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Effect of Organic, Inorganic and Natural Farming Practices on Microbial Activity at Rhizosphere in Cotton and Greengram Intercropping System

Sravani Arem [a++*], Chandrashekara C. P [b#], Potdar M. P [c†] and Geeta D. Goudar [d†]

[a] Department of Agronomy, College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad- 580 005, Karnataka, India.
[b] College of Forestry, Sirsi-581401, Karnataka, India.
[c] Department of Agronomy, College of Agriculture, Dharwad-580 005, Karnataka, India.
[d] Department of Microbiology, University of Agricultural Sciences, Dharwad-580 005, Karnataka, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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[++] Master Student;
[#] Professor of Agronomy, Principal Scientist and Head of AICRP on OFR- IFS- Project;
[†] Professor;
**Corresponding author: E-mail: satyasravani2020@gmail.com;*

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ABSTRACT

A field experiment was conducted during the *kharif* season 2021-22 at Natural Farming Project plot - E 131, Main Agricultural Research Station, UAS, Dharwad on clayey soils to study the effect of different farming practices and foliar application of different organic liquid manures on soil microbial activity of cotton+ greengram rhizosphere. The results revealed that maximum number of microbial populations *viz*., Bacteria (18.50, 59.22 and 33.83 $\times 10^5$ cfu g soil^{-1} (cfu {colony forming unit}), fungi (4.67, 4.61 and 3.67 $\times 10^4$ cfu g soil^{-1}), actinomycetes (11.72, 9.61 and7.17 $\times 10^3$ cfu g soil^{-1}), N_2 fixers (12.61, 19.61 and 17.44 $\times 10^5$ cfu g soil^{-1}) and PSM´S (6.94, 14.83 and 13.11 $\times 10^5$ cfu g soil^{-1}) at harvest stage of greengram, at 90 DAS and harvest stage of cotton was significantly found in organic farming practices. Among liquid organic manures, foliar application of *Jeevamrutha* @100 % recorded higher number of bacteria (21.17, 61.67 and 35.83 $\times 10^5$ cfu g soil^{-1}), fungi (5.17, 6.17 and 5.17 $\times 10^4$ cfu g soil^{-1}), actinomycetes (12.83, 10.50 and 7.00 $\times 10^3$ cfu g soil^{-1}), N_2 fixers (15.67, 21.33 and 18.50 $\times 10^5$ cfu g soil^{-1}) and PSM´S (8.50, 17.00 and 15.17 $\times 10^5$ cfu g soil^{-1}) at harvest stage of green gram, 90 DAS and harvest stage of cotton. When compared with recommended package of practices, foliar application of *Jeevamrutha* @100 % under organic farming practices recorded higher number of bacteria (26.33, 64.00 and 36.33 $\times 10^5$ cfu g soil^{-1}), fungi (5.67, 6.67 and 5.67 $\times 10^4$ cfu g soil^{-1}), actinomycetes (13.67, 11.00 and 8.00 $\times 10^3$ cfu g soil^{-1}) and PSM´S (9.33, 18.00 and 16.33 $\times 10^5$ cfu g soil^{-1}) at harvest stage of greengram, at 90 DAS and harvest stage of cotton than all other treatments. Foliar application of vermiwash @ 20% recorded highest N2 fixers (23.67 and19.67 $\times 10^5$ cfu g soil^{-1}) at 90 DAS and harvest stage of cotton.

Keywords: Actinomycetes; bacteria; fungi; organic; microorganisms and natural farming practices.

1. INTRODUCTION

Cotton (*Gossypium hirsutum*) is one of the most widely cultivated and economically important crops globally, providing a vital source of fiber, food, and livelihood for millions of people. During 2023-24 globally cotton area and production are projected as31.8 million hectares and 113 million bales of 217.72 kg each (Agricultural market intelligence centre, PJTSAU). India has distinction of having the largest area under cotton cultivation with 119.66 lakh ha, which is about 37% of the world area under cotton cultivation. India contributes about 24% of the world cotton production. The yield per hectare which is presently 447 kg ha-1is still lower against the world average yield of 808 kg ha^{-1}.

Growing two or more crops at the same time in a same location is known as intercropping, and it has become popular because of economy, ecology, and environment. (Whitmore & Schroder, 2007). Intercropping systems with legumes helps to reduce economic risks (Gabhane, et al., 2016, Rao, et al., 2016). Due to the rising expense of artificial fertilisers, declining soil fertility, health and environmental issues brought on by pesticide use, and the anticipated higher pricing for organically cultivated products, farmers are becoming more interested in growing crops under organic farming. By adopting natural and organic farming practices, farmers can improve soil fertility, increase crop yields and enhance ecosystem resilience. This study was aims to investigate the effect of natural, organic and inorganic nutrient management on soil microbial activity (Ramesh, et al., 2005). Despite its importance, cotton production faces numerous challenges, including water scarcity, soil degradation, pests, and diseases by Sattar et al., (2013). Application of organic solid and liquid manures helps in restoring the fertility of the soil.

Numerous beneficial microorganisms, including fungi, bacteria, actinomycetes, and some micronutrients, can be found in liquid manures (Somasundaram & Amanullah, 2007). The mixture acts as a tonic to improve the soil and encourage plant vigour with high-quality output. Fungi, bacteria, *Lactobacillus*, total anaerobes, acid formers, and methanogens are among the many microbes found in *panchagavya*. According to Jaya Kumar et al., (2017) organic priming techniques, particularly *panchagavya*, significantly differed from controls in terms of cotton seedling germination, length, fresh weight, dry weight and vigour index. Vermiwash application into the soil have a substantial impact on the biogeochemical cycles of nitrogen and phosphorus (Chattopadhyay, 2015) and was helpful in boosting soil fertility quickly (Yadav & Mowade, 2004).

2. MATERIALS AND METHODS

A field experiment was carried out at Natural farming project plot No. E-131, at Main Agricultural Research Station, Dharwad, Karnataka, India during *Kharif* season 2021-22. The soil was black clay in texture having pH (7.64, 7.67 and7.79), electrical conductivity of (0.20, 0.23 and 0.25 d Sm^{-1}), soil organic carbon content (5.5, 6.0 and 5.2 g kg^{-1}), low in available nitrogen (186.60, 214.00 and 222.00 kg ha^{-1}), medium in available P_2O_5 (35.10, 44.00 and 40.00 kg ha^{-1}) and high in available K_2O (400, 420.00 and 440.00 kg ha^{-1}) and metallic micro nutrients Fe (2.80, 3.30 and 3.10 ppm), Mn (3.68, 4.76 and 4.21 ppm), Zn (0.80, 1.00 and 0.90 ppm), Cu (0.89, 1.05 and 0.92 ppm) in natural, organic farming and inorganic farming plots respectively. The experiment was laid out in split plot design consisting of two main plots consisting of Natural farming (NF) and Organic farming (OF)], six sub plot treatments (*Cow urine* (CU) @ 50 %, *Jeevamrutha (JM)* @ 100 %, Vermiwash (VW) @ 10 %, *Gokrupamrutha* (GK) @ 20 %, VW- CU- JM- GK-VW at 21, 42, 63, 84, 105 and 126 DAS (6 times) in cotton and 3 times in greengram. Foliar application of *Jeevamrutha* as per ZBNF recommendations (5 %, 7.5 % and 10 % at vegetative, flowering and boll development stage in cotton and at vegetative stage, peak flowering stage and pod development stage in green gram at 21 days interval starting from 21 DAS (21, 42, 63, 84, 105, & 126 DAS) and one uneven control (Recommended package of practices). The treatments were replicated thrice.

The cotton variety ARBC 1651 was sown at the rate of 7.5 kg ha^{-1} with bullock drawn seed drill (pora method) with 60 cm × 30 cm row spacing. Greengram variety IPM-02-14 was sown as intercrop at the rate of 15 kg ha^{-1} in between the cotton rows. The seeds were treated with *beejamrutha* for all the natural farming treatments and with *Azospirillum* and P-solubilizing bacteria for recommended package of practice and organic farming practice treatments prior to sowing. *Ghanajeevamrutha* @ 1000 kg ha^{-1} was applied in two equal splits before sowing operation and at 30 DAS. Soil drenching of *jeevamrutha*@ 500 l ha^{-1} was applied at 21 days interval from 21 to 126 DAS in all the natural farming plots. In organic farming plots, the nutrients were supplied equivalent to 100 per cent RDN through FYM and Vermicompost @ 50 % and neem cake @ 2.5 q ha^{-1} each before sowing was applied and foliar spraying of panchagavya @ 3 % peak flowering and pod and boll development stage greengram and cotton in all organic farming plots. The application of NPK fertilizers were applied based on recommendation of UAS, Dharwad package of practices by calculating in the form of Urea, DAP, and MOP to the RPP to supply fertilizers @ 40, 25 and 25 kg for cotton and 12.5: 25: 0 kg N: P_2O_5: K_2O for 50 % greengram population. Seed treatment was done with *Rhizobium* (500 g) and PSB (1250g) at the time of sowing. Recommended nitrogen doses were applied in 2 equal splits at the time of sowing as basal dose and 30 DAS @ 20 kg ha^{-1} each time. The entire dose of phosphorus and potassium were applied as basal dose. The FYM at the rate of 5 t $ha^{-1}$was incorporated in RPP as per recommendations. Soil samples of rhizosphere were collected and microbial population was analysed by using serial dilution plate count technique.

3. RESULTS AND DISCUSSION

3.1 Effect of Farming Practices on Cotton in Cotton+ Greengram Intercropping

Among different farming practices, significantly higher number of bacteria, fungi, actinomycetes, N_2 fixers and PSM population were recorded in organic farming (18.50×10^5 cfu g^{-1} dry soil, 4.67×10^4 cfu g^{-1} dry soil, 11.72×10^3 cfu g^{-1} dry soil, 12.61×10^5 cfu g^{-1} dry soil and 6.94×10^5 cfu g^{-1} dry soil) than natural farming at harvest stage of greengram. However, at 90 DAS significantly higher number of bacteria, fungi, N_2 fixers and PSM population were recorded in organic farming (59.22×10^5 cfu g^{-1} dry soil, 5.67×10^4 cfu g^{-1} dry soil, 19.61×10^5 cfu g^{-1} dry soil and 17.00×10^5 cfu g^{-1} dry soil). There was no significant difference was recorded among the farming practices. At harvest stage of cotton, significantly higher number of bacteria, fungi, actinomycetes, N_2 fixers and PSM population were recorded in organic farming (33.83×10^5 cfu g^{-1} dry soil, 4.67×10^4 cfu g^{-1} dry soil, 7.17×10^3 cfu g^{-1} dry soil, 17.44×10^5 cfu g^{-1} dry soil and 13.11×10^5 cfu g^{-1} dry soil) (Tables 1,2 and 3). The increased general and beneficial micro flora was due to the population in soil increased after application of *jeevamrutha* and farm yad manure, vermicompost coupled with neem cake are purely organic source and it contains diverse microbial population. However, *Jeevamrutha* was also added to the soil and roots exudates provided food materials for microbes which helps in increasing microbial population. However,

Table 1. General and beneficial microflora of green gram rhizosphere at harvest as influenced by different farming practices and foliar nutrition in cotton + green gram intercropping system during *kharif* 2021-22

Treatment	Bacteria (cfu $\times 10^5$ g soil^{-1})	Fungi (cfu $\times 10^4$ g soil^{-1})	Actinomycetes (cfu $\times 10^3$ g soil^{-1})	N_2- fixers (cfu $\times 10^5$ g soil^{-1})	PSM´S (cfu $\times 10^5$ g soil^{-1})
Main plot: Farming Practices (M)					
M_1: Natural Farming	12.83^{b}	3.28^{b}	10.50^{b}	9.11^{b}	5.28^{b}
M_2: Organic Farming	18.50^{a}	4.67^{a}	11.72^{a}	12.61^{a}	6.94^{a}
S.Em. ±	0.36	0.16	0.20	0.31	0.14
Sub Plot: Liquid formulations foliar spray at 21, 42, 63, 84,105 and 126 DAS (S)					
S_1: Cow urine @ 50 %	17.00^{ab}	4.17^{a-c}	11.50^{ab}	10.50^{b}	6.00^{b}
S_2: Jeevamrutha @ 100 %	21.17^{a}	5.17^{a}	12.83^{a}	15.67^{a}	8.50^{a}
S_3: Vermiwash @ 10%	19.83^{a}	4.33^{ab}	11.83^{ab}	14.83^{a}	8.00^{a}
S_4: Gokrupamrutha @ 20 %	14.33^{bc}	4.00^{bc}	11.00^{ab}	9.00^{b}	5.33^{b}
S_5: S_1-S_2- S_3- S_4- S_1-S_2	12.00^{c}	3.17^{bc}	10.50^{bc}	8.00^{b}	4.67^{b}
S_6: Foliar application of Jeevamrutha as per natural farming Practices	11	3.00^{c}	9.00^{c}	7.17^{b}	4.17^{b}
S.Em. ±	1.05	0.28	0.42	0.82	0.42
Interaction: Farming practices × Foliar sprays (M × S)					
T_1-M_1S_1:	13.33^{d-g}	3.67^{cd}	11.00^{bc}	8.67^{d-f}	5.00^{c-g}
T_2-M_1S_2:	16.00^{de}	4.67^{a-c}	12.00^{a-c}	13.33^{b}	7.67^{ab}
T_3-M_1S_3:	15.67^{d-f}	3.67^{cd}	11.33^{bc}	11.33^{b-d}	6.67^{b-d}
T_4-M_1S_4:	12.00^{e-g}	3.33^{de}	10.67^{bc}	8.00^{d-f}	4.67^{d-g}
T_5-M_1S_5:	11.33^{fg}	2.33^{ef}	10.00^{c}	7.00^{ef}	4.00^{e-g}
T_6-M_1S_6:	8.67^{g}	2.00^{f}	8.00^{d}	6.33^{ef}	3.67^{fg}
T_7-M_2S_1:	20.67^{bc}	4.67^{a-c}	12.00^{a-c}	12.33^{bc}	7.00^{bc}
T_8-M_2S_2:	26.33^{a}	5.67^{a}	13.67^{a}	18.00^{a}	9.33^{a}
T_9-M_2S_3:	24.00^{ab}	5.00^{ab}	12.33^{ab}	18.33^{a}	9.33^{a}
T_{10}-M_2S_4:	16.67^{cd}	4.67^{a-c}	11.33^{bc}	10.00^{b-e}	6.00^{b-e}
T_{11}-M_2S_5:	12.67^{d-g}	4.00^{b-d}	11.00^{bc}	9.00^{c-f}	5.33^{c-f}
T_{12}-M_2S_6:	10.67^{g}	4.00^{b-d}	10.00^{c}	8.00^{d-f}	4.67^{d-g}
S.Em. ±	1.32	0.39	0.56	1.04	0.52
RPP	9.67^{g}	2.00^{f}	5.67^{e}	5.67^{f}	3.00^{g}
S.Em. ±	1.41	0.38	0.62	1.11	0.67

Table 2. General and beneficial microflora of cotton rhizosphere at 90 DAS as influenced by different farming practices and foliar nutrition in cotton + green gram intercropping system during kharif 2021-22

Treatment	Bacteria (cfu $\times 10^5$ g soil^{-1})	Fungi (cfu $\times 10^4$ g soil^{-1})	Actinomycetes (cfu $\times 10^3$ g soil^{-1})	N_2- fixers (cfu $\times 10^5$ g soil^{-1})	PSM´S (cfu $\times 10^5$ g soil^{-1})
Main plot: Farming Practices (M)					
M_1: Natural Farming	53.78^{b}	4.61^{b}	8.67^{a}	17.17^{b}	13.39^{a}
M_2: Organic Farming	59.22^{a}	5.67^{a}	9.61^{a}	19.61^{a}	14.83^{a}
S.Em. ±	0.820	0.171	0.239	0.283	0.239
Sub Plot: Liquid formulations foliar spray at 21, 42, 63, 84,105 and 126 DAS (S)					
S_1: Cow urine @ 50 %	56.67^{ab}	5.33^{ab}	9.50^{ab}	19.00^{ab}	14.00^{bc}
S_2: *Jeevamrutha* @ 100 %	61.67^{a}	6.17^{a}	10.50^{a}	21.33^{a}	17.00^{a}
S_3: Vermiwash @ 10%	60.67^{a}	5.67^{ab}	9.83^{ab}	20.00^{ab}	15.00^{b}
S_4: *Gokrupamrutha* @ 20 %	54.67^{b}	5.00^{ab}	9.00^{a-c}	18.00^{bc}	13.33^{bc}
S_5: S_1-S_2- S_3- S_4- S_1-S_2	53.33^{b}	4.50^{b}	8.50^{bc}	16.50^{c}	12.83^{c}
S_6: Foliar application of Jeevamrutha as per natural farming Practices	52.00^{b}	4.17^{b}	7.50^{c}	15.50^{c}	12.50^{c}
S.Em. ±	1.34	0.36	0.39	0.55	0.46
Interaction: Farming practices × Foliar sprays (M × S)					
T_1-M_1S_1:	55.33^{cd}	4.67^{cde}	9.00^{bc}	18.00^{c-e}	13.33^{c-e}
T_2-M_1S_2:	59.33^{a-c}	5.67^{a-d}	10.00^{ab}	19.00^{b-d}	16.00^{ab}
T_3-M_1S_3:	58.00^{a-c}	5.00^{b-e}	9.33^{a-c}	18.67^{cd}	14.00^{b-d}
T_4-M_1S_4:	52.00^{c-e}	4.33^{de}	8.67^{b-d}	17.00^{d-g}	12.67^{c-e}
T_5-M_1S_5:	50.00^{de}	4.00^{e}	8.00^{c-e}	15.33^{fg}	12.33^{de}
T_6-M_1S_6:	48.00^{e}	4.00^{e}	7.00^{de}	15.00^{gh}	12.00^{de}
T_7-M_2S_1:	58.00^{a-c}	6.00^{abc}	10.00^{ab}	20.00^{bc}	14.67^{bc}
T_8-M_2S_2:	64.00^{a}	6.67^{a}	11.00^{a}	23.67^{a}	18.00^{a}
T_9-M_2S_3:	63.33^{ab}	6.33^{ab}	10.33^{ab}	21.33^{b}	16.00^{ab}
T_{10}-M_2S_4:	57.33^{a-d}	5.67^{a-d}	9.33^{a-c}	19.00^{b-d}	14.00^{b-d}
T_{11}-M_2S_5:	56.67^{a-d}	5.00^{b-e}	9.00^{bc}	17.67^{c-f}	13.33^{c-e}
T_{12}-M_2S_6:	56.00^{b-d}	4.33^{de}	8.00^{c-e}	16.00^{e-g}	13.00^{c-e}
S.Em. ±	1.93	0.48	0.56	0.76	0.63
RPP	45.67^{e}	3.33^{e}	6.33^{e}	12.67^{h}	11.33^{e}
S.Em. ±	2.24	0.49	0.58	0.78	0.66

Table 3. General and beneficial microflora of cotton rhizosphere at harvest as influenced by different farming practices and foliar nutrition in cotton + green gram intercropping system during kharif 2021-22

Treatment	Bacteria (cfu $\times 10^5$ g soil^{-1})	Fungi (cfu $\times 10^4$ g soil^{-1})	Actinomycetes (cfu $\times 10^3$ g soil^{-1})	N_2- fixers (cfu $\times 10^5$ g soil^{-1})	PSM´S (cfu $\times 10^5$ g soil^{-1})
Main plot: Farming Practices)					
M_1: Natural Farming	29.89^{b}	3.67^{b}	5.44^{b}	15.11^{b}	11.72^{b}
M_2: Organic Farming	33.83^{a}	4.67^{a}	7.17^{a}	17.44^{a}	13.11^{a}
S.Em. ±	0.483	0.136	0.157	0.245	0.196
Sub Plot: Liquid formulations) Foliar spray at 21, 42, 63, 84,105 and 126 DAS					
S_1: Cow urine @ 50 %	32.00^{ab}	4.17^{ab}	6.50^{ab}	17.00^{a-c}	12.17^{bc}
S_2: *Jeevamrutha* @ 100 %	35.83^{a}	5.17^{a}	7.00^{a}	18.50^{a}	15.17^{a}
S_3: Vermiwash @ 10%	33.00^{ab}	4.50^{ab}	6.83^{ab}	17.67^{ab}	14.33^{ab}
S_4: *Gokrupamrutha* @ 20 %	31.17^{ab}	4.00^{ab}	6.17^{ab}	15.83^{a-c}	11.83^{c}
S_5: S_1-S_2- S_3- S_4- S_1-S_2	30.00^{b}	3.67^{ab}	6.00^{ab}	14.83^{bc}	10.67^{c}
S_6: Foliar application of Jeevamrutha as per natural farming Practices	29.17^{b}	3.50^{b}	5.33^{b}	13.83^{c}	10.33^{c}
S.Em. ±	1.11	0.33	0.34	0.73	0.55
Interaction: Farming practices × Foliar sprays (M × S)					
T_1-M_1S_1:	29.67^{b-d}	3.67^{b-d}	5.67^{cd}	16.00^{b-d}	11.67^{b-e}
T_2-M_1S_2:	35.33^{a}	4.67^{a-c}	6.00^{b-d}	17.33^{a-c}	14.00^{ab}
T_3-M_1S_3:	31.33^{a-d}	4.00^{b-d}	6.00^{b-d}	17.00^{a-c}	13.00^{bc}
T_4-M_1S_4:	28.67^{cd}	3.33^{cd}	5.33^{d}	14.33^{cd}	11.33^{c-e}
T_5-M_1S_5:	27.33^{de}	3.33^{cd}	5.00^{d}	13.00^{de}	10.33^{d-f}
T_6-M_1S_6:	27.00^{de}	3.00^{d}	4.67^{d}	13.00^{de}	10.00^{ef}
T_7-M_2S_1:	34.33^{ab}	4.67^{a-c}	7.33^{ab}	18.00^{ab}	12.67^{b-d}
T_8-M_2S_2:	36.33^{a}	5.67^{a}	8.00^{a}	19.67^{a}	16.33^{a}
T_9-M_2S_3:	34.67^{ab}	5.00^{ab}	7.67^{a}	18.33^{ab}	15.67^{a}
T_{10}-M_2S_4:	33.67^{ab}	4.67^{a-c}	7.00^{a-c}	17.33^{a-c}	12.33^{b-e}
T_{11}-M_2S_5:	32.67^{a-c}	4.00^{bcd}	7.00^{a-c}	16.67^{a-c}	11.00^{c-e}
T_{12}-M_2S_6:	31.33^{a-d}	4.00^{b-d}	6.00^{b-d}	14.67^{cd}	10.67^{c-e}
S.Em. ±	1.45	0.43	0.46	0.91	0.70
RPP	22.67^{e}	2.67^{d}	4.67^{d}	10.33^{e}	8.00^{f}
S.Em. ±	1.52	0.45	0.50	0.97	0.77

availability of nutrients through various organic sources helps in growth and multiplication of microbial load in the soil in organic farming practices. Similar results are in line with the findings of Channagouda et al., (2015) who reported that enhanced microbial activity was due to favourable soil environment and availability of energy in the form of carbon and protein sources through organic manure in cotton crop. These results are in close conformity with Nagar et al., (2016).

3.2 Effect of Different Liquid Organic Formulations on Cotton in Cotton + Greengram Intercropping System

Among subplots, foliar application of *jeevamrutha* @ 100 per cent was recorded significantly higher number of bacteria, fungi, actinomycetes, N_2 fixers and PSM population (21.17×10^5 cfu g^{-1} dry soil, 5.17×10^4 cfu g^{-1} dry soil, 11.72 × 10^3 cfu g^{-1} dry soil, 15.67 ×10^5 cfu g^{-1} dry soil and 6.94 ×10^5 cfu g^{-1} dry soil). However, application of vermiwash @10 per cent recorded on par results with application of *jeevamrutha* @ 100 per cent. than all other treatments at harvest stage of greengram. Significantly higher number of bacteria, fungi, actinomycetes, N_2 fixers and PSMS population were recorded in foliar application of *jeevamrutha* @ 100 per cent (61.67 and 35.83 ×10^5 cfu g^{-1} dry soil, 6.17 and 5.17 ×10^4 cfu g^{-1} dry soil, 10.50 and 7.17 ×10^3 cfu g^{-1} dry soil, 21.33 and 18.50 ×10^5 cfu g^{-1} dry soil and 17.00 and 15.17 ×10^5 cfu g^{-1} dry soil) at 90 DAS and harvest stage of cotton which is on par with vermiwash @10 per cent, cow urine @ 50 per cent. The foliar application of *jeevamrutha* @ 100 per cent helps in increasing soil general and beneficial microflora in sub plots. This was due to foliar created stimuli in the plant system and increased the production of growth regulators in cell system and the action of growth regulators in plant system ultimately stimulated root exudates was act as a food material for microbes for their easy multiplication. Similar results were also observed by Ramesh et al., (2018) Vinay et al., (2020), Chandrakala et al. (2008) in chilli crop, Gore and Sreenivasa (2011) in tomato, Biradar et al., (2017) in French bean, Gopal et al., (2010) and Potkile et al., (2017) in soyabean -wheat cropping system.

3.3 Recommended Practice Versus Farming System and Organic Foliar Nutrition Treatment Combinations

When treatment combinations were compared with RPP, application of *jeevamrutha* @ 100 per cent (T_8) under organic farming practices recorded significantly higher number of bacteria, fungi and actinomycetes population (26.33 ×10^5 cfu g^{-1} dry soil, 5.67 ×10^4 cfu g^{-1} dry soil and 13.67 ×10^3 cfu g^{-1} dry soil). Meanwhile, N_2 fixers and PSMS (18.33×10^5 cfu g^{-1} dry soil and 9.33×10^5 cfu g^{-1} dry soil) were recorded significantly higher by application of vermiwash @10 per cent at harvest stage of greengram than all other foliar treatments and RPP.

At 90 DAS and harvest stage of cotton, application of *jeevamrutha* @ 100 per cent (T_8) was recorded significantly higher number of bacteria, fungi, actinomycetes, N2 fixers and PSMS population (64.00 ×10^5 cfu g^{-1} dry soil, 6.67 ×10^4 cfu g^{-1} dry soil, 11.00 ×10^3 cfu g^{-1} dry soil, 23.67 ×10^5 cfu g^{-1} dry soil and 18.00 ×10^5 cfu g^{-1} dry soil) at 90 DAS of cotton and (36.33 ×10^5 cfu g^{-1} dry soil, 5.67 ×10^4 cfu g^{-1} dry soil, 7.67 ×10^4 cfu g^{-1} dry soil, 19.67 ×10^5 cfu g^{-1} dry soil and 16.33 ×10^5 cfu g^{-1} dry soil) at harvest stage of cotton which was on par with vermiwash @ 10 per cent. The higher general microflora and beneficial microflora were due to addition of organic matter and through liquid organic formulation management strategies and adding organic amendments results in higher microbial activity. These organic amendments and formulations had favourable impact on microbial activity and formation of exudates that are rich in enzyme substrates, plant roots increase enzyme activity. Due to the ongoing addition of organic manures in the form of FYM, vermicompost, green manure, and bio-fertilizers, enzyme activity in soil increased under organic nutrient management practises when compared to inorganic nutrient management practises and the experiment was carried out in those plots, where organic and natural farming practices were followed on permanent plots from last 3 years, similar results were found in Channagouda et al., (2014) in cotton, Kesarwani et al., (2009) in sorghum and Mrkovacki et al., (2012) in maize and soybean.

4. CONCLUSION

It can be concluded that soil microorganisms are helpful in decomposition of organic matter and nutrient cycling of soils in organic cotton production. Organic farming practices and application of jeevamrutha @100 % in cotton + greengram intercropping system recorded higher general and beneficial microbial activity. Whereas, recommended package of practices recorded lower microbial activity in cotton + greengram rhizosphere.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of this manuscript. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. ChatGPT

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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