EFFECT OF LONG-TERM FERTILIZERS AND MANURES ON SOIL PHYSICAL AND CHEMICAL PROPERTIES OF SOIL

Abstract

To study the effect of different nutrient management practices on different soil physical and chemical properties in the permanent manurial experiment field of Tamil Nadu Agricultural University which was established during 1982 at Agriculture Research Station, Kovilpatti. Soil physical and chemical properties are mainly affected by the continuous application of fertilizers or manures from years together. To study the above mentioned properties of soil the soil samples were collected from the permanent manurial experiment of kovilpatti where the Randomized Block Design (RBD) was followed with nine different treatments *viz.,* T_1- Control; T_2- 100 % RDF (40:20:40 NPK kg ha^{-1}); T_3- 50% RDF (20:10:20 NPK kg ha^{-1}); T_4- 50% N (Crop residues); T_5- 50 % N (FYM); T_6- 50 % Inorganic N+ 50% organic N (crop residues) + P (50%) + K (50%) ; T_7- 50 % Inorganic N+ 50% organic N (FYM) + P (50%) + K (50%); T_8- 100 % RDF + 25 kg ZnSO4 ha^{-1}; T_9- FYM - 12.5 t ha^{-1}. The effect of these treatments along with the depth (0-15 cm; 15-30 cm and 30-45 cm) was compared. The treatment receiving organics *viz.,* T_9- FYM - 12.5 t ha^{-1} was observed to be the best in all the physical and chemical properties which was then followed by INM *viz.,* T_7- 50 % Inorganic N+ 50% organic N (FYM) + P (50%) + K (50%) and T_6- 50 % Inorganic N+ 50% organic N (crop residues) + P (50%) + K (50%).

Key words: *Permanent manurial experiment, physical properties, chemical properties,*

Introduction

Cotton is one of the major commercial crops that is been cultivated all over the world. Textile industry's primary source of raw materials is cotton. In India the total cultivated area is of 129.57 lakh ha with the production value of 371 lakh bales and productivity of 486.76 kg ha^{-1} (*As estimated by Committee on Cotton Production and Consumption (COCPC) in its meeting held on 25.01.2021). In Tamil Nadu it is cultivated in an area of 1.31 lakh ha with production of 6.00 lakh bales and productivity 778.63 kg ha^{-1}. (*Source: Cotton Advisory Board (CAB) P-Provisional as estimated by CAB on 18.6.2019).

Cotton's growth and yield are influenced by the interaction of the environment with the genetic makeup of the variety or hybrid, as well as a variety of inputs such as water, fertilizer, pesticides, and other factors. Fertilizers are one of the most influential factors in plant growth and development. Micronutrients and growth promoters are applied as foliar feeding, while primary nutrients such as N, P, and K are usually delivered to the crop through the soil.

The use of chemical fertilizers to enhance crop productivity has often negatively affected the complex system of the biogeochemical cycles ([1]Perrott et al., 1992; [2]Steinshamn et al., 2004) due to their continuous long-term use. The overall strategy for increasing crop yields on sustainable basis could be the conjunctive use of organic and inorganic sources of nutrients, along with other complementary measures. Organics are known to have favorable effects on soil structure, texture, and tilth and facilitate quick and greater availability of plant nutrients. Organics thus provide a better environment for root growth and proliferation, thereby creating more absorptive surface for uptake of nutrients ([3]Avnimelech, 1986). Some researchers have reported that integrated use of organic and inorganic sources of nutrients along with biofertilizers resulted in greater productivity, fertility and net returns in soybean ([4]Singh and Rai, 2004; [5]Bhattacharyya et al., 2008).

[6]Wu et al. (2005) reported that microbial inoculants increased the growth and nutritional assimilation total nitrogen (N), phosphorus (P), and potassium (K)] of maize and improved soil properties. [7]Singh (2010) found an increase in organic carbon and microbial biomass carbon in the treatments receiving application of organic manures (particularly FYM), green manure, and bio-fertilizers in conjunction with inorganic fertilizer. [8]More and Hangarge (2003) noticed that grain and fodder yields of sorghum were greater in treatments receiving nutrients only through organics such as FYM, crop residues, and inoculation with azotobacter compared to nutrient supply only through chemical fertilizer. Studying the long-term effect of INM practices in terms of soil quality is of presumable importance in rainfed agriculture.

2. Materials and Methods

2.1 site description and soil analysis

In the year 1982, the Agricultural Research Station, Kovilpatti, located in the southern zone of Tamil Nadu (9.20' N altitude, 77.87' E longitude, 90m above MSL), began a permanent manurial experiment (PME) in the Cotton (KC 3) cropping system viz., cotton-fallow-fallow. With an annual mean rainfall of 743 mm and evapotranspiration of 812mm, the area is classified as a hot semi-arid region. The experimental site's soil falls under Kalathur soil series with fine montmorillonitic, isohyperthermic, Udorthentic Chromusterts with heavy clay texture (table. 1). Soil samples were collected from each treatment followed for the past 30 years (table. 2) at three different depths of 0-15, 15-30 and 30-45cm by following quadrant method for the assessment of soil quality index in the Permanent manurial experiment. The samples collected were shade dried, ground with a wooden hammer and passed through a 2 mm sieve. Finally 1 kg of representative sample was preserved in a labeled cloth bag for laboratory analysis.

Table 1. Initial soil properties of experimental plot of Permanent manurial experiment in 1992

Properties	Value
EC	0.49 ds m^{-1}
pH	8.2
Organic carbon	1.5 g kg^{-1}
N	80 kg ha^{-1}
P	10 kg ha^{-1}
K	586 kg ha^{-1}
Available Zn	1.2 Kg ha^{-}
Bulk density	1.23 to 1.30 Mg m^{-3}
Particle density	1.60 to 1.69 Mg m^{-3}

Infiltration rate	0.7 to 0.9 cm hr^{-1}
Percentage of pore space	48.3 to 48.9
Permanent wilting point	14%
Field capacity	35 %
Coarse sand	10.90 to 11.50 %
Fine sand	9.45 to 14.10 %
Silt	15.6 to 19.95 %
Clay	48.05 to 53.00 %
Texture	Clay

Table.2 Permanent Manurial Experiment – Treatment details

T_1	Control
T_2	100 % RDF (40:20:40 NPK kg ha^{-1})
T_3	50% RDF (20:10:20 NPK kg ha^{-1})
T_4	50% N (Crop residues)
T_5	50 % N (FYM)
T_6	50 % Inorganic N+ 50% organic N (crop residues) + P (50%) + K (50%)
T_7	50 % Inorganic N+ 50% organic N (FYM) + P (50%) + K (50%)
T_8	100 % RDF + 25 kg ZnSO4 ha^{-1}
T_9	FYM - 12.5 t ha^{-1}

*SSP- Single super Phosphate; FYM- Farm Yard Manure

2.2Soil Analysis

2.2.1Soil physical properties

The samples were analyzed for its physical properties *viz.,* texture, Bulk density(BD), Particle density(PD), porosity, infiltration rate (IR), Wet aggregate stability (WAS), Dry aggregate stability (DAS) and hydraulic conductivity as mentioned in table.3.

Table.3 Details of analytical methods for soil physical properties analysis

S.No	Parameter	Methods adopted	Reference
1.	Bulk density, and pore space	Core sampler method	[9]Gupta & Dakshinamoorthi (1981)
2.	Hydraulic Conductivity	Constant hydraulic head method	[10]Richards (1954)

2.2.2 Soil Chemical Properties

The chemical properties *viz.,* Soil reaction (pH), Electrical Conductivity (EC), Cation exchange capacity (CEC), Organic Carbon (OC), Nitrogen (N), Phosphorus (p), potassium (K) of the soil sample were analyzed by following the standard procedure as mentioned in table.4.

Table.4 Details of analytical methods for soil Chemical properties analysis

S.No	Parameter	Methods adopted	Reference
1.	Soil reaction (pH)	1:2.5 soil water extract	[11]Jackson (1973)

1.	Electrical conductivity	1:2.5 soil water extract	[11]Jackson (1973)
2.	Organic carbon	Chromic acid wet digestion	[12]Walkley and Black (1934)
3.	Available Nitrogen ($KMnO_4$ – N)	Alkaline permanganate method	[13]Subbiah and Asijia (1956)
4.	Available phosphorus (Olsen – P)	Extraction with 0.5M $NaHCO_3$	[14]Olsen *et al.* (1954)
5.	Available potassium (NH_4 OA_C – K)	Extraction with neutral normal ammonium acetate and Flame photometry	[15]Stanford and English (1949)

2.3 Statistical Analysis

Randomized Block Design (RBD) was used for the experiment and the difference among the treatments were compared by Least Significant Difference (LSD) test at a significance level of $p< 0.05$ using OPISTAT according to [16]Gomez and Gomez (1984).

Results and Discussion

The soil samples collected from PME of Kovilpatti were analyzed for different physical (Table.5, 6) and chemical (Table.7, 8) properties and the results were discussed in detail below.

Physical properties

The highest and the lowest values across the depth were discussed below in detail. Bulk densities (BD) of the samples analyzed varied from 1.55 to 1.31 Mg m-3 at three different depths and are significantly different. Among all, the treatment receiving FYM @ 12.5 t ha^{-1} have the lowest bulk density (1.31 Mg m^{-3}) at 0-15 cm when compared to control (1.55 Mg m^{-3}) at 30-45 cm depth. The values were observed to increase with increase in depth. Maximum reduction in bulk density was recorded when FYM was applied along with chemical fertilizers which may be due to positive effect of organic manure on soil aggregation. The higher bulk density in control and in only N fertilizer treated plots may be due to low organic matter content in soil and formation of compact layer ([17]Islam et al. 2011). However, porosity varied along the depth with a decreasing trend and was significantly different. The values ranged from 49.02% (FYM @ 12.5 t ha^{-1}) at 0-15 cm depth to 23.26% (control) at 30-45 cm depth which may be due to positive effect of organic manure on soil aggregation ([18]Meng *et al.* 2005). The similar trend was recorded in field capacity (33.21% in FYM @ 12.5 t ha^{-1} at 0-15 cm to 20.71% in control at 30-45 cm depth). Permanent Wilting Point was seen highest in FYM @ 12.5 t ha^{-1} but not in a decreased trend and the values ranged from 18.80% (FYM @ 12.5 t ha^{-1} at 30-45 cm) to 13.89% (control at 0-15 cm depth). Available Water was observed to follow the same trend of porosity and field capacity (15.54% in FYM @ 12.5 t ha^{-1} at 0-15 cm to 8.30 % in control at 30-45 cm depth) which decreased with depth and are significantly different. Hydraulic conductivity ranged from 3.11cm hr^{-1} (FYM @ 12.5 t ha^{-1}) at 0-15 cm to 1.80 cm hr^{-1} (control) at 30-45 cm depth, the decrease in SHC values at lower depth may also be due to an increase in the clay content of soil ([19] Edoga 2010). Clay offers a higher resistance to movement of water because of its high proportion of micro pores that store water in film or gyroscopically.

To conclude, the soil physical properties were well maintained under organics alone which was almost similar with organics applied along with inorganics. It was also observed that the same trend was seen with all the three depths with a decreasing trend with increasing depth.

Table.5 Effect of continuous application of fertilizers or manures on physical properties of soil under different depths

	Bulk Density ($Mg\ m^{-3}$)			Porosity (%)			Field Capacity (%)		
	0-15	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**
Control	1.50	1.53	1.55	24.81	23.66	23.26	27.16	23.98	20.71
100 % RDF	1.43	1.47	1.49	32.14	30.88	30.60	30.42	26.25	21.18
50% RDF	1.48	1.52	1.54	27.41	26.52	26.15	29.15	24.66	20.80
50% N (Crop residues)	1.40	1.44	1.46	37.06	36.69	36.50	30.10	24.77	21.09
50 % N (FYM)	1.38	1.41	1.43	37.93	37.32	37.14	30.87	25.99	21.14
50 % Inorganic N+ 50% organic N (crop residues) + P (50%) + K (50%)	1.35	1.40	1.42	42.57	41.26	41.13	31.63	27.43	25.34
50 % Inorganic N+ 50% organic N (FYM) + P (50%) + K (50%)	1.33	1.38	1.40	46.00	44.83	44.76	31.92	27.36	22.01
100 % RDF + 25 kg $ZnSO_4\ ha^{-1}$	1.43	1.45	1.47	33.57	33.33	33.09	31.00	26.61	21.64
FYM - 12.5 t ha^{-1}	1.31	1.35	1.37	49.02	47.97	47.95	33.21	29.25	27.10
Mean	**1.40**	**1.44**	**1.46**	**36.72**	**35.83**	**35.62**	**30.61**	**26.26**	**22.33**
CD	**0.051**	**0.052**	**0.053**	**2.900**	**2.886**	**2.413**	**1.454**	**1.248**	**2.570**
SE(d)	**0.024**	**0.024**	**0.025**	**1.368**	**1.361**	**1.138**	**0.686**	**0.588**	**1.213**

Table.6 Effect of continuous application of fertilizers or manures on physical properties of soil under different depths

	Permanent Wilting Point (%)			**Available Water Content (%)**			**Hydraulic Conductivity ($cm\ hr^{-1}$)**		
	0-15	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**
Control	13.89	13.89	15.20	13.27	10.09	5.51	2.51	2.07	1.80
100 % RDF	16.24	15.96	14.68	14.18	10.29	6.50	2.68	2.29	1.95
50% RDF	15.06	15.00	15.13	14.09	9.66	5.67	2.57	2.24	1.91
50% N (Crop residues)	15.84	14.14	14.36	14.26	10.63	6.73	2.62	2.40	2.02
50 % N (FYM)	16.65	15.20	14.20	14.22	10.79	6.94	2.76	2.46	2.09
50 % Inorganic N+ 50% organic N (crop residues) + P (50%) + K (50%)	17.22	16.50	17.41	14.41	10.93	7.93	2.81	2.52	2.21
50 % Inorganic N+ 50% organic N (FYM) + P (50%) + K (50%)	17.52	16.19	13.76	14.40	11.17	8.25	2.98	2.53	2.27

100 % RDF + 25 kg $ZnSO_4$ ha^{-1}	16.80	16.22	14.96	14.20	10.39	6.68	2.78	2.31	2.01
FYM - 12.5 t ha^{-1}	17.67	17.97	18.80	15.54	11.28	8.30	3.11	2.65	2.32
Mean	**16.32**	**15.67**	**15.39**	**14.29**	**10.58**	**6.95**	**2.76**	**2.39**	**2.06**
CD	**0.777**	**0.575**	**0.565**	**1.144**	**1.342**	**1.134**	**0.446**	**0.385**	**0.334**
SE(d)	**0.366**	**0.271**	**0.266**	**0.539**	**0.633**	**0.535**	**0.210**	**0.182**	**0.158**

Chemical Properties

Soil reaction (pH) varied from slightly alkaline to slightly neutral with increase in depth where the highest pH was observed in Control (8.16) at 0-15 cm depth and the lowest in the treatment FYM @ 12.5 t ha^{-1} (7.60) at 30-45 cm depth may probably due to organic acids released during decomposition of organic matter resulting lower pH [20] Liang *et al* (2012); [21]Arulmozhiselvan *et al.* (2015) and [22]Malarkodi *et al.* (2019). Correspondingly Electrical Conductivity (EC) ranged from 0.19 dS m^{-1}in FYM @ 12.5 t ha^{-1} at 0-15 cm to 0.10 dS m^{-1} in control at 30-45 cm depth. Organic Carbon was significantly different in between the treatments and ranged from 3.60 g kg^{-1} (FYM @ 12.5 t ha^{-1}) at 0-15 cm to 0.78 g kg^{-1} (Control) at 30-45 cm depth which was in a decreasing trend. A decreasing trend with increase in depth was followed for all the available nutrients with, Nitrogen (N) ranging from 150 kg ha^{-1} to 69 Kg ha^{-1}, Phosphorus (P) from 20.59 kg ha^{-1} to 4.53 kg ha^{-1}, Potassium from 416 kg ha^{-1} to 137 kg ha^{-1}. This might be due to integrated nutrient application, higher microbial population and high organic carbon, organic form of nutrients are converted to inorganic ([23]Dhaliwal *et al.,* 2019).

To summarize, the treatment which received organics alone was notice to perform well in maintain soil chemical properties which was nearly similar with the treatment of organics applied along with inorganics. The values were observed to decrease with increase with depth with same trend.

Table.7 Effect of continuous application of fertilizers or manures on chemical properties of soil under different depths

	pH			**Electrical Conductivity ($dS\ m^{-1}$)**			**Organic Carbon ($g\ kg^{-1}$)**		
	0-15	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**
Control	8.16	8.09	7.89	0.12	0.10	0.10	1.40	1.10	0.78
100 % RDF	8.03	7.84	7.71	0.12	0.1	0.1	2.30	1.90	1.80
50% RDF	8.05	7.95	7.86	0.13	0.11	0.11	1.80	1.50	1.20
50% N (Crop residues)	7.94	7.91	7.78	0.13	0.11	0.11	2.00	1.80	1.50
50 % N (FYM)	7.91	7.87	7.73	0.13	0.12	0.12	2.20	1.90	1.50
50 % Inorganic N+ 50% organic N (crop residues) + P (50%) + K (50%)	7.85	7.73	7.62	0.15	0.13	0.13	3.10	2.40	2.30
50 % Inorganic N+ 50% organic N	7.84	7.71	7.65	0.16	0.15	0.14	3.40	2.50	2.50

(FYM) + P (50%) + K (50%)									
100 % RDF + 25 kg $ZnSO_4$ ha^{-1}	7.89	7.81	7.68	0.14	0.13	0.13	2.40	2.10	2.00
FYM - 12.5 t ha^{-1}	7.81	7.63	7.60	0.19	0.18	0.16	3.60	3.20	2.80
Mean	**7.94**	**7.84**	**7.72**	**0.14**	**0.13**	**0.12**	**2.47**	**2.04**	**1.82**
CD	**0.777**	**0.575**	**0.565**	**1.144**	**1.342**	**1.134**	**0.416**	**0.344**	**0.312**
SE(d)	**0.366**	**0.271**	**0.266**	**0.539**	**0.633**	**0.535**	**0.196**	**0.162**	**0.147**

Table.8 Effect of continuous application of fertilizers or manures on Chemical properties of soil under different depths

	Nitrogen (kg ha^{-1})			**Phosphorus (kg ha^{-1})**			**Potassium (kg ha^{-1})**		
	0-15	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**	**0-15**	**15-30**	**30-45**
Control	100	90	69	10.86	8.60	4.53	308	215	137
100 % RDF	137	112	94	13.58	9.05	7.24	372	295	218
50% RDF	125	103	85	11.09	8.60	7.01	313	221	159
50% N (Crop residues)	131	106	88	11.31	8.70	7.24	329	252	174
50 % N (FYM)	134	109	91	11.31	8.82	7.24	356	256	201
50 % Inorganic N+ 50% organic N (crop residues) + P (50%) + K (50%)	144	120	100	14.03	9.38	7.69	395	321	240
50 % Inorganic N+ 50% organic N (FYM) + P (50%) + K (50%)	147	128	107	14.48	9.41	8.01	404	326	246
100 % RDF + 25 kg $ZnSO_4$ ha^{-1}	141	116	97	13.58	9.13	7.47	381	304	227
FYM - 12.5 t ha^{-1}	150	137	110	20.59	9.73	8.37	416	339	255
Mean	**134**	**113**	**93.4**	**13.4**	**9.05**	**7.20**	**364**	**281**	**206**
CD	**10.80**	**9.135**	**7.530**	**2.215**	**1.460**	**1.176**	**13.38**	**10.42**	**7.69**
SE(d)	**5.095**	**4.309**	**3.552**	**1.045**	**0.689**	**0.555**	**6.31**	**4.92**	**3.63**

Conclusion

The present investigation revealed that the application of organics *viz*., T_9- FYM @ 12.5 t ha^{-1} resulted in improving the soil physical, chemical properties. Improving these properties may directly improves the soil health which increases the production and productivity of crops. The organics was then followed by application of organics along with inorganics *viz.,* T_7- 50 % Inorganic N+ 50% organic N (FYM) + P (50%) + K (50%) and T_6- 50 % Inorganic N+ 50% organic N (crop residues) + P (50%) + K (50%). It was also observed that the all the values were decreased with increase in depth. So it is concluded that application of organics is best in improving soil health, if not available it can be substituted with organics+ inorganics.

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