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Long term effect of FYM and vermicompost on soil physical and chemical properties under pearl millet-chickpea cropping sequence

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Abstract
The long term effect of FYM and vermicompost under pearl millet-chickpea cropping sequence on soil physical and chemical properties was studied during 2013 to 2018 on fixed site at research farm of Bajra Research Scheme, College of Agriculture, Dhule. The soil physical properties *viz.* hydraulic conductivity, mean weight diameter and soil chemical properties *viz.* soil pH, electrical conductivity, available N in soil, available K in soil were significantly influenced in the treatment of 100% RDN through FYM as compared to the treatment receiving 100% RDF through inorganic fertilizers at the end of 6th cycle of pearl millet-chickpea cropping sequence. The hydraulic conductivity (0.64 mm hr^{-1}) and mean weight diameter (0.61 mm) were significantly increased in the treatment of 100% RDN through FYM (T_3). The soil pH (7.40) and electrical conductivity (0.33 dSm^{-1}) were significantly decreased and soil available N (244 kg ha^{-1}) and K (273 kg ha^{-1}) were significantly increased in the treatment of 100% RDN through FYM (T_3) as compared to the treatment receiving 100% RDF through inorganic fertilizers (T_2).

Keywords: Hydraulic conductivity, mean weight diameter, Soil pH, electrical conductivity, soil available N and K

Introduction
The food grain production is decreasing day by day due to deterioration of soil health and imbalanced use of nutrients particularly secondary and micronutrients. Under such situation scientific management of land for soil fertility through organic recycling has to play key role in achieving sustainability in agriculture production (Prasad and Powar 1991) [20].

Soil physical properties are influenced by FYM and vermicompost, which found to be an important attributes of soil quality. Most of the physical properties of soil are largely influenced and the changes exhibited only under long term application of organic matter. The important physical properties of soil *viz*., bulk density, hydraulic conductivity, and mean weight diameter are generally considered as soil quality indicators.

The soil fertility status and their availability to plants are strongly affected by nutrient management practices and cropping systems (Bhandari *et al*., 2002; Kundu *et al*., 2002) [2, 12]. The loss of soil fertility, in many developing countries, due to continuous nutrient depletion by crops without adequate replenishment poses an immediate threat to food and environmental securities. There is a need to revive the age-old practice of application of farmyard manure (FYM) to maintain soil fertility and also to supplement many essential plant nutrients for crop productivity. The pearl millet is grown on 8.76 lakh ha of land with 4.01 lakh tonnes of grain production having productivity of 467 kg ha^{-1}. However, chickpea is also prime pulse crop grown on about 20 lakh ha area with total production of 17.61 lakh tonnes and productivity of 881 kg ha^{-1} in Maharashtra (GOI 2018) [7]. Considering the paramount importance of soil physical and chemical properties, the long term field experiment was conducted to study the effect of FYM and vermicompost on soil physical and chemical properties under pearl millet-chickpea cropping sequence.

Material and Methods
The experiment was conducted during 2013 to 2018 on fixed site at research farm of Bajra Research Scheme, College of Agriculture, Dhule to study the long term effect of application of FYM and vermicompost on soil physical and chemical properties under pearl millet-chickpea

cropping sequence. The experiment was laid out in randomized block design with eight treatments replicated three times. Treatments for pearl millet composed of T_1: Control, T_2: 100% RDF through inorganic fertilizers, T_3: 100% RDN through FYM, T_4: 100% RDN through vermicompost, T_5: 50% RDN through FYM + 50% RDN through vermicompost, T_6: 5 ton FYM ha^{-1}, T_7: 3 ton vermicompost ha^{-1} and T_8: 2.5 ton FYM ha^{-1} + 1.5 ton vermicompost ha^{-1}, however, treatments for chickpea composed of T_1: Control, T_2: 100% RDF through inorganic fertilizers, T_3 to T_8: residual effect of previous treatment. The organic manure *viz.*, FYM and vermicompost were applied in field as per the treatments (T_3 to T_8) one day before sowing of pearl millet crop in every year.

The soil of experimental site was medium black with the following chemical properties: pH 8.06, electrical conductivity (EC) 0.37 dS m^{-1}, organic carbon (5.12 g kg^{-1}), calcium carbonate (47 g kg^{-1}), available N (178 kg ha^{-1}), available (Olsen-P) P (11.4 kg ha^{-1}) and available (NH_4OAc-K) K (254 kg ha^{-1}).

In order to know the physical and chemical compositions of experimental field, soil samples at 0 to 30 cm depth were collected initially from different location from experimental area and composite sample was prepared and analyzed. Soil samples were taken after completion of 6 year trial after harvest of chickpea crop by using core sampler. For physical and chemical analysis air dried samples were used. Bulk density was determined by core method (Black and Hartge 1986) [4]. Hydraulic conductivity was determined by constant water head method (Klute and Dirksen 1986) [10]. Mean weight diameter was determined by wet sieving method (Boodt *et al*. 1961) [5]. Soil pH (1:2.5) was determined by potentiometric method and electrical conductivity (1:2.5) was determined by conductometric method (Jackson 1973) [8]. Organic carbon in soil was determined by wet oxidation method (Nelson and Sommer 1982) [16]. $CaCO_3$ content was determined by acid neutralization method (Allison and Moodie 1965) [1]. Available N in soil was determined by alkaline permanganate method (Subbiah and Asija 1956) [24]. Available P in soil was determined by $NaHCO_3$ (0.5 *M*) method (Olsen *et al.* 1954) [17]. Available K in soil was determined by N *N* NH_4OAc method (Knudsen *et al.* 1982) [11].

Result and Discussion

Soil physical properties

Bulk density

The result indicated that bulk density was non significantly affected by all treatments combinations (Table 1). The bulk density ranged between 1.33 to 1.46 Mg m^{-3}. The numerically lower bulk density (1.33 Mg m^{-3}) was recorded in the treatment (T_3) 100% RDN through FYM and numerically higher bulk density was recorded in the treatment (T_1) absolute control treatment (1.46 Mg m^{-3}). The numerically lower bulk density value in the treatments of organics as compared to control and treatment of inorganic could be attributed to higher organic carbon content in the treatments of organics which had better soil aggregate and larger macro pore space (Bellaki *et al.* 1998) [3].

Hydraulic conductivity

Results indicated that hydraulic conductivity was significantly affected with the application of FYM and vermicompost (Table 1). The hydraulic conductivity ranged between 0.51 to 0.64 mm hr^{-1}in the present study. The treatment T_3 (100% RDN through FYM) recorded significantly higher hydraulic conductivity 0.64 mm hr^{-1}. The treatments (T_4) 100% RDN through vermicompost (0.61 mm hr^{-1}), (T_5) 50% RDN through FYM + 50% RDN through vermicompost (0.61 mm hr^{-1}), (T_6) 5 t FYM ha^{-1} (0.60 mm hr^{-1}) and (T_8) 2.5 t FYM ha^{-1} + 1.5 t vermicompost ha^{-1} (0.60 mm hr^{-1}) found at par with each other. The 100% RDF through inorganic fertilizers (T_2) treatment recorded the hydraulic conductivity of 0.53 mm hr^{-1}. The Significantly lower hydraulic conductivity was reported in the treatment (T_1) absolute control (0.51 mm hr^{-1}). Similar increase in hydraulic conductivity with FYM application was also observed by Singh *et al.* (2016) [23]; Pant *et al.* (2017) [18]; Pant and Ram (2018) [19].

The hydraulic conductivity was significantly increased in the treatments of long term application of FYM and vermicompost over their initial value (0.56 mm hr^{-1}) but magnitude of increase was less in the plot where only chemical fertilizers applied. After addition of long term application of FYM and vermicompost increase soil texture, soil structure, total porosity due to increasing organic matter content resulted in increase in hydraulic conductivity (Singh *et al.* 2016) [23].

Mean weight diameter

The mean weight diameter (MWD) ranged between 0.48 to 0.61 mm in the present study (Table 1). The treatment T_3 (100% RDN through FYM) recorded significantly higher mean weight diameter (MWD) 0.61 mm. The treatments (T_5) 50% RDN through FYM + 50% RDN through vermicompost (0.60 mm) and (T_4) 100% RDN through vermicompost (0.59 mm) found at par with the treatment T_3 (100% RDN through FYM). The 100% RDF through inorganic fertilizers (T_2) treatment recorded the mean weight diameter of 0.51 mm. The Significantly lower mean weight diameter was reported in the treatment of absolute control (0.48 mm). Similar increase in mean weight diameter (MWD) with FYM application was also observed by Pant *et al.* (2017) [18]; Ghosh *et al.* (2018) [6]; Pant and Ram (2018) [19].

Mean weight diameter (MWD) was significantly increased in the treatments of long term application of FYM and vermicompost over their initial value (0.52 mm) but magnitude of increase was less in the plot where only chemical fertilizers applied. Long term application of FYM and Vermicompost increase the organic matter content in soil and by microbial decomposition increase organic carbon content they might be responsible for stabilization of aggregate stability hence higher mean weight diameter (Rasool *et al.* 2007) [22]. Tripathi *et al.* (2014) [26] also recorded higher MWD in FYM applied plot than the plots applied with inorganic fertilizer alone and unfertilized control because FYM promotes soil aggregation and improves physical conditions of soil.

Soil chemical properties

Soil pH

The soil pH was observed in the range of 7.40 to 8.16 (Table 2). The treatment of 100% RDF through inorganic fertilizers (T_2) recorded significantly higher pH (8.16) than all other treatment combinations. Similar increase in soil pH due to application of inorganic fertilizers was also noticed by Nagar *et al.* (2016) [15] and Ramanandan *et al.* (2020) [21]. It was followed in the descending order of (T_1) absolute control (8.01) > (T_7) 3 t vermicompost ha^{-1} (7.67) = (T_8) 2.5 t FYM ha^{-1} + 1.5 t vermicompost ha^{-1} (7.67) > (T_6) 5 t FYM ha^{-1} (7.53) > (T_4) 100% RDN through vermicompost (7.50) > (T_5)

50% RDN through FYM + 50% RDN through vermicompost (7.43) > (T_3) 100% RDN through FYM (7.40). Similar decreases in soil pH with FYM application was also recorded by Singh *et al.* (2016) [23]. The soil pH was significantly decreased in the treatments of long term application of FYM and vermicompost over their initial value (8.06), might be due to the process of decomposition of organic matter including root biomass and release of several organic acids which results in decrease in soil pH.

Electrical conductivity

The electrical conductivity of soil (EC) was observed in the range of 0.33 to 0.40 dSm^{-1} (Table 2). The treatment of 100% RDF through inorganic fertilizers (T_2) recorded significantly higher electrical conductivity (0.40 dSm^{-1}) than all other treatment combinations. Similar increase in electrical conductivity due to application of inorganic fertilizers was also noticed by Nagar *et al.* (2016) [15] and Ramanandan *et al.* (2020) [21].

Available N

The soil available nitrogen at the end of 6th cycle of wheat-chickpea cropping sequence was significantly influenced due to the application of different treatment combinations (Table 3). The treatment of 100% RDN through FYM (T_3) recorded significantly higher soil available nitrogen content (244 kg ha^{-1}) as compared to rest of the treatments. However, this treatment was at par with all the treatments of organic combinations as (T_5) 50% RDN through FYM + 50% RDN through vermicompost (241 kg ha^{-1}), (T_4) 100% RDN through vermicompost (240 kg ha^{-1}), (T_6) 5 t FYM ha^{-1} (238 kg ha^{-1}), (T_8) 2.5 t FYM ha^{-1} + 1.5 t vermicompost ha^{-1} (237 kg ha^{-1}) and (T_7) 3 t vermicompost ha^{-1} (236 kg ha^{-1}). The treatment (T_1) absolute control recorded significantly lower soil available nitrogen (130 kg ha^{-1}) at harvest of chickpea crop at the end of 6th crop cycle. Similar results are also reported by Khamparia *et al.* (2018) [9] and Ramanandan *et al.* (2020) [21] with application of FYM over other inorganic fertilizer. The soil available nitrogen was significantly improved with the addition of organic manure over control was also noticed by Thakare and Wake (2014) [25].

All the organic sources of nutrients improved the available N status of the soil as compared to the inorganic sources of nutrients and control. Higher N under organic treatments might be due to continuous application of FYM and organic sources. These sources may enhance organic matter status in soil, which further improves soil physical as well as microbiological activities and increases the availability of plant nutrients (Kumar and Dhar, 2010; Meena *et al.* 2014) [13, 14].

Available P

The treatment of 100% RDF through inorganic fertilizers (T_2) recorded significantly superior value (18.52 kg ha^{-1}) of soil available phosphorus (Table 3). The treatment (T_3) 100% RDN through FYM (14.41 kg ha^{-1}), (T_5) 50% RDN through FYM + 50% RDN through vermicompost (14.03 kg ha^{-1}) and (T_4) 100% RDN through vermicompost (13.51 kg ha^{-1}) were at par with each other. The treatment (T_1) absolute control recorded significantly lower soil available phosphorus (10.04 kg ha^{-1}) at harvest of chickpea crop at the end of 6th crop cycle. Similar increase with inorganic fertilizer was observed by Pant *et al.* (2017) [18] and Ramanandan *et al.* (2020) [21].

Available K

Results indicated that available K was significantly affected with the application of FYM and vermicompost (Table 3). The soil available potassium at the end of 6th cycle of wheat-chickpea cropping sequence ranged between 232 to 273 kg ha^{-1}. The treatment of 100% RDN through FYM (T_3) recorded significantly higher soil available potassium content (273 kg ha^{-1}) as compared to the absolute control (232 kg ha^{-1}). However, treatment of 100% RDN through FYM (T_3) was at par with the (T_5) 50% RDN through FYM + 50% RDN through vermicompost (269 kg ha^{-1}), (T_4) 100% RDN through vermicompost (266 kg ha^{-1}), (T_6) 5 t FYM ha^{-1} (266 kg ha^{-1}), (T_2) 100% RDF through inorganic fertilizers (262 kg ha^{-1}), (T_8) 2.5 t FYM ha^{-1} + 1.5 t vermicompost ha^{-1} (262 kg ha^{-1}) and (T_7) 3 t vermicompost ha^{-1} (259 kg ha^{-1}). Similar results are also reported by and Nagar *et al.* (2016) [15] and Khamparia *et al.* (2018) [9].

The available K in soil increased with the application of organic manures which is due to solubilising action of organic acids produced during FYM decomposition and its higher capacity to hold K in available form (Vidyavathi *et al.* 2011) [27]. Also application of organic manure secrets organic acid during process of decomposition which led to mineralization of the fixed potassium and increased the availability of potassium (Nagar *et al.* 2016) [15].

Table 1: Long term effect of FYM and vermicompost on soil physical properties

Sr. No.	Treatments	Bulk density ($Mg\ m^{-3}$)	Hydraulic conductivity ($mm\ hr^{-1}$)	Mean weight diameter (mm)
T_1	Control	1.46	0.51^{e}	0.48^{e}
T_2	100% RDF through inorganic fertilizers	1.43	0.53^{d}	0.51^{d}
T_3	100% RDN through FYM	1.33	0.64^{a}	0.61^{a}
T_4	100% RDN through vermicompost	1.35	0.61^{b}	0.59^{ab}
T_5	50% RDN through FYM + 50% RDN through vermicompost	1.35	0.61^{b}	0.60^{a}
T_6	5 t FYM ha^{-1}	1.36	0.60^{bc}	0.57^{bc}
T_7	3 t vermicompost ha^{-1}	1.37	0.58^{c}	0.56^{c}
T_8	2.5 t FYM ha^{-1} + 1.5 t vermicompost ha^{-1}	1.36	0.60^{bc}	0.59^{ab}
	SE (m)+	0.009	0.008	0.008
	CD at 5%	N.S.	0.024	0.024

Table 2: Long term effect of FYM and vermicompost on soil chemical properties

Sr. No.	Treatments	pH (1: 2.5)	EC ($dS\ m^{-1}$)
T_1	Control	8.01^{b}	0.36^{b}
T_2	100% RDF through inorganic fertilizers	8.16^{a}	0.40^{a}
T_3	100% RDN through FYM	7.40^{e}	0.33^{d}

T_4	100% RDN through vermicompost	7.50^{de}	0.34^{c}
T_5	50% RDN through FYM + 50% RDN through vermicompost	7.43^{de}	0.33^{d}
T_6	5 t FYM ha^{-1}	7.53^{d}	0.36^{b}
T_7	3 t vermicompost ha^{-1}	7.67^{c}	0.36^{b}
T_8	2.5 t FYM ha^{-1} + 1.5 t vermicompost ha^{-1}	7.67^{c}	0.36^{b}
	SE (m)+	0.042	0.008
	CD at 5%	0.126	0.025

Table 3: Long term effect of FYM and vermicompost on soil available nutrients

Sr. No.	Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	Control	130^{c}	10.04^{e}	232^{b}
T_2	100% RDF through inorganic fertilizers	213^{b}	18.52^{a}	264^{a}
T_3	100% RDN through FYM	244^{a}	14.41^{b}	273^{a}
T_4	100% RDN through vermicompost	240^{a}	13.51^{bc}	266^{a}
T_5	50% RDN through FYM + 50% RDN through vermicompost	241^{a}	14.03^{b}	269^{a}
T_6	5 t FYM ha^{-1}	238^{ab}	12.47^{cd}	266^{a}
T_7	3 t vermicompost ha^{-1}	236^{ab}	11.28^{d}	259^{a}
T_8	2.5 t FYM ha^{-1} + 1.5 t vermicompost ha^{-1}	237^{ab}	12.47^{cd}	262^{a}
	SE (m)+	8.28	0.41	7.73
	CD at 5%	25.11	1.24	23.4

Conclusion

It is concluded that for intensively cultivated pearl millet-chickpea cropping sequence, the hydraulic conductivity and mean weight diameter (MWD) were significantly increased in the treatment of 100% RDN through FYM. The soil pH and electrical conductivity were significantly decreased and soil available N and K were significantly increased in the treatment of 100% RDN through FYM as compared to the treatment receiving 100% RDF through inorganic fertilizers at the end of 6th cycle of pearl millet-chickpea cropping sequence.

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