count (TBC), Total Fungal Count (TFC) and Total Actinomycetes Count (TAC). The Anova of the respective analysis is represented in *Table2, Table 3 and Table 4*. In the present study, perusal of data infers variation in the soil microbial population with different levels of irrigation and fertilizers (*Table 5*). The maximum value for TFC (3.60 cfu $g^{-1}$, $p>0.05$) and TAC (5.19 cfu $g^{-1}$, $p>0.05$) is observed in $I_1F_2$ (50% PE 100% RDF) and TBC in $I_1F_3$ (50% PE 100% RDF) (6.90 cfu $g^{-1}$, $p<0.05$), and the minimum value for TBC (5.81 cfu $g^{-1}$) in $I_1F_4$ (50% PE 150% RDF), TFC (2.35 cfu $g^{-1}$) in $I_2F_4$ (100% PE 150% RDF) and TAC (2.16 cfu $g^{-1}$) in $I_4F_4$ (125% PE 150% RDF), respectively. On comparing the main plot as a whole, among the irrigation treatments, the maximum value for TBC (6.30 cfu $g^{-1}$, $p<0.05$), TFC (3.49 cfu $g^{-1}$, $p>0.05$) is observed under $I_3$ (100% PE) and TAC (4.30 cfu $g^{-1}$, $p<0.05$) under $I_1$ (50% PE), where TBC (5.95 cfu $g^{-1}$) and TAC (2.81 cfu $g^{-1}$) is reduced under maximum irrigation level (125% PE) on contrary, TFC (3.06 cfu $g^{-1}$) is reduced under minimum irrigation level (50% PE). Where under different fertilizer levels, TBC (6.53 cfu $g^{-1}$), TFC (3.38 cfu $g^{-1}$) and TAC (4.19 cfu $g^{-1}$) is maximum at lower fertilizer level (75% RDF) on contrary TBC (6.07 cfu $g^{-1}$) and TAC (3.53 cfu $g^{-1}$) is minimum at $F_4$ (150% RDF) and TFC (3.10 cfu $g^{-1}$) is observed minimum at $F_2$ (100% RDF), respectively.


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***Table 2.*** *Anova table for split plot analysis for Total Bacterial Count (TBC)*

| Tests of Between-Subjects Effects | | | | | |
|---|---|---|---|---|---|
| **Dependent Variable: TBC** | | | | | |
| **Source** | **Type III Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Corrected Model | 4.772[a] | 23 | .207 | 2.669 | .010 |
| Intercept | 1839.916 | 1 | 1839.916 | 23672.122 | .000 |
| Irrigation | 1.858 | 3 | .619 | 7.967 | .001 |
| Fertilizer | 1.012 | 3 | .337 | 4.341 | .014 |
| Replication | .032 | 2 | .016 | .205 | .816 |
| Irrigation * Fertilizer | 1.673 | 9 | .186 | 2.391 | .043 |
| Irrigation * Replication | .197 | 6 | .033 | .423 | .856 |
| Error | 1.865 | 24 | .078 | | |
| Total | 1846.553 | 48 | | | |
| Corrected Total | 6.637 | 47 | | | |

a. R Squared = .719 (Adjusted R Squared = .450)

***Table 3.*** *Anova table for split plot analysis for Total Fungal Count (TFC)*

| Tests of Between-Subjects Effects | | | | | |
|---|---|---|---|---|---|
| **Dependent Variable: TFC** | | | | | |
| **Source** | **Type III Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Corrected Model | 10.926[a] | 23 | .475 | .782 | .721 |
| Intercept | 502.072 | 1 | 502.072 | 826.469 | .000 |
| Irrigation | .692 | 3 | .231 | .380 | .769 |
| Fertilizer | 1.226 | 3 | .409 | .673 | .577 |
| Replication | .691 | 2 | .345 | .568 | .574 |
| Irrigation * Fertilizer | 4.347 | 9 | .483 | .795 | .624 |
| Irrigation * Replication | 3.970 | 6 | .662 | 1.089 | .397 |
| Error | 14.580 | 24 | .607 | | |
| Total | 527.578 | 48 | | | |
| Corrected Total | 25.506 | 47 | | | |

a. R Squared = .428 (Adjusted R Squared = -.119)

***Table 4.*** *Anova table for split plot analysis for Total Actinomycetes Count (TAC)*

| Tests of Between-Subjects Effects | | | | | |
|---|---|---|---|---|---|
| **Dependent Variable: TAC** | | | | | |
| **Source** | **Type III Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Corrected Model | 59.835[a] | 23 | 2.602 | 2.527 | .014 |
| Intercept | 675.675 | 1 | 675.675 | 656.213 | .000 |
| Irrigation | 3.468 | 3 | 1.156 | 1.123 | .036 |
| Fertilizer | 17.386 | 3 | 5.795 | 5.629 | .075 |
| Replication | 4.606 | 2 | 2.303 | 2.237 | .129 |
| Irrigation * Fertilizer | 19.831 | 9 | 2.203 | 2.140 | .066 |
| Irrigation * Replication | 14.543 | 6 | 2.424 | 2.354 | .063 |
| Error | 24.712 | 24 | 1.030 | | |
| Total | 760.222 | 48 | | | |
| Corrected Total | 84.547 | 47 | | | |

a. R Squared = .708 (Adjusted R Squared = .428)


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***Table 5.*** *Impact of fertigation on Total Microbial Count*

| Main Plot | Subplot | Total Bacterial Count (cfu $g^{-1}$) | Total Fungal Count (cfu $g^{-1}$) | Total Actinomycetes Count (cfu $g^{-1}$) |
|---|---|---|---|---|
| $I_1$ | $F_1$ | $6.73^{bc}$ | $3.28^{a}$ | $3.68^{a}$ |
| | $F_2$ | $6.69^{bc}$ | $3.60^{a}$ | $5.19^{a}$ |
| | $F_3$ | $6.90^{c}$ | $3.28^{a}$ | $5.12^{a}$ |
| | $F_4$ | $5.81^{a}$ | $3.39^{a}$ | $2.78^{a}$ |
| $I_2$ | $F_1$ | $6.07^{ab}$ | $3.39^{a}$ | $4.50^{a}$ |
| | $F_2$ | $6.27^{abc}$ | $3.06^{a}$ | $3.92^{a}$ |
| | $F_3$ | $6.13^{abc}$ | $3.58^{a}$ | $2.53^{a}$ |
| | $F_4$ | $5.85^{a}$ | $2.35^{a}$ | $4.04^{a}$ |
| $I_3$ | $F_1$ | $6.24^{abc}$ | $3.12^{a}$ | $4.78^{a}$ |
| | $F_2$ | $5.91^{a}$ | $3.43^{a}$ | $3.60^{a}$ |
| | $F_3$ | $6.07^{ab}$ | $3.29^{a}$ | $3.50^{a}$ |
| | $F_4$ | $6.14^{abc}$ | $3.44^{a}$ | $2.28^{a}$ |
| $I_4$ | $F_1$ | $6.15^{abc}$ | $2.37^{a}$ | $4.24^{a}$ |
| | $F_2$ | $6.03^{ab}$ | $3.23^{a}$ | $4.31^{a}$ |
| | $F_3$ | $6.09^{ab}$ | $3.47^{a}$ | $3.40^{a}$ |
| | $F_4$ | $5.99^{ab}$ | $3.49^{a}$ | $2.16^{a}$ |
| Control | | 4.98 | 3.22 | 2.18 |
| SE.M | | 0.148 | 0.448 | 0.676 |
| **Irrigation** | | | | |
| $I_1$ | | $6.29^{B}$ | $3.06^{A}$ | $4.30^{B}$ |
| $I_2$ | | $6.22^{AB}$ | $3.25^{A}$ | $4.26^{B}$ |
| $I_3$ | | $6.30^{B}$ | $3.49^{A}$ | $3.64^{AB}$ |
| $I_4$ | | $5.95^{A}$ | $3.14^{A}$ | $2.81^{A}$ |
| SE.M | | 0.0739 | 0.224 | 0.338 |
| **Fertilizers** | | | | |
| $F_1$ | | $6.53^{B}$ | $3.38^{A}$ | $4.19^{A}$ |
| $F_2$ | | $6.08^{A}$ | $3.10^{A}$ | $3.75^{A}$ |
| $F_3$ | | $6.09^{A}$ | $3.32^{A}$ | $3.54^{A}$ |
| $F_4$ | | $6.07^{A}$ | $3.14^{A}$ | $3.53^{A}$ |
| SE.M | | 0.0739 | 0.224 | 0.338 |

### *Soil physiochemical properties corresponding to Total Microbial Count*

The soil properties influencing MC is estimated in terms of soil pH, Electrical Conductivity (EC), Soil Organic Carbon (%), Soil Total Nitrogen (%) and C:N ratio (*Table 6*). The soil pH (7.13), Electrical conductivity (0.168 $dSm^{-1}$), Organic Carbon (0.717 %), Total Nitrogen (0.046%) and C:N (19.1) is observed maximum at $I_1F_1$ (50% PE 75% RDF), $I_4F_2$ (125% PE 100% RDF), $I_1F_3$ (50% PE 125% RDF), $I_3F_4$ (100% PE 150% RDF) and $I_2F_4$ (75% PE 150% RDF) respectively where the minimum values for pH (6.54), Electrical conductivity (0.141 $dSm^{-1}$), Organic Carbon (0.513 %), Total Nitrogen (0.033%) and C:N (13.3) is registered under $I_3F_3$ (100% PE 125% RDF), $I_2F_1$ (75% PE 75% RDF), $I_4F_2$ (125% PE 100% RDF), $I_1F_1$ (50% PE 75% RDF) and $I_4F_2$ (125% PE 100% RDF) respectively.


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***Table 6.*** *Impact of fertigation on soil physiochemical parameters*

| Main Plot | Subplot | pH | Electrical Conductivity ($dSm^{-1}$) | Organic Carbon (%) | Total Nitrogen (%) | C:N |
|---|---|---|---|---|---|---|
| $I_1$ | $F_1$ | $7.13^{c}$ | $0.145^{ab}$ | $0.613^{ab}$ | $0.033^{a}$ | $18.5^{bc}$ |
| | $F_2$ | $6.98^{bc}$ | $0.149^{abcd}$ | $0.614^{ab}$ | $0.035^{b}$ | $17.5^{abc}$ |
| | $F_3$ | $7.12^{c}$ | $0.155^{abcd}$ | $0.717^{b}$ | $0.038^{cde}$ | $19.0^{c}$ |
| | $F_4$ | $6.85^{abc}$ | $0.147^{abc}$ | $0.690^{ab}$ | $0.037^{c}$ | $18.5^{bc}$ |
| $I_2$ | $F_1$ | $6.84^{abc}$ | $0.141^{a}$ | $0.573^{ab}$ | $0.034^{b}$ | $16.6^{abc}$ |
| | $F_2$ | $6.95^{bc}$ | $0.166^{cd}$ | $0.580^{ab}$ | $0.035^{b}$ | $16.4^{abc}$ |
| | $F_3$ | $6.76^{ab}$ | $0.159^{abcd}$ | $0.733^{b}$ | $0.039^{ef}$ | $18.9^{c}$ |
| | $F_4$ | $7.05^{bc}$ | $0.167^{cd}$ | $0.727^{b}$ | $0.038^{cde}$ | $19.1^{c}$ |
| $I_3$ | $F_1$ | $6.83^{abc}$ | $0.155^{abcd}$ | $0.563^{ab}$ | $0.034^{a}$ | $17.0^{abc}$ |
| | $F_2$ | $7.10^{bc}$ | $0.152^{abcd}$ | $0.650^{ab}$ | $0.043^{f}$ | $15.2^{abc}$ |
| | $F_3$ | $6.54^{a}$ | $0.151^{abcd}$ | $0.687^{ab}$ | $0.045^{f}$ | $15.1^{abc}$ |
| | $F_4$ | $6.96^{bc}$ | $0.159^{abcd}$ | $0.630^{ab}$ | $0.046^{f}$ | $13.8^{ab}$ |
| $I_4$ | $F_1$ | $6.93^{bc}$ | $0.163^{bcd}$ | $0.557^{ab}$ | $0.040^{f}$ | $14.0^{ab}$ |
| | $F_2$ | $7.02^{bc}$ | $0.168^{d}$ | $0.513^{a}$ | $0.039^{def}$ | $13.3^{a}$ |
| | $F_3$ | $6.91^{abc}$ | $0.165^{bcd}$ | $0.590^{ab}$ | $0.038^{cde}$ | $15.7^{abc}$ |
| | $F_4$ | $6.74^{ab}$ | $0.166^{cd}$ | $0.660^{ab}$ | $0.040^{f}$ | $16.7^{abc}$ |
| Control | | 6.56 | 0.167 | 0.571 | 0.034 | 16.4 |
| SE.M | | 0.0704 | 0.00385 | 0.0355 | 0.00197 | 0.909 |
| **Irrigation** | | | | | | |
| $I_1$ | | $6.93^{AB}$ | $0.151^{A}$ | $0.658^{B}$ | $0.036^{A}$ | $18.4^{B}$ |
| $I_2$ | | $7.01^{B}$ | $0.158^{AB}$ | $0.653^{B}$ | $0.037^{B}$ | $17.8^{B}$ |
| $I_3$ | | $6.83^{A}$ | $0.158^{AB}$ | $0.632^{AB}$ | $0.042^{D}$ | $15.3^{A}$ |
| $I_4$ | | $6.90^{AB}$ | $0.160^{B}$ | $0.580^{A}$ | $0.039^{C}$ | $14.9^{A}$ |
| SE.M | | 0.0352 | 0.00192 | 0.0177 | 0.00985 | 0.455 |
| **Fertilizers** | | | | | | |
| $F_1$ | | $7.02^{B}$ | $0.149^{A}$ | $0.577^{A}$ | $0.036^{A}$ | $16.5^{A}$ |
| $F_2$ | | $6.90^{AB}$ | $0.158^{BC}$ | $0.589^{A}$ | $0.037^{B}$ | $15.6^{A}$ |
| $F_3$ | | $6.86^{A}$ | $0.154^{AB}$ | $0.682^{B}$ | $0.040^{C}$ | $17.2^{A}$ |
| $F_4$ | | $6.90^{AB}$ | $0.165^{C}$ | $0.677^{B}$ | $0.040^{C}$ | $17.0^{A}$ |
| SE.M | | 0.0352 | 0.00192 | 0.0177 | 0.00985 | 0.455 |

### *Correlations between soil parameters with Total Microbial Count*

In order to correlate the impact of soil parameters on total microbial population, Karl Pearson's correlation analysis (*Table 7*) and Canonical Correlation Analysis (CCA) (*Figure 3*) was conducted. For Karl Pearson's correlation analysis, TBC is positively correlated to pH (0.251), total nitrogen (0.339) ($p<0.05$) and negatively correlated to electrical conductivity (-0.284), organic carbon (-0.014) ($p<0.05$), and C: N (-0.258) where TFC is positively correlated to pH (0.066), and C: N (0.139) negatively correlated to electrical conductivity (-0.031), organic carbon (-0.051), and total nitrogen (-0.017). For TAC, positively correlated to pH (0.201) and organic carbon (0.021) where negatively correlated to electrical conductivity (-0.161), C: N (-0.194) and total nitrogen (-0.114).


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***Table 7.*** *Correlations between soil parameters with Total Microbial Count*

| Karl Pearson's Correlations | pH | EC | Organic Carbon | C:N | Nitrogen | Total Bacterial Count | Total Fungal Count | Total Actinomycetes Count |
|---|---|---|---|---|---|---|---|---|
| **pH** | 1 | | | | | | | |
| **EC** | .040 | 1 | | | | | | |
| **Organic Carbon** | -.017 | -.174 | 1 | | | | | |
| **C:N** | .134 | -.299* | .760** | 1 | | | | |
| **Nitrogen** | -.242 | .184 | .239 | .443** | 1 | | | |
| **Total Bacterial Count** | .251 | -.284 | -.014* | -.258 | .339* | 1 | | |
| **Total Fungal Count** | .066 | -.031 | -.051* | .139 | -.017 | .097 | 1 | |
| **Total Actinomycetes Count** | .201 | -.161 | .021 | -.194* | -.114 | .306* | -.040 | 1 |

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed)

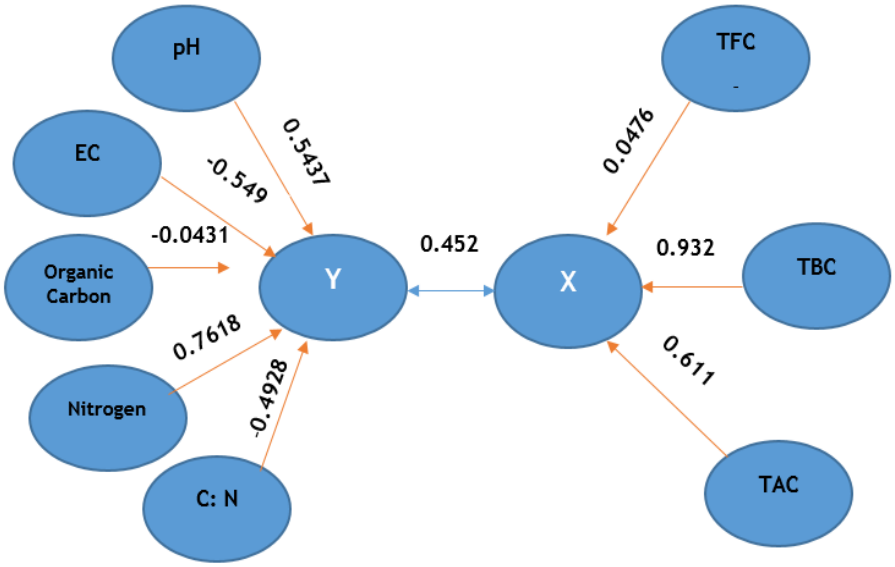


***Figure 3.*** *Canonical Correlations between soil parameters with Total Microbial Count*

Canonical correlations analysis (*Figure 3*) between the set of dependent variables (TBC, TFC, TAC) with independent variables (pH, EC, organic carbon, Total nitrogen, C: N) indicates positive correlation between dependent and independent variables. TFC, TBC and TAC is positively correlated to the covariate of independent variable (X) where pH, total nitrogen is positively and EC, organic carbon, C: N is negatively correlated to the covariate of dependent variable (Y).

## Discussions

The microbial population represented in terms of Total Bacterial Count, Total Fungal Count and Total Actinomycetes Count varies in their representative count (*Figure 4*). The microbial population in the current study is observed minimum at higher level of fertilizer dosage ($F_4$) and maximum at optimum fertilizer dosages ($F_2$ and $F_3$). Higher


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fertilizer dosage observed detrimental impact on soil active microorganisms. More than the irrigation factor taken as main plot, the fertilizer factor has more impact on determining the microbial population under fertigation system. Similar negative results are concluded by Nannipieri et al. (2012) and Lazcano et al. (2013) under fertigation systems, on contrary positive effects (Guo et al., 2011; Geisseler and Scow, 2014) and neutral effects (Li et al., 2021) of fertigation on soil microbial population has also been reported. The microbial population registers dynamic correlation with respect to soil physiochemical parameters. Nitrogen fertilization can alters the microbial compositions of the soil as these acts as a source of direct nutrient supplies to soil influencing soil pH and stimulating the decomposition process (Voroney et al., 1981; Beare et al., 2002; Francioli et al., 2016). There is not much significant variations in the fungal populations compared to bacterial populations (*Figure 4*) as fungi-dominated communities are generally associated with slower organic matter turnover and decompositions (Crowther et al., 2019). Soil microbial population will be majorly negative correlated towards the soil organic carbon, C:N and positively towards soil pH (Frouz and Novakova, 2005) and total nitrogen owing to the fact that soil microbial activity requires more amount of soil carbon and higher C:N indicates more nitrogen leaching or loss from the system (Wieder et al., 2013; Crowther et al., 2019; Muhammad et al., 2021) the present study also predominantly infers the same, though contrary observations are registered in some values the changes are not significant. The variations in the fertigation dosages among the plots is responsible for the alterations in the soil physiochemical parameters contributing to the yield of the crop is hence also influences the microbial population dynamics of the soil altering the system.

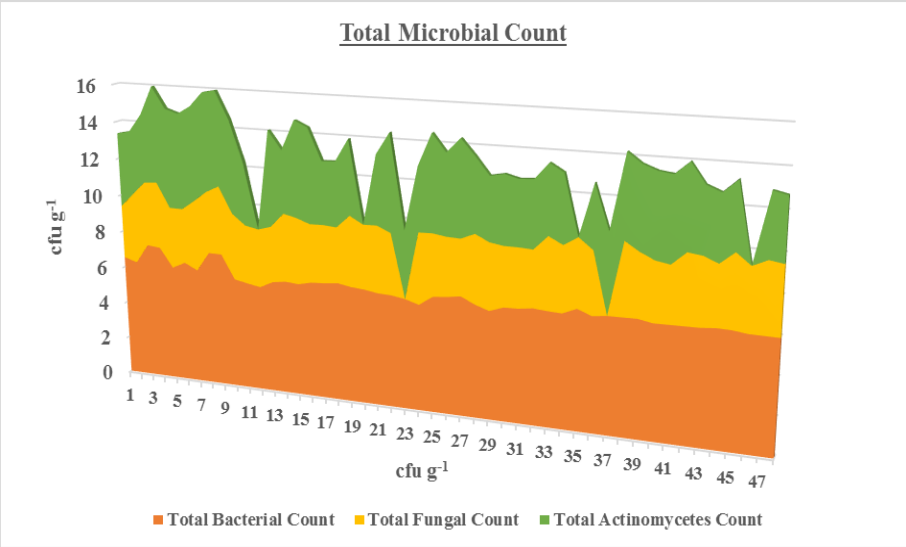


***Figure 4.*** *Comparison between soil microbial populations*

## Conclusion

Soil functioning and fertility is predominantly a function of decomposition activity of soil microbial biomass which in turn determines the crop productivity. Chemical fertilizers can impact the productivity by inducing variations in soil nutrient dynamics while can have impact on the microbial populations affecting soil biological properties


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in the long run. In the present study, the microbial populations are registered maximum in $I_1F_2$ (50% PE 100% RDF). There was a decrease in the microbial population at higher fertigation doses with significant variations in soil physiochemical properties. The current field experiment indicates a relatively permanent response of soil bacterial and fungal and actinomycetes communities under farm forestry conditions to long-term fertilization and provides a clear picture on effects of fertilization regimes on sustainable soil development thus indicating the need of conducting chemical fertilizer management without compromising soil health.

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