



RESEARCH ARTICLE

# Effect of organic sources on soil microbes and soil enzymes activity in finger millet under a finger millet - horse gram cropping system

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## Abstract

The study finger millet (*Eleusine coracana* (L.) Gaertn) is originally native to the Ethiopian highland and was introduced into India approximately 4000 years ago. Intensive cultivation of finger millet has caused a decline in soil fertility and reduced microbial activity in semi- arid regions of India. Therefore, the field investigation was carried out during kharif, 2021 and 2022 to find the effect of different combinations of composts and fertilisers on microbes and enzymes activity. The experiment was laid out in randomised block design (RBD) with 12 treatments and 3 replications. The treatments consisted of different combination of recommended nitrogen (RN) doses that are supplied through T<sub>1</sub>- control, T<sub>2</sub>- 100 % recommended dose of fertilisers (RDF), T<sub>3</sub>- 75 % recommended nitrogen (RN) through chemical fertilisers RN (CF) + 25 % RN green leaf manure compost (GLMC), T<sub>4</sub>- 75 % RN (CF) + 25 % RN groundnut oil cake (GOC), T<sub>5</sub>- 75 % RN (CF) + 25 % RN pressmud compost (PMC), T<sub>6</sub>- 75 % RN (CF) + 25 % RN coir pith compost (CPC), T<sub>7</sub>- 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC), T<sub>8</sub>- 50 % RN (CF) + 25 % RN (PMC) + 25 % RN (CPC), T<sub>9</sub>- 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (PMC), T<sub>10</sub>- 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (CPC), T<sub>11</sub>- 50 % RN (CF) + 25 % RN (GOC) + 25 % RN (PMC) and T<sub>12</sub>- 50 % RN (CF) + 25 % RN (GOC) + 25 % RN (CPC). Finger millet cv. CO 14 was grown with proper cultural practices. The results revealed that T<sub>7</sub> recorded the significantly highest bacterial populations of 22.7, 29.9 and 23.8 (colony forming unit (CFU) × 10<sup>6</sup>) at 30 days after transplanting (DAT), 60 DAT and at post-harvest soil respectively. This treatment also significantly increased the fungal and actinomycetes population, thus following a similar trend. The activities were also recorded under (T<sub>7</sub>) at 30 DAT, 60 DAT and at post-harvest soil were 47.0, 64.2 and 54.6 respectively.

**Keywords:** composts; enzyme activity; finger millet; fertilisers; microbes

## Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn) is an important minor millet crop that cultivated is traditionally rainfed and confined to marginal soils, resulting in significant yield gaps. Optimisation of nutrient management with emphasis on organics will help in attaining and sustaining higher yields (1). It is often referred to as crop cultivated in resource-limited regions. Of the total millet area in the world, 12 % is finger millet, spread over more than 25 countries in Africa and Asia accounting for 10 % of the total millet production (2). In general, millets are rich in many minerals (e.g., calcium (Ca), iron (Fe), zinc (Zn)) and have longer storage life, as long as 50 years and hence termed "Famine reserves" (3).

The use of chemical fertilisers alone does not sustain productivity under continuous intensive cropping, inclusion of organics improves soil physical properties, builds up soil fertility and increases crops yield. Thus, an effort is needed to develop a nutrient management strategy input package with a combination of organic and inorganic fertilisers for finger millet.

The integrated plant nutrient system is the most logical concept for managing long-term soil fertility and productivity (4). The use of chemical fertilisers and organic manures has been found promising in arresting the declining trend in soil health and productivity through the correction of marginal deficiencies of some secondary and micro-nutrients, micro-flora and fauna and their beneficial influence on physical and biological properties of soil.

## Materials and Methods

A field investigation was carried out during kharif, 2021 and 2022 at the Farmers Field, Valiyampattu Village, Sankarapuram Taluk, Kallakurichi District, Tamil Nadu, India. The experiments were laid out in randomised block design (RBD), finger millet CO-14 grown as the test crop. The experimental soil was sandy loam in texture with a pH of 7.63. The experiment consisted of 12 treatments which were 3 replications. The 12 treatments were T<sub>1</sub>- absolute control, T<sub>2</sub>- 100 % recommended dose fertiliser (RDF) (N : P<sub>2</sub>O<sub>5</sub> : K<sub>2</sub>O) (60 : 30 : 30 kg ha<sup>-1</sup>), T<sub>3</sub>- 75 % recommended

nitrogen chemical fertiliser RN (CF) + 25 % RN green leaf manure compost (GLMC), T<sub>4</sub>- 75 % RN (CF) + 25 % RN groundnut oil cake (GOC), T<sub>5</sub>- 75 % RN (CF) + 25 % RN pressmud compost (PMC), T<sub>6</sub>- 75 % RN (CF) + 25 % RN coir pith compost (CPC), T<sub>7</sub>- 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC), T<sub>8</sub>- 50 % RN (CF) + 25 % RN (PMC) + 25 % RN (CPC), T<sub>9</sub>- 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (PMC), T<sub>10</sub>- 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (CPC), T<sub>11</sub>- 50 % RN (CF) + 25 % RN (GOC) + 25 % RN (PMC) and T<sub>12</sub>- 50 % RN (CF) + 25 % RN (GOC) + 25 % RN (CPC). The recommended dose of fertilisers (N : P<sub>2</sub>O<sub>5</sub> : K<sub>2</sub>O) (60 : 30 : 30 kg ha<sup>-1</sup>) were applied to the field through urea, single superphosphate (SSP) and muriate of potash (MOP) respectively. Nitrogen was applied in two splits at 20 and 40 days after sowing (DAS). The full dose of P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O were given as basal by band placement method. The physio-chemical characteristics of the soil organic carbon (2.86 g kg<sup>-1</sup>), pH (7.27), EC (0.33 dSm<sup>-1</sup>), N (267.2 (kg ha<sup>-1</sup>), P (11.2 kg ha<sup>-1</sup>) and K (195.5 kg ha<sup>-1</sup>). The different composts viz., GLMC, PMC and CPC and groundnut oil cake were applied as per the N equivalent to the respective plot. The ragi cv. CO-14 was grown with recommended cultural practices. The soil samples were collected from each treatment and replication and analysed as per standard procedures for their microbial population and enzyme activity (Table 1).

### Statistical analysis

The data from the observations was analysed using statistical method called analysis of variance (ANOVA) for RBD suggested by Gomez and Gomez (8). The statistical significance was tested by *F*-test at 5 % probability level. when the '*F*' value was found significant, critical difference (CD) was calculated to determine the significance.

## Results and Discussion

### Microbial populations

#### Bacterial population

Application of different treatments significantly influenced the microbial population in the soil of finger millet at 30, 60 DAT and at harvest stages respectively.

#### Kharif, 2021

The minimum bacterial population was registered in treatment control (T<sub>1</sub>) 10.5, 15.9 and 11.7 colony forming unit (CFU) × 10<sup>6</sup> were observed at 30, 60 DAT and at harvest stages respectively (Table 2). The different stages of crop were recorded 30, 60 DAT and at harvest stages, application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC) (T<sub>7</sub>) recorded significantly maximum bacterial populations of 22.7, 29.9 and 23.8 CFU × 10<sup>6</sup>. This was followed by 21.4, 28.2 and 22.4 CFU × 10<sup>6</sup> were observed at the above respective stages with T<sub>11</sub> which was received 50 % RN (CF) + 25 % RN (GOC) + 25 % RN (PMC) (T<sub>11</sub>). At all the stages, the treatment T<sub>7</sub> was "on par" with T<sub>11</sub>. The treatment T<sub>8</sub>, T<sub>9</sub> and T<sub>10</sub> registered bacterial populations at 30, 60 DAT and at harvest stages were 18.6, 26.2 and 18.4 CFU × 10<sup>6</sup>; 18.8, 26.3 and 19.8 CFU × 10<sup>6</sup>; 18.7, 26.2 and 19.7 CFU × 10<sup>6</sup> "on par" each other.

#### Kharif, 2022

In the year kharif 2022 the bacterial populations recorded due to different treatments ranged between 30 DAT (12.8 to 26.3), 60 DAT (17.2 to 32.8) and at harvest stage (13.1 to 27.6) CFU × 10<sup>6</sup>, respectively shown in (Table 3). Application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC) (T<sub>7</sub>) registered highest bacterial populations at 30, 60 DAT and at harvest stages were 26.3, 32.8 and 27.6 CFU × 10<sup>6</sup>, respectively. Application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN

**Table 1.** Analytical methods of soil for their microbes and enzyme activity

| Sl. No. | Determination          | Methodology                                     | Reference |
|---------|------------------------|-------------------------------------------------|-----------|
| 1       | Bacteria               | Standard plate techniques (soil microorganisms) | (5)       |
| 2       | Fungi                  | Standard plate techniques (soil microorganisms) | (6)       |
| 3       | Actinomycetes          | Standard plate techniques (soil microorganisms) | (6)       |
| 4       | Urease activity        | Urea distillation method                        | (7)       |
| 5       | Dehydrogenase activity | TPF colorimetric method                         | (7)       |
| 6       | Phosphatase activity   | p-Nitrophenol colorimetric method               | (6)       |

**Table 2.** Direct effect of inorganic fertilisers and composts on soil microbial population at different stages of finger millet cv.CO14 in finger millet - horse gram cropping sequence during kharif (2021)

| Treatments            | Bacteria (CFU × 10 <sup>-6</sup> ) |        |         | Fungi (CFU × 10 <sup>-5</sup> ) |        |         | Actinomycetes (CFU × 10 <sup>-4</sup> ) |        |         |
|-----------------------|------------------------------------|--------|---------|---------------------------------|--------|---------|-----------------------------------------|--------|---------|
|                       | 30 DAT                             | 60 DAT | Harvest | 30 DAT                          | 60 DAT | Harvest | 30 DAT                                  | 60 DAT | Harvest |
| T <sub>1</sub>        | 10.5                               | 15.9   | 11.7    | 7.63                            | 10.4   | 7.67    | 5.46                                    | 8.71   | 6.89    |
| T <sub>2</sub>        | 15.1                               | 21.4   | 13.3    | 9.57                            | 13.2   | 10.5    | 6.81                                    | 9.79   | 8.80    |
| T <sub>3</sub>        | 13.8                               | 23.6   | 17.0    | 11.8                            | 15.2   | 12.4    | 7.59                                    | 11.6   | 10.5    |
| T <sub>4</sub>        | 15.5                               | 19.3   | 18.0    | 9.38                            | 12.8   | 10.1    | 6.85                                    | 9.62   | 8.84    |
| T <sub>5</sub>        | 15.1                               | 21.8   | 18.6    | 11.3                            | 14.2   | 11.5    | 7.12                                    | 10.4   | 9.77    |
| T <sub>6</sub>        | 16.3                               | 22.0   | 15.3    | 10.5                            | 14.0   | 11.3    | 7.03                                    | 10.4   | 9.68    |
| T <sub>7</sub>        | 22.7                               | 29.9   | 23.8    | 15.8                            | 18.7   | 15.4    | 9.86                                    | 14.6   | 12.8    |
| T <sub>8</sub>        | 18.6                               | 26.2   | 18.4    | 12.6                            | 16.3   | 13.2    | 8.14                                    | 12.6   | 11.3    |
| T <sub>9</sub>        | 18.8                               | 26.3   | 19.8    | 14.0                            | 17.6   | 14.1    | 8.97                                    | 13.4   | 12.0    |
| T <sub>10</sub>       | 18.7                               | 26.2   | 19.7    | 13.5                            | 17.2   | 14.0    | 8.68                                    | 13.2   | 11.9    |
| T <sub>11</sub>       | 21.4                               | 28.2   | 22.4    | 14.9                            | 18.5   | 14.4    | 9.46                                    | 14.0   | 12.7    |
| T <sub>12</sub>       | 17.5                               | 24.7   | 17.1    | 12.5                            | 16.1   | 12.5    | 8.07                                    | 11.9   | 11.2    |
| S.Ed                  | 0.55                               | 0.61   | 0.57    | 0.34                            | 0.40   | 0.30    | 0.21                                    | 0.28   | 0.30    |
| CD ( <i>p</i> = 0.05) | 1.12                               | 1.26   | 1.16    | 0.69                            | 0.84   | 0.62    | 0.44                                    | 0.58   | 0.62    |

CFU: colony forming unit; DAT: days after transplanting.

**Table 3.** Direct effect of inorganic fertilisers and composts on soil microbial population at different stages of finger millet cv. CO14 in finger millet - horse gram cropping sequence during kharif (2022)

| Treatments        | Bacteria (CFU $\times 10^{-6}$ ) |        |         | Fungi (CFU $\times 10^{-5}$ ) |        |         | Actinomycetes (CFU $\times 10^{-4}$ ) |        |         |
|-------------------|----------------------------------|--------|---------|-------------------------------|--------|---------|---------------------------------------|--------|---------|
|                   | 30 DAT                           | 60 DAT | Harvest | 30 DAT                        | 60 DAT | Harvest | 30 DAT                                | 60 DAT | Harvest |
| T <sub>1</sub>    | 12.8                             | 17.2   | 13.1    | 11.2                          | 14.3   | 12.0    | 7.37                                  | 9.64   | 7.86    |
| T <sub>2</sub>    | 17.6                             | 22.5   | 18.9    | 13.6                          | 17.2   | 14.4    | 8.98                                  | 11.6   | 10.4    |
| T <sub>3</sub>    | 20.7                             | 26.5   | 22.3    | 15.0                          | 18.8   | 15.9    | 10.3                                  | 13.6   | 12.5    |
| T <sub>4</sub>    | 16.2                             | 20.6   | 17.4    | 13.0                          | 16.5   | 13.7    | 8.36                                  | 10.6   | 9.29    |
| T <sub>5</sub>    | 19.3                             | 24.6   | 20.7    | 14.4                          | 18.1   | 15.2    | 9.66                                  | 12.7   | 11.4    |
| T <sub>6</sub>    | 19.2                             | 24.3   | 20.5    | 14.3                          | 18.0   | 15.1    | 9.60                                  | 12.5   | 11.3    |
| T <sub>7</sub>    | 26.3                             | 32.8   | 27.6    | 17.3                          | 21.3   | 18.5    | 12.3                                  | 16.8   | 15.9    |
| T <sub>8</sub>    | 22.5                             | 28.7   | 24.2    | 15.8                          | 19.6   | 16.9    | 11.0                                  | 14.8   | 13.6    |
| T <sub>9</sub>    | 24.7                             | 30.7   | 26.0    | 16.6                          | 20.4   | 17.7    | 11.6                                  | 15.9   | 14.7    |
| T <sub>10</sub>   | 24.0                             | 30.6   | 25.8    | 16.5                          | 20.4   | 17.6    | 11.4                                  | 15.7   | 14.5    |
| T <sub>11</sub>   | 26.2                             | 32.6   | 27.5    | 17.2                          | 21.2   | 18.4    | 12.2                                  | 16.8   | 15.8    |
| T <sub>12</sub>   | 22.2                             | 28.4   | 23.9    | 15.7                          | 19.5   | 16.6    | 10.9                                  | 14.5   | 13.5    |
| S.Ed              | 0.63                             | 0.86   | 0.71    | 0.28                          | 0.33   | 0.32    | 0.28                                  | 0.39   | 0.49    |
| CD ( $p = 0.05$ ) | 1.26                             | 1.76   | 1.44    | 0.57                          | 0.68   | 0.64    | 0.57                                  | 0.79   | 0.99    |

CFU: colony forming unit; DAT: days after transplanting.

(PMC) (T<sub>9</sub>) recorded 24.7, 30.7 and 26.0 were “on par” 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (CPC) (T<sub>10</sub>) registered 24.0, 30.6 and 25.8 CFU  $\times 10^{-6}$  respectively. The treatment T<sub>9</sub> was “on par” T<sub>10</sub>.

#### Fungal population (CFU $\times 10^{-5}$ )

##### Kharif, 2021

Table 2 shows the fungal population at 30, 60 DAT and at harvest stages, highest values (15.8, 18.7 and 15.4 CFU  $\times 10^{-5}$ ) were recorded in the treatment T<sub>7</sub> (50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC). These were followed by T<sub>9</sub>- 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (PMC) registered 14.0, 17.6 and 14.1 CFU  $\times 10^{-5}$  respectively. Application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (CPC) (T<sub>10</sub>) registered fungal populations at 30, 60 DAT and at harvest stages were 13.5, 17.2 and 14.0 CFU  $\times 10^{-5}$  respectively. The treatment T<sub>9</sub> was “on par” T<sub>10</sub> (Table 2). However, lowest fungal populations at 30, 60 DAT and at harvest stages were 7.63, 10.4 and 7.67 CFU  $\times 10^{-5}$  respectively found to be with control (T<sub>1</sub>).

##### Kharif, 2022

Microbial population was found with application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC) (T<sub>7</sub>) registered significantly highest fungal populations at 30, 60 DAT and at harvest stages were 17.3, 21.3 and 18.5 CFU  $\times 10^{-5}$  compared to control recorded 11.2, 14.3 and 12.0 CFU  $\times 10^{-5}$  respectively (Table 3). The treatments T<sub>9</sub> and T<sub>10</sub>; T<sub>5</sub> and T<sub>6</sub> were found to be non-significant.

#### Actinomycetes population (CFU $\times 10^{-4}$ )

##### Kharif, 2021

Applying of organics increases actinomycetes population at 30, 60 DAT and at harvest stages, application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC) (T<sub>7</sub>) registered significantly highest actinomycetes population of 9.86, 14.6 and 12.8 CFU  $\times 10^{-4}$  respectively (Table 2). Whereas the lowest actinomycetes populations at 30, 60 DAT and at harvest stages were 5.46, 8.71 and 6.89 CFU  $\times 10^{-4}$  recorded in control (T<sub>1</sub>). Among the different treatments tried, T<sub>9</sub> and T<sub>10</sub>; T<sub>5</sub> and T<sub>6</sub> were “on par” at all the above respective stages.

##### Kharif, 2022

The increase of actinomycetes population with application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC) (T<sub>7</sub>) registered significantly highest actinomycetes populations of 12.3, 16.8 and 15.9 CFU  $\times 10^{-4}$  respectively. The control treatment (T<sub>1</sub>) recorded significantly lowest actinomycetes populations of 7.37, 9.64 and 7.86 CFU  $\times 10^{-4}$  respectively (Table 3). However, T<sub>9</sub>- 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (PMC) registered actinomycetes

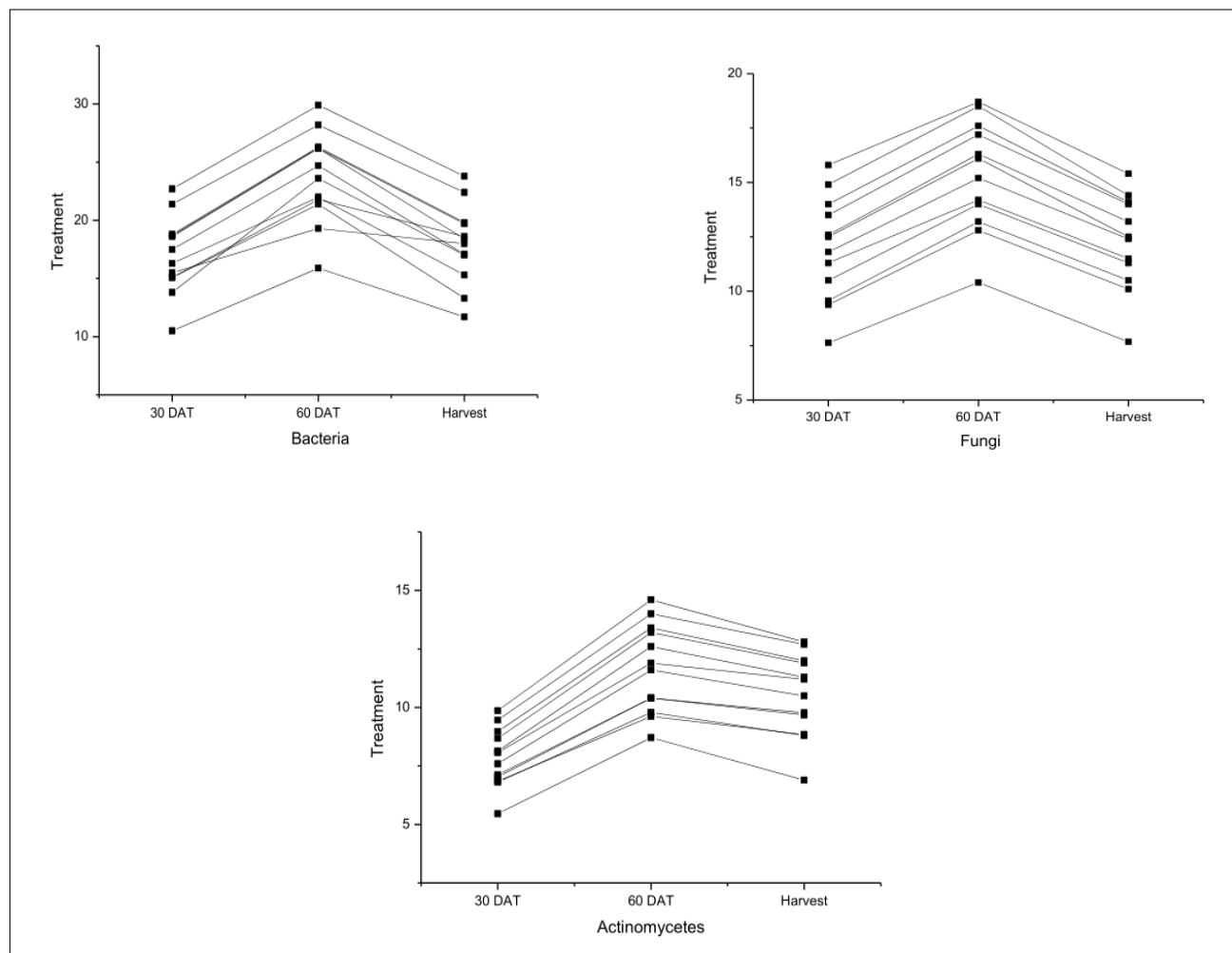
populations of 12.3, 16.8 and 15.9 CFU  $\times 10^{-4}$  respectively were “on par” with T<sub>10</sub> registered actinomycetes populations of 11.6, 15.7 and 14.6 CFU  $\times 10^{-4}$  respectively. Similarly, T<sub>5</sub> was found to be “on par” with T<sub>6</sub>. The highest soil microbes at 30 DAT, 60 DAT and at post-harvest stages were bacteria (22.7, 29.9, 23.8), fungi (15.8, 18.7, 18.7) and actinomycetes (9.86, 14.6, 12.8) in during kharif, 2021 and bacteria (26.3, 32.8, 27.6), fungi (17.3, 21.3, 18.5) and actinomycetes (12.3, 16.8, 15.9) in during kharif, 2022, respectively highest microbes recorded with 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC) (T<sub>7</sub>) over control during kharif, 2021 and 2022. Soil microbial populations play a vital role in soil quality and can provide an index of changes in metabolic capacity and nutrient cycling owing to management practices. The enhancement of soil microbial population influence crop productivity and nutrient cycling (9). The growth and colonisation of soil microorganisms could be influenced by the physical, chemical and biological properties of the soil. The availability of macro and micronutrients could limit microbial population growth, such as nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca), magnesium (Mg) and micronutrients influenced the microbial population as these nutrient elements are also needed for microbial growth and activity of soil (10). Application of inorganic fertilisers and composts significantly influenced soil microbial population viz., bacteria, fungi and actinomycetes. The highest microbes recorded in the treatment. A similar study was confirmed by previous findings (11). This might be due to an increase in the fungal population due to the integrated use of organic and inorganic fertilisers, which provide carbon and other essential nutrients for microbial growth. The favourable soil pH improved the fungal growth in soil. Along with the application of inorganic fertilisers, pressmud recorded a higher microbial population. This might be due to the increased activity of microflora in organic source treated soil to high organic matter accumulation, carbon, N content of composts and the moisture availability for the growth of microbes (Fig. 1 and 2). The shift in microbial population signified the maintenance of soil fertility and productivity due to the faster rate of decomposition and smooth mineralisation of organic materials. The results were reported by early findings (12, 13).

#### Soil enzyme activity

##### Urease activity ( $\mu\text{g NH}_4\text{-N}$ )

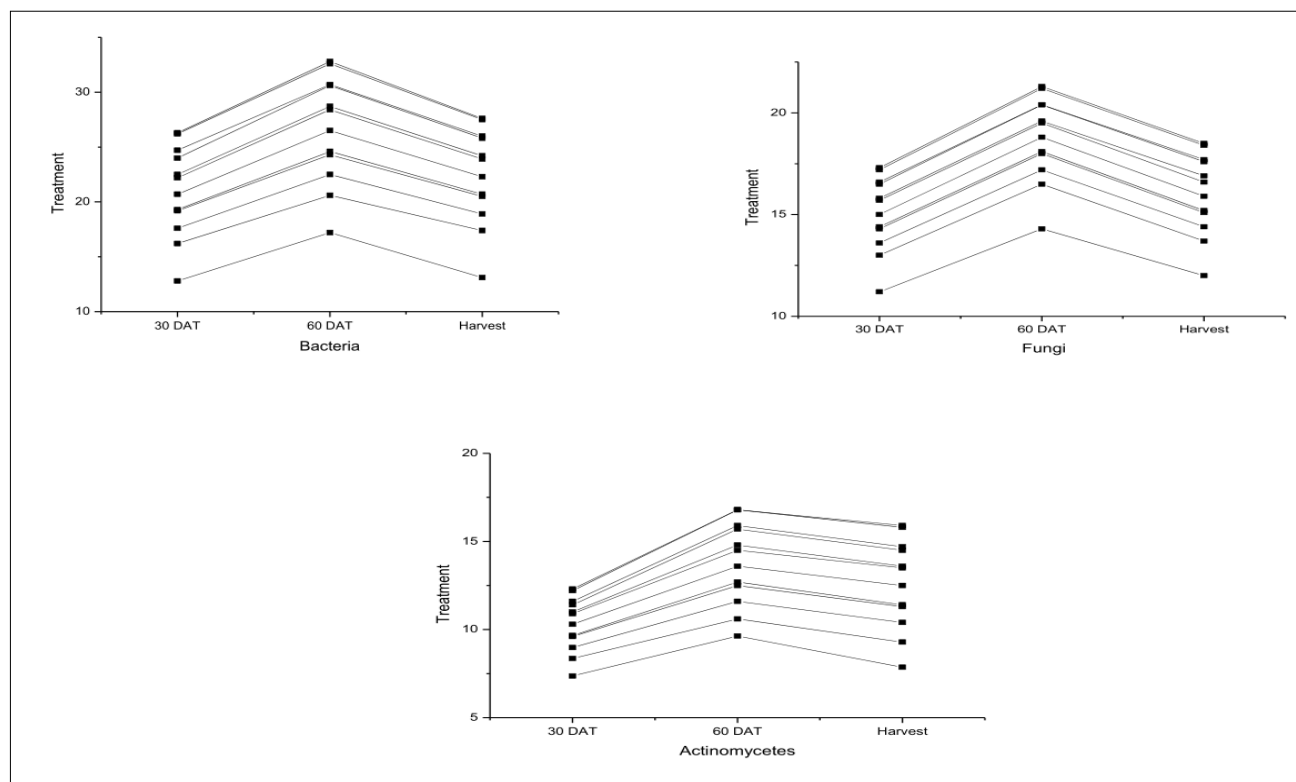
##### Kharif, 2021

Soil enzyme activities during kharif, 2021 and 2022 are presented in Table 4 and 5 respectively. There was a significance difference



**Fig. 1.** Direct effect of compost and inorganic on bacteria, fungi and actinomycetes in finger millet on finger millet - horse gram cropping sequence during kharif 2021.

DAT: days after transplanting.



**Fig. 2.** Direct effect of compost and inorganic on bacteria, fungi and actinomycetes in finger millet on finger millet - horse gram cropping sequence during kharif 2022.

DAT: days after transplanting.

was observed among treatments. The urease activity in soil of finger millet under various treatments at 30, 60 DAT and harvest ranged between 32.6–47.0, 41.0–64.2 and 37.3–54.6 respectively.

Urease activity of the treatments tried at 30, 60 and harvest stages application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC) ( $T_7$ ) recorded the highest urease activity of 47.0, 64.2 and 54.6  $\mu\text{g NH}_4\text{-N}$ . This was followed by treatments recorded  $T_{11}$  (46.3, 63.3, 54.0),  $T_9$  (45.0, 61.0, 52.1) and  $T_{10}$  (44.9, 53.2, 51.9  $\mu\text{g NH}_4\text{-N}$  were found to be respectively. The treatment  $T_9$  was “on par”  $T_{10}$ . Application of 50 % RN (CF) + 25 % RN (PMC) + 25 % RN (CPC) ( $T_8$ ) registered urease activity of (43.6, 58.8, 50.0  $\mu\text{g NH}_4\text{-N}$ ). However, lowest urease activity of (32.6, 41.0, 37.3  $\mu\text{g NH}_4\text{-N}$ ) was found to be with control ( $T_1$ ).

#### Kharif, 2022

During the year 2022 application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC) ( $T_7$ ) registered significantly highest urease activity at 30, 60 DAT and at harvest stages were 53.8, 71.3 and 63.2 respectively. Whereas the control ( $T_1$ ) registered lowest urease activity of 37.2, 46.2 and 29.9  $\mu\text{g NH}_4\text{-N}$  (Table 4 and 5). The treatment  $T_2$  (100 % RDF) recorded the urease activity at 30, 60 DAT and at harvest stages were 42.1, 56.3 and 41.2 respectively. The treatment  $T_9$  was “on par”  $T_{10}$ . Similarly,  $T_5$  recorded urease activity of 44.5, 59.3 and 45.6  $\mu\text{g NH}_4\text{-N}$  at 30, 60 DAT and at harvest stages were “on par”  $T_6$  registered 44.1, 59.1 and 45.4  $\mu\text{g NH}_4\text{-N}$  respectively.

#### Phosphatase activity ( $\mu\text{g p-nitrophenol}$ )

##### Kharif, 2021

The effect of treatments tried at 30, 60 and harvest stages application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC) ( $T_7$ ) recorded the highest phosphatase activity of (17.8, 23.9, 19.7  $\mu\text{g p-nitrophenol}$ ) was “on par” (17.7, 23.2, 19.4  $\mu\text{g p-nitrophenol}$ ) was found to be with 50 % RN (CF) + 25 % RN (GOC) + 25 % RN (PMC) ( $T_{11}$ ). This was followed by (16.6, 21.9, 18.2 and 15.9, 21.7, 18.1 were found to be with  $T_9$  and  $T_{10}$  respectively. The treatment  $T_9$  was “on par”  $T_{10}$ . Application of 75 % RN (CF) + 25 % RN (PMC) ( $T_5$ ) and 75 % RN (CF) + 25 % RN (PMC) ( $T_6$ ) registered phosphatase activity of 12.9, 17.5, 13.3 and 12.5, 16.8, 13.3  $\mu\text{g p-nitrophenol}$  respectively. The control registered, lowest phosphatase activity of 7.71, 12.0, 8.21  $\mu\text{g p-nitrophenol}$  was to be with control ( $T_1$ ) (Table 4, 5).

##### Kharif, 2022

Phosphatase activity was increased the different treatments tried in the confirmation trial, application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC) ( $T_7$ ) registered phosphatase activity at 30, 60 DAT and at harvest were 21.9, 26.8 and 23.7  $\mu\text{g p-nitrophenol}$ , respectively. The lowest values at the above respective stages were 9.46, 14.2 and 11.9  $\mu\text{g p-nitrophenol}$ , respectively. Application of 50 % RN (CF) + 25 % RN (GOC) + 25 % RN (PMC) ( $T_{11}$ ) recorded phosphatase activity at 30, 60 DAT and at harvest were 21.3, 26.5 and 23.5  $\mu\text{g p-nitrophenol}$  respectively.

The treatments  $T_7$  and  $T_{11}$ ;  $T_5$  and  $T_6$  were found to be “on par” at all

**Table 4.** Direct effect of inorganic fertilisers and composts on soil enzyme activity at different stages of finger millet cv.CO14 in finger millet - horse gram cropping sequence during kharif (2021)

| Treatments      | Urease ( $\mu\text{g NH}_4\text{-N/g soil/24 hr}$ ) |        |         | Phosphatase ( $\mu\text{g p-nitrophenol/g soil/hr}$ ) |        |         | Dehydrogenase ( $\mu\text{g TPF/g soil/24 hr}$ ) |        |         |
|-----------------|-----------------------------------------------------|--------|---------|-------------------------------------------------------|--------|---------|--------------------------------------------------|--------|---------|
|                 | 30 DAT                                              | 60 DAT | Harvest | 30 DAT                                                | 60 DAT | Harvest | 30 DAT                                           | 60 DAT | Harvest |
| $T_1$           | 32.6                                                | 41.0   | 37.3    | 7.71                                                  | 12.0   | 8.21    | 46.3                                             | 52.2   | 48.9    |
| $T_2$           | 37.5                                                | 50.7   | 40.6    | 10.0                                                  | 15.5   | 12.0    | 56.8                                             | 66.2   | 57.7    |
| $T_3$           | 40.6                                                | 55.8   | 47.9    | 13.5                                                  | 18.7   | 14.7    | 64.7                                             | 76.7   | 65.4    |
| $T_4$           | 36.2                                                | 48.9   | 42.5    | 11.2                                                  | 15.3   | 10.9    | 54.1                                             | 60.7   | 56.1    |
| $T_5$           | 39.3                                                | 53.4   | 45.7    | 12.9                                                  | 17.5   | 13.5    | 61.0                                             | 72.1   | 62.1    |
| $T_6$           | 38.8                                                | 53.2   | 44.7    | 12.5                                                  | 16.8   | 13.3    | 60.7                                             | 71.0   | 61.7    |
| $T_7$           | 47.0                                                | 64.2   | 54.6    | 17.8                                                  | 23.9   | 19.7    | 79.0                                             | 93.3   | 79.6    |
| $T_8$           | 43.6                                                | 58.8   | 50.0    | 14.7                                                  | 20.3   | 16.8    | 69.3                                             | 83.4   | 72.1    |
| $T_9$           | 45.0                                                | 61.0   | 52.1    | 16.6                                                  | 21.9   | 18.2    | 74.6                                             | 88.4   | 76.2    |
| $T_{10}$        | 44.9                                                | 60.8   | 51.9    | 15.9                                                  | 21.7   | 18.1    | 72.9                                             | 87.8   | 75.4    |
| $T_{11}$        | 46.3                                                | 63.3   | 54.0    | 17.7                                                  | 23.2   | 19.4    | 78.2                                             | 92.8   | 79.5    |
| $T_{12}$        | 41.9                                                | 57.7   | 49.8    | 14.6                                                  | 19.9   | 15.9    | 68.7                                             | 81.8   | 68.9    |
| S.Ed            | 0.60                                                | 0.89   | 0.80    | 0.49                                                  | 0.56   | 0.57    | 1.74                                             | 2.04   | 1.50    |
| CD ( $p=0.05$ ) | 1.21                                                | 1.86   | 1.62    | 1.02                                                  | 1.16   | 1.15    | 3.49                                             | 4.12   | 3.04    |

DAT: days after transplanting, TPF: total phenolic fraction.

**Table 5.** Direct effect of inorganic fertilisers and composts on soil enzyme activity at different stages of finger millet cv.CO14 in finger millet - horse gram cropping sequence during kharif (2022)

| Treatments      | Urease ( $\mu\text{g NH}_4\text{-N/g soil/24 hr}$ ) |        |         | Phosphatase ( $\mu\text{g p-nitrophenol/g soil/hr}$ ) |        |         | Dehydrogenase ( $\mu\text{g TPF/g soil/24 hr}$ ) |        |         |
|-----------------|-----------------------------------------------------|--------|---------|-------------------------------------------------------|--------|---------|--------------------------------------------------|--------|---------|
|                 | 30 DAT                                              | 60 DAT | Harvest | 30 DAT                                                | 60 DAT | Harvest | 30 DAT                                           | 60 DAT | Harvest |
| $T_1$           | 37.2                                                | 46.2   | 29.9    | 9.46                                                  | 14.2   | 11.9    | 46.6                                             | 59.3   | 51.3    |
| $T_2$           | 42.1                                                | 56.3   | 41.2    | 13.3                                                  | 18.0   | 15.4    | 60.3                                             | 72.4   | 62.1    |
| $T_3$           | 46.5                                                | 62.2   | 50.2    | 16.5                                                  | 21.5   | 18.8    | 70.1                                             | 82.1   | 71.4    |
| $T_4$           | 40.1                                                | 53.1   | 36.8    | 15.0                                                  | 16.3   | 13.8    | 55.4                                             | 67.3   | 57.7    |
| $T_5$           | 44.5                                                | 59.3   | 45.6    | 14.9                                                  | 19.9   | 17.3    | 65.4                                             | 77.3   | 67.0    |
| $T_6$           | 44.1                                                | 59.1   | 45.4    | 11.4                                                  | 19.6   | 16.9    | 65.1                                             | 77.2   | 66.5    |
| $T_7$           | 53.8                                                | 71.3   | 63.2    | 21.9                                                  | 26.8   | 23.7    | 85.3                                             | 97.3   | 86.3    |
| $T_8$           | 49.0                                                | 65.1   | 54.9    | 18.2                                                  | 23.2   | 20.3    | 75.5                                             | 87.0   | 76.5    |
| $T_9$           | 51.7                                                | 68.4   | 59.0    | 19.8                                                  | 25.0   | 22.0    | 80.4                                             | 92.0   | 81.5    |
| $T_{10}$        | 51.0                                                | 67.9   | 58.8    | 19.6                                                  | 24.8   | 21.8    | 80.2                                             | 91.7   | 80.9    |
| $T_{11}$        | 53.6                                                | 71.3   | 62.9    | 21.3                                                  | 26.5   | 23.5    | 85.1                                             | 96.7   | 85.8    |
| $T_{12}$        | 48.5                                                | 65.0   | 54.5    | 18.1                                                  | 23.1   | 20.3    | 74.9                                             | 86.9   | 75.9    |
| S.Ed            | 0.91                                                | 1.29   | 1.86    | 0.73                                                  | 0.74   | 0.70    | 2.30                                             | 2.29   | 2.15    |
| CD ( $p=0.05$ ) | 1.83                                                | 2.59   | 3.73    | 1.46                                                  | 1.49   | 1.42    | 4.60                                             | 4.58   | 4.31    |

DAT: days after transplanting, TPF: total phenolic fraction.

the stages.

### Dehydrogenase activity ( $\mu\text{g TPF}$ )

The inorganic fertilisers and composts on soil dehydrogenase activity at 30, 60 DAT and at harvest stages of finger millet during kharif, 2021 and 2022 were statistically significant (Table 4 and 5).

#### Kharif, 2021

Application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC) ( $T_7$ ) registered highest dehydrogenase activity of 79.0, 93.3, 79.6  $\mu\text{g TPF}$  was “on par” with  $T_{11}$  (78.2, 92.8, 79.5  $\mu\text{g TPF}$ ) compared to control ( $T_1$ ). The treatment  $T_7$  was “on par”  $T_{11}$ . Application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (PMC) ( $T_9$ ) (74.6, 88.4, 76.2) and 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (CPC) ( $T_{10}$ ) (72.9, 87.8, 75.4) were also “on par”. The treatment  $T_5$  was “on par”  $T_6$  (61.0, 72.1, 62.1  $\mu\text{g TPF}$ ), which was received 75 % RN (CF) + 25 % RN (CPC). However, control ( $T_1$ ) recorded lowest dehydrogenase activity of 46.3, 52.2, 48.9  $\mu\text{g TPF}$ .

#### Kharif, 2022

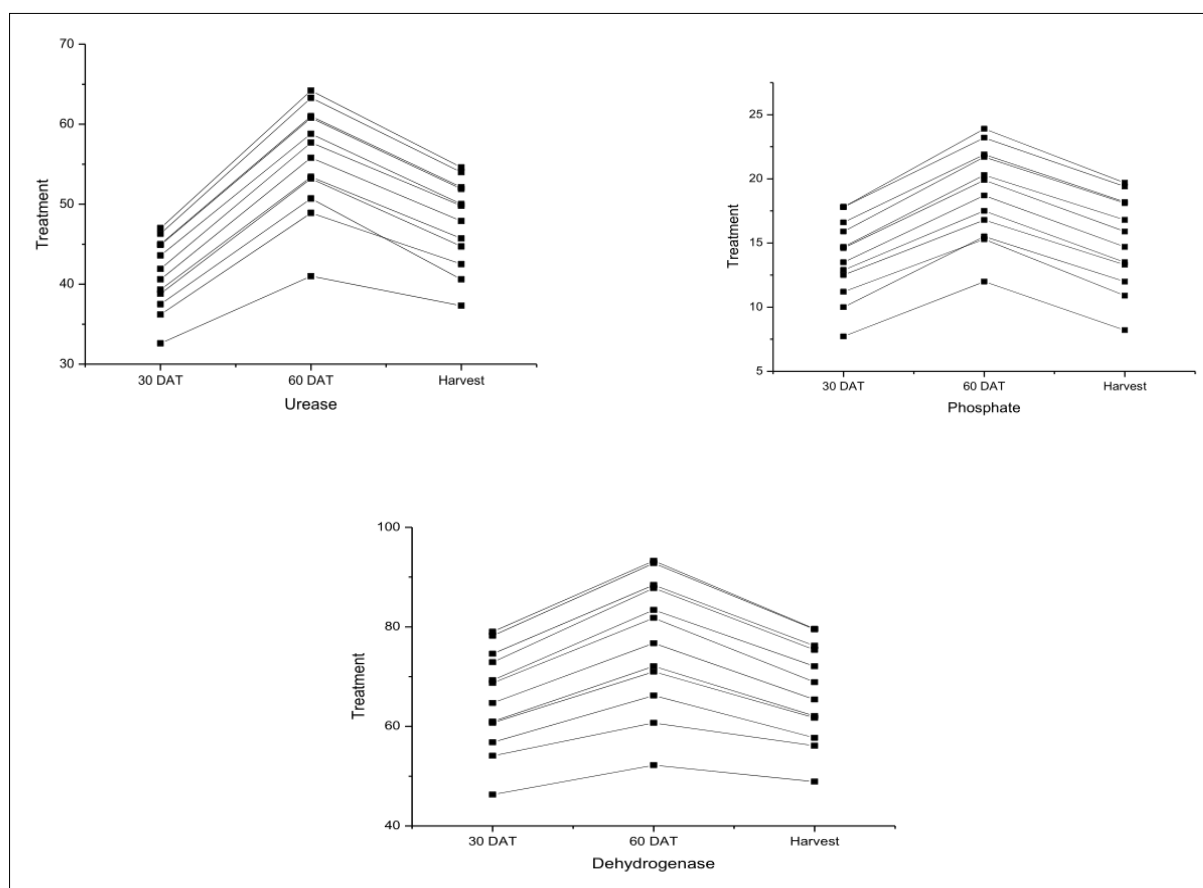
Higher dehydrogenase activities at 30, 60 DAT and at harvest stages were 85.3, 97.3 and 86.3 was found to be with  $T_7$ , which was received 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC). Application of 50 % RN (CF) + 25 % RN (GOC) + 25 % RN (PMC) registered dehydrogenase activities at 30, 60 DAT and at harvest stages were 85.1, 96.7 and 85.8 respectively. The treatment  $T_7$  was “on par”  $T_{11}$  at all above stages. The treatment  $T_9$  recorded dehydrogenase activities at 30, 60 DAT and at harvest stages were 80.4, 92.0 and 81.5 were non-significant with  $T_{10}$  registered 80.2, 91.7 and 80.9  $\mu\text{g TPF}$  respectively. However, control recorded the lowest dehydrogenase activities at 30, 60 DAT and at harvest

stages were 46.6, 59.3 and 51.3  $\mu\text{g TPF}$  respectively (Table 4, 5).

Application of 50 % RN (CF) + 25 % RN (GLMC) + 25 % RN (GOC) ( $T_7$ ) registered significantly highest soil enzyme activities viz., urease, phosphatase and dehydrogenase at 30 DAT, 60 DAT and at post-harvest stages were 47.0, 64.2, 54.6 and 17.8, 23.9, 19.7 and 79.0, 93.3, 79.6 in during kharif, 2021 and 53.8, 71.3, 63.2 and 21.9, 26.8, 23.7 and 85.3, 97.3, 86.3 respectively. (Fig. 3 and 4). The increased rate of N application and composts added to the soil as well as the root exudates promoted the nitrogenous substances which have induced the urease activity. Urease activity in soil originated from soil microbes containing urease and approximately 17–30 % of soil bacteria and 78–98 % of soil fungi can hydrolyse urea into ammonia (14).

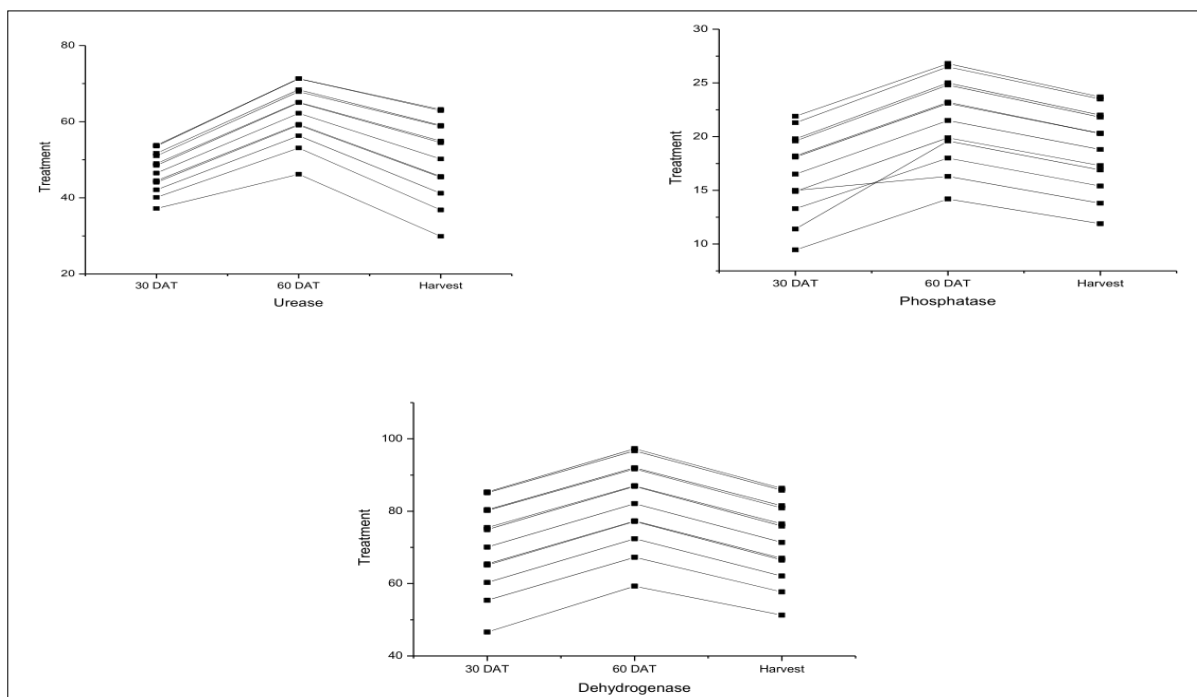
Soil urease plays a major role in the catalysis of the hydrolysis of urea to ammonical form, which will be subsequently oxidised by nitrifiers to nitrate form, which increased the utilisation rate of N fertiliser. The higher N status in soil stimulated heterotrophic microbial activity and resulted in higher activity of hydrolytic enzymes in turn urease activity was enhanced. Urease activity increased with application of composts in combination with inorganic fertilisers compared to control (15, 16).

Among the treatments, control registered lowest urease, phosphatase and dehydrogenase at 30 DAT, 60 DAT and at post-harvest stages were 32.6, 41.0, 37.3 and 7.71, 12.0, 8.21 and 46.3, 52.2, 48.9 in during kharif, 2021 and 37.2, 46.2, 29.9 and 9.46, 14.2, 11.9 and 46.6, 59.3, 51.3 respectively. The lowest enzymatic activity in the absolute control might be due to the non-supply of organic sources which are pre-requisite for microbial growth and enzymatic activity (17). The combined application of composts



**Fig. 3.** Direct effect of compost and inorganic on urease, phosphatase and dehydrogenase in finger millet on finger millet - horse gram cropping sequence during kharif 2021.

DAT: days after transplanting.



**Fig. 4.** Direct effect of compost and inorganic on urease, phosphatase and dehydrogenase in finger millet on finger millet - horse gram cropping sequence during kharif 2022.

DAT: days after transplanting.

and inorganic fertilisers influenced an increase in the soil phosphatase activity could have been due to the soil substrate enrichment caused by the addition of mineral fertilisers. The phosphates added through organics and fertiliser improved the phosphatase activity, which might be ascribed to the stabilised extracellular fraction of the enzyme. Many authors in the past (18–20) also reported the increasing phosphatase activity by the application of organics (Fig. 3 and 4).

In the present study, added inorganic fertiliser and composts significantly increased the dehydrogenase activity. The highest dehydrogenase activity might be due to incorporation of organics, owing to an increase in microbial activity in the soil. The favourable effect of organics on the activity of dehydrogenase in soil was more pronounced due to the combined application of organics along with NPK fertilisers which were attributed to increased mineralisation of nutrients from microbial decomposition of organic matter (21–23). Dehydrogenase is an enzyme that occurs in all intact viable microbial cells and functions as a measurement of the metabolic state of soil microorganisms by relating it to the presence of viable microorganisms through their oxidative capacity.

The application of pressmud along with inorganic fertilisers recorded second best dehydrogenase activity in the soil. This might be due to the reason that beneficial microbes in organic manures may provide microbial diversity and activity of microorganisms accompanied by better dehydrogenase activity (24–27).

## Conclusion

From the present investigation, it can be concluded that the application of ( $T_7$ ) 50 % recommended nitrogen chemical fertilisers RN (CF) + 25 % RN green leaf manure compost (GLMC) + 25 % RN groundnut oil cake (GOC) significantly increased the soil microbial populations like bacterial, fungal and actinomycetes populations.

The same recorded significantly highest urease, phosphatase and dehydrogenase activities at 30, 60 goat organic compost (DAT) and at harvest stages of finger millet grown in entisols soil. Improved nutrient availability by GLMC and GOC release nutrients slowly, reducing N leaching. Urease, dehydrogenase and phosphatase enzymes break down organic matter into bio-available forms for the crop and soil structure and crop productivity.

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## Authors' contributions

SS provided guidance throughout the study and contributed to the research design. SS also assisted in data interpretation, manuscript drafting and critical revision of the manuscript. PA conceptualised and designed the study and carried out its implementation, including field experiments, sample analysis, data analysis and interpretation of the results and drafted the manuscript. Both authors have read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interest to declare.

**Ethical issues:** None

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