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Microbial Population and Soil Health under Organic Cotton Production System

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A B S T R A C T

A field experiment was carried out at MARS, University of Agricultural Sciences, Dharwad during *Kharif*, 2010 -11 and 2011-12 to study the "Nutrient management options for sustainable organic cotton production" The results of the two years pooled data revealed integrated application of EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF with foliar spray of panchagavya @ 5% recorded significantly available soil N, P_2O_5 and K_2O (284, 29.7, 330 kg ha^{-1}, respectively), soil organic carbon (5.7 g kg^{-1}, respectively), bacteria (71.63 cfuX10^6/g of soil), fungi (23.71 cfuX10^3/g of soil), actinomycetes (37.32 cfuX10^2/g of soil), N_2-fixers (34.55cfuX10^3/g of soil), P-solubilizer (27.1 cfuX10^3/g of soil), phosphatase (24.52µg pnpTPF/g of soil/hr) and dehydrogenase enzyme activity (10.88 µg TPF/g of soil/day) and soil respiration rate (10.95 mg of CO_2/hr/100 g soil) over FYM @ 5 t ha^{-1} + RDF.

Introduction

The continuous use of chemical fertilizers for attaining main goal of maximum yield but not considered sustainable yield in long term and restless monocropping deplete the inherent fertility of the soil much faster than it can be replenished and reduce yield. Exclusive use of chemical fertilizers and pesticides in agriculture not only shattered the hope of farmers, but also received sever criticism from environmentally conscious people who opined that increase in agricultural production achieved at the cost of soil health. To the maximum extent organic production rely on crop 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 being popular among the farmers for sustainable crop production and maintain soil health on sustainable basis.

In India, cotton is grown over an area of about 11.25 m.ha with a total production of 34.23 m. bales (Anon., 2016). 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}. World organic cotton production is 241276 MT (1.1 million bales) grown on 0.46 million ha of land. The Organic Cotton Farm and Fiber Report reveals that India, Syria, and Turkey are the leading organic cotton producers in the world. India remains the top producer of organic cotton, out of the twenty-three organic cotton-producing cowntries, growing 80% of the fiber grown worldwide. In India, organic cotton is grown over an area of about 57,705 ha with a production of 2,58,823 bales which is 25% of world share. The global retail market of organic cotton has increased from 583 million to 4.3 billion in 2009 with an annual growth rate of 3.5% (Anon., 2014). The information on nutrient management practices through organics for sustainable organic cotton production is very much limited which is a need of the hour. The proposed study aims at developing integrated organic nutrient management practices which is one of the important components to sustain the cotton production and soil productivity in terms of fertility and beneficial microorganism load.

Materials and Methods

A Field experiment was conducted at MARS, Dharwad during 2010 and 2011 to study the "Nutrient management practices for organic cotton production". The soil of the experiment site was clay, having medium carbon (0.41%) and available NPK (264.70:24.80:285.30 NPK kg ha^{-1}). The experiment was laid out in split plot design with three replication. The main plot comprises of five manurial treatments as M1: Recommended dose of fertilizer (RDF)(80:40:40 N:P_2O_5:K_2O kg ha^{-1}+ FYM @5 t ha^{-1}), M2: Crop residues equivalent to 50% RDN with compost culture + vermicompost equivalent to 50% RDN M3: Crop residues equivalent to 50% RDF with Compost culture + vermicompost equivalent to 50% RDF, M4: Compost equivalent to 50% RDN + vermicompost equivalent to 50% RDN, M5: Compost equivalent to 50% RDF + vermicompost equivalent to 50% RDF and sub plot consists of six green manures treatments are S1: Gliricidia GLM mulch @ 7.5 t $ha^{-1,}$ S2: Gliricidia GLM mulch @ 7.5 t ha^{-1}+ Soil application of jeevamrutha @ 500 lit ha^{-1} at sowing, 30, 60 and 90 DAS, S3: Lucerne GM alone as inter crop (1:2 row proportion), S4: Lucerne GM as inter crop + Soil application of Jeevamrutha @ 500 lit ha^{-1}, S5: Sunnhemp GM alone as inter crop (1:2 row proportion), S6: Sunnhemp GM as inter crop + Soil application of jeevamrutha @ 500 lit ha^{-1}, two control treatments are T1: Recommended dose of fertilizer (RDF)(80:40:40 N:P_2O_5:K_2O kg ha^{-1}+ FYM @ 5 t ha^{-1}) and T2: Recommended dose of fertilizer (RDF)(80:40:40 N:P_2O_5:K_2O kg ha^{-1}) only. The seeds were treated with cow urine, *Azospirilum*, Phosphate solubalizing bacteria, *Pseudomonas striata*, Trichoderma and cow dung slurry before sowing. The seeds were hand dibbled with two cotton seeds per hill on 12, july, 2010 and 15 june, 2011. Nitrogen estimation was done by Kjeldahl's method, phosphorus by vanado molybdate phosphoric yellow colour method and potassium by flame photometric method. The soil adhering to the roots was carefully collected and used for enumeration of actinomycetes, by Kusters agar for actinomycetes. The microbial populations were expressed as number of colony farming units per gram dry weight of soil.

Results and Discussion

The uptake of major nutrients mainly nitrogen, phosphorus and potassium differed significantly due to organic manures. Among the organic manurial treatments, application of EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF recorded significantly higher uptake of N, P_2O_5 and K_2O (72.53,

14.26 and 77.3 kg ha^{-1}, respectively) over EC (1/3) + VC (1/3) + GLM (1/3) equivalent to RDN. Among the recommended nutrient practices, integrated application of FYM @ 5 t ha^{-1} + RDF recorded significantly higher uptake of N, P and K (79.0, 17.1 and 80.9 kg ha^{-1}, respectively) accounting for 16.52, 36.77 and 5.35 per cent, respectively (Table 2) higher over EC (1/3) + VC (1/3) + GLM (1/3) equivalent to RDN. The increase in total dry matter production and seed cotton yield could be ascribed to increased uptake of nutrients (Lokesh *et al.,* 2008). Foliar spray of panchagavya @ 5% recorded significantly higher uptake of N, P and K (74.33, 15.23 and 79.36 kg ha^{-1}, respectively) over bio-digester @ 20% and was on par with borax @ 0.2% + $MgSO_4$ @ 1% and vermiwash @ 20 %.

Among the organic 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 uptake of N, P_2O_5 and K_2O (73.80, 15.16 and 78.4 kg ha^{-1}, respectively) over other organic combinations and was on par with (1/3) + VC (1/3) + GLM (1/3) equivalent to RDF with borax @ 0.2% + $MgSO_4$ @ 1% and RDF + FYM. Similar results were also observed by Sanjutha *et al.,* (2008) and Tolanur (2008). Application of organics with foliar spray of panchagavya noticed enhanced biological efficiency of crop plants and created greater source and sink in the plant system (Boomathi *et al.,* 2005). Integrated application of FYM @ 5 t ha^{-1} + RDF + panchagavya @ 5% recorded significantly higher uptake of nitrogen, phosphorus and potassium (80.20, 17.39 and 81.82 kg ha^{-1}, respectively) over rest of the combinations but was on par with FYM @ 5 t ha^{-1} + RDF + borax @ 0.2% + $MgSO_4$ @ 1% and FYM @ 5 t ha^{-1} + RDF + vermiwash @ 20%. This might be due to higher total dry matter production in this treatment. Foliar application of boron accelerates the translocation of nitrogen compounds, increased the protein synthesis and stimulates fruiting and hastens the translocation of nitrogen and sugars thus improving fruiting resulted in higher biomass production and yield.

Among the nutrient management practices, integrated application of EC (1/3) + VC (1/3) + GLM (1/3) equivalent to RDF and EC (1/3) + VC (1/3) + GLM (1/3) equivalent to RDN recorded significantly higher organic carbon (5.6 and 5.5 g kg^{-1}, respectively) over FYM @ 5 t ha^{-1} + RDF (5.2 g kg^{-1}). It was higher by 7.96 per cent over FYM @ 5 t ha^{-1} + RDF. Lower organic carbon content was recorded in plots supplemented (Table 1) with RDF + FYM as compared to 100% organic manures application.

The foliar spray of panchagavya @ 5% was recorded significantly higher soil organic carbon (5.5 g kg^{-1}) over foliar spray of bio-digester @ 20% (5.3 g kg^{-1}) and was on par with borax @ 0.2% + $MgSO_4$ @ 1% (5.5 g kg^{-1}). Among the different treatment combinations, application EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF with foliar spray of panchagavya @ 5% recorded significantly higher soil organic carbon (5.7 g kg^{-1}) over RDF + FYM (5.0 g kg^{-1}) and was on par with EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF with foliar spray of borax @ 0.2% + $MgSO_4$ @ 1% and EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF with vermiwash @ 20% (5.6 and 5.5 g kg^{-1}, respectively).

The available soil N, P_2O_5 and K_2O varied significantly due to different nutrient management practices. Among the nutrient management practices, integrated application of EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF recorded (Table 2) significantly higher available soil N, P_2O_5 and K_2O (282.5, 28.8, 328.3 kg ha^{-1}, respectively) over FYM @ 5 t ha^{-1} + RDF.

Table.1 Bulk density in soil and uptake of N, P and K by cotton crop as influenced by organic manures, GLM, liquid organic manures and micronutrients

Treatment	2010				2011				Pooled			
	Bulk density (g/cc)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Bulk density (g/cc)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Bulk density (g/cc)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Organic Manure (M)												
M_1	1.28a	77.5a	16.0a	79.6a	1.27a	80.6a	18.1a	82.2a	1.28a	79.0a	17.1a	80.9a
M_2	1.27a	66.3c	11.6c	75.6b	1.25a	69.3c	13.3c	77.9b	1.26ab	67.8c	12.5c	76.8c
M_3	1.27a	70.4b	13.5b	76.1b	1.24a	74.6b	15.0b	78.5b	1.25b	72.5b	14.2b	77.3b
S.Em.±	0.0082	0.30	0.11	0.20	0.011	0.26	0.10	0.17	0.0082	0.28	0.10	0.10
Foliar spray of liquid manures + micronutrients (L)												
L_1	1.27a	72.4a	14.2a	78.1a	1.25a	76.2a	16.2a	80.5a	1.26a	74.3a	15.2a	79.3a
L_2	1.26a	69.6b	12.7b	75.6c	1.23a	72.3d	14.2b	77.9c	1.27a	71.0b	13.5b	76.8d
L_3	1.27a	71.3a	13.7a	76.7bc	1.26a	74.7c	15.4a	79.0bc	1.27a	73.0a	14.5a	77.8c
L_4	1.27a	71.6a	13.7a	77.2ab	1.25a	75.1c	15.5a	79.8ab	1.26a	73.3a	14.6a	78.5b
L_5	1.27a	72.2a	14.1a	77.1ab	1.25a	75.7b	16.0a	80.4a	1.26a	74.0a	15.1a	79.1ab
S.Em.±	0.011	0.43	0.28	0.42	0.014	0.14	0.26	0.39	0.0105	0.42	0.27	0.21
Interactions (MXL)												
M_1 L_1	1.28ab	78.5a	16.1a	80.5a	1.26a-d	81.9a	18.6a	83.0a	1.27ab	80.2a	17.3a	81.8a
M_1 L_2	1.27a-c	76.0b	15.8a	78.3b-e	1.27ab	78.5bc	17.7ab	80.9b-d	1.27ab	77.3bc	16.7ab	79.6cd
M_1 L_3	1.28ab	77.2ab	16.0a	79.1a-d	1.27a-d	80.2ab	18.0ab	81.5a-c	1.27ab	78.7ab	17.0ab	80.3bc
M_1 L_4	1.28a	77.6ab	16.0a	79.9a-c	1.27a-c	80.8a	18.2a	82.5ab	1.28a	79.2ab	17.1a	81.2ab
M_1 L_5	1.28a	78.3ab	16.1a	80.3ab	1.26a-e	81.4a	18.3a	83.0a	1.27ab	79.8a	17.2a	81.6a
M_2 L_1	1.27bc	67.2f	12.1cd	76.6e-g	1.24c-e	70.7fg	14.1ef	79.1d-f	1.26d-f	68.9fg	13.1ef	77.9f-h
M_2 L_2	1.27bc	64.4g	10.5e	74.2i	1.26a-d	66.6h	11.0g	76.3g	1.27a-d	65.5h	11.1g	75.3h
M_2 L_3	1.27a-c	66.4fg	11.7de	75.0g-i	1.26a-d	69.3g	13.2f	77.3fg	1.27a-c	67.8g	12.5f	76.2ij
M_2 L_4	1.26c	66.6f	11.7de	75.7g-i	1.25a-e	69.8fg	13.4f	78.1e-g	1.26b-e	68.2fg	12.6f	76.9hi
M_2 L_5	1.27a-c	67.1f	12.1cd	76.5e-h	1.25b-e	70.2fg	14.1ef	78.9d-f	1.26b-e	68.7fg	13.1ef	77.7f-h
M_3 L_1	1.26c	71.5cd	14.3b	77.1d-g	1.23e	76.0de	15.9cd	79.5c-e	1.25f	73.8de	15.1cd	78.3ef
M_3 L_2	1.27a-c	68.4ef	11.9d	74.4hi	1.25b-e	71.8f	13.2f	76.6g	1.26c-f	70.1f	12.6f	75.5j
M_3L_3	1.27bc	70.4de	13.4bc	75.8f-i	1.25a-e	74.6e	14.9de	78.2e-g	1.26b-e	72.5e	14.2de	77.0g-i
M_3 L_4	1.26c	70.5de	13.5bc	76.3e-i	1.24de	74.8de	15.0de	78.8ef	1.25ef	72.6e	14.2de	77.5f-h
M_3 L_5	1.27a-c	71.2d	14.2b	76.8e-g	1.24de	75.6de	15.8cd	79.3d-f	1.26d-f	73.4de	15.0cd	78.1e-g
C_1	1.28ab	73.0fc	14.7ab	78.0c-f	1.28a	77.1cd	16.7bc	80.0c-e	1.28a	75.3cd	15.7bc	79.0de
S.Em.±	0.0033	0.72	0.46	0.67	0.0082	0.71	0.43	0.63	0.0033	0.69	0.43	0.35

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 Organic carbon and available N, P_2O_5 and K_2O in soil as influenced by organic manures, GLM, liquid organic manures and micronutrients

Treatment	2010				2011				Pooled			
	OC (g kg^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	OC (g kg^{-1}))	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	OC (g kg^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
Organic Manure (M)												
M_1	5.1b	270.8c	25.6c	311.4b	5.3b	275.5c	27.0c	317.6b	5.2b	273.2c	26.3c	314.5b
M_2	5.3ab	275.5b	26.2b	323.4a	5.6a	279.8b	28.3b	330.5a	5.5a	277.6b	27.3b	327.0a
M_3	5.4a	277.7a	27.6a	324.7a	5.7a	287.3a	30.1a	331.8a	5.6a	282.5a	28.8a	328.3a
S.Em.±	0.0058	0.35	0.13	0.49	0.0058	0.30	0.15	0.81	0.0041	0.29	0.08	0.56
Foliar spray of liquid manures + micronutrients (L)												
L_1	5.3a	276.1a	27.3a	320.9a	5.7a	282.7a	29.4a	328.0a	5.5a	279.4a	28.3a	324.4a
L_2	5.2b	272.9b	25.4b	318.8b	5.4c	278.2b	26.8b	325.3c	5.3d	275.6b	26.1b	322.1b
L_3	5.3ab	274.4ab	26.2ab	319.2ab	5.5bc	280.5ab	28.3a	325.9bc	5.4cd	277.5a	27.3a	322.6ab
L_4	5.3ab	274.6ab	26.4ab	319.7ab	5.5a-c	280.9ab	28.5a	326.5a-c	5.4bc	277.8a	27.5a	323.1ab
L_5	5.3a	275.3a	27.1a	320.7a	5.6ab	282.1a	29.2a	327.5ab	5.5ab	278.7a	28.1a	324.1a
S.Em.±	0.0043	0.68	0.42	0.56	0.0065	0.56	0.38	0.54	0.0030	0.62	0.38	0.47
Interactions (MXL)												
M_1 L_1	5.2c-f	272.7d-f	26.5a-d	312.7c	5.4c-e	277.2c-f	27.8c-e	319.0b	5.3f-i	275.0de	27.2b-e	315.9c
M_1 L_2	5.0ef	269.7gh	24.2de	310.0c	5.2de	273.8fg	25.1fg	316.0b	5.1ij	271.8ef	24.6fg	313.0c
M_1 L_3	5.1d-f	270.3f-h	25.4b-e	310.4c	5.2de	274.6fg	27.1d-f	316.4b	5.2h-j	272.5e	26.2ef	313.4c
M_1 L_4	5.1d-f	270.3f-h	25.5b-e	311.5c	5.3c-e	275.2e-g	27.2d-f	317.7b	5.2g-i	272.7e	26.4d-f	314.6c
M_1 L_5	5.2b-f	271.2e-h	26.3a-d	312.6c	5.4b-e	276.8c-f	27.7c-e	318.8b	5.3e-i	274.0e	27.0c-e	315.7c
M_2 L_1	5.4a-d	276.2a-d	27.0a-c	323.8ab	5.8ab	281.6bc	29.1a-d	331.3a	5.6a-c	278.9c	28.1a-e	327.5ab
M_2 L_2	5.2b-f	274.0c-f	25.2c-e	322.8b	5.5a-d	275.9d-f	26.6e-g	329.6a	5.4d-h	275.0de	25.9f-g	326.2bab
M_2 L_3	5.3a-d	275.3a-d	25.9a-d	323.2ab	5.5a-d	280.0c-e	28.1c-e	330.2a	5.4c-g	277.7cd	27.0c-e	326.7ab
M_2 L_4	5.3a-d	275.8a-d	26.1a-d	323.3ab	5.6a-c	280.6b-d	28.6b-e	330.5a	5.5b-e	278.2c	27.3b-e	326.9ab
M_2 L_5	5.4a-d	276.0a-d	26.9a-c	323.9ab	5.8ab	281.1bc	29.1a-d	331.1a	5.6a-c	278.5c	28.0a-e	327.5ab
M_3 L_1	5.5a	279.4a	28.3a	326.4a	5.9a	289.4a	31.2a	333.6a	5.7a	284.4a	29.7a	330.0a
M_3 L_2	5.3a-e	275.0b-e	26.8a-c	323.5ab	5.6a-d	285.0ab	28.7b-e	330.5a	5.4b-f	280.0bc	27.8a-e	327.0ab
M_3L_3	5.4a-d	277.6a-c	27.4a-c	324.2ab	5.7a-c	286.9a	29.7a-c	331.2a	5.5a-d	282.2ab	28.5a-d	327.7ab
M_3 L_4	5.4a-c	277.9a-c	27.7ab	324.1ab	5.6a-c	287.0a	29.9a-c	331.4a	5.5a-d	282.5ab	28.8a-c	327.7ab
M_3 L_5	5.5ab	278.6ab	28.0a	325.5ab	5.8ab	288.4a	30.8ab	332.7a	5.6ab	283.5a	29.4ab	329.1ab
C_1	4.9f	267.5h	23.5e	291.7d	5.1e	270.9g	24.6g	290.2c	5.0j	269.2e	24.1g	291.0d
S.Em.±	0.0088	1.28	0.71	1.0.3	0.011	1.52	0.68	1.42	0.0058	1.05	0.66	1.00

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 Actinomycetes (cfuX102 / g of soil) and N_2 (cfuX103 / 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
$M_3 L_3$	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

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 PSM (cfuX103 / 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_3L_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.5 Phosphatase activity (µg pnpTPF /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
$M_3 L_3$	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}

It was higher by 3.42, 9.72 and 4.38 per cent over FYM @ 5 t ha^{-1} + RDF. Organic manures in conjunction with foliar spray of panchagavya recorded significantly higher available soil N, P_2O_5 and K_2O (279.46, 28.38 and 324.49 kg ha^{-1}, respectively) as compared to foliar spray of bio-digester @ 20% and was on par with borax @ 0.2% + $MgSO_4$ @ 1% and vermiwash @ 20 % and cow urine @ 10 %.

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 available soil N, P_2O_5 and K_2O (284.4, 29.7 and 330.0 kg ha^{-1}, respectively) accounting for 5.66, 23.51 and 13.40 per cent, higher available NPK over RDF + FYM (269.2, 24.1 and 291.0 kg ha^{-1}) 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%.

Application of EC (1/3) + VC (1/3) + GLM (1/3) equivalent to RDF with foliar spray of panchagavya @ 5% recorded higher gain in available N, P_2O_5 and K_2O over RDF + FYM and closely followed by EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF with borax @ 0.2% + $MgSO_4$ @ 1%. Higher soil available N, P_2O_5 and K_2O may be due to higher soil microbial in soil activity. These results are in confirmity with findings of Kademani *et al.*, (2004). Integrated application of EC (1/3) + VC (1/3) + gliricidia GLM (1/3) equivalent to RDF recorded significantly higher 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 3-5), 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 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 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%. These results are in line with the findings of Solaiappan (2004). 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 soil properties.

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