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Impact of Organic Farming Practices on Soil Microbial Population in Cotton

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ABSTRACT: *The field experiment was carried out at MARS, Dharwad during* Kharif, *2010-11 and 2011-12 to study the "Impact of organic farming practices on soil microbial population in cotton" The results of the two years pooled data revealed that, among the nutrient management practices, application of compost (50%) + vermicompost (50%) equivalent to RDF recorded significantly higher bacteria, fungi, actinomycetes, phosphorus solubilizing bacteria, N_2-fixers, and enzyme activities phosphatase, dehydrogenase and soil respiration rate (74.65 cfu X10^6/ g of soil, 27.41 cfu X10^3/ g of soil, 37.63 cfu X10^2/ g of soil, 29.33 cfu X10^3/ g of soil, 39.97 cfu X10^3/ g, 23.69 µ pnp/g of soil/hr, 11.12 µ TPF/g of soil/day and 10.72 mg of CO_2/ hr/100 g of soil respectively) over FYM @ 5 t ha^{-1} + RDF. The application of gliricidia GLM @ 7.5 t ha^{-1} with surface application of jeevamrutha @ 500 l ha^{-1} recorded significantly higher population of bacteria, fungi, actinomycetes, N_2-fixers. phosphorus solubilizing bacteria and phosphatase, dehydrogenase enzyme activity and soil respiration rate (74.65 cfu X10^6/ g of soil, 27.41, cfu X10^3/ g of soil, 37.63 cfu X10^2/ g of soil, 36.67 cfu X10^3/ g of soil, 25.70 cfu X10^3/ g of soil, 23.25 µ pnp/g of soil/hr, 10.94 µ TPF/g of soil/day and 10.54 mg of C or CO_2/ hr/100 g of soil, respectively) as compared to* in situ *sunnhemp GM alone. The combined application of compost (50%) + vermicompost (50%) equivalent to RDF + gliricidia GLM with surface application of jeevamrutha @ 500 l ha^{-1} recorded significantly higher population of bacteria, fungi, actinomycetes, N_2-fixers, PSM, phosphatase, dehydrogenase enzyme activity and soil respiration rate (75.96 cfu X10^6/ g of soil, 27.97 cfu X10^3/ g of soil, 40.31 cfu X10^2/ g of soil, 42.86 cfu X10^3/ g of soil, 32.38 cfu X10^3/ g of soil, 24.44 µ pnp/g of soil/hr,11.63 µ TPF/g of soil/day and 11.37 mg of CO_2/ hr/100 g of soil, respectively) as compared to RDF alone and RDF + FYM*

Keywords: N_2-fixers. phosphorus solubilizing bacteria and dehydrogenase enzyme activity

Promoting organic agriculture offers one of the most promising options available for achieving food security and other basic needs of humanity apart from conserving natural resources. Application of scientific approaches to organic farming practices holds the possibility of maintaining and in some cases increasing the yield over long run, while sustaining bio-diversity, soil fertility, soil biological cycles and natural ecosystem processes and services that underpin the agriculture. It offers us productive way out of increasing environmental degradation that has triggered by many intensive agricultural practices. Apart from this, it allows the farmers to overcome the risk of crop failures and increased cost of production. Organic farming encourages producing healthy food and fibre of high quality.

Green manuring with the application of green leaf manures like gliricidia, subabul *etc*., and green manures like sunnhemp (100-120 kg N/ha/yr), lucerne (120-150 kg N/ha/yr) and cowpea *etc*., grown in between two rows of cotton improves soil fertility and productivity apart from suppressing the weeds.

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 countries, 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., 2009). The crop yield was higher with green manuring mainly due to

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biological nitrogen fixation and addition of organic matter. In the process they release of organic acids and CO_2 which help in solubilization of phosphorus and enhance the K content in soil solution. A significant beneficial effect of green manures has been attributed to their rapid growth, nitrogen fixation, greater biomass accumulation, nutrient conservation in their green tissues and mineralization of the nutrients allowing increase in the uptake of nutrients by crops (Singh and Ahuja, 1990). In this context, to make the organic cotton production more sustained the field studies were carried out to study the microbial population in organic production system.

MATERIAL METHODS

A Field experiment was conducted at MARS, Dharwad during 2010-11 and 2011-12 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. As per the treatments the organic manures equivalent to RDN and RDF through farm yard manure, cotton stalks (50%), 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 cou urine, *Azospirilum*, Phosphate solubalizing bacteria, *Pseudomonas striata*, Trichoderma and cou dung slurry before sowing. The seed of Hybrid cotton DHB-915 was obtained from ARS Dharwad, Hebballi farm and were hand dibbled with two cotton seeds per hill on 12, july, 2010 and 15 june, 2011.Two rows of sunnhemp and lucerne at 30 cm apart were grown as a green manure crops in between two rows of cotton (90 cm). Sunnhemp was cut at 30-35 DAS was mulched in between the rows where lucerne was regularly harvested (3 times during the year) at 30 to 35 days interval and used as mulch between the rows. Gliricidia green leaf manures @ 7.5 t ha^{-1} were mulched in between the cotton row at 30 DAS. 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

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. In the present study, significant improvement in the population of soil micro-organisms *viz*., bacteria, fungi, actinomycetes, phosphorus solubilizing bacteria, N_2-fixers, enzyme activity mainly phosphatase, dehydrogenase activity and soil respiration rate was noticed with application of organic manures, green manures and liquid organic manures at 60 and 90 DAS. Soil micro-flora and fauna need regular addition and maintenance of soil organic matter at higher level. 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). Application of vermicompost or crop residues stimulate activity of primary

decomposers and the phosphorus solubilizing bacteria and N_2- fixing bacteria were *Azotobacter* and *Rhizobium sp.* (Dey and Mukherjee, 1984).

At peak growing period 60 DAS, among the nutrient management practices, application of compost (50%) + vermicompost (50%) equivalent to RDF (Table 1to 6) recorded significantly higher bacteria, fungi, actinomycetes, phosphorus solubilizing bacteria, N_2-fixers, and enzyme activities phosphatase, dehydrogenase and soil respiration rate (74.65 cfu $X10^6$/ g of soil, 27.41 cfu $X10^3$/ g of soil, 37.63 cfu $X10^2$/ g of soil, 29.33 cfu $X10^3$/ g of soil, 39.97 cfu $X10^3$/ g, 23.69 µ pnp/g of soil/hr, 11.12 µ TPF/g of soil/day and 10.72 mg of $CO_{2/}$ hr/100 g of soil respectively) over FYM @ 5 t ha^{-1} + RDF and was on par with crop residue (50%) + vermicompost (50%) equivalent to RDF, compost (50%) + vermicompost (50%) equivalent to RDN and crop residue (50%) + vermicompost (50%) equivalent to RDN. These results corroborate with the findings of Malewar *et al*. (1999). As the bacterial and fungal population came down, the actinomycetes take upper hand, since they act on somewhat complex organic substances. Whereas, organic manures alone were able to increase the microbial counts comparable to RDF + FYM due to build up of organic carbon content. Similarly, Manna and Ganguly (1997) reported that the soil microbial biomass appeared to be controlled by organic carbon addition. Whereas, RDF + FYM did not cause significant changes in the soil microbial biomass, growth and functioning of soil microbial biomass as carbon substrate availability is limited. Similarly, Bhawalkar (1991) observed that the added chemical fertilizers resulted in a smaller effect on living organisms. At Dharwad, application of crop residue with compost culture, FYM and vermicompost treatments recorded significantly higher bacteria, fungal and actinomycetes population over chemical fertilizer alone cotton (Babalad, 1999)

The application of gliricidia GLM @ 7.5 t ha^{-1} with surface application of jeevamrutha @ 500 l ha^{-1} recorded significantly higher population of bacteria, fungi, actinomycetes, N_2-fixers. phosphorus solubilizing bacteria and phosphatase, dehydrogenase enzyme activity and soil respiration rate (74.65 cfu $X10^6$/ g of soil, 27.41, cfu $X10^3$/ g of soil, 37.63 cfu $X10^2$/ g of soil, 36.67 cfu $X10^3$/ g of soil, 25.70 cfu $X10^3$/ g of soil, 23.25 µ pnp/g of soil/hr, 10.94 µ TPF/g of soil/day and 10.54 mg of C or CO_2/ hr/100 g of soil, respectively) as compared to *in situ* sunnhemp GM alone and was on par with lucerne GM + surface application of jeevamrutha @ 500 l ha^{-1}. These results are in agreement with those of Tarhalkar *et al*. (1996) and Satyanarayana Rao and Janawade (2009). Gumaste (1981) from Dharwad reported that intercropping of lucerne GM in hybrid cotton and sorghum increased the *Azotobacter* population in the rhizosphere of soil.

The combined application of compost (50%) + vermicompost (50%) equivalent to RDF + gliricidia GLM with surface application of jeevamrutha @ 500 l ha^{-1} recorded significantly higher population of bacteria, fungi, actinomycetes, N_2-fixers, PSM, phosphatase, dehydrogenase enzyme activity and soil respiration rate (75.96 cfu $X10^6$/ g of soil, 27.97 cfu $X10^3$/ g of soil, 40.31 cfu $X10^2$/ g of soil, 42.86 cfu $X10^3$/ g of soil, 32.38 cfu $X10^3$/ g of soil, 24.44 µ pnp/g of soil/hr,11.63 µ TPF/g of soil/day and 11.37 mg of CO_2/ hr/100 g of soil, respectively) as compared to RDF alone and RDF + FYM and was on par with compost (50%) + vermicompost (50%) equivalent to RDF + lucerne GM with surface application of jeevamrutha @ 500 l ha^{-1} and crop residue (50%) + vermicompost (50%) equivalent to RDF + gliricidia GLM with surface application of jeevamrutha @ 500 l ha^{-1}). 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 inturn 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. 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

Table 1
Bacterial (cfu x 10^6/g of soil) Population at 60 and 90 DAS as Influenced by Organic Manures, Green Manures and Liquid Organic Manures

Treatment	*2010-11*		*2011-12*		*Pooled*	
	60 DAS	*90 DAS*	*60 DAS*	*90 DAS*	*60 DAS*	*90 DAS*
Organic Manure (M)						
M_1-RDF + FYM 67.61b	64.97b	68.75b	65.78b	68.18b	65.37b	
M_2-CR (1/2) + VC(1/2) equi.to RDN	73.09a	71.03a	74.34a	72.90a	73.72a	71.97a
M_3-CR (1/2) + VC (1/2) equi.to RDF	73.72a	71.39a	74.64a	72.98a	74.18a	72.19a
M_4-C (1/2) + VC (1/2) equi.to RDN	73.57a	71.22a	74.43a	73.08a	74.00a	72.15a
M_5-C (1/2) + VC (1/2) equi.to RDF	74.23a	71.83a	75.06a	73.36a	74.65a	72.59a
S.Em.±	0.42	0.31	0.48	0.29	0.36	0.25
Green Manures + Liquid Manures (G)						
G_1 - GLM alone72.93ab	70.16b	73.82ab	71.98ab	73.37ab	71.07bc	
G_2 - GLM + jeevamrutha	73.98a	71.73a	74.89a	73.02a	74.43a	72.38a
G_3 - Lucerne alone72.27bc	69.80b	73.31ab	71.44a-c	72.79bc	70.62cd	
G_4 - Lucerne + jeevamrutha	73.35ab	71.51a	74.47a	72.47a	73.91ab	71.99ab
G_5 - Sunnhemp alone	70.67d	69.07bc	71.85b	69.98c	71.26d	69.52d
G_6 - Sunnhemp + jeevamrutha	71.47cd	68.27c	72.35b	70.82bc	71.91cd	69.54d
S.Em.±	0.48	0.41	0.67	0.52	0.47	0.42
Interactions (MXG)						
M_1G_1	68.00de	64.84h-j	68.99de	66.74c-e	68.49e-g	65.79g-i
M_1G_2	70.00cd	67.33gh	70.83b-e	67.74c	70.42de	67.54fg
M_1G_3	67.00de	64.67h-j	68.28e	65.08c-e	67.64e-g	64.87g-i
M_1G_4	68.33de	65.67h-j	70.09c-e	66.94cd	69.21ef	66.30gh
M_1G_5	65.33ef	63.00jk	66.50e	63.41ef	65.92g	63.21ij
M_1G_6	67.00de	64.33i-k	67.83e	64.74c-e	67.42e-g	64.54hi
M_2G_1	73.67ab	71.30b-f	74.77a-c	73.18ab	74.22a-c	72.24a-e
M_2G_2	74.33ab	72.00b-f	75.51ab	73.85ab	74.92a-c	72.93a-d
M_2G_3	73.00a-c	71.33b-f	74.31a-c	73.18ab	73.65a-d	72.26a-e
M_2G_4	73.89ab	71.90b-f	75.00ab	73.83ab	74.45a-c	72.87a-d
M_2G_5	71.67bc	70.00e-g	73.11a-d	71.85ab	72.39b-d	70.93c-e
M_2G_6	72.00a-c	69.67e-g	73.37a-d	71.52ab	72.69ad	70.59c-e
M_3G_1	74.67ab	72.33a-e	75.16ab	73.34ab	74.91a-c	72.84a-d
M_3G_2	75.33ab	73.33a-d	76.29a	75.24a	75.81a	74.29ab
M_3G_3	73.00a-c	70.67c-f	74.11a-d	72.58ab	73.56a-d	71.62a-e
M_3G_4	75.00ab	72.67a-e	75.91a-d	73.58ab	75.45a-c	73.12a-c
M_3G_5	71.67bc	69.00fg	72.80a-c	70.91b	72.23cd	69.96d-f
M_3G_6	72.33a-c	70.33d-f	73.62ab	72.24ab	72.98a-d	71.29b-e
M_4G_1	73.67ab	71.33b-f	74.88a-c	73.19ab	74.28a-c	72.26a-e
M_4G_2	74.56ab	72.00b-f	75.55ab	73.86ab	75.06a-c	72.93a-d
M_4G_3	73.67ab	71.33b-f	74.84a-c	73.19ab	74.25a-c	72.26a-e
M_4G_4	74.53ab	72.33a-e	75.17ab	74.19ab	74.85a-c	73.26a-c
M_4G_5	72.00a-c	69.67e-g	73.22a-d	71.53ab	72.61a-d	70.60c-e
M_4G_6	73.00ab	70.67c-f	72.92a-d	72.53ab	72.96a-d	71.60a-e
M_5G_1	74.67ab	71.00c-f	75.28ab	73.45ab	74.97a-c	72.23a-e
M_5G_2	75.67a	74.00ab	76.26a	74.41ab	75.96a	74.21ab
M_5G_3	74.67ab	71.00c-f	75.01ab	73.19ab	74.84a-c	72.10a-e
M_5G_4	75.00ab	75.00a	76.19a	73.83ab	75.60a-c	74.41a
M_5G_5	72.67a-c	73.67a-c	73.62a-d	72.19ab	73.14a-d	72.93a-d
M_5G_6	73.03a-c	66.33hi	73.98a-c	73.06ab	73.51a-c	69.70ef
C_1 – RDF+ FYM	66.00ef	63.67i-k	66.76e	63.67d-f	66.38fg	63.67h-j
C_2 - RDF alone	62.87f	61.67k	60.17f	60.67f	61.52h	61.17j
S.Em.±	1.06	0.88	1.43	1.09	1.05	0.88

Table 2
Fungi (cfu x 10^3/g of soil) Population at 60 and 90 DAS as Influenced by Organic Manures, Green Manures and Liquid Organic Manures

Treatment	*2010-11*		*2011-12*		*Pooled*	
	60 DAS	*90 DAS*	*60 DAS*	*90 DAS*	*60 DAS*	*90 DAS*
Organic Manure (M)						
M_1-RDF + FYM 19.22c	18.35d	24.34c	23.00c	21.78d	20.67e	
M_2-CR (1/2) + VC(1/2) equi.to RDN	22.56b	20.28c	27.93b	25.31b	25.24c	22.79d
M_3-CR (1/2) + VC (1/2) equi.to RDF	23.72a	22.11ab	29.67a	27.35a	26.70b	24.73b
M_4-C (1/2) + VC (1/2) equi.to RDN	22.94b	21.78b	28.33b	25.67b	25.64c	23.72c
M_5-C (1/2) + VC (1/2) equi.to RDF	24.36a	22.61a	30.46a	28.12a	27.41a	25.36a
S.Em.±	0.24	0.22	0.27	0.4	0.16	0.18
Green Manures + Liquid Manures (G)						
G_1 - GLM alone22.60ab	21.07ab	28.16ab	25.96ab	25.38a-c	23.51ab	
G_2 - GLM + jeevamrutha	23.53a	21.73a	28.76a	26.62a	26.14a	24.17a
G_3 - Lucerne alone22.37ab	20.78ab	27.98ab	25.83ab	25.18bc	23.30ab	
G_4 - Lucerne + jeevamrutha	23.39a	21.57a	28.64a	26.46a	26.02ab	24.02a
G_5 - Sunnhemp alone	21.47b	20.27b	27.53b	25.12b	24.50c	22.69b
G_6 - Sunnhemp + jeevamrutha	22.00b	20.73ab	27.81ab	25.34b	24.90c	23.04b
S.Em.±	0.39	0.33	0.31	0.36	0.31	0.29
Interactions (MXG)						
M_1G_1	19.33e-h	18.67fg	24.56e	23.30e-h	21.95g	20.98j-m
M_1G_2	20.00d-h	19.00e-g	24.89e	23.77d-h	22.45fg	21.38h-m
M_1G_3	19.00f-h	17.90g	24.22e	22.87f-h	21.61g	20.38lm
M_1G_4	20.00d-h	18.87fg	24.89e	23.23e-h	22.45fg	21.05i-m
M_1G_5	18.33gh	17.67g	23.56e	22.20gh	20.95g	19.94m
M_1G_6	18.67f-h	18.00g	23.89e	22.60f-h	21.28g	20.30m
M_2G_1	22.33a-e	20.67a-	28.07a-d	25.41a-g	25.20b-e	23.04c-j
M_2G_2	24.00a-c	21.33a-e	28.43a-d	26.04a-f	26.22a-e	23.69a-h
M_2G_3	22.33a-e	20.00c-g	27.73cd	25.27a-g	25.03c-e	22.63e-l
M_2G_4	23.67a-c	21.00a-e	28.27a-d	26.00a-f	25.97a-e	23.50a-h
M_2G_5	21.33c-g	19.00e-g	27.47d	24.53c-g	24.40ef	21.77g-m
M_2G_6	21.67b-f	19.67d-g	27.63cd	24.60c-g	24.65d-f	22.13f-m
M_3G_1	23.67a-c	22.00a-d	29.56a-d	27.21a-d	26.61a-e	24.60a-e
M_3G_2	24.67ab	23.00a	30.56a-d	28.21ab	27.61ab	25.60ab
M_3G_3	23.33a-c	22.00a-d	29.56a-d	27.21a-d	26.45a-e	24.60a-e
M_3G_4	24.33a-c	22.67ab	30.23a-d	28.04a-c	27.28a-c	25.35a-c
M_3G_5	23.00a-d	21.33a-e	28.89a-d	26.54a-e	25.95a-e	23.94a-g
M_3G_6	23.33a-c	21.67a-d	29.23a-d	26.87a-d	26.28a-e	24.27a-f
M_4G_1	23.00a-d	21.33a-e	27.96a-d	25.61a-g	25.48a-e	23.47a-h
M_4G_2	24.00a-c	22.33a-c	28.96a-d	26.61a-e	26.48a-e	24.47a-f
M_4G_3	22.67a-d	22.00a-d	27.75b-d	25.55a-g	25.21b-e	23.78a-g
M_4G_4	24.00a-c	22.33a-c	28.92a-d	26.61a-e	26.46a-e	24.47a-e
M_4G_5	21.67b-f	21.00a-f	28.09a-d	24.69b-g	24.88c-e	22.84d-k
M_4G_6	22.33a-e	21.67a-d	28.30a-d	24.94a-g	25.32b-e	23.31b-i
M_5G_1	24.67ab	22.67ab	30.63a-d	28.27a	27.65ab	25.47ab
M_5G_2	25.00a	23.00a	30.93a	28.46a	27.97a	25.73a
M_5G_3	24.53a-c	22.00a-d	30.65a-c	28.23a	27.59ab	25.12a-d
M_5G_4	24.96a	23.00a	30.90ab	28.42a	27.93a	25.71ab
M_5G_5	23.00a-d	22.33a-c	29.66a-d	27.63a-c	26.33a-e	24.98a-e
M_5G_6	24.00a-c	22.67ab	29.98a-d	27.69a-c	26.99a-d	25.18a-d
C_1 – RDF+ FYM	18.73f-h	20.33b-f	18.42f	20.87h	18.57h	20.60l-m
C_2 - RDF alone	17.45h	18.00g	15.51g	16.77i	16.48h	17.38n
S.Em.±	0.95	0.71	0.91	1.02	0.75	0.69

Table 3
Actinomycetes (cfu x 10^2/g of soil) Population at 60 and 90 DAS as Influenced by Organic Manures, Green Manures and Liquid Organic Manures

Treatment	*2010-11*		*2011-12*		*Pooled*	
	60 DAS	*90 DAS*	*60 DAS*	*90 DAS*	*60 DAS*	*90 DAS*
Organic Manure (M)						
M_1-RDF + FYM 32.37b	30.68c	32.66d	32.66b	32.52d	31.95c	
M_2-CR (1/2) + VC(1/2) equi.to RDN	35.37a	34.52b	37.18c	37.42a	36.28c	35.97b
M_3-CR (1/2) + VC (1/2) equi.to RDF	36.73a	35.63a	37.77a	37.46a	37.25a	36.55a
M_4-C (1/2) + VC (1/2) equi.to RDN	35.63a	34.27b	37.57b	37.26a	36.45b	35.92b
M_5-C (1/2) + VC (1/2) equi.to RDF	35.72a	37.34a	37.55a	37.92a	37.63a	36.64a
S.Em.±	0.78	0.53	0.0037	0.31	0.32	0.26
Green Manures + Liquid Manures (G)						
G_1 - GLM alone35.57bc	34.71a-c	36.66c	38.18b	36.12a	36.45a	
G_2 - GLM + jeevamrutha	38.57a	36.07a	40.15a	39.48a	39.36a	37.77a
G_3 - Lucerne alone33.57cd	34.26bc	35.11d	35.17c	34.34ab	34.72b	
G_4 - Lucerne + jeevamrutha	37.82ab	35.76ab	39.33b	39.07a	38.57a	37.42a
G_5 - Sunnhemp alone	31.91d	33.54c	33.48f	34.23d	32.69b	33.88b
G_6 - Sunnhemp + jeevamrutha	32.24d	33.91c	33.82e	34.56cd	33.03b	34.24b
S.Em.±	0.86	0.539	0.0041	0.26	1.02	0.567
Interactions (MXG)						
M_1G_1	33.00b-f	30.40e-i	32.90cd	34.62ab	32.95ef	32.51g-j
M_1G_2	36.00a-e	33.33c-h	36.39a-d	35.92ab	36.19a-e	34.63d-g
M_1G_3	31.00ef	29.67f-j	31.35cd	31.61b	31.17ef	30.64h-j
M_1G_4	35.24a-f	32.33d-i	35.56a-d	35.51ab	35.40a-f	33.92f-i
M_1G_5	29.33fg	29.00h-j	29.72d	30.67b	29.53f	29.84j
M_1G_6	29.67fg	29.33g-j	30.05d	31.00b	29.86f	30.17ij
M_2G_1	36.00a-e	34.33a-f	37.42a-c	38.82a	36.71a-e	36.58a-g
M_2G_2	39.00ab	35.13a-e	40.91ab	40.12a	39.95ab	37.63a-f
M_2G_3	34.00a-f	34.32a-f	35.87a-d	35.81ab	34.93a-f	35.07c-g
M_2G_4	38.24a-d	35.13a-e	40.08ab	39.71a	39.16a-d	37.42a-f
M_2G_5	32.33d-f	34.09a-f	34.24b-d	34.87ab	33.29d-f	34.48e-h
M_2G_6	32.67c-f	34.13a-f	34.57a-d	35.20ab	33.62c-f	34.67d-g
M_3G_1	36.26a-e	37.33a-c	37.70a-c	39.17a	36.98a-e	38.25a-e
M_3G_2	39.26a	38.00a-c	41.19ab	40.47a	40.22a	39.24a-c
M_3G_3	34.26a-f	36.33a-d	36.15a-d	36.16ab	35.20a-f	36.25a-g
M_3G_4	38.50a-d	37.67a-d	40.36ab	40.06a	39.43a-c	38.87a-d
M_3G_5	32.59c-f	35.40a-d	34.52a-d	35.22ab	33.56c-f	35.31b-g
M_3G_6	32.93b-f	35.67a-c	34.85a-d	35.55ab	33.89c-f	35.61a-g
M_4G_1	36.26a-e	34.00a-d	37.50a-c	38.97a	36.88a-e	36.49a-g
M_4G_2	39.26a	35.00a-d	40.99ab	40.27a	40.12a	37.64a-f
M_4G_3	34.26a-f	33.67c-g	35.95a-d	35.96ab	35.10a-f	34.81d-g
M_4G_4	38.50a-d	35.00a-e	40.16ab	39.86a	39.33a-d	37.43a-f
M_4G_5	32.59c-f	33.87b-g	34.32a-d	35.02ab	33.46c-f	34.44e-h
M_4G_6	32.93b-f	34.07a-f	34.65a-d	35.35ab	33.79c-f	34.71d-g
M_5G_1	36.35a-e	37.50a-c	37.79a-c	39.32a	37.07a-e	38.41a-e
M_5G_2	39.35a	38.87a	41.28a	40.62a	40.31a	39.74a
M_5G_3	34.35a-f	37.33a-c	36.24a-d	36.31ab	35.29a-f	36.82a-f
M_5G_4	38.59a-c	38.67ab	40.45ab	40.21a	39.52a-c	39.44ab
M_5G_5	32.68c-f	35.33a-d	34.61a-d	35.37ab	33.65c-f	35.35b-g
M_5G_6	33.02b-f	36.33a-d	34.94a-d	35.70ab	33.98b-f	36.02a-g
C_1 – RDF+ FYM	30.95ef	28.00ij	31.00cd	31.06b	30.98ef	29.53j
C_2 - RDF alone	25.37g	25.37j	20.20e	24.17c	22.79g	24.77k
S.Em.±	1.77	1.41	2	1.99	1.76	1.23

Table 4
PSM (cfu x 10^5/g of soil) Population at 60 and 90 DAS in Cotton Field as Influenced by Organic Manures, Green Manures and Liquid Organic Manures

Treatment	*2010-11*		*2011-12*		*Pooled*	
	60 DAS	*90 DAS*	*60 DAS*	*90 DAS*	*60 DAS*	*90 DAS*
Organic Manure (M)						
M_1-RDF + FYM 17.72e	16.22d	21.92e	18.89e	19.82e	17.55e	
M_2-CR (1/2) + VC(1/2) equi.to RDN	20.06d	18.56c	25.72d	22.45d	22.89d	21.25d
M_3-CR (1/2) + VC (1/2) equi.to RDF	25.39b	23.50b	31.70b	28.34b	27.60b	26.87b
M_4-C (1/2) + VC (1/2) equi.to RDN	23.28c	22.44b	29.76c	26.89c	26.52c	25.08c
M_5-C (1/2) + VC (1/2) equi.to RDF	27.44a	25.94a	34.03a	31.22a	29.99a	29.33a
S.Em.±	0.42	0.39	0.31	0.29	0.33	0.21
Green Manures + Liquid Manures (G)						
G_1 - GLM alone23.20a-c	21.73b	29.14b	26.06bc	25.44b	24.63b	
G_2 - GLM + jeevamrutha	24.27a	23.00a	30.14a	27.13a	26.57a	25.70a
G_3 - Lucerne alone22.40b-d	20.67c	27.86c	25.23cd	24.27c	23.82c	
G_4 - Lucerne + jeevamrutha	23.73ab	22.40ab	29.47ab	26.59ab	25.94ab	25.16ab
G_5 - Sunnhemp alone	21.07d	19.73d	27.01d	23.78e	23.37d	22.43d
G_6 - Sunnhemp + jeevamrutha	22.00cd	20.47cd	28.13c	24.55de	24.30c	23.28c
S.Em.±	0.47	0.29	0.26	0.32	0.27	0.28
Interactions (MXG)						
M_1G_1	18.33k-m	17.00n-p	22.65m-o	19.62m-o	20.49kl	18.31n-p
M_1G_2	19.33i-l	18.00l-o	23.66l-n	20.62l-n	21.50jk	19.31m-o
M_1G_3	17.67lm	15.67o-q	21.29op	18.29op	19.48lm	16.98op
M_1G_4	18.67k-m	17.33m-p	22.98m-o	19.95m-o	20.83kl	18.64n-p
M_1G_5	15.33m	14.00q	19.62p	16.62p	17.48m	15.31q
M_1G_6	17.00lm	15.33pq	21.29op	18.25op	19.15m	19.13pq
M_2G_1	20.33h-l	19.00k-n	25.94jk	22.92i-k	23.14ij	20.96lm
M_2G_2	22.33f-j	21.00h-k	27.92hi	24.92hi	25.13gh	22.96jk
M_2G_3	19.33i-l	17.67l-p	24.60k-m	21.59k-m	21.97jk	19.63mn
M_2G_4	21.33g-k	20.00i-l	26.92ij	23.92ij	24.13hi	21.96kl
M_2G_5	18.00k-m	16.67n-p	23.67l-n	20.59l-n	20.84kl	18.63n-p
M_2G_6	19.00j-l	17.00n-p	25.26j-l	20.79k-n	22.13jk	18.90m-o
M_3G_1	26.00a-e	23.33d-h	32.32cd	28.97c-f	29.16c-e	26.15c-f
M_3G_2	26.33a-e	25.33b-d	32.98bc	29.97b-d	29.66bc	27.65b-d
M_3G_3	24.67c-g	23.00d-h	30.98d-g	27.97d-g	27.83d-g	26.49d-g
M_3G_4	26.00a-e	24.33c-f	31.99c-e	29.60b-d	29.00cd	26.97c-e
M_3G_5	24.33d-g	22.33f-i	30.64d-g	26.60gh	27.49d-g	24.47f-j
M_3G_6	25.00c-f	22.67e-h	31.31c-f	26.93e-h	28.16d-f	24.80e-i
M_4G_1	23.33e-h	22.67e-h	30.05e-g	27.04e-h	26.69d-g	24.86g-j
M_4G_2	24.33d-g	23.00d-h	30.37d-g	27.37e-g	27.35d-g	25.19e-i
M_4G_3	23.00f-j	22.00f-j	29.37f-h	27.09e-h	26.19fg	24.55h-j
M_4G_4	24.00d-g	23.00d-h	30.04e-g	27.09e-h	27.02d-g	25.05i-k
M_4G_5	22.33f-j	21.67g-j	29.04gh	26.04gh	25.69f-h	23.86h-j
M_4G_6	22.67e-i	22.33f-i	29.71f-h	26.70f-h	26.19e-g	24.52i-k
M_5G_1	28.00a-c	26.67a-c	34.75ab	31.75gh	31.38ab	29.21h-j
M_5G_2	29.00a	27.67a	35.75a	32.75f-h	32.38a	29.71ab
M_5G_3	27.33a-d	25.00c-e	33.08bc	31.23ab	30.21bc	28.12a
M_5G_4	28.67ab	27.33ab	35.42a	32.41a	32.05a	29.87a-c
M_5G_5	25.33b-f	24.00d-g	32.08cd	29.08c-e	28.71c-e	26.54a
M_5G_6	26.33a-e	25.00c-e	33.08bc	30.08b-d	29.71bc	27.54d-g
C_1 – RDF+ FYM	22.33f-j	15.33h-m	17.95no	22.67j-l	20.14i-k	19.00b-d
C_2 - RDF alone	20.00h-l	14.67j-n	16.37q	19.23no	18.19lm	16.95o
S.Em.±	1.08	0.74	0.63	0.71	0.64	0.64

Table 5
Dehydrogenase Activity (ug TPF/g of soil/day) at 60 and 90 DAS in Cotton Field as Influenced by Organic Manures, Green Manures and Liquid Organic Manures

Treatment	*2010-11*		*2011-12*		*Pooled*	
	60 DAS	*90 DAS*	*60 DAS*	*90 DAS*	*60 DAS*	*90 DAS*
Organic Manure (M)						
M_1-RDF + FYM 9.17c	7.51c	10.44d	9.99d	9.81d	8.75d	
M_2-CR (1/2) + VC(1/2) equi.to RDN	9.88b	8.22b	11.46c	11.01c	10.67c	9.62c
M_3-CR (1/2) + VC (1/2) equi.to RDF	9.99b	8.33b	11.75b	11.30b	10.87b	9.82b
M_4-C (1/2) + VC (1/2) equi.to RDN	9.90b	8.24b	11.51c	11.06c	10.71c	9.65c
M_5-C (1/2) + VC (1/2) equi.to RDF	10.28a	8.62a	11.95a	11.50a	11.12a	10.06a
S.Em.±	0.042	0.038	0.038	0.038	0.039	0.037
Green Manures + Liquid Manures (G)						
G_1 - GLM alone 9.81c	8.15c	11.39c	10.94c	10.60c	9.55c	
G_2 - GLM + jeevamrutha	10.15a	8.49a	11.72a	11.27a	10.94a	9.88a
G_3 - Lucerne alone9.75cd	8.09cd	11.32cd	10.87cd	10.54cd	9.48cd	
G_4 - Lucerne + jeevamrutha	10.01b	8.35b	11.59b	11.14b	10.80b	9.75b
G_5 - Sunnhemp alone	9.65d	7.99d	11.22d	10.77d	10.44d	9.38d
G_6 - Sunnhemp + jeevamrutha	9.70cd	8.04cd	11.28cd	10.83cd	10.49cd	9.44cd
S.Em.±	0.047	0.046	0.046	0.045	0.046	0.045
Interactions (MXG)						
M_1G_1	9.19g-i	7.57g-i	10.50e	10.05de	9.85e-g	9.04f
M_1G_2	9.50fg	7.83fg	10.76de	10.31d	10.13e	9.07gh
M_1G_3	9.02i	7.37i	10.30e	9.85de	9.66f-h	8.61fg
M_1G_4	9.36gh	7.70gh	10.63e	10.18de	10.00ef	8.94h
M_1G_5	8.93ij	7.27ij	10.20e	9.75e	9.57gh	8.51gh
M_1G_6	8.99i	7.33i	10.26e	9.81de	9.63gh	8.59de
M_2G_1	9.86c-e	8.20c-e	11.44c	10.99c	10.65cd	9.60c-e
M_2G_2	10.03b-e	8.37b-e	11.61c	11.16bc	10.82b-d	9.77de
M_2G_3	9.86c-e	8.20c-e	11.44c	10.99c	10.65cd	9.60c-e
M_2G_4	9.96b-e	8.30c-e	11.54c	11.09bc	10.75cd	9.70e
M_2G_5	9.76ef	8.10ef	11.34cd	10.89c	10.55d	9.50de
M_2G_6	9.83c-f	8.17de	11.41cd	10.96c	10.62d	9.57c-e
M_3G_1	9.93c-e	8.27c-e	11.69c	11.24bc	10.81b-d	9.76bc
M_3G_2	10.29b	8.63b	12.05a-c	11.60ab	11.17b	10.12c-e
M_3G_3	9.93c-e	8.27c-e	11.69c	11.24bc	10.81b-d	9.76c-e
M_3G_4	10.06b-e	8.40b-e	11.82a-c	11.37bc	10.94b-d	9.89de
M_3G_5	9.83d-f	8.17de	11.59c	11.14bc	10.71b-d	9.66c-e
M_3G_6	9.89c-e	8.23c-e	11.65c	11.20bc	10.77cd	9.72de
M_4G_1	9.86c-e	8.20c-e	11.47c	11.02c	10.67cd	9.61c-e
M_4G_2	10.13b-d	8.47b-d	11.74bc	11.29bc	10.94b-d	9.88de
M_4G_3	9.86c-e	8.20c-e	11.47c	11.02c	10.67d	9.61c-e
M_4G_4	9.99b-e	8.33b-e	11.60c	11.15bc	10.80d	9.74de
M_4G_5	9.79d-f	8.13d-f	11.40cd	10.95c	10.60bc	9.54c-e
M_4G_6	9.79d-f	8.13d-f	11.40cd	10.95c	10.60bc	9.54de
M_5G_1	10.19bc	8.53bc	11.86a-c	11.41bc	11.03b-d	9.97de
M_5G_2	10.79a	9.13a	12.46a	12.01a	11.63a	10.57cd
M_5G_3	10.06b-e	8.40b-e	11.73bc	11.28bc	10.90b-d	9.84a
M_5G_4	10.69a	9.03a	12.36ab	11.91a	11.53a	10.47c-e
M_5G_5	9.93c-e	8.27c-e	11.60c	11.15bc	10.77cd	9.71ab
M_5G_6	9.99b-e	8.33b-e	11.67c	11.22bc	10.83b-d	9.78c-e
C_1 – RDF+ FYM	9.16hi	7.50hi	8.01f	9.05f	8.59h	8.28i
C_2 - RDF alone	8.66j	7.00j	6.39g	7.00g	7.53i	7.00j
S.Em.±	0.103	0.1	0.206	0.161	0.116	0.129

Table 6
Phosphatase Activity (ug of pnp /g of soil/hr) at 60 and 90 DAS in Cotton Field as Influenced by Organic Manures, Green Manures and Liquid Organic Manures

Treatment	*2010-11*		*2011-12*		*Pooled*	
	60 DAS	*90 DAS*	*60 DAS*	*90 DAS*	*60 DAS*	*90 DAS*
Organic Manure (M)						
M_1-RDF + FYM 19.85c	18.12c	21.45c	20.51c	20.65d	19.31c	
M_2-CR (1/2) + VC(1/2) equi.to RDN	21.59b	20.15b	23.49b	22.50b	22.54c	21.33b
M_3-CR (1/2) + VC (1/2) equi.to RDF	21.73b	20.39b	23.73b	22.74b	22.73bc	21.57b
M_4-C (1/2) + VC (1/2) equi.to RDN	21.87b	20.30b	23.63b	22.64b	22.75b	21.47b
M_5-C (1/2) + VC (1/2) equi.to RDF	22.41a	21.64a	24.97a	23.94a	23.69a	22.79a
S.Em.±	0.136	0.093	0.095	0.095	0.061	0.093
Green Manures + Liquid Manures (G)						
G_1 - GLM alone 22.09a	20.21bc	23.54bc	22.56bc	22.81a	21.38bc	
G_2 - GLM + jeevamrutha	22.45b	20.71a	24.05a	23.06a	23.25a	21.89a
G_3 - Lucerne alone21.87a	20.07c	23.41c	22.42c	22.64a	21.25c	
G_4 - Lucerne + jeevamrutha	22.20c	20.49ab	23.82ab	22.83ab	23.01a	21.66ab
G_5 - Sunnhemp alone	21.09c	19.53d	22.86d	21.92d	21.97c	20.72d
G_6 - Sunnhemp + jeevamrutha	21.53b	19.71d	23.04d	22.01d	22.29b	20.86d
S.Em.±	0.109	0.121	0.121	0.124	0.078	0.122
Interactions (MXG)						
M_1G_1	19.88i	18.17ij	21.50h	20.53hi	20.69j	19.35jk
M_1G_2	19.25ij	18.53i	21.87h	20.88g-i	20.56j	19.71jk
M_1G_3	19.98i	17.87ji	21.20h	20.21hi	20.59j	19.04jk
M_1G_4	18.96j	18.60i	21.93gh	20.96f-h	20.45j	19.78j
M_1G_5	19.32ij	17.58j	20.92h	20.19hi	20.12j	18.89k
M_1G_6	21.70c-h	17.94jk	21.28h	20.29hi	21.49i	19.12jk
M_2G_1	22.35b-d	20.32c-h	23.65c-f	22.66b-e	23.00bc	21.49c-i
M_2G_2	21.44e-h	20.97b-d	24.30b-d	23.31a-d	22.87b-e	22.14b-d
M_2G_3	21.77c-g	20.06e-h	23.39c-f	22.42c-e	22.58c-g	21.24e-i
M_2G_4	20.88h	20.39c-g	23.72c-f	22.73b-e	22.30d-h	21.56c-h
M_2G_5	21.06gh	19.50h	22.83fg	21.84e-g	21.95g-i	20.67i
M_2G_6	22.01c-f	19.68gh	23.02ef	22.03d-g	22.52c-g	20.86hi
M_3G_1	22.35b-d	20.63c-f	23.97b-e	22.99b-e	23.16bc	21.81c-g
M_3G_2	21.55d-h	20.97b-d	24.30b-d	23.31a-d	22.92b-e	22.14b-d
M_3G_3	22.11b-e	20.17d-h	23.50c-f	22.51c-e	22.81b-f	21.34d-i
M_3G_4	21.21f-h	20.73b-e	24.07b-e	23.07b-e	22.64c-f	21.90b-f
M_3G_5	21.41e-h	19.83f-h	23.17ef	22.17c-e	22.29e-h	21.00g-i
M_3G_6	21.77c-g	20.03e-h	23.37c-f	22.37c-e	22.57c-g	21.20e-i
M_4G_1	22.45bc	20.39c-g	23.73c-f	22.73b-e	23.09bc	21.56c-h
M_4G_2	21.52d-h	21.07bc	24.40bc	23.41a-c	22.96b-d	22.24bc
M_4G_3	21.91c-g	20.14d-h	23.47c-f	22.48c-e	22.69b-f	21.31d-i
M_4G_4	21.15gh	20.53c-g	23.86b-f	22.87b-e	22.50c-g	21.70c-h
M_4G_5	21.27e-h	19.77f-h	23.10ef	22.11c-f	22.19f-h	20.94hi
M_4G_6	22.91ab	19.89e-h	23.23d-f	22.23c-e	23.07bc	21.06f-i
M_5G_1	23.41a	21.53ab	24.87ab	23.87ab	24.14a	22.70ab
M_5G_2	23.51a	22.03a	25.37a	24.37a	24.44a	23.20a
M_5G_3	23.58a	22.13a	25.47a	24.47a	24.52a	23.30a
M_5G_4	22.32b-d	22.20a	25.53a	24.54a	23.93a	23.37a
M_5G_5	22.38b-d	20.94b-d	24.28b-d	23.29a-d	23.33b	22.12b-d
M_5G_6	19.25ij	21.00b-d	24.33bc	23.11b-f	21.79hi	22.06b-e
C_1 – RDF+ FYM	18.18k	17.87ij	18.70i	19.70i	18.44k	18.78jk
C_2 - RDF alone	16.80l	16.80k	13.95j	15.05j	15.38l	15.92l
S.Em.±	0.256	0.259	0.321	0.385	0.197	0.259

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 compost (50%) + vermicompost (50%) equivalent to RDF + gliricidia GLM with surface application of jeevamrutha @ 500 l ha^{-1} recorded significantly higher microbial population.

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