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Effect of continuous use of organic and inorganic fertilizers on soil physico-chemical properties in a rice-rice cropping system on *Inceptisols*

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Abstract

One of the key factors influencing agricultural productivity is soil fertility, which is often increased by applying minerals, primarily in the form of inorganic and organic fertilizers. The physico-chemical properties of the soil, which creates suitable environment for the availability and uptake of these nutrients, is generally ignored. In order to study the effect of continuous application of manures and fertilizers on soil physico-chemical properties under rice-rice cropping system, a AICRP on LTFE-field experiment was conducted since 2000-01 at Regional Agriculture Research Station of the Professor Jayashankar Telangana State Agricultural University at Jagtial with 8 treatments involving combinations of organic and inorganic sources of nutrients and three replications laid under Randomized Block Design, were collected, processed and analyzed for different soil physicochemical properties *viz.* pH, EC, calcium carbonate and OC properties during *rabi,* 2023-24. To study the effect of varied fertilization practices in the long run which help in assessing the soil health status. Results showed that over 23 years of continuous use of organic and inorganic fertilizers on soils physico-chemical properties did not vary significantly (pH and EC) among different treatments except calcium carbonate and organic carbon content. The pH, electrical conductivity (EC), calcium carbonate and organic carbon ranged from 7.94 to 8.08, 0.57 to 0.64 dSm^{-1}, 5.09 to 6.52 percent and 4.2 to 10.5 g kg^{-1}, respectively at surface layer and 8.20 to 8.28, 0.54 to 0.58 dSm^{-1}, 5.24 to 6.47 percent and 3.1 to 6.3 g kg^{-1} at sub surface layer. As the depth increases the pH and calcium carbonate content increases. While, the EC and organic carbon decreases with increasing in depth.

Keywords: Long term, manures and fertilizers, rice-rice cropping system, soil pH, EC, calcium carbonate and organic carbon

1. Introduction

Modern agricultural input technologies, including fertilizers, nutrient responsive crop varieties and modified tillage practices, have significantly increased production and productivity of the crop. However, this has caused the soil, our most valuable natural resource, to be overexploited. Long-term research showed that applying only inorganic fertilizers to plants reduced soil organic matter, which in turn reduced soil production (Jat *et al.*, 2017) [7]. Organic sources of plant nutrients offer the twin benefits of increasing organic matter content and improving the physical and chemical qualities of soil, in addition to providing nutrients to crops. Integrated nutrient management is one of the most crucial techniques for increasing resource efficiency and yielding crops at lower cost. In order to maintain soil fertility and crop productivity, integrated nutrient management (INM) refers to the coordinated use of all available nutrient sources, including organic, inorganic and bio fertilizers, based on economic considerations. In addition to increasing crop productivity and profitability, the integrated application of both organic and inorganic sources of nutrients contributes to the preservation of soil fertility. Compared to using each component separately, integrated nutrition management has shown to have a longer-term positive impact (Palaniappan and Annadurai, 2007) [12]. Increased porosity, infiltration rate, soil organic carbon, reduced bulk density, soluble salt concentration, pH and green manuring with *Sesbania aculeata* all result in improved soil structure. According to Antil and Mandeep (2007) [2], the pH of the soil was lowered by applying organic manures continuously for ten years, either by themselves or in conjunction with fertilizers. Soil fertility is based on soil organic carbon (SOC). Applying organic manures helps maintain production and increase soil fertility. The physical, chemical and biological qualities of soil are enhanced by the application of organic manure in addition to providing major and micronutrients (Nanda *et al.*, 2016) [11]. Among organic manures, farmyard manure (FYM) is the readily available, reasonably priced and scientifically confirmed nutrition source that Indian farmers used for years (Nanda *et al.*, 2016) [11]. If applied consistently, it can enhance soil health and rice yield over time (Nanda *et al.*, 2016) [11]; it can also prevent micronutrient mining (Singh *et al.*, 2019) [13]. However, an uneven application of fertilizer might disrupt the availability of nutrients, which lowers soil production (Singh *et al.*, 2019) [13]. Applying chemical fertilizers and organic manures together can effectively address issues with declining crop output and soil health (Singh *et al.*, 2019; Upadhyay and Viswakarma 2014) [13, 15]. Keeping these facts in view, this investigation was made to address the issues of varying physico-chemical properties of soil in rice– rice cropping system.

2. Materials and Methods

2.1 Experimental site

The long-term fertilizer experiment is being conducted at Regional Agricultural Research station, Jagtial with rice-rice cropping sequence initiated during the year 2000-01. Jagtial is in the Deccan Plateau and Eastern Ghats agro ecological zone of the country (Agro ecological Zone no. 7 of India) in Telangana state.

During the year *kharif* 2000-01 initial soil samples which were collected at random and a composite soil sample of the experimental plot were analysed for different physical, physico chemical and chemical properties by the standard methods. The soil of the experimental site is clayey in texture and slightly alkaline in reaction and belongs to the order - *Inceptisol*, which comes under sub group *Ustochrept*.

2.2 Experimental design and treatments

The experiment was conducted with 8 treatments involving combinations of organic and inorganic sources of nutrients and three replications laid under Randomized Block Design

Table 1: Treatment details and source of nutrients

Trt. No.	Treatment	N - P_2O_5 - K_2O (kg ha^{-1})	Nutrient sources			Remarks
			N	P	K	
1.	50% NPK	60-30-20	Urea	SSP	MOP	
2.	100% NPK	120-60-40	Urea	SSP*	MOP	100% NPK level fixed based on initial soil test values for a target of 60 q grain ha $^{-1}$
3.	150% NPK	180-90-60	Urea	SSP	MOP	
4.	100% NP	120-60-0	Urea	SSP	-	
5.	100% N	120-0-0	Urea	-	-	
6.	100% NPK+FYM	120-60-40	Urea	SSP	MOP	*5 t FYM ha^{-1} in *kharif*
7.	FYM	0-0-0	-	-	-	*15 t FYM ha^{-1} each in *kharif* and *rabi*
8.	Control	0-0-0	-	-	-	Without application of organic and inorganic fertilizers

* S added through SSP= 45 kg S ha^{-1} in 100% NPK treatment.

* 5 t FYM ha^{-1} each in *kharif* (on dry weight basis) from *kharif* 2011 onwards- T_{8*}

* 15 t FYM ha^{-1} each in *kharif* and *Rabi* (on dry weight basis) from *kharif* 2011 onwards- T_{10}

2.3 Soil sample collection

Soil sample were collected after harvesting of rice crop from each plot in $1m^3$ soil profile based upon the morphogenetic feature of soil profile (Table 2).

Table 2: Layers of soil profile ($1m^3$)

Treatments	Layer 1	Layer 2	Layer 3
50% NPK	0-27 cm	27-76 cm	76-100 cm
100%NPK	0-28 cm	28-81 cm	81-100 cm
150% NPK	0-26 cm	26-72 cm	72-100 cm
100% NP	0-27 cm	27-78 cm	78-100 cm
100% N	0-20 cm	20-53 cm	53-100 cm
100%NPK+FYM	0-34 cm	34-72 cm	72-100 cm
FYM	0-30 cm	30-64 cm	64-100 cm
Control	0-26 cm	26-72 cm	72-100 cm

2.4 Laboratory analysis of soil samples

2.4.1 Soil reaction (pH)

Soil pH was measured using a digital pH meter in a 1:2.5 soil and water solution after 30 minutes of intermittent stirring with a glass rod (Jackson, 1973) [6].

2.4.2 Electrical Conductivity (dS m^{-1})

The electrical conductivity was measured with a digital EC meter after continuously stirring the soil in 1:2.5 ratio in soil water suspension and allowing it to settle (Jackson, 1973) [6].

2.4.3 Calcium carbonate (%)

Calcium carbonate was determined by method as suggested by Drouineau (1942) [4].

$$\text{Per cent Calcium Carbonate} = [(50 \times \text{N HCl}) - (\text{R} \times \text{N NaOH})] \times 0.05 \times \frac{100}{\text{weight of soil (g)}}$$

2.4.4 Organic carbon (g kg^{-1})

The oxidizable organic carbon was quantified through the application of the Walkley and Black wet oxidation method (Walkley and Black, 1934) [16].

3. Results and Discussion

3.1 Soil reaction (pH)

Soil pH is an important electrochemical property of soil that aids in understanding processes and the speciation of chemical elements in soil. The soil pH was slightly alkaline in response, with an average of 8.02 in surface soil (Table 3). The analysis of the data on soil response (pH) of the experimental soil revealed that intense cropping with continuous use of FYM alone or in conjunction with inorganic fertilizers over 23 years resulted in a small change in soil pH. However, the change was not found significantly. Long term use of fertilizers and manures in rice-rice cropping system had no adverse effect on soil pH and might be due to high buffering capacity of soils Suman *et al.* (2017) [14].

The pH of soil ranges from 7.94 to 8.08, 8.20 to 8.28 and 8.36 to 8.46 in layer1, layer 2 and layer 3, respectively. The data also show that surface soil had a lower pH than subsurface soil in all the treatments. Similar findings were reported by Khandagle *et al.* (2019) [8] and Nagawanshi *et al.* (2023) [10].

Table 3: Continuous application of manure and fertilizers on pH at different depths of soil profile in rice –rice cropping system

Treatments	pH		
	Layer 1	**Layer 2**	**Layer 3**
50% NPK	8.05	8.27	8.43
100%NPK	8.08	8.24	8.42
150% NPK	8.07	8.23	8.41
100% NP	7.97	8.22	8.39
100% N	8.07	8.28	8.46
100% NPK+FYM	7.97	8.21	8.37
FYM	7.94	8.20	8.36
Control	8.05	8.25	8.41
Mean	8.02	8.24	8.41
S.Em±	0.10	0.09	0.02
CD (p=0.05)	NS	NS	NS

3.2 Electrical Conductivity (dSm^{-1})

Data clearly revealed that the continuous application of manures and fertilizers had no significant effect on the electrical conductivity (EC) of in different depths of soil under rice-rice cropping systems (Table 4).

The EC of the Layer 1 ranged from 0.57 to 0.64 dSm^{-1}, while the layer 2 from 0.54 to 0.58 dSm^{-1} and layer 3 from 0.51 to 0.56 dSm^{-1}. Furthermore, it was clearly noticed that the electrical conductivity of surface soil was higher than that of sub surface soils in all treatments. Similar results reported by Nagawanshi *et al.* (2023) [10].

Lowest EC was recorded in control treatment at different depths where no fertilizers was applied similar results were observed by Bhatt *et al.* (2019) [3]. The rise in soil EC with continuous fertilizer application was caused by the addition of salts through fertilizers and the solubilisation of minerals due to pH lowering (Hemalatha *et al*., 2013) [5].

Table 4: Continuous application of manure and fertilizers on EC (dSm^{-1}) at different depths of soil profile in rice –rice cropping system

Treatments	EC (dSm^{-1})		
	Layer 1	**Layer 2**	**Layer 3**
50% NPK	0.61	0.56	0.52
100%NPK	0.62	0.56	0.51
150% NPK	0.64	0.58	0.56
100% NP	0.61	0.55	0.54
100% N	0.56	0.53	0.51
100% NPK+FYM	0.62	0.55	0.53
FYM	0.58	0.55	0.52
Control	0.57	0.53	0.51
Mean	*0.60*	*0.55*	*0.52*
S.Em±	0.03	0.02	0.02
CD (p=0.05)	NS	NS	NS

3.3 Calcium carbonate

The data pertaining to the long-term effects of manure and fertilizers on calcium carbonate levels in various depths of soil profile are given in Table 5. The data clearly demonstrated that different nutrient application treatments had a significant effect on calcium carbonate levels in soil at various depths. The data also revealed that the significantly higher calcium carbonate content of surface soil under application of150% NPK treatment (6.52%) as compared with all other nutrient treatments, while it was lowest in control (5.09%). The findings were well supported by Nagawanshi *et al.* (2023) [10].

Calcium carbonate of soil ranges from 5.09 to 6.52%, 5.24 to 6.47% and 5.46 to 6.65 in layer 1, layer 2 and layer 3, respectively. The findings are well supported by Nagawanshi *et al.* (2023) [10].

Irrespective of treatments increase the $CaCO_3$ content with increase depth of soil it could be caused by the dissolving impact of organic acids created during soil organic matter decomposition. Similar results were reported by Nagawanshi *et al.* (2023) [10].

Table 5: Continuous application of manure and fertilizers on calcium carbonate (%) at different depths of soil in rice-rice cropping systems

Treatments	Calcium carbonate (%)		
	Layer 1	**Layer 2**	**Layer 3**
50% NPK	5.64	6.10	6.26
100%NPK	5.82	6.24	6.45
150% NPK	6.52	6.47	6.65
100% NP	5.73	6.04	6.17
100% N	5.31	5.91	6.07
100% NPK+FYM	6.17	6.35	6.58
FYM	6.27	6.23	6.40
Control	5.09	5.24	5.46
Mean	5.8	6.1	6.3
S.Em±	0.16	0.17	0.17
CD (p=0.05)	0.49	0.50	0.51

3.4 Soil organic carbon (g kg^{-1})

The impact of continuous application of organic and inorganic nutrients in intense cropping on soil organic carbon during the last 23 years is shown in Table 4.6. Results for organic carbon content with continuous fertilizer application alone or in combination with organic manures show a substantial change from the control treatment. The soil organic carbon ranges from 4.2 to 9.8 g kg^{-1}, 3.1 to 6.3 g kg^{-1} and 2.1 to 4.6 g kg^{-1} in layer 1, layer 2 and layer 3, respectively.

Among all different nutrient treatments, significantly higher soil organic carbon content was observed under FYM treatment at different depths of soil profile *i.e.*, 9.8 g kg^{-1}, 6.3 g kg^{-1} and 4.6 g kg^{-1} followed 100% NPK + FYM (9.1 g kg^{-1},5.1 g kg^{-1} and 4.0 g kg^{-1}) treatment as compared to all other treatments in rice-rice cropping system. Soil organic carbon values increased proportionally with fertilizer addition at 50% NPK (suboptimal), 100% NPK (optimal) and 150% NPK (super optimal), with organic carbon content of 6.5, 7.8 and 7.9 g kg^{-1}, respectively, in layer 1; the same trend was observed in the layer 2 and layer 3. These results appeared to be attributable to greater crop root development, which resulted in higher residues as a result of intensive farming with constant fertilizer treatments (Kumar *et al.*, 2019; Anantha *et al.*, 2020) [9, 1].

The lowest soil organic carbon recorded with the control treatment in layer 1 is 4.2 g kg^{-1}, in layer 2 is 3.1g kg^{-1} and in layer 3 is 2.1 kg^{-1}which could be attributed to poor crop growth due to less availability of nutrients, resulting in lower crop biomass production and crop residue incorporation in soil (Kumar *et al.*, 2019 and Bhatt *et al.*, 2019) [9, 3].

Among all the treatments as the depth increases the soil organic carbon decreases. The magnitude of organic carbon was higher on the surface and reduced with depth, which could be related to cultivation and promoted the decomposition of plant wastes at the surface (Nagawanshi *et al.*, 2023) [10].

Table 6: Continuous application of manure and fertilizers on soil organic carbon (g kg^{-1}) at different depths of soil in rice-rice cropping systems

Treatments	Soil organic carbon (g kg^{-1})		
	Layer 1	Layer 2	Layer 3
50% NPK	6.5	3.7	2.9
100%NPK	7.8	4.1	3.5
150% NPK	7.9	4.8	3.6
100% NP	7.4	4.5	3.3
100% N	5.8	3.4	2.7
100% NPK+FYM	9.1	5.1	4.0
FYM	9.8	6.3	4.8
Control	4.2	3.1	2.1
Mean	7.3	4.4	3.3
S.Em±	0.27	0.35	0.24
CD (p=0.05)	0.81	1.07	0.72

4. Conclusion

over 23 years of continuous use of organic and inorganic fertilizers on soils physico-chemical properties did not vary significantly (pH and EC) among different treatments except calcium carbonate and organic carbon content. The conjugate application of inorganics with organics (100% NPK + FYM) improved the soil organic carbon. In surface soils, an increase of 34.61 and 23.07% was observed in OC content in 100% NPK+FYM and FYM treatments, respectively when compared with the 100% NPK. As the depth increases the pH and calcium carbonate content increases. Whereas, the EC and organic carbon decreases with increasing in depth. FYM alone or in combination with inorganic fertilizers under long-term fertilizer experiments improved physico- chemical properties of soils and sustained the crop productivity in inceptisol under semi-arid conditions.

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