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Response of organic manures on water use efficiency, yield and soil properties in finger millet under rainfed condition

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Abstract
The present study was carried out to know the effective organic manures to substitute for chemical fertilizers in enhancing productivity of Fingermillet under rainfed condition with different organic manures viz., FYM, sewage sludge, poultry manure compost, urban garbage compost, enriched urban garbage compost and vermicompost at the rate equivalent to recommended nitrogen and comparison with inorganic fertilizers.

Highest grain yield (1870 kg ha^{-1}) and straw yield (3105 kg ha^{-1}) of finger millet was recorded with application of sewage sludge followed by poultry manure compost (1833 and 3052 kg ha^{-1}, respectively) over all other treatments. Maximum water use of efficiency (6.20 and 6.01 Kg ha mm^{-1}, respectively) was noticed with use of poultry manure compost and sewage sludge. Application of sewage sludge recorded highest Soil microbial population viz., bacteria, fungi, actinomycetes population, microbial biomass carbon and microbial biomass N (17.00q X 10^7 cfu/g, 23.29 X 10^4 cfu/g, 21.46 X10^3 cfu/g, 1862.2 mg/g and 217.6 mg/g of soil**,** re**s**pectively) followed by poultry manure compost and lowest in inorganic fertilizer. Organic sources of nutrients tended to improve soil physico-chemical properties viz, bulk density, water holding capacity, Porosity and organic carbon. The highest organic carbon content was noticed with the application of sewage sludge (0.64 %) followed by poultry manure.

Keywords: Finger millet yield, wue, properties of soil and sewage sludge /poultry manure

Introduction
The continuous use of inorganic fertilizers under intensive cropping system has caused widespread deficiency of secondary and micronutrients in soil (*Anon*, 2005) [2]. Green revolution brought about a great change in Indian agriculture, which was rightly termed as "from begging bowl to bread basket". This was mainly achieved with high yielding, fertilizer responsive crop cultivars and increased fertilizer use led to deterioration of land and soil health there by slowly reduced the productivity (Mukesh Kumar Pandey *et al.*, 2008) [14]. Among the millets Fingermillet (*Eleusine coracara* (L.) Gaertn.) is one of the major staple food crop of Karnataka grown in an area of 10.5 lakh ha, with an annual production of 15.7 lakh tonnes and productivity of 1889 kg ha $^{-1}$. In India it accounting for 54 per cent area and 44.9 per cent production (Krishne Gowda, *et al.*, 2007) [13]. Although the millet crops are reported to be most tolerant to moisture stress but even for short period of moisture stress during critical stages of growth, markedly reduces the yield (Udayakumar *et al.*, 1986). The present study was undertaken to evaluate the Fingermillet under organic production system. The information on sustainable productivity of finger millet with use of organic manures viz., FYM, urban garbage compost, sewage sludge, poultry manure compost and vermicompost in fingermillet is very meager under rainfed condition.

Materials and Methods
Field experiment was conducted during the *Kharif* season of 2006 and 2007 at Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bangalore. The soil of the experimental site was red sandy loam in texture classified under the order *Alfisols*, Vijapura series, isohyperthermic family of *oxihaplustaf*. pH was slightly acidic (6.44) having low cation exchange capacity (7.50 C mol kg^{-1}) with an electrical conductivity of 0.23 dSm^{-1}. The organic carbon content was 0.47 per cent. The soil was low in available nitrogen (202.8 kg ha^{-1}), high in available phosphorus (26.2 kg ha^{-1}) and medium in available potassium (217.10 kg ha^{-1}). The average annual rainfall was 927 mm distributed in 62 rainy days (> 2.5 mm). An amount of 595 mm and 690 mm of rainfall was received during cropping period in 2006 and 2007 respectively. It was slightly lower than the normal rainfall (24.3 and 5 per cent respectively).

The experiment was laid out in RCBD with four replications. The treatments comprised of different organic sources of nutrients such as FYM, sewage sludge, poultry manure compost (PMC), urban garbage compost, vermicompost (VC) and enriched urban garbage compost were applied equivalent to recommended nitrogen basis and compared with recommended inorganic fertilizers (50:40:25 kg NPK/ha). The information on nitrogen content and quantity of organic manure used in the experiment is presented in Table 1.

Soil Physical Properties viz., Bulk density of soil was recorded by Keen's cup method developed by Piper (1966). It is recorded after harvest of crops from each plot and expressed in g cm^{-3}. Maximum water holding capacity was recorded by Keen's cup method developed by Piper (1966). It is recorded after harvest of crops from each plot and expressed in percentage. Per cent of pore space of soil was recorded by Keen's cup method developed by Piper (1966). It is recorded after harvest of crops from each plot and expressed in percentage.

Enumeration of soil micro-organisms

The rhizosphere soil samples collected from experiments were analyzed for different soil microorganisms *viz*., total bacteria, total fungi and total actinomycetes, using standard dilution plate count technique by using specific nutrient media such as Nutrient agar, Martin's Rose Bengal agar and Kuster's Agar respectively. The petriplates were incubated at 30 ^{0}C for mesophiles and 50 ^{0}C for thermophiles for three to six days and population was counted and expressed per unit dry weight of substrate,

Microbial biomass C and N-Microbial biomass was estimated following fumigation and extraction method as proposed by Carter (1991). Ninhydrin – reaction nitrogen released during the fumigation of soil was determined by using Ninhydrin reagent. The suspension was filtered using Whatman No. 42 filter paper. In a similar manner unfumigated set of the same soil sample was extracted. The microbial biomass C and microbial biomass N were calculated using the following formulae.

$$\text{Biomass C g}^{-1}\text{ soil} = \frac{\text{Ninhydrin reactive in fumigated soil} - \text{Ninhydrin reactive-N in unfumigated soil}}{\text{Weight of the soil sample}} \times 24$$

$$\text{Biomass N g}^{-1}\text{ soil} = \frac{\text{Ninhydrin reactive-N in fumigated soil} - \text{Ninhydrin reactive-N in unfumigated soil}}{\text{Weight of the soil sample}} \times 2.8$$

Total water use (mm ha^{-1})

The total water use of water in terms of mile meter per hectare was calculated by adding effective rainfall and irrigation water applied by using FAO Moisture balance method and procedure adopted by Frere and Popov (1979).

Total water used = Effective rainfall + Irrigation water applied

Water use efficiency

Water use efficiency was worked out from the grain yield of crops and amount of water used (Viets, 1972) and expressed in kg ha^{-1} mm.

Water use efficiency = Grain yield (Kg ha^{-1}) /Quantity of total water applied (mm).

Plant biometric observations were recorded at 30, 60, 90 DAS and at harvest in both the component crops. The weather conditions were favorable for raising crops and protective irrigations were provided during dry spells. Both the component crops were free from pest and diseases by timely prophylactic measures. The experimental data were analysed statistically by following Fischer's method of analysis of variance wherever 'F' test was significant at P=0.05. The results have been compared among treatments based on critical difference at same level of significance.

Table 1: Composition of organic manures used in the experiment

Organic manure	2006		2007	
	N (%)	Quantity used(t/ha)	N (%)	Quantity used(t/ha)
Farm yard manure	0.55	9.1	0.47	10.6
Urban Garbage Compost	0.75	6.7	0.63	8.0
Sewage Sludge	1.43	3.5	1.24	4.0
Poultry Manure Compost	1.93	2.6	1.71	3.0
Enriched Urban Garbage compost	1.26	4	1.02	5.0
Vermicompost	1.4	3.6	1.33	3.5

Results and Discussion

Biological properties

Soil microbial population viz., bacteria, fungi and actinomycetes fluctuated in soils due to different organic nutrient sources. Organic matter in soil plays an important role in supplying nutrients to plants by a process called mineralization but under tropical conditions, the soil organic matter gets depleted faster due to rapid oxidation process (Lathwell and Bouldin, 1981). However, the rate of mineralization depends on rate of microbial activity, which in turn varies with kind of organic matter used its composition and local climatic condition.

Application of sewage sludge recorded highest Soil microbial population viz., bacteria, fungi, actinomycetes population, microbial biomass carbon and microbial biomass N (17.00q X 10^7 cfu/g, 23.29 X 10^4 cfu/g, 21.46 X10^3 cfu/g, 1862.2 mg/g and 217.6 mg/g of soil**,** re**s**pectively) followed by poultry manure compost (16.95 X 10^7 cfu/g, 22.18 X 10^4 cfu/g, 21.18 X10^3 cfu/g, 1798.1 mg/g and 211.0 mg/g of soil, respectively) and lowest in inorganic fertilizer(11.66 X 10^7 cfu/g, 15.39 X 10^4 cfu/g, 12.82 X10^3 cfu/g, 1242.7 mg/g and 155.5 mg/g of soil, respectively) (Table 2). Similar results were found by Anand (1995) that among the microbial population relatively more bacteria in soil because of the availability of simpler carbon compounds for growth of the bacteria and constant activity throughout the crop growth period. The increase in fungal population in treatments amended with different organic substrates was due to synergistic effect in supplying nutrients to microorganisms as these organic manures had higher nutrient composition. This could be due to actinomycetes prefer neutral or alkaline pH and are able to degrade relatively complex organic substances (Sandyarani and Ramaswamy (1996) and Anand (1995). It may be due to a high microbial activity in soil as a result of faster mineralization and nitrification of dead cells there by an increase in NO_3-N. It was also reported by earlier workers (Goyal *et al*. (1992). This was attributed to carbon-limited growth after decomposition of organic manures (Aoyama and Nozama, 1993).

Physico-chemical properties

Application of organic sources tended to improve soil physico-chemical properties viz, bulk density, water holding capacity, porosity, organic carbon and available NPK content of soil compared to initial status. Application of organic manures resulted in lower bulk density (1.41 to 1.46 g cm^{-3}) and higher water holding capacity (37.38to 39.80 %) and porosity (41.47 to 42.99 %) after the harvest of crops as compared to inorganic fertilizer (Table 3)**.** They could have increased the looseness of soil resulting in increased soil volume and other favorable soil physical condition as compared to that of inorganic fertilizers. Therefore, it could be concluded that organic manures are good source of nutrients besides improving soil physical environment. Similar results were showed by Rukmanagada Reddy *et al.*, (2007), Dinesh Kumar (2006), Poornesh *et al*. (2004). Further, slow and steady rate of nutrient release into soil solution was also responsible for better absorption of nutrients by Fingermillet (Devagowda, 1997 and Dosani *et al*., 1999).

In the present investigation, the electrical conductivity and pH of the soil did not differ significantly among treatments. However, slight increase in pH was observed due to use of poultry manure compost, urban garbage compost and farm yard manure which could have been due to their alkaline nature. While application of recommended dose of fertilizer had maximum pH and electrical conductivity (6.68 and 0.25ds/m, respectively). Further, sewage sludge lowered the pH and EC of soil (6.39 and 0.21 ds/m, respectively) (Table 3). These results are in agreement with the findings of Rukmanagada Reddy *et al.,* (2007), Dinesh Kumar (2006), Poornesh *et al*. (2004) and Yogananda (2001). Soil organic carbon content was significantly improved by the application of organic manures viz., sewage sludge, poultry manure compost, enriched urban garbage compost, vermicompost, urban garbage compost and farm yard manure as compared to inorganic fertilizer application. The highest organic carbon content was noticed with the application of sewage sludge (0.64%) followed by poultry manure compost (0.63%). Nevertheless, application of nutrients in organic form would improve the crop growth and leaves behind several residues including crop roots. While, organics distinctly but not significantly had higher carbon content in soil. Perhaps, slow mineralization could lead to organic carbon accumulation in soil. The findings are in agreement with those of Subbaiah and Sree Ramulu (1979) and Dinesh Kumar (2006). Improved soil organic carbon could be mainly responsible for better soil aggregation, porosity, water holding capacity and nutrient storage in soils. Besides, microbial populations and other flora of rhizosphere could have been enhanced by soil carbon.

Grain and straw yield of Finger millet

Highest grain yield (1870 kg ha^{-1}) and straw yield (3105 kg ha^{-1}) of finger millet was recorded with application of sewage sludge followed by poultry manure compost (1833 and 3052 kg ha^{-1}, respectively) over all other treatments lowest by application of FYM (Table 4). This could be ascribed to the higher nutrient composition (Table 1) coupled with pattern of nutrient release into soil solution to match the required absorption pattern (Anand, 1995). The production of photosynthates and their translocation to sink depends upon the availability of mineral nutrients besides soil moisture in fingermillet. Masthan Reddy *et al*. (2005), Poornesh *et al.* (2004) reported application of different organic manures profound impact on fingermillet productivity. Many of the earlier reports have also indicated that the soil physico-chemical and biological properties were improved with the favourable application of either sewage sludge or poultry manure *viz*., water storage, bulk density, organic carbon, available nutrients, soil pH, EC, CEC and microbial population of the rhizosphere (Jha *et al*., 2001). Further, slow and steady rate of nutrient release into soil solution was also responsible for better absorption of nutrients by fingermillet (Devagowda, 1997 and Dosani *et al*., 1999).

Sewage sludge contains about 60 per cent of its nitrogen as uric acid, 30 per cent as more stable organic form of N and less than 10 per cent as mineral N. The uric acid rapidly converts N to ammonical form subsequently into available No_3 and also contain growth promoting hormones and produce better root growth than fertilizers application. Similar results of higher yield were reported by Dinesh Kumar (2006) in fingermillet. Favourable effects of sewage sludge and poultry manure compost on soil pH, EC, redox potential, CEC and microbial population of the rhizosphere is well documented by Yogananda and Reddy (2004). Therefore, it could be concluded that sewage sludge and poultry manure compost serves as a good amendment as well as store house of nutrients for plant growth

Water use efficiency: The total water used by the crop ranged from 311.3 mm under rainfed condition. Efficient use of water has always been an important factor under water scarce condition. Higher water use efficiency (6.20 to 5.02 kg ha^{-1} mm) was recorded with rainfed condition. Maximum water use of efficiency (6.20 and 6.01 Kg ha mm^{-1}, respectively) was noticed with use of poultry manure compost and sewage sludge. (Table 4.). Increased WUE under was mainly due to higher yield. It was attributed to maintaining of favourable soil moisture for long period and more efficient nutrient use for producing high yields .These results are in agreement with the earlier findings of Udayakumar *et al.*, (1986), Krishnamurthy (1996), and Venkateswaralu *et al.* (1994). In the present study, moisture condition significantly influenced the grain and straw yield of finger millet.

Conclusion

Application of sewage sludge and poultry manure compost was found to be effective as organic manure in enhancing productivity of soil and yield in Fingermillet. Further, these manures are also cost effective and a potential substitute for chemical fertilizers to replenishing nutrient requirement of crops and found to be sustainable.

Table 2: Biological properties of soil in Fingermillet under organic production system in rainfed condition. (Data pooled over two years).

Treatment	Biological properties of soil				
	Bacteria (1 X 10^7 cfu g^{-1}soil),	Fungi (1 X 10^7 cfu g^{-1} soil),	Actinomycetes (1 X 10^7 cfu g^{-1} soil),	Microbial Biomass-Carbon (µG G^{-1} Soil)	Microbial Biomass – Nitrogen (µg/ g^{-1} Soil)
Recommended NPK	11.66	15.39	12.82	1242.7	155.3
Farm yard manure	14.80	20.07	17.19	1609.5	191.8
Urban garbage compost	14.70	20.26	17.81	1630.6	193.8
Sewage sludge	17.00	23.29	21.46	1862.2	217.6
Poultry manure compost	16.95	22.18	21.18	1798.1	211.0
Enriched urban garbage compost	16.27	21.94	20.38	1737.9	204.5
Vermicompost	16.20	21.80	20.20	1721.5	202.2
S.Em ±	0.41	0.48	0.41	40.76	4.12
CD at 5 %	1.21	1.43	1.22	122.27	12.35

Note: Organic manures used were equivalent to recommended dose of 50 kg nitrogen ha^{-1}

Table 3: Physical and chemical properties of soil in Fingermillet under organic production system in rainfed condition (Data pooled over two years).

Treatment	Physical properties of soil			Chemical properties of soil		
	Bulk Density (g cc-1)	Maximum Water Holding Capacity (%)	Porosity (%)	pH	EC ds/m	Organic Carbon (%)
Recommended NPK	1.67	33.94	37.63	6.68	0.25	0.49
Farm yard manure	1.46	37.38	41.47	6.45	0.23	0.55
Urban garbage compost	1.45	37.48	41.95	6.42	0.23	0.56
Sewage sludge	1.41	39.80	42.99	6.39	0.21	0.64
Poultry manure compost	1.42	38.91	42.87	6.40	0.21	0.63
Enriched urban garbage compost	1.42	38.16	42.98	6.40	0.22	0.62
Vermicompost	1.42	38.12	42.24	6.42	0.22	0.61
S.Em ±	0.03	0.65	0.68	0.22	0.01	0.01
CD at 5 %	0.09	1.94	2.03	NS	NS	0.03

Note: Organic manures used were equivalent to recommended dose of 50 kg nitrogen ha^{-1}

Table 4: Productivity and Water use efficiency of Fingermillet under organic production system in rainfed condition. (Data pooled over two years)

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index	Total water used (mm)	Grain yield (Kg ha^{-1})	WUE (Kg ha^{-1} mm^{-1})
Recommended NPK	1583	2598	0.38	298.22	1583	5.40
Farm yard manure	1520	2538	0.37	303.66	1520	5.02
Urban garbage compost	1558	2609	0.37	293.52	1558	5.30
Sewage sludge	1870	3105	0.38	311.58	1870	6.01
Poultry manure compost	1833	3052	0.38	296.04	1833	6.20
Enriched urban garbage compost	1759	2889	0.38	299.64	1759	5.86
Vermicompost	1726	2841	0.38	306.18	1726	5.70
S.Em ±	34.55	55.82	0.01	-	-	-
CD at 5 %	103.65	167.46	NS	-	-	-

Note: Organic manures used were equivalent to recommended dose of 50 kg nitrogen ha^{-1}

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