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Effect of Fourteen Years of Long Term Organic and Inorganic Fertilization on Productivity, Soil Quality and Grain Quality of Rice (*Oryza sativa* L.)

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ABSTRACT

Background: Considering the importance of organic farming and growing demand for organically produced foods, field studies were conducted for 14 kharif years (2007 to 2020) on a black clayey vertisol soil at Regional Agricultural Research Station, Nandyal, India to study the influence of organic and conventional farming systems on productivity, grain quality, soil health and economic returns of super fine rice variety BPT-5204.

Methods: The experiment was laid out in non replicated two block design with each block of an area of 2000 m^2 each. The organic plot was green manured with Dhaincha (*Sesbania aculeata*) and FYM @ 10 t ha^{-1}, Castor cake and Neem cake were applied @ 500 kg ha^{-1} as basal dose of manure and topdressing of vermicompost was added as a nutrient sources. In in-organic plot, 100% RDF (240:80:80 kg NPK ha^{-1}) was applied.

Result: The pooled mean grain yield of paddy grown in vertisols under K.C. Canal ayacut under organic farming treatment was 4.04 t/ha while it was 5.6 t ha^{-1} under control (Inorganic/Conventional farming) and the straw yield also was 5.07 t ha^{-1} under organic farming and 7.96 t ha^{-1} under control. The average yield increase in in organic plot was 27% and for straw it was 35%. The organic carbon status was highest in organic plot (0.60%) when compared to the inorganic plot (0.36%).

Key words: Economic returns, Long term fertilization experiment, Organic farming in rice, Paddy grain quality, Rice productivity, Soil health.

INTRODUCTION

Soil health and fertility decline significantly due to intensive use of inorganic and agrochemical fertilizers (Souri 2016; Ge *et al.* 2018). Maintaining soil health and restoring degraded gricultural land are the major strategies that need to be adapted. Rice stands second in the world after wheat in area and production. Organic farming can enhance soil biodiversity, alleviate environmental concerns and improve food safety through eliminating the applications of synthetic chemicals. However, yield reduction due to nutrient limitation and pest incidence in the early stages of transition from conventional to organic systems is a major concern for organic farmers and is thus a barrier to implementing the practice of organic farming. Therefore, identifying transition strategies that minimize yield loss is critical for facilitating the implementation of organic practices. Soil microor ganisms play a dominant role in nutrient cycling and pest control in organic farming systems and their responses to changes in soil management practices may critically impact crop growth and yield (Tu Cong *et al.* 2006).

Studies on the influence of organic farming practice on the yield and quality parameters of rice grain and on soil physico-chemical properties in vertisols of K.C. Canal ayacut is meager. Also, since the consumption of rice is more, it is highly essential to study the influence of organic farming in rice keeping in view the human health and soil health for achieving sustainability in quality rice yields and improving the productivity of soils.

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MATERIALS AND METHODS

Experimental site characteristics

A field experiment was initiated during *Kharif* 2007 and was conducted for 14 *kharif* seasons of 14 crop years, from 2007 to 2020 at Regional Agricultural Research Station, Nandyala Andhra Pradesh. The soil of experimental site was medium deep black, clay loam in texture, low in organic carbon

(0.25%), low in Nitrogen (116 kg ha^{-1}) high in available P_2O_5 (69.5 kg ha^{-1}) and available K_2O(536 kg ha^{-1}).

Treatments details

The experiment was laid out in non replicated two block design with each block of an area of 2000 m^2 each. The details of nutrient composition of different organic sources used in experiment was given in Table 1. The organic plot was green manured with green manure crop, Dhaincha (*Sesbania aculeata*) before one month of paddy crop transplanting. Dhaincha was grown for 45 days and at flowering stage of Dhaincha it was incorporated in the same organic plot. FYM @ 10 t ha^{-1}, castor cake and neem cake were applied by broadcasting method @ 500 kg ha^{-1}as basal dose of manure and topdressing of vermicompost @ 500 kg ha^{-1} was added in two splits at panicle initiation time and at max tillering stage as a nutrient sources. In in-organic plot, 100% RDF (240:80:80 kg NPK ha^{-1}) through urea, single superphosphate and muriate of potash, was applied. Nitrogen was given in three equal splits at basal (before transplanting), maximum tillering (30 days after transplanting) and panicle initiation (60 days after transplanting) stages, whereas P and K were given as basal doses only. Through organic fertilizers, the nitrogen dose was adjusted to the recommended level based on the moisture content and total nitrogen concentration on dry-weight basis was applied. Nutrient composition of different organic sources was presented and explained in Table 1.

Soil pH was measured in 1:2 soil water suspensions, with pH meter. The electrical conductivity was measured in 1:2 soil water suspension using conductivity meter. Organic C was determined by the modified Walkley-Black wet digestion method. Available nitrogen was estimated by alkaline- $KMnO_4$ method. Available phosphorous was extracted with 0.5 M sodium bicarbonate (pH of 8.5) and was determined colorimetrically. Available Potassium (K) was extracted with neutral normal ammonium acetate solution and the extract was analyzed for potassium by flame photometer.

Bulk density, Total porosity, water holding capacity was measured by Keen box method. Mean weight diameter and the distribution of water stable aggregates was determined by wet sieving technique.

RESULTS AND DISCUSSION

Soil quality parameters

Application of organic manures and inorganic NPK fertilizers showed marked difference on physico-chemical properties of soil (pH and EC) at tillering, panicle initiation and harvest stage of rice. At all growth stages of rice, the highest available nitrogen, phosphorus, potassium, micronutrients (Fe, Mn, Zn and Cu), urease, dehydrogenase and microbial population (bacteria, fungi and actinomycetes) in soil were recorded with application of In-organics+Dhaincha @ 10 t ha^{-1}. Changes in soil physical, chemical and biological parameters were monitored at the end of every year and results at the end of fifth year are presented in Tables 1 to 4. There was a significant improvement in soil physical (bulk density and water stable aggregates), fertility (organic carbon and available N, P_2O_5 and K_2O) and biological properties (soil microbial populations and enzyme activities *viz*. Urease, glucosidase, phosphatase and dehydrogenase), with organics compared to inorganic fertilizers. Compared to inorganics, there was an increase in soil organic carbon (SOC), available N, P and K by 59-65, 3-10, 10-27 and 8-25% with organics, respectively, at the end of 14 *kharif* years.Application of organic manures and inorganic NPK fertilizers showed marked difference on physico-chemical properties of soil (pH and EC) at tillering, panicle initiation and harvest stage of rice. At all growth stages of rice, the highest available nitrogen, phosphorus, potassium, micronutrients (Fe, Mn, Zn and Cu), urease, dehydrogenase and microbial population (bacteria, fungi and actinomycetes) in soil were recorded with application of RDNK+Dhaincha @ 10 t $ha^{-1.}$

Pattern of organic carbon (%) status from 2007 was presented in Fig 1 and the organic carbon status was

Table 1: Nutrient composition of different organic sources.

Organic source	Fresh biomass accumulation (t ha^{-1})	Dry matter (t ha^{-1})	Nutrient concentration (%)			Nutrient accumulation (kg ha^{-1})		
			N	P_2O_5	K_2O	N	P_2O_5	K_2O
Dhaincha	25.2	3.2	2.18	0.37	1.09	69.7	11.84	34.9
Organic source	**Quantity applied**		**Nutrient concentration (%)**			**Total quantity of nutrient added (kg ha^{-1})**		
	(t ha^{-1})		N	P_2O_5	K_2O	N	P_2O_5	K_2O
FYM	10 t ha^{-1}		0.44	0.37	0.41	44.0	37.0	41.0
Castor cake	500 kg ha^{-1}		4.23	2.63	2.21	21.2	13.2	11.1
Neem cake	500 kg ha^{-1}		3.62	1.96	2.08	18.1	9.8	10.4
Vermicompost	500 kg ha^{-1}		0.48	0.37	0.41	2.4	1.9	2.1
Quantity of nutrients						85.7	61.9	64.6
Dhaincha accumulation						69.7	11.84	34.9
Total quantity of nutrients added through organics in organic plot						155.4	73.7	99.5
Total quantity of nutrients added through In-organics in RDF plot						240	80	80

medium in organic plot (0.59%) when compared to the inorganic plot (0.34%). Comparable increases in organic carbon, available N, P and K through addition of organic materials was also reported (Carpenter-Boggs 2000 and Melero *et al.* 2008). Superior soil fertility status on organic farms compared to soils fertilized with chemical fertilizers was also reported by Mader *et al.* 2002 and Nataraja *et al.* 2021.

Rasool *et al*. (2007) observed that the average mean weight diameter (MWD), total porosity and water holding capacity (WHC) were highest in FYM treated plots both in rice (0.237 mm) and wheat (0.249 mm). Application of organic manures significantly improved the soil organic carbon content and available nutrient status of soil compared to either the chemical fertilizers or the control. At the end of cropping cycle, soil organic carbon was the highest in treatment receiving vermicompost (0.69%) followed by cattle dung manure (0.68%) (Ramesh *et al*. 2008).

Increased organic carbon of soil due to application of manures was reported by Babhulkar *et al*. (2000). Babu and

Table 2: Effect of Organic manures and In organic fertilizers on physical properties of organic and inorganic plots in organic farming experiment (from 2007 to 2020).

Parameter	Initial	Organic farming	Inorganic
Bulk density (Mg m^3)	1.48	1.23	1.36
% Non capillary porosity	13.2	12.3	11.1
% capillary pores	34.8	36.4	37.0
Total porosity	46.8	48.7	48.0
MWHC (%)	58.9	60.3	57.9
Field capacity (%)	34.1	32.5	33.7
MWD	0.48	0.54	0.51
% WSA	42.1	47.3	40.7

Table 3: Chemical properties of organic farming research in rice grown in vertisols under from 2007.

Chemical properties	Initial properties	Organic plot			In-organic plot		
	2007	2012	2017	2020	2012	2017	2020
pH	8.65	8.19	8.12	8.02	8.50	8.56	8.64
EC (dS/m)	0.39	0.28	0.15	0.17	0.41	0.53	0.81
OC %	0.30	0.43	0.56	0.60	0.27	0.33	0.36
Available N (kg/ha)	225	186	125	257	168	188	224
Available P (kg/ha)	40	38	33	45	42	38	41
Available K (kg/ha)	438	525	418	424	496	390	448
DTPA - Zn (ppm)	0.38	0.44	0.45	0.50	0.48	0.44	0.40
DTPA - Fe (ppm)	14.24	14.25	15.36	15.65	14.35	13.85	13.56
DTPA - Mn (ppm)	82.60	81.68	83.48	82.36	80.65	84.25	85.65
DTPA - Cu (ppm)	0.52	0.56	0.65	0.66	0.60	0.62	0.66

Table 4: Mean Grain and straw yield results of Paddy organic farming experiment (2007-2020).

Year	Grain yield			Straw yield		
	Organic	Inorganic	% decrease over inorganic	Organic	Inorganic	% decrease over inorganic
2007	4262	6197	31.2	4366	6309	30.8
2008	3430	3253	5.1	3724	3258	12.5
2009	4542	6637	31.6	4966	6934	28.4
2010	3910	5380	27.3	4250	8720	51.3
2011	4700	6800	30.9	5240	8860	40.9
2012	4200	4400	4.5	4478	5862	23.6
2013	4025	6010	33	6000	9375	36
2014	3575	5515	35.2	3845	8978	57.2
2015	2210	3568	38.1	2760	6290	56.1
2016	3970	5020	20.9	5420	7238	25.1
2017	4700	6610	28.8	6250	8248	24.22
2018	3840	6320	39.24	4875	8920	48.3
2019	4280	6840	37.4	8200	9600	43.8
2020	4865	5832	16.5	6657	7856	15.2
Mean	4036	5599	27	5074	7961	35
t cal	4.34			3.74		
t tab	2.07			2.08		

Reddy (2000) recorded significant increase in the organic carbon content of sandy clay loam soil from 0.61 to 0.92% due to the addition of FYM and inorganic nitrogen @ 5 t ha^{-1} and 50 kg ha^{-1}, respectively in rice. Hemalatha *et al.* (2000) reported higher content of organic carbon in soil with the application of dhaincha, followed by sunhemp and FYM. Swarup and Yaduvanshi (2000) reported that soil organic carbon was significantly lower in treatments receiving inorganic fertilizers as compared to the treatments involving organics. According to Kumar *et al.* (2001), inclusion of green manure crop in the rice cropping system increased the organic carbon and available N, P and K of soil. Continuous and adequate use of organics with proper management can increase organic carbon content and physical properties of soils (Atiyeh *et al.,* 2002).

Soil physical properties like bulk density, porosity, void ratio, water permeability and hydraulic conductivity were significantly improved when FYM (10 t ha^{-1}) was applied in combination with chemical amendments of sodic soil (Hussain *et al.,* 2001). The bulk density of Vertisol decreased considerably with application of FYM (1.00 Mg m^{-3}) or sunnhemp incorporation (1.04 Mg m^{-3}) or retention of stubbles on soil surface (1.02 Mg m^{-3}) compared to farmer practice (1.18 Mg m^{-3}) is use of inorganic fertilizer (Guled *et al.*, 2002). Sheeba and Chellamuthu (2002) reported significant improvement in properties of VerticUstropept by continuous use of FYM @ 10 t ha^{-1} over twenty two years span of time. They reported significant increase in aggregate stability (68.49%), per cent water stable aggregates (78.22) and total porosity (55.73%) with application of FYM @ 10t ha^{-1} as compared to application of 100 per cent N, P_2O_5 and K_2O through inorganic fertilizers *i.e.* 64.30, 75.70 and 51.03 per cent, respectively. They also noticed decrease in bulk density with the application of FYM @ 10 t ha^{-1} .

Grain and straw yield trends in 14 years of organic farming experiment

The pooled mean grain yield and straw yield of paddy grown in vertisols under K.C. Canal ayacut were given in Table 4. Under organic farming treatment grain yield was 4.04 t/ha while it was 5.6 t/ha under control (Inorganic/ Conventional farming) and the straw yield also was 5.07 t/ha under organic farming and 7.96 t/ha under control. The average yield increase in in organic plot was 27% and for straw it is 35%.

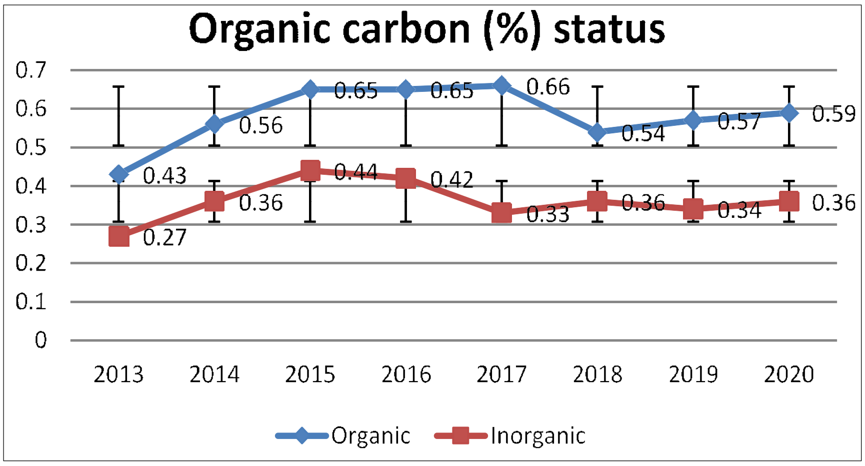

Fig 1: Pattern of Organic carbon (%) status from 2007 in organic rice experiment.

Table 5: Grain quality parameters of organic farming research in rice variety BPT - 5204 grown in vertisols under K.C. canal ayacut (quality parameters in the grain samples).

Parameter	Organic			Inorganic		
	07-08	08-09	19-20	07-08	08-09	19-20
Total moisture (%)	11.00	11.67	9.05	10.78	11.62	10.25
Total ash (%)	1.72	1.50	1.55	1.55	1.47	1.50
Total protein (%)	5.95	7.64	5.89	5.40	8.40	8.25
Reducing sugars	1.82	0.48	0.473	1.03	0.35	0.293
Total sugars	2.61	1.57	1.528	2.49	1.14	0.906
Chromium (mg %)	0.0034	0.70	1.75	0.003	1.30	2.20
Cadmium (mg %)	0.0003	BDL	BDL	0.0002	BDL	BDL
Lead (mg %)	0.019	0.01	0.01	0.030	0.01	0.02
Pesticide residues	BDL	-	BDL	BDL	-	BDL

Note:- BDL- Below detection level.

The data on no. of tillers per hill, panicle length (cm) and no. of grains per panicle were also highest or superior in the inorganic plot compared to organic plot.

During all the 14 *kharif* seasons, inorganic fertilizer applied plots were near stable ranging from 6.1 to 6.8 t/ha and superior to organics (3.4 to 4.8 t/ha). This could be due to mismatch of nutrient release from organic sources and crop demand as influenced by seasonal conditions in the initial years and once the soil fertility was built up sufficiently, organic system also produced equal yields as conventional system. Thus, slow and gradual release of nutrients from organics during the initial years of conversion to organic farming could not result in increased yields. But, repeated application of organics over the years built up sufficient soil fertility by improving soil biological activity.

Grain quality parameters

Grain quality parameters recorded at the end of 2020 was presented in Table 5. Most of the grain quality parameters were not influenced even after fourten years of study, though moderate improvement in nutritional quality was recorded with organicsand polishing reduced the quality improvement. Nutritional grain quality parameters-total moisture (%), total Ash (%), total Protein (%), total sugars, reducing sugars and heavy metals like chromium, cadmium and lead (Pb), pesticide residues were not influenced by the nutrient sources even after 14 years of study. However, in the fifth year, there was an improvement in Total protein by 9.5%, with organics over inorganics (Table 5). A significant improvement in nutritional quality (Fe and Mn), with combined application of 2 or more organic sources and with 3 or 4 organic sources, Improvement in HRR, kernel length, breadth and L/B ratio after cooking with the application of organic sources alone was also reported by Surekha and Satish Kumar 2014.

CONCLUSION

From the present 14-year study of crop productivity, soil fertility and grain quality under organic and conventional rice production systems, it can be concluded that in the initial years of experimentation when the field was under transition, organic fertilizers did not result in increased yields and chemical fertilizers were found superior. However, repeated application of organics over the years resulted in sufficient buildup of soil fertility and improved the grain yield. Further, organic production systems improved the soil properties like pH,Bulk denity and Aggregate stability,soil organic carbon status, productivity, soil quality indices of the soil when compared to conventional production system.

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Conflict of interest: None.

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