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Beneficial Microbial Load under Organic Cotton Production System

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A B S T R A C T

The field experiment was carried out at MARS, Dharwad during *Kharif*, 2010-11 and 2011-12 to study the "Beneficial microbial load under organic cotton production system " Among the nutrient management practices, integrated application of EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF recorded significantly higher Integrated application of EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF recorded significantly higher bacteria, fungal, actinomycetes, N_2-fixers, enzymes mainly phosphatase and dehydrogenase activity and soil respiration rate (73.19 cfu $X10^6$/ g of soil, 26.84 cfu $X10^3$/ g of soil, 39.65 cfu $X10^2$/ g of soil and 29.52 cfu $X10^3$/ g of soil, respectively) at 60 DAS as compared to application of FYM @ 5 t ha^{-1} + RDF. Among the different treatment combinations, application of EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF with foliar spray of panchagavya @ 5% recorded significantly higher bacteria, fungi, actinomycetes and N_2-fixers over RDF + FYM

Introduction

Currently, the energy crises associated with hike in prices of N, P_2O_5 and K_2O fertilizers has made the use of chemical fertilizers in crop production not only costly but also in short supply. It is imperative to develop and make use of on-farm organic sources of nutrients to maintain healthy crop growth and obtain sustainable yield and quality apart from reduction in cost of chemical fertilizers. It is worth to note that nutrient management through organics play a major role in maintaining soil health due to build up of soil organic matter, beneficial microbes and enzymes, besides improving soil physical, chemical and biological properties. To achieve sustainable soil fertility and crop productivity, the role of green manures, organic manures, biofertilizers and other nutrient sources like

use of fermented organic nutrients mainly panchagavya, jeevamruth, cow urine, vermiwash, bio-digester etc, are becoming popular among the farmers. Organic agriculture in the world has emerged as an alternative to the chemicals oriented intensive modern agriculture. The global retail market of organic cotton has increased from 583 million to 4.3 billion in 2009 with an annual growth rate of 3.8% (Anon., 2015). In India, cotton is grown over an area of about 11.14 m.ha with a total production of 34.93 m. bales (Anon., 2015). India ranks fifth in area and third in production of cotton after USA and China. The productivity of cotton is 510 kg of lint ha^{-1} which is much lower than the world average of 621 kg ha^{-1}. Among the cotton growing states, Karnataka ranks fifth with an area of 3.90 lakh ha and sixth in production with 9.0 lakh bales of lint with an average productivity of 392 kg of lint ha^{-1}.

Presently, the chemical fertilizers are the major source of nutrients but escalating cost, coupled with increasing demand of chemical fertilizers and depleting soil health necessitates the safe and efficient use of organics in crop production. These practices gaining much popularity to enhance and maintain soil health for obtaining sustainable crop yields. The crop management practices such as cultivation, cultural practices, crop rotation, residue management and organic manures exert a considerable influence on the level of organic matter retention in soil over a period of time, regulation of soil microbial biomass, nutrient cycling and organic matter turnover. The enhancement of soil microbial biomass is known to influence crop productivity and nutrient cycling. Application of compost, vermicompost, compost, green manures and liquid organic manures are known to harness the beneficial micro flora and suppress soil pathogens (Bhawalkar and Bhawalkar, 1991). In this context, to field experiment were carried out to study the beneficial microbial load in organic production system.

Materials and Methods

The field experiment was conducted at MARS, Dharwad during 2010-11 and 2011-12 to study the "Effect of organic manures, green leaf manures, liquid organic manures and micronutrients on yield and economics of cotton". The soil of the experiment site was medium deep black, having medium carbon (0.48%) and available NPK (264.70:21.80: 285.30 NPK kg ha^{-1}). The experiment was laid out in split plot design with three replications. The main plot comprises of three manurial treatments as M_1 : Recommended dose of fertilizer (RDF) (80:40:40 $N:P_2O_5:K_2O$ kg ha^{-1} + FYM @5 t ha^{-1}), M_2: EC (1/3) + VC (1/3) + GLM (1/3) equivalent to RDN M_3: EC (1/3) + VC (1/3) + GLM (1/3) equivalent to RDF and sub plot consists of five liquid organic manures treatments are L_1 : Foliar application of panchagavya @ 5% at sympodial branching, square, flower and boll development stages, L_2: Foliar application of bio-digester @ 20%, L_3: Foliar application of cow urine @ 10%, L_4: Foliar application of vermiwash, L_5: Foliar application borax @ 0.2% + $MgSO_4$ and one control treatment was T_1: Recommended dose of fertilizer (RDF) (80:40:40 $N:P_2O_5:K_2O$ kg ha^{-1}+ FYM @ 5 t ha^{-1}). As per the treatments the organic manures equivalent to RDN and RDF through farm yard manure, enriched compost (50%), green leaf manure were applied 15 days before sowing and 50% vermicompost was spot applied to the soil before dibbling of cotton seeds and top dressing with remaining 50% of vermicompost was done at 60 DAS. The chemical fertilizers as per the recommended package alone and along with farm yard manure were applied to the check treatments. The seeds were treated with cow urine, *Azospirilum*, Phosphate solubalizing bacteria, *Pseudomonas striata*, Trichoderma and cow

dung slurry before sowing. The seed of Hybrid cotton DHH-11 was obtained from ARS Dharwad (ARS, Hebballi) and were hand dibbled with two cotton seeds per hill on 12, July, 2010 in 1st year and 8, June, 2011 in 2nd year. The soil adhering to the roots was carefully collected and used for enumeration of total bacteria, fungi and actinomycetes, by standard serial dilution plate count technique using soil extract agar for bacteria count (Bunt and Rovira, 1955), Martin's Rose Bengal agar for fungi (Martin, 1950) and Kusters agar for actinomycetes (Kuster and Williams, 1964). The microbial populations were expressed as number of colony farming units per gram dry weight of soil.

Results and Discussion

Integrated application of EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF recorded significantly higher bacteria, fungal, actinomycetes, phosphorus solubilising bacteria, N_2-fixers, enzymes mainly phosphatase and dehydrogenase activity and soil respiration rate (73.19 cfu $X10^6$/ g of soil, 26.84 cfu $X10^3$/ g of soil, 39.65 cfu $X10^2$/ g of soil (Table 1-4), 26.15 cfu $X10^3$/ g of soil, 29.52 cfu $X10^3$/ g of soil, 25.01µ pnp/g of soil/hr, 11.99 µ TPF/g of soil/day, and 9.51 mg of C or CO_2/ hr/100 g of soil respectively) at 60 DAS as compared to application of FYM @ 5 t ha^{-1} + RDF. The foliar spray of panchagavya @ 5% in combination with organic manures recorded significantly higher population of bacteria, fungi, actinomycetes, N_2-fixers and PSM, phosphatase and dehydrogenase enzyme activity and soil respiration rate over foliar spray of bio-digester @ 20% with organic manures and was on par with borax @ 0.2% + $MgSO_4$ @ 1% and vermiwash @ 20 %. Among the different treatment combinations, application of EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF with foliar spray of panchagavya @ 5% recorded significantly higher bacteria, fungi, actinomycetes, N_2-fixers and P-solubilizer, phosphatase and dehydrogenase enzyme activity and soil respiration rate over RDF + FYM and was on par with EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF with borax @ 0.2% + $MgSO_4$ @ 1%, EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF with vermiwash @ 20% and EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF with cow urine @ 10%. The enhanced soil microbial activity as indicated by both population, microbial diversity and enzymatic activity was mainly due to favourably soil environment, sufficient energy in the form of carbon and protein sources with organic sources of nutrition. These results are in conformity with the findings of

Solaiappan (2002) who opined that, the addition of organic manures have improved the microbial activity and enhanced the availability of native and applied nutrients which in turn increased the yield of cotton. Higher dehydrogenase and phosphatase activity was observed with higher levels of organic matter, narrow C: N ratio. This facilitated the greater release and availability of micronutrients in the soil. This has influenced higher uptake of nutrients in above treatments and improved crop performances indicated by ultimately resulted in higher kapas yield of cotton. These results are in confirmation with the findings of Kavallappa (1989) and Singaram and Kamala (1995). There has been an increasing interest in the soil enzymes as indicators of soil fertility, as the soil enzyme activity depends on numerous factors such as climate, amendment type, cultivation practices, crop type and edaphic properties. Naseby and Lynch (1997) considered enzymatic determinations as more useful than microbial population measures.

Table.1 Bacteria (cfuX10^6 / g of soil) and fungal (cfuX10^3 / g of soil) population observed in cotton soil as influenced by organic manures, GLM, liquid organic manures and micronutrients

Treatment	2010				2011				Pooled			
	Bacterial population		Fungal population		Bacterial population		Fungal population		Bacterial population		Fungal population	
	60 DAS	90DAS	60 DAS	90DAS	60 DAS	90DAS	60 DAS	90DAS	60 DAS	90DAS	60 DAS	90DAS
Organic Manure (M)												
M_1	65.52b	62.73c	23.00b	20.67b	66.95c	64.60c	25.28b	23.10b	66.23c	63.67c	24.14c	21.88c
M_2	68.86a	67.21b	23.73b	21.53b	71.61b	69.99b	26.00b	23.81b	70.24b	68.60b	24.87b	22.67b
M_3	71.25a	68.75a	25.53a	22.53a	75.13a	73.00a	28.15a	25.95a	73.19a	70.87a	26.84a	24.24a
S.Em.±	0.697	0.187	0.301	0.225	0.241	0.135	0.255	0.261	0.437	0.153	0.0523	0.048
Foliar spray of liquid manures + micronutrients (L)												
L_1	69.21a	67.22a	24.11a	21.67a	72.16a	68.79a	26.21a	24.00a	70.69a	68.01a	25.16a	22.83a
L_2	67.33a	64.44b	23.56a	21.11a	69.44b	68.90a	26.17a	24.00a	68.39a	66.67a	24.86a	22.55a
L_3	68.44a	66.33a	24.11a	21.56a	70.88ab	69.37a	26.74a	24.55a	69.66a	67.85a	25.43a	23.05a
L_4	68.72a	66.50a	24.22a	21.67a	71.79ab	69.46a	26.53a	24.33a	70.26a	67.98a	25.37a	23.00a
L_5	69.00a	66.66a	24.44a	21.89a	71.87ab	69.46a	26.74a	24.55a	70.44a	68.06a	25.59a	23.22a
S.Em.±	1.063	0.96	0.463	0.456	0.817	0.617	0.349	0.351	0.841	0.583	0.249	0.225
Interactions (MXL)												
M_1 L_1	66.00b-e	64.00cd	23.00cd	21.00a-c	67.83c-e	65.53cd	25.39c	23.16c	66.91c-f	64.77cd	24.20b	22.08b
M_1 L_2	64.67de	61.67cd	22.67cd	20.33bc	65.30de	64.20c-e	24.96c	22.83c	64.98f	62.93de	23.81b	21.58b
M_1 L_3	65.33b-e	62.33cd	23.00cd	20.33bc	67.10c-e	64.86c-e	25.36c	23.16c	66.22ef	63.60de	24.18b	21.75b
M_1 L_4	65.67b-e	62.67cd	23.00cd	20.67a-c	67.24c-e	63.86de	25.03c	22.83c	66.45d-f	63.27de	24.02b	21.75b
M_1 L_5	65.93a-d	63.00cd	23.33b-d	21.00a-c	67.27c-e	64.53c-e	25.68c	23.50c	66.60d-f	63.77de	24.51b	22.25b
M_2 L_1	69.63a-e	68.00a	23.33d-d	22.00ab	72.82ab	67.25c	25.60c	23.41c	71.23a-c	67.62b	24.47b	22.70b
M_2 L_2	67.00a-e	64.67bc	23.33b-d	20.67a-c	69.48b-d	70.23b	25.60c	23.41c	68.24b-f	67.45bc	24.47b	22.04b
M_2 L_3	69.00a-e	67.67a	24.00a-c	21.33a-c	70.38bc	70.31b	26.27bc	24.07bc	69.69a-e	68.99ab	25.13b	22.70b
M_2 L_4	69.17a-e	67.83a	24.00a-c	21.67ab	72.64ab	71.25bab	26.27bc	24.07bc	70.90a-d	69.54ab	25.13b	22.87b
M_2 L_5	69.52a-e	67.90a	24.00a-c	22.00ab	72.75ab	70.91ab	26.27bc	24.07bc	71.14a-c	69.41ab	25.14b	23.04b
M_3 L_1	72.00a	69.67a	26.00a	22.00ab	75.84a	73.60a	27.65ab	25.42ab	73.92a	71.63a	26.82a	23.71b
M_3 L_2	70.33a-d	67.00ab	24.67a-c	22.33ab	73.54ab	72.26ab	27.94ab	25.75ab	71.94ab	69.63ab	26.30a	24.04a
M_3L_3	71.00a-c	69.00a	25.33a-c	23.00a	75.16a	72.93ab	28.61a	26.42a	73.08a	70.97a	26.97a	24.71a
M_3 L_4	71.33ab	69.00a	25.67ab	22.67ab	75.50a	73.26ab	28.28a	26.08a	73.42a	71.13a	26.97a	24.38a
M_3 L_5	71.56ab	69.08a	26.00a	22.67ab	75.59a	72.93ab	28.28a	26.08a	73.58a	71.00a	27.14a	24.38a
C_1	63.67e	61.37d	21.33d	19.00c	63.89e	61.82e	21.48d	19.53d	63.78f	61.59e	21.41c	19.27c
S.Em.±	1.75	0.97	0.784	0.751	1.38	0.978	0.581	0.593	1.39	0.933	0.402	0.381

Note: EC- Enriched compost; C- Compost; VC – Vermicompost ; M_1 – RDF – 80:40:40 NPK kg ha^{-1} + FYM @ 5 t ha^{-1} ; M_2 - EC (1/3)+ VC(1/3) + GLM (1/3) equi.to RDN ; M_3- EC (1/3)+ VC(1/3) + GLM (1/3) equi.to RDF; L_1- Panchagavvy @ 5%; L_2- Bio-digester @ 20% ; L_3- Cow urine @ 10%; L_4- Vermiwash @ 20%; L_5- borax @ 0.2% + $MgSO_4$ @ 1% ; C_1- RDF – 80:40:40 NPK kg + FYM @ 5 t ha^{-1}

Table.2 Actinomycetes (cfuX10^2 / g of soil) and N_2 (cfuX10^3 / g of soil) fixers population observed in cotton soil as influenced by organic manures, GLM, liquid organic manures and micronutrients

Treatment	2010				2011				Pooled			
	Actinomycetes at 60 DAS	Actinomycetes at 90 DAS	N_2 fixers at 60 DAS	N_2 fixers at 90 DAS	Actinomycetes at 60 DAS	Actinomycetes at 90 DAS	N_2 fixers at 60 DAS	N_2 fixers at 90 DAS	Actinomycetes at 60 DAS	Actinomycetes at 90 DAS	N_2 fixers at 60 DAS	N_2 fixers at 90 DAS
Organic Manure (M)												
M_1	34.40c	32.13c	23.93c	22.33c	36.83c	34.68c	25.79c	23.75c	35.62c	33.41c	24.86c	23.04c
M_2	36.67b	34.27b	27.60b	25.00b	38.78b	36.58b	30.81b	28.46b	37.72b	35.43b	29.21b	26.73b
M_3	38.27a	35.67a	32.00a	27.47a	41.03a	38.73a	34.31a	31.57a	39.65a	37.20a	33.15a	29.52a
S.Em.±	0.239	0.154	0.539	0.353	0.182	0.136	0.511	0.235	0.174	0.143	0.335	0.294
Foliar spray of liquid manures + micronutrients (L)												
L_1	36.67a	34.44a	30.56a	28.78a	39.02a	36.73ab	34.06a	32.07a	37.85a	35.59ab	32.31a	30.42a
L_2	35.89a	33.33b	24.56b	21.67c	38.49a	35.61b	26.72c	23.92c	37.19a	34.47b	25.64c	22.79c
L_3	36.11a	33.78ab	25.56b	22.33c	38.78a	36.73ab	27.90c	25.19c	37.45a	35.25ab	26.73c	23.76c
L_4	37.11a	34.44a	28.56a	25.33b	39.00a	37.29a	30.81b	28.62b	38.06a	35.87a	29.68b	26.98b
L_5	36.44a	34.11ab	30.00a	26.56b	39.11a	36.95ab	32.03b	29.85b	37.78a	35.53ab	31.02ab	28.20b
S.Em.±	0.45	0.329	0.779	0.729	0.385	0.438	0.625	0.761	0.278	0.37	0.504	0.732
Interactions (MXL)												
M_1 L_1	34.33d-f	32.33cd	26.33d-f	25.00c-e	36.74d	34.69fg	28.38e-g	26.78d-f	35.54e	33.51d	27.36ef	25.89d-f
M_1 L_2	33.67ef	32.00cd	20.67hi	20.00gh	36.77d	34.19g	22.77i	20.73hi	35.22e	33.09d	21.72g	20.36hi
M_1 L_3	34.33d-f	32.00cd	21.33g-i	20.67f-h	36.85d	34.80fg	23.89hi	21.70g-i	35.59e	33.40d	22.61g	21.19g-i
M_1 L_4	35.00c-f	32.00cd	25.33d-g	22.33f-g	36.74d	34.69fg	26.30gh	24.11f-h	35.87de	33.34d	25.82f	23.22e-h
M_1 L_5	34.67d-f	32.33cd	26.00d-f	23.67d-g	37.07d	35.02fg	27.63fg	25.45e-g	35.87de	33.68d	26.82f	24.56e-g
M_2 L_1	36.67a-d	35.00ab	31.33a-c	29.00ab	39.25bc	36.88b-f	34.84bc	32.65bc	37.96bc	35.94bc	33.09bc	30.83bc
M_2 L_2	36.67a-d	33.33bc	23.67f-i	21.67e-g	38.35cd	35.19e-g	27.27fg	24.28f-h	37.51c	34.26cd	25.47f	22.98f-h
M_2 L_3	36.00b-e	33.67bc	24.33e-h	22.00e-g	38.47cd	36.42c-g	27.95e	25.72e-g	37.24cd	35.04cd	26.14f	23.86e-h
M_2 L_4	38.00ab	35.67a	28.00c-e	25.33b-e	39.25bc	38.21a-d	31.17de	28.98c-e	38.63a-c	36.94ab	29.59de	27.16c-e
M_2 L_5	36.00b-e	33.67bc	30.67a-c	27.00b-d	38.58cd	36.21d-g	32.84bc	30.65b-d	37.29cd	34.94cd	31.75cd	28.83b-d
M_3 L_1	39.00a	36.00a	34.00a	32.33a	41.08ab	38.63a-c	38.96a	36.77a	40.04a	37.32ab	36.48a	34.55a
M_3 L_2	37.33b-c	34.67ab	29.33b-d	23.33d-g	40.35a-c	37.46a-e	30.14d-f	26.74d-f	38.84a-c	36.06a-c	29.74de	25.04d-g
M_3L_3	38.00ab	35.67a	31.00a-c	24.33d-f	41.01ab	38.96ab	31.85cd	28.14d-f	39.51ab	37.32ab	31.42cd	26.24d-f
M_3 L_4	38.33ab	35.67a	32.33ab	28.33bc	41.01ab	38.96ab	34.96bc	32.77bc	39.67a	37.32ab	33.65bc	30.55bc
M_3 L_5	38.67a	36.33a	33.33ab	29.00ab	41.68a	39.63a	35.63b	33.44ab	40.17a	37.98a	34.48ab	31.22ab
C_1	33.33f	31.00d	20.00i	17.67h	33.60e	31.48h	21.16i	18.99i	33.47f	31.24e	20.58g	18.33i
S.Em.±	0.77	0.539	1.29	1.17	0.658	0.728	1.057	1.318	0.511	0.59	0.83	1.21

Note: EC- Enriched compost; C- Compost; VC – Vermicompost ; M_1 - RDF – 80:40:40 NPK kg ha^{-1} + FYM @ 5 t ha^{-1} ; M_2 - EC (1/3)+ VC(1/3) + GLM (1/3) equi.to RDN ; M_3- EC (1/3)+ VC(1/3) + GLM (1/3) equi.to RDF; L_1- Panchagavvy @ 5%; L_2- Bio-digester @ 20% ; L_3- Cow urine @ 10%; L_4- Vermiwash @ 20%; L_5- borax @ 0.2% + $MgSO_4$ @ 1% ; C_1- RDF – 80:40:40 NPK kg + FYM @ 5 t ha^{-1}

Table.3 PSM (cfuX10^3 / g of soil) population and dehydrogenase activity (µg TPF /g of soil / day) observed in cotton soil as influenced by organic manures, GLM, liquid organic manures and micronutrients

Treatment	2010				2011				Pooled			
	PSM at 60 DAS	PSM at 90DAS	Dehydrogenase at 60 DAS	Dehydrogenase at 90 DAS	PSM at 60 DAS	PSM at 90 DAS	Dehydrogenase at 60 DAS	Dehydrogenase at 90 DAS	PSM at 60 DAS	PSM at 90 DAS	Dehydrogenase at 60 DAS	Dehydrogenase at 90 DAS
Organic Manure (M)												
M_1	16.73c	14.82c	8.51c	7.09b	17.77c	15.81c	10.14c	8.42c	17.25c	15.31c	9.33c	7.76c
M_2	20.80b	18.47b	9.48b	8.02a	23.20b	21.42b	12.54b	10.75b	22.00b	19.94b	11.01b	9.38b
M_3	24.67a	22.73a	9.85a	8.22a	27.64a	25.89a	14.13a	12.32a	26.15a	24.31a	11.99a	10.27a
S.Em.±	0.478	0.499	0.0935	0.129	0.202	0.271	0.149	0.171	0.245	0.421	0.029	0.072
Foliar spray of liquid manures + micronutrients (L)												
L_1	22.89a	20.56a	9.69a	8.27a	25.30a	23.26a	12.71a	10.97a	24.09a	21.91a	11.20a	9.62a
L_2	18.89d	17.78cd	8.87b	7.04b	20.20c	19.22c	11.68c	9.84c	19.55d	18.50cd	10.27b	8.44c
L_3	19.33cd	16.89d	8.99b	7.57ab	21.58c	19.53c	12.03bc	10.27bc	20.46c	18.21ab	10.51b	8.92b
L_4	20.89bc	18.67bc	9.35a	7.92a	23.19b	21.14b	12.38ab	10.62ab	22.04b	19.91ab	10.86a	9.27ab
L_5	21.67ab	19.47ab	9.51a	8.09a	24.08ab	22.03ab	12.56ab	10.79ab	22.87b	20.75ab	11.03a	9.44a
S.Em.±	0.482	0.497	0.119	0.245	0.521	0.542	0.189	0.202	0.289	0.413	0.111	0.159
Interactions (MXL)												
$M_1 L_1$	18.67d-g	16.33ef	8.89e-g	7.47b-g	19.93f-h	17.88ef	10.59f	8.83f	19.30gh	17.11g-i	9.74f	8.15fg
$M_1 L_2$	15.33g	13.33g	8.17h	6.77g	16.12i	14.48gh	9.50gh	7.96fg	15.73j	13.91jk	8.84h	7.37gh
$M_1 L_3$	15.67g	14.33fg	8.22h	6.80fg	16.62i	14.57gh	9.92f-h	8.16f	16.14j	14.45jk	9.07gh	7.48gh
$M_1 L_4$	16.67fg	14.67fg	8.56gh	7.13d-g	17.59hi	15.55f-h	10.25f-g	8.50f	17.13ij	15.11i-k	9.40fg	7.82g
$M_1 L_5$	17.33fg	15.42fg	8.72f-h	7.30c-g	18.59g-i	16.55fg	10.44f-g	8.66f	17.96hi	15.98h-j	9.58fg	7.98fg
$M_2 L_1$	22.33e-g	20.00cd	9.86a-d	8.43a-d	24.97cd	22.93cd	12.97b-d	11.21cd	23.65cd	21.47de	11.42c	9.82b-d
$M_2 L_2$	19.33c-f	18.33de	9.05e-g	7.43b-g	20.94e-g	20.22de	11.88e	9.98e	20.14fg	19.28e-g	10.47e	8.71ef
$M_2 L_3$	20.00c-e	16.33ef	9.22d-f	7.80a-g	22.45d-f	20.41de	12.33de	10.57de	21.23ef	18.37f-h	10.78de	9.19de
$M_2 L_4$	21.00cd	18.67de	9.56b-e	8.13a-e	23.64c-e	21.60cd	12.67c-e	10.91de	22.32de	20.13d-f	11.11cd	9.52c-e
$M_2 L_5$	21.33cd	19.00c-e	9.72a-d	8.30a-d	23.97cd	21.93cd	12.83b-e	11.07c-e	22.65c-e	20.47d-f	11.28cd	9.69b-d
$M_3 L_1$	27.67a	25.33a	10.33a	8.90a	31.00a	28.95a	14.56a	12.86a	29.33a	27.14a	12.45a	10.88a
$M_3 L_2$	22	21.67bc	9.38c-f	6.93e-g	23.54c-e	22.95cd	13.64a-c	11.57b-d	22.77c-e	22.31cd	11.51c	9.25c-e
$M_3 L_3$	22.33bc	20.00cd	9.52b-e	8.10a-f	25.66c	23.62c	13.83ab	12.06a-c	24.00c	21.81de	11.68bc	10.08a-c
$M_3 L_4$	25.00ab	22.67b	9.92a-c	8.50a-c	28.33b	26.29b	14.22a	12.46ab	26.67b	24.48bc	12.07ab	10.48ab
$M_3 L_5$	26.33a	24.00ab	10.09ab	8.67ab	29.66ab	27.62ab	14.39a	12.63ab	28.00ab	25.81ab	12.24a	10.65a
C_1	16.00g	12.67g	8.20h	6.77g	16.67i	13.48h	9.07h	6.96g	16.34j	13.08k	8.64h	6.87h
S.Em.±	0.986	0.878	0.207	0.395	0.874	0.876	0.321	0.351	0.515	0.817	0.179	0.261

Note: EC- Enriched compost; C- Compost; VC – Vermicompost ; M_1 - RDF – 80:40:40 NPK kg ha^{-1} + FYM @ 5 t ha^{-1} ; M_2 - EC (1/3)+ VC(1/3) + GLM (1/3) equi.to RDN ; M_3- EC (1/3)+ VC(1/3) + GLM (1/3) equi.to RDF; L_1- Panchagavvy @ 5%; L_2- Bio-digester @ 20% ; L_3- Cow urine @ 10%; L_4- Vermiwash @ 20%; L_5- borax @ 0.2% + $MgSO_4$ @ 1% ; C_1- RDF – 80:40:40 NPK kg + FYM @ 5 t ha^{-1}

Table.4 Phosphatase activity (µg pnp TPF /g of soil / hr) and CO_2 exchange rate (mg of CO_2 /hr/ 100 g soil) in cotton soil as influenced by organic manures, GLM, liquid organic manures and micronutrients

Treatment	2010				2011				Pooled			
	Phosphatase at 60 DAS	Phosphatase at 90 DAS	CO_2 exchange at 60 DAS	CO_2 exchange at 90 DAS	Phosphatase at 60 DAS	Phosphatase at 90 DAS	CO_2 exchange at 60 DAS	CO_2 exchange at 90 DAS	Phosphatase at 60 DAS	Phosphatase at 90 DAS	CO_2 exchange at 60 DAS	CO_2 exchange at 90 DAS
Organic Manure (M)												
M_1	18.60c	17.42c	9.34c	8.47c	20.20c	18.71c	9.94c	8.64c	19.40c	18.07c	9.64c	8.55c
M_2	20.83b	19.53b	9.54b	8.81b	24.35b	22.68b	10.13b	9.23b	22.59b	21.11c	9.84b	9.02b
M_3	22.91a	21.78b	10.29	9.34c	27.10a	25.49a	11.12a	9.69a	25.01a	23.64a	10.70a	9.51a
S.Em.±	0.22	0.33	0.142	0.140	0.18	0.18	0.014	0.13	0.120	0.123	0.07	0.08
Foliar spray of liquid manures + micronutrients (L)												
L_1	22.02a	20.67a	9.94a	9.04a	25.21a	23.32a	10.64a	9.49a	23.61a	22.00a	10.29a	9.26a
L_2	19.54c	18.64b	9.59a	8.51a	22.67d	21.35c	10.44c	8.67b	21.10e	20.00c	10.01b	8.59b
L_3	19.96c	18.70b	9.56a	8.82a	23.39cd	21.62bc	10.31d	9.10ab	21.68d	20.16c	9.94b	8.96a
L_4	20.94b	19.69ab	9.93a	9.00a	23.78bc	22.35ab	10.53b	9.32a	22.36c	21.02b	10.23a	9.16a
L_5	21.44ab	20.19a	9.60a	9.01a	24.37b	22.85a	10.05e	9.36a	22.90b	21.52ab	9.82b	9.19a
S.Em.±	0.26	0.365	0.137	0.193	0.251	0.319	0.007	0.198	0.168	0.296	0.069	0.105
Interactions (MXL)												
M_1 L_1	19.46f	18.13d-f	9.58b-d	8.60a-d	20.97e	19.58f	10.38f	8.90a-e	20.21h	18.86g-i	9.98de	8.75e-g
M_1 L_2	17.68hi	16.93e-g	9.02d	8.17cd	19.08f	17.63gh	9.58j	8.23de	18.38i	17.28jk	9.30f	8.20gh
M_1 L_3	17.84g-i	16.53fg	9.38cd	8.46b-d	19.74ef	17.98fg	9.93h	8.62c-e	18.79i	17.26jk	9.66ef	8.54fg
M_1 L_4	18.84f-h	17.60e-g	9.64b-d	8.56a-d	20.46e	19.04fg	10.28g	8.80b-e	19.65h	18.32ij	9.96de	8.68e-g
M_1 L_5	19.16fg	17.90d-f	9.08d	8.55a-d	20.74e	19.34fg	9.53k	8.66b-e	19.95h	18.62h-j	9.31f	8.61e-g
M_2 L_1	22.41bc	21.17a-c	9.62b-d	8.91a-d	26.14bc	24.05b-d	10.28g	9.52a-c	24.27cd	22.61cd	9.95de	9.22b-e
M_2 L_2	19.65ef	18.13d-f	9.49b-d	8.56a-d	22.90d	21.72e	10.28g	8.73b-e	21.28g	19.93f-h	9.88de	8.65e-g
M_2 L_3	19.71ef	18.47de	8.99d	8.79a-d	23.74d	21.99e	9.53k	9.14a-d	21.72fg	20.23fg	9.26f	8.97d-f
M_2 L_4	20.91de	19.67cd	10.16a-c	8.92a-d	23.79d	22.55de	10.84d	9.32a-d	22.35f	21.11ef	10.50bc	9.12c-f
M_2 L_5	21.48cd	20.23bc	9.46b-d	8.89a-d	25.20c	23.12c-e	9.74i	9.46a-c	23.34f	21.68de	9.60ef	9.17c-e
M_3 L_1	24.19a	22.70a	10.62a	9.60a	28.53a	26.34a	11.28b	10.04a	26.36a	24.52a	10.95a	9.82a
M_3 L_2	21.29cd	20.87a-c	10.25a-c	8.80a-d	26.01bc	24.69a-c	11.48a	9.05a-d	23.65de	22.78b-d	10.86ab	8.93d-f
M_3L_3	22.34bc	21.10a-c	10.32ab	9.20a-c	26.71b	24.89ab	11.48a	9.53a-c	24.52c	23.00b-d	10.90ab	9.37a-d
M_3 L_4	23.07ab	21.82ab	10.00a-c	9.52ab	27.09b	25.46ab	10.48e	9.83ab	25.08bc	23.64a-c	10.24cd	9.67a-c
M_3 L_5	23.67ab	22.43a	10.25a-c	9.60a	27.16b	26.08a	10.88c	9.97a	25.42b	24.26ab	10.56a-c	9.79ab
C_1	17.41i	15.83g	8.19e	7.81d	17.68g	16.16h	8.43l	7.84e	17.54j	16.00k	8.31g	7.82h
S.Em.±	0.456	0.576	0.264	0.327	0.437	0.553	0.0091	0.345	0.278	0.476	0.133	0.183

Note: EC- Enriched compost; C- Compost; VC – Vermicompost ; M_1 - RDF – 80:40:40 NPK kg ha^{-1} + FYM @ 5 t ha^{-1} ; M_2 - EC (1/3)+ VC(1/3) + GLM (1/3) equi.to RDN ; M_3- EC (1/3)+ VC(1/3) + GLM (1/3) equi.to RDF; L_1- Panchagavvy @ 5%; L_2- Bio-digester @ 20% ; L_3- Cow urine @ 10%; L_4- Vermiwash @ 20%; L_5- borax @ 0.2% + $MgSO_4$ @ 1% ; C_1- RDF – 80:40:40 NPK kg + FYM @ 5 t ha^{-1}

However, at all the growth stages, enzymatic activity was found significantly higher in treatments with application of organic manures and liquid organic manures as compared to chemical fertilization. This can be attributed to cumulative effect of organic manures and liquid organic manures on proliferation of microbial population and they provide carbon and energy sources for growth and development of soil micro flora. Shwetha *et al.,* (2009) observed that bacteria, fungi, actinomycetes and enzymes mainly dehydrogenase and phosphatase activity significantly higher in treatments supplemented with organic manures in combination of beejamruhta + jeevamrutha + panchagavya as compared to RDF + FYM. The increase in soil microbial population was due to addition of vermicompost, compost which being enriched with the beneficial organism like P-solubalizers, N_2-fixers and entmophagus fungi (Indira, 1998).

Finally concluded that combined application of EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDN with foliar spray of panchagavya @ 5% improved beneficial microorganisms in soil.

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