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Dynamics of soil biological properties under integrated nutrient management in pearl millet grown on vertisol

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Abstract
The field experiment was conducted at research farm of Bajra Research Scheme, College of Agriculture, Dhule with an objectives to evaluate the changes in soil biological properties influenced by inorganic and organic inputs under pearl millet. The experiment was laid out in Randomized Block Design with eight treatments consists of inorganic fertilizers in combination with organics *viz*., FYM, vermicompost and poultry manure. Soil biological properties *viz*., soil microbial biomass C and N, carbon and nitrogen mineralization, dehydrogenase activity, fungal, bacterial and actinomycetes population were found higher at 45 days of sowing than at harvest. The significantly maximum SMBC (157.01 µg C g^{-1} soil), SMBN (48.12 µg N g^{-1} soil), C and N mineralization (18.20 µg C g^{-1} soil d^{-1} and 1.06 µg N g^{-1} soil d^{-1}, respectively), dehydrogenase activity (81.36 µg TPF g^{-1} soil 24^{-1}), fungal (28.00 x 10^4 cfu g^{-1} soil), bacterial (57.00 x 10^7 cfu g^{-1} soil) and actinomycetes (48.00 x 10^6 cfu g^{-1} soil) population were recorded with the application of 50% RDN through fertilizers + 50% N through FYM followed by 100% RDN through FYM. The enhancement in soil biological properties was noticed with the application of vermicompost. The influence if organics on biological activities was in the order of FYM > vermicompost > poultry manure. Application of organic manures and fertilizer was an important approach in soil fertility improvement. Application of 50% RDN through fertilizers + 50% N through FYM and 100% RDN through FYM with recommended dose of fertilizers performed better as compared to sole chemical fertilizer.

Keywords: Soil biological properties, integrated nutrient management, vertisol

Introduction
After the green revolution, increasing cropping intensity, use of a modern high yielding varieties, cultivation of high biomass potential crops, nutrient leaching and unbalanced fertilizer application with no or little addition of organic manure have resulted in nutrient mining from soil. To stop nutrient mining and use of imbalance of fertilizers, it is not justified to just increase the use of inorganic fertilizers, the organic sources of plant nutrients *viz*; cow dung, poultry manure, compost, green manure etc. need to be also considered. Organic matter is known as ‘store house of plant nutrients’ and ‘life force of a soil’. Organic manure such as FYM and vermicompost can be prepared at own fields of farmers and thus reducing the cost of cultivation. Therefore, to achieve improved and sustainable soil fertility and crop yield, balanced and integrated application of chemical and organic fertilizers is the key factor. Pearl millet or *Bajra* (*Pennisetum glaucum*) is the most widely grown type of millet. India is largest producer of pearl millet of 8.2 million ha with production of 9.96 million tones and with productivity of 1312 kg ha^{-1} during 2016-17 (GOI, 2017-18) [9]. In Maharashtra, this crop is grown on 8.76*lakh* ha of land with 4.01*lakh* tonnes of grain production having productivity of 467 kg ha^{-1} in 2016-2017. However, in Dhule district, pearl millet is grown on 1.20 lakh ha of land with 0.71 lakh of tonnes of grain production having productivity of 592 kg ha^{-1} in 2016-17 (Anonymous, 2017-18) [1]. High aboveground biomass yield is obviously accompanied by an active root system, which releases an array of organic compounds into the rhizosphere. Plant roots release about 17 per cent of the photosynthate captured, most of which is available to soil organisms (Nguyen, 2003) [12]. These compounds support the growth of the microbial community and result in increased population density and also affect their level and diversity of functions. Microbial communities are important for the functioning of the ecosystem, both in relation to direct interactions with plants and with regard to nutrient and organic matter cycling. It can be hypothesized that application of chemical fertilizers and organic manures like FYM, vermicompost and poultry manure can enhance the soil biological activity, which subsequently helpful to maintain soil fertility in terms of nutrient availability and nutrient

balance and will be economically feasible method for sustaining yield and quality of pearl millet. Soil is the habitat for plants, animals and microorganisms. As plants build up organic matter, soil animals feed on them and their debris, whilst microbes decompose the complex organic compounds to their mineral components and CO_2. Hence, tremendous scope to study the biological activities *viz*., microbial biomass, mineralization and enzymes which are greatly influenced by the soil micro biota under different cropping systems and environmental conditions. Dependent on chemical fertilizers for future agriculture growth would mean further loss in soil quality, possibilities of water contamination and unsustainable burden on the fiscal system. Keeping in view all these facts, the present investigation was planned and conducted during *kharif* season at the farm of Bajra Research Scheme, College of Agriculture, Dhule with an objectives to evaluate the changes in soil biological activities as influenced by inorganic and organic inputs under pearl millet.

Materials and Methods

The experiment was carried out at Bajra Research Scheme, College of Agriculture, Dhule (Maharashtra) during *kharif* to study the dynamics of soil biological properties under integrated nutrient management in pearl millet on vertisol. The experimental soil was clayey in texture, low in available nitrogen (172.06 kg ha^{-1}) and phosphorus (13.76 kg ha^{-1}), high in available potassium (252.40 kg ha^{-1}) content and moderately alkaline in reaction (pH 8.0) with EC 0.39 dSm^{-1}. The pearl millet variety aadishakti was used for this study. The sowing was done by dibbling method. The required cultural practices (thinning and weeding) were done at proper time. The organic manures were applied in field as per the treatments before ten days of sowing of crop. The experiment was laid out in Randomized Block Design with eight treatments replicated three times. Treatment composed of T_1: control, T_2: 100% RDF (50:25:25 NPK kg ha^{-1}), T_3: 100% RDN through FYM, T_4: 100% RDN through vermicompost, T_5: 100% RDN through poultry manure, T_6: 50% RDN through fertilizers + 50% N through FYM, T_7: 50% RDN through fertilizers + 50% N through vermicompost and T_8: 50% RDN through fertilizers + 50% N through poultry manure. Recommended dose of P and K common for T_3 to T_8 treatments. Initially, FYM, vermicompost and poultry manure were analyzed for chemical properties. Soil biological properties *viz*., soil microbial biomass C and N, C and N mineralization, microbial populations and dehydrogenase enzyme activity were estimated at 45 days of sowing and at harvest.

Table 1: Proximate analysis of FYM, vermicompost and poultry manure

Sr. No.	Parameters	FYM	Vermicompost	Poultry manure
1	pH	7.12	6.82	5.58
2	EC (dSm^{-1})	0.53	0.66	0.50
3	Organic C (%)	14.7	21.60	30.0
4	Total N (%)	0.63	1.19	2.09
5	Total P (%)	0.42	0.90	2.41
6	Total K (%)	0.67	1.12	1.57
7	C:N ratio	23.33	18.18	14.35

Organic carbon was estimated by combustion method (Black 1982) [3], total N by Microkjeldahl (Digestion distillation) method (Parkinson and Allen 1975) [13] and total P estimated by Vanadomolybdophosphoric yellow color method (Piper 1966) [14] and total K by Flame photometry (Chapman and Pratt 1961) [6]. Chloroform fumigation extraction method was used for estimation of SMBC (Vance *et al.* 1987) [20] and SMBN (Brookes *et al*. 1985) [4]. Carbon and nitrogen mineralization was estimated by using alkali trap method described by Pramer and Schmidt (1965) [15] and by estimating NH_4–N and NO_3-N (Black 1965) [2]. Microbial populations was enumerated by Serial dilution plate method (Dhingra and Sinclair 1993) [7] and Dehydrogenase activity by spectrophotometric method (Casida *et al.* 1964) [5].

Results and Discussion

Soil Microbial biomass C and N Results (Table 2) indicated that SMBC was significantly affected with the application of organic and inorganic fertilizers. At 45 days, the SMBC ranged between 118.75 to 157.01 µg C g^{-1} soil. Significantly highest microbial biomass carbon (157.01 µg C g^{-1} soil) was noted in treatment T_6 (50% RDN through fertilizers + 50% N through FYM) which was more superior to other treatments and followed by T_3 i.e. application of 100% RDN through FYM (143.07 µg C g^{-1} soil). While, 50% RDN through fertilizers + 50% N through vermicompost (T_7) significantly increased the SMBC (140.22 µg C g^{-1} soil) over 100% RDN through vermicompost (134.41 µg C g^{-1} soil) however, this treatment (T_4) found at par with the application of 50% RDN through fertilizers + 50% N through poultry manure (T_8). Similar trend was noticed at harvest of pearl millet and the microbial biomass C was ranged between 101.12 to 136.77 µg C g^{-1} soil. However, the magnitude of increase in SMBC at harvest with different manures treatments i.e. T_3, T_4, T_5, T_6, $T_7$and $T_8$are of 15.94, 9.86, 2.62, 17.70, 10.23 and 5.42 per cent, respectively over 100% RDF alone. Further, higher SMBC was noticed at 45 days and it gradually declined at harvest. Soil microbial biomass carbon was significantly increased by the application of organic manures with fertilizers over their initial values (control plot) but magnitude of increase was less in the plot where only chemical fertilizers applied. Similar increased in SMBC with compost application was noticed by Manna *et al*. (2003) [10] and with FYM application was showed by Mondal *et al*. (2015) [11]. Soil microbial biomass nitrogen significantly affected due to application of organic and inorganic fertilizers. At 45 days, SMBN ranged between 21.84 to 48.12 µg N g^{-1}soil. The lowest content was recorded under control and the highest under T_6 i.e.50% RDN through fertilizers + 50% N through FYM followed by (T_3) 100% RDN through FYM (47.90 µg N g^{-1} soil) and (T_2) 100% RDF (47.10 µg N g^{-1} soil). Similarly, application of 100% and 50% RDN through vermicompost and poultry manure significantly increases the SMBN over control. At harvest of pearl millet, the soil microbial biomass N was ranged between 11.27 to 37.18 µg N g^{-1}soil. At this stage also application of RDN through FYM showed the enhancement in SMBN as compared to vermicompost and poultry manure. The higher SMBN (37.18 µg N g^{-1} soil) was noted under treatment (T_6) 50% RDN through fertilizers + 50% N through FYM followed by (T_3) 100% RDN through FYM (35.24 µg N g^{-1} soil) and (T_2) 100% RDF (34.92 µg N g^{-1} soil). Microbial biomass was a small but very dynamic component of soil organic matter fluctuating with weather, crop, input and season by as much as 40% in native ecosystems and agricultural systems (Mondal *et al*. 2015) [11].

Significant increase in SMBN under different organic input was also reported by Thakare and Bhoyar (2012) [19].

C and N mineralization

Data (Table 2) inferred that at 45 days of pearl millet, the C mineralization rate was observed from 7.85 to 18.20 µg C g^{-1} soil d^{-1}. The maximum C mineralization (18.20 µg C g^{-1} soil d^{-1}) was recorded with 50% RDN through fertilizers + 50% N through FYM and found at par with 100% RDN through FYM (17.90 µg C g^{-1} soil d^{-1}). However, the increase in C mineralization was also noticed for T_7 (50% RDN through fertilizers + 50% N through vermicompost) and T_4 (100% RDN through vermicompost). Application of poultry manure significantly increased the C mineralization over 100% RDF alone, but values are lower as compared to FYM treatments. At harvest of pearl millet, the rate of C mineralization was reduced as compared to previous stage. At the end of crop, the highest C mineralization (9.27 µg C g^{-1} soil d^{-1}) was observed under (T_6) 50% RDN through fertilizers + 50% N through FYM followed by 100% RDN through FYM (8.56 µg C g^{-1} soil d^{-1}). Further, the increase in C mineralization rate was about 67.84 to 81.76 per cent for FYM, 42.35 to 55.49 per cent for vermicompostand and 11.96 to 23.14 per cent for poultry manure treatments over 100% RDF alone treatment. The cumulative values of evolved CO_2-C increased rapidly from sowing to flowering, thereafter, it was decreased at harvest of crop. As the time progressed the differences between the treatments were more conspicuous. The treatment, 50% RDN through fertilizers + 50% N through FYM showed greatest carbon mineralization throughout the period, while, the lowest mineralization was observed in control. At 45 days of sowing (Table 2), the rate of N mineralization was ranged between 0.60 to 1.06 µg N g^{-1} soil d^{-1}. The treatment 50% RDN through fertilizers + 50% N through FYM (T_6) showed maximum (1.06 µg N g^{-1} soil d^{-1}) N mineralization and which was followed by T_3 i.e. 100% RDN through FYM (0.98 µg N g^{-1} soil d^{-1}) and T_2 i.e. 100% RDF (0.95 µg N g^{-1} soil d^{-1}). Further, data indicates the significant increased in mineralization rate with the incorporation of vermicompost and poultry manure over control. At the end of crop i.e. at harvest of pearl millet, the rate of N mineralization was found to be decreased as compared to previous stages. Among the FYM treatments, the highest N mineralization rate (0.56 µg N g^{-1} soil d^{-1}) was noted with 50% RDN through fertilizers + 50% N through FYM which was at par with 100% RDN through FYM (T_3) treatment (0.54 µg N g^{-1} soil d^{-1}). Potentially mineralizable N is frequently used as a reliable indicator of the potential N supplying capacity of a soil. Manure application created conditions that promoted an increase in the easily mineralizable inorganic-N pool, which was predominantly ammoniacal. The total inorganic N mineralized was 45-48 per cent higher in INM and organic nutrient management compared to chemical nutrient management due to greater organic matter levels because N mineralization is a microbial process that is influenced both by the quantity and quality of soil organic matter was previously reported by Dinesh *et al.* (2010) [8]. Application of integrated nutrient supply increased C and N mineralization at grand growth stages of sorghum-wheat cropping system as compared to their individual application, results showed that application of FYM + wheat straw + green manuring augmented C and N mineralization (Thakare, 2009) [18].

Microbial populations

Data pertaining to the fungal, bacterial and actinomycetes population influenced by fertilizer and manure application was incorporated in Table 3. Results indicated that, at 45 days, the fungal, bacterial and actinomycetes population were varied from 8.00 to 28.00 x 10^4 cfu g^{-1} soil, 24 to 57 x 10^7 cfu g^{-1} soil and 19 to 48 x 10^6cfu g^{-1} soil, respectively further, it was declined at harvest of pearl millet. Significantly maximum fungal (28.00 x 10^4 cfu g^{-1} soil), bacterial (57 x 10^7 cfu g^{-1} soil) and actinomycetes (48 x 10^6 cfu g^{-1} soil) population were recorded with 50% RDN through fertilizers + 50% N through FYM (T_6) followed by 100% RDN through FYM (T_3) i.e. 25 x104, 54 x 10^7 and 42 x 10^6 cfu g^{-1} soil, respectively and 50% RDN through fertilizers + 50% N through vermicompost (T_7) treatment. At harvest of pearl millet, the maximum fungal population (20.67 x10^4 cfu g^{-1} soil) was noted in 50% RDN through fertilizers + 50% N through FYM followed by 100% RDN through FYM (19.00 x10^4 cfu g^{-1} soil). Higher population (16.67 x10^4 cfu g^{-1} soil) was also observed with 50% RDN through fertilizers + 50% N through vermicompostover 100% RDF alone. Further, noticed that poultry manure treatments also significantly enhanced the fungal population over control. At harvest of pearl millet, the integrated management practices enhanced the bacterial population over 100% RDF alone and control. The bacterial population recorded at the end of crop was in ranged between 19 to 45 x 10^7 cfu g^{-1} soil. The treatments *viz*., 100% RDN through FYM, 100% RDN through vermicompost, 50% RDN through fertilizers + 50% N through FYM, 50% RDN through fertilizers + 50% N through vermicompost and 50% RDN through fertilizers + 50% N through poultry manure recorded bacterial population 42, 36, 45, 40 and 31 x 10^7 cfu g^{-1} soil, respectively which were 50.00, 28.57, 60.71, 42.86 and 10.71 per cent, respectively increase over 100% RDF alone treatment. At the end i.e. at harvest of pearl millet, the maximum actinomycetes population (37 x 10^6 cfu g^{-1} soil) was recorded with 50% RDN through fertilizers + 50% N through FYM followed by 100% RDN through FYM (33 x 10^6 cfu g^{-1} soil) which were found to be 105.55 and 83.33 per cent, respectively increased over 100% RDF alone treatment. Regular addition of organic manures is the only way to increase soil organic matter status. Repeated application of farmyard manure for 10 years developed a different microbial community compared to that amended only with chemical fertilizers. Thakare and Gupta (2003) [17] also studied the effect of nutrient management on microbial population in vertisol. They noticed the higher microbial population under plot receiving treatment N through FYM, wheat straw and green manuring as compared to 100% NPK and control.

Dehydrogenase activity

The soil dehydrogenase activity was assayed at 45 days and at harvest of pearl millet crop and data is presented in Table 3. Results indicated that at 45 days, the dehydrogenase activity ranged from 39.50 to 81.36 µg TPF g^{-1} soil 24 h^{-1} and the maximum dehydrogenase activity (81.36 µg TPF g^{-1} soil 24 h^{-1}) was recorded under 50% RDN through fertilizers + 50% N through FYM (T_6) and superior than others. The 100% RDN through FYM also increased the dehydrogenase activity (79.32 µg TPF g^{-1} soil 24 h^{-1}) followed by (T_7) 50% RDN through fertilizers + 50% N through vermicompost (75.72 µg TPF g^{-1} soil 24 h^{-1}). Dehydrogenase activity was found to be reduced at harvest of pearl millet. At the end of cropping, the highest activity (54.21 µg TPF g^{-1} soil 24 h^{-1}) was noted with 50% RDN through fertilizers + 50% N through FYM (T_6) followed by T_3 i.e. 100% RDN through FYM (48.12 µg TPF g^{-1} soil 24 h^{-1}). The 50% RDN through fertilizers + 50% N through vermicompost also recorded the higher (42.32 µg TPF g^{-1} soil 24 h^{-1}) dehydrogenase activity than chemical fertilizer. The dehydrogenase activity under T_3, T_6 and T_7 were increased by 18.40, 33.39, and 4.13 per cent, respectively over 100% RDF alone (T_2). Incorporation of organic materials influences soil enzymatic activities because the added material may contain intra- and extracellular enzymes and may also stimulate microbial activity in the soil, the organic amendment had a positive effect on the activity of these enzymes, particularly when the amendment was at the high dose, probably due to the higher microbial biomass produced in response recorded by Tejada and Gonzalez (2006) [16]. The application of balanced amounts of nutrients and manures improved the organic matter and MBC status of soils, which corresponded with higher enzyme activity noted by Mondal *et al*. 2015) [11].

Table 2: Soil microbial biomass C and N and mineralization as influenced by organic and inorganic fertilizer application

Treatment	SMBC (µg C g^{-1} soil)		SMBN (µg N g^{-1} soil)		Carbon mineralization (µg C g^{-1} soil d^{-1})		Nitrogen mineralization (µg N g^{-1} soil d^{-1})	
	At 45 days	At harvest	At 45 days	At harvest	At 45 days	At harvest	At 45 days	At harvest
T_1 Control	118.75	101.12	21.84	11.27	7.85	3.54	0.60	0.23
T_2 100% RDF (50:25:25 NPK kg ha^{-1})	122.43	116.20	47.10	34.92	10.34	5.10	0.95	0.50
T_3 100% RDN through FYM	143.07	134.72	47.90	35.24	17.90	8.56	0.98	0.54
T_4 100% RDN through vermicompost	134.41	127.66	31.51	22.71	14.46	7.26	0.88	0.37
T_5 100% RDN through poultry manure	128.60	119.24	27.48	19.27	12.62	5.71	0.85	0.30
T_6 50% RDN through fertilizers + 50% N through FYM	157.01	136.77	48.12	37.18	18.20	9.27	1.06	0.56
$T_7$50% RDN through fertilizers + 50% N through vermicompost	140.22	128.09	38.92	29.40	16.35	7.93	0.94	0.47
T_8 50% RDN through fertilizers + 50% N through poultry manure	133.93	122.50	36.27	25.64	13.74	6.28	0.92	0.43
SE ±	3.39	2.13	0.05	0.44	0.10	0.18	0.03	0.01
CD at 5%	10.29	6.46	0.14	1.33	0.31	0.54	0.08	0.04

Table 3: Soil microbial population and dehydrogenase activity as influenced by organic and inorganic fertilizer application

Treatment	Fungi (x 10^4 cfu g^{-1} soil)		Bacteria (x 10^7 cfu g^{-1} soil)		Actinomycetes (x 10^6 cfu g^{-1} soil)		Dehydrogenase activity (µg TPF g^{-1} soil 24 h^{-1})	
	At 45 days	At harvest	At 45 days	At harvest	At 45 days	At harvest	At 45 days	At harvest
T_1 Control	8.00	4.00	24	19	19	10	39.50	26.17
T_2 100% RDF (50:25:25 NPK kg ha^{-1})	21.00	15.67	37	28	27	18	74.61	40.64
T_3 100% RDN through FYM	25.00	19.00	54	42	42	33	79.32	48.12
T_4 100% RDN through vermicompost	17.00	9.67	44	36	37	25	69.22	36.27
T_5 100% RDN through poultry manure	15.00	8.00	32	24	25	14	62.40	31.48
T_6 50% RDN through fertilizers + 50% N through FYM	28.00	20.67	57	45	48	37	81.36	54.21
$T_7$50% RDN through fertilizers + 50% N through vermicompost	23.33	16.67	47	40	39	28	75.72	42.32
T_8 50% RDN through fertilizers + 50% N through poultry manure	18.67	13.00	39	31	30	19	73.12	38.84
S.E±	0.51	0.41	0.67	0.67	0.67	0.61	0.01	0.51
CD at 5%	1.56	1.25	2.03	2.03	2.03	1.86	0.03	1.54

Conclusion

Implicit with the foregone discussion, it is concluded soil biological properties are enhanced due to the application of FYM in combination with inorganic fertilizers over vermicompost and poultry manure under pearl millet on Vertisol. The effect of organics are in order FYM > vermicompost > poultry manure. Application of 50% RDN through fertilizers + 50% N through FYM and 100% RDN through FYM with recommended dose of fertilizers performed better as compared to sole chemical fertilizer. The overall interpretation of these diverse sets of data is that the quality of soil enhanced with the incorporation of manures (FYM, vermicompost and poultry) in pearl millet over sole chemical fertilizer, ultimately might be increased the crop production per unit area.

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