International Research Journal of Pure & Applied Chemistry

20(3): 1-14, 2019; Article no.IRJPAC.52242
ISSN: 2231-3443, NLM ID: 101647669

Long Term Effect (17 Years) of Different Nutrient Management Practices on Crop Yield Trends, Soil Productivity and Sustainability in Rice-rice Cropping System under Semi Arid Tropical Climatic Condition in an Inceptisol of India

G. Kiran Reddy[1*], S. H. K. Sharma[1], K. Chandra Shaker[1], P. Ravi[1], Muneshwar Singh[2] and W. Ravi[2]

[1]Department of Soil Science and Agricultural Chemistry, PJTSAU, Hyderbad, India.
[2]AICRP on Long Term Fertilizer Experiments, Indian Institute of Soil Science, Bhopal, India.

Authors' contributions

This work was carried out in collaboration among all authors. Authors GKR, SHKS, KCS, PR conducted the experiment. Author GKR wrote the protocol, carried the statistical analysis and also managed literature searches. Authors SHKS, KCS, PR also managed the analysis and also did literature search. Authors MS and WR coordinated the experiment on soil science and agronomy point of view respectively.

Article Information

DOI: 10.9734/IRJPAC/2019/v20i330135
Editor(s):
(1) Dr. Li Cai, Associate Professor, Department of Chemistry, University of South Carolina Lancaster, Lancaster, SC 29721-0889, USA.
(2) Dr. Surendra Reddy Punganuru, Department of Biomedical Sciences, School of Pharmacy, Texas Tech University Health Sciences Center, Amarillo, USA.
(3) Dr. Wolfgang Linert, Professor, Institute of Applied Synthetic Chemistry, Vienna University of Technology Getreidemarkt, Austria.
Reviewers:
(1) Jamile Da Silva Oliveira, EMBRAPA, Brazil.
(2) Karima Bouhafa National, Institute of Agronomic Research, Morocco.
(3) Cristiane Ramos Vieira, University of Cuiabá, Brazil.
Complete Peer review History: https://sdiarticle4.com/review-history/52242

Original Research Article

Received 13 August 2019
Accepted 30 October 2019
Published 06 November 2019

ABSTRACT

A long term fertilizer experiment was initiated at PJTSAU sub campus, Jagtial, Telangana state, during rainy season of the year 2000-01 in rice-rice continuous cropping system. The experiment was conducted in a fixed plan layout with 11 treatments (and 1 fallow) which included various combinations of inorganic and organic fertilizers and was replicated 4 times under randomized block

**Corresponding author: E-mail: gkiranreddy43@gmail.com;*

design. At the initiation of Experiment the soil properties were clay texture with pH 8.22, organic carbon 7.9 g/kg, Available Nitrogen (N) 107.6 kg/ha, Available Phosphorus (P) 19.6 kg/ha and Available Potassium (K) 364 kg/ha. The study was conducted over a period of 17 years comprising of 34 cropping cycles, in rainy season where all treatments received optimum dose (100% NPK), super optimum dose (150% NPK) and integrated treatments (100% NPK + FYM 5 t/ha) (FYM – farm yard manure) gave onpar yields. However in the post rainy season, 150% NPK treatment gave superior yield compared to all treatments except NPK+ FYM 5 t/ha. NPK + FYM 5 t/ha and 150% NPK treatments recorded the most sustainable yield index (SYI) of 0.65 in rainy and post rainy season respectively. Over all mean SYI, was highest for NPK + FYM 5 t/ha and 150% NPK i.e., 0.63 and the least was observed in 100% N alone 0.50. There was an increase in organic carbon, Available N, Available P and Available K in NPK + FYM 5 t/ha and 150% NPK treatments compared with other treatments. Treatment receiving N alone i.e. imbalance nutrient supply retrogress the crop yields and soil productivity in long run.

Keywords: Long term fertilizer experiment; rice; sustainability yield index; integrated treatment; yield trends; time series analysis.

1. INTRODUCTION

Rice has been India's major food crop along with wheat, it is also the important cereal crop. In India, from food security point of view sustainable and increased production of rice is very vital. Rice-rice cropping system is the predominant cropping system in India in general and Telangana state in particular. Rice crop occupies an area of 43.94 million ha. with the production of 159.20 million tonnes and average productivity of 3623 kg/ha in India. It is about 1.42 million ha. with the production of 4.44 million tonnes with an average productivity of 3138 kg/ha in Telangana state [1]. From the Past three decades, rice production has kept pace with the increasing population. According to recent statistics, rice yield trends are slipping down [2]. The major reason for the decline in rice production is inadequate indigenous nutrient supply and low organic carbon. Several scientists have tried to find out the factors responsible for such decline [3] from long-term fertility experiments.

Sustaining the production has become a major concern in agriculture in many parts of India, especially semi arid tropical climatic conditions of India. The positive yield trend in the last two decades is due to the increased use of inorganic fertilizers. Long-term fertilizer usage results in differences physio-chemical, chemical properties of soil which in return, causes the changes in the overall soil quality [4]. Inappropriate long-term nutrient management practices lead to diminishing of organic matter and soil productivity. As a consequence it causes permanent soil degradation. As such, agricultural sustainability has become a major concern. Issues of agricultural sustainability are related to soil quality.

Adoption of nutrient management practices involving the integration of organic and inorganic fertilizers is the best viable alternative to make the production system more sustainable and profitable. Organic fetilizers are often considered as a potential tool for reducing the use of inorganic fertilizers and enriching the soil health. Long term fertilizer experiments are invariably a potential tool for knowing the crop yields, yield trends. They are used to assess sustainability of system, potential carrying capacity of soil and predicting soil productivity [5]. Long term fertilizer experiments were initiated in India during 1970's with the changing agricultural outlines in the country by cultivating high yielding varieties which require higher doses of inorganic fertilizers. Very little information is available on long term impacts of inorganic fertilizers on crop yields, yield trend, sustainability of crop yields and soil in semi arid tropics of India. Therefore, this study was taken to assess long term impacts of inorganics and organics under different nutrient management systems on yield, sustainability and soil health of rice-rice cropping sequence in an Inceptisol under semi arid tropical climatic condition of India.

2. MATERIALS AND METHODS

2.1 Experimental Site

The present study is a part of an ongoing long term fertilizer experiment. One of the experiments was conducted at PJTSAU sub campus, Jagtial (Block No I, field numbers 7, 7a, 8, and 8a) with rice-rice cropping sequence initiated during the year 2000-01. Experimental site is located at 18º45' N to 19º0' N latitude and 78º45' E to 79º0' E longitude. Jagtial is in the

Deccan Plateau and Eastern Ghats agro ecological zone of the country (Agro ecological Zone no. 7 of India). The soil of experimental site belongs to order - Inceptisol, having clay texture and comes under sub group Ustochrept. The initial properties of soil are represented in Table 1.

2.2 Experimental Details

There were 11 treatments (and 1 fallow) replicated four times in Randomized Block Design. The treatments consists of different combinations and doses of inorganic and organic fertilizers (FYM) and one fallow. The 100% optimum dose of NPK fixed based on soil test values at the initiation of experiment is 120–60–40 kg NPK/ha. The treatments were *viz.,* T1-50% NPK, T2-100% NPK, T3-150% NPK, T4–T1+hand weeding, T5–T1+$ZnSO_4$ @ 25 kg/ha, T6-100% NP, T7-100% N alone, T8–T1+FYM @ 5 t/ha, T9–T1 (-S), T10 FYM @ 15 t/ha, T11–Control (nutrients are not given to crop) and T12 – Fallow (crop was not grown, but pebbling and irrigation were given). Different treatment combinations applied are presented in Table 2. The sources of N, P and K used were urea, single super phosphate (SSP) and muriate of potash (MOP). In sulphur free treatment (T9), diammonium phosphate (DAP) was used instead of SSP as a source of P. The plots and treatments were fixed at initiation and same were being followed continuously. The rice varieties *viz.,* Polasa prabha (medium duration) up to 2003-04, Jagtiala sannalu (short duration) from 2004-05 to 2007-08 and Karimnagar Samba (medium duration) from 2008-09 onwards. All the treatments except T4 were sprayed with pre emergence herbicide butachlor EC a.i. 50% at 2 L/ha on 3rd day of transplanting for controlling weeds. Plot size was 12 m X 9 m (108 m^2), the spacing within the hill and within the row was 15*15 cm.

2.3 Crop Management Practices

The plots were puddle separately (without mixing) within the plot bunds. Transplanting of rice was done in the months of August and January in rainy and post rainy seasons respectively after puddling every year. Dose of inorganic fertilizers through urea, SSP, MOP and DAP were applied as per the treatments. FYM was applied before puddling. The 1/3rd N and 1/2 of K, full dose of P and Zn were applied as basal and the 1/3rd N was top dressed during active tillering stage. Remaining 1/3rd N, 1/2 K was top dressed at panicle initiation stage.

Table 1. Initial soil properties of experimental site (before rainy season 2000-01)

S.No	Property	
1	Soil type (local name)	Black clay
2	Subgroup	Ustochrept
3	Sand (%)	34.88
4	Silt (%)	21.50
5	Clay (%)	43.62
6	Soil texture	Clay
7	Soil colour (dry)	10YR 5/3 brown
	Soil colour (moist)	10 YR 4/2 dark grayish brown
8	Bulk Density (g/cm^3)	1.47
9	Infiltration rate (cm/ha)	0.6
10	PH (1:2)	8.22
11	EC (1:2) (dS/m)	0.47
12	Organic carbon (g/kg)	7.9
	Available nutrients* (kg/ha)	
13	N	107.6
14	P	19.6
15	K	364
	Available nutrients (mg/kg)	
16	S	14.0
17	Fe	14.48
18	Mn	8.72
19	Cu	2.58
20	Zn	2.64

** Available nutrient is any nutrient in the soil solution that can be readily absorbed by the plant roots*

Table 2. Different treatment combinations applied in the long-term fertilizer experiment

Tr. No	Treatments (% of recommended NPK)		N - P - K (kg/ha)
	Rice (rainy season)	Rice (post rainy season)	
T1	50% NPK	50% NPK	60-30-20
T2	NPK	NPK	120-60-40
T3	150% NPK	150% NPK	180-90-60
T4	NPK+ HW	NPK+ HW	120-60-40
T5	NPK + Zn	NPK + Zn	120-60-40
T6	100% NP	100% NP	120-60-0
T7	100% N	100% N	120-0-0
T8	NPK+FYM*	NPK	120-60-40
T9	NPK-S	NPK-S	120-60-40
T10	FYM**	FYM**	0-0-0
T11	Control	Control	0-0-0
T12	Fallow	Fallow	0-0-0

NPK – 100% NPK; S added through SSP - 45 kg S/ha in 100% NPK treatments
*HW – Hand weeding; * FYM 5 t/ha (in rainy season only); ** FYM 15 t/ha (rainy and post rainy season)*

Except T4 all other treatments weeds were controlled by herbicide. Standard agronomic practices were followed for cultivating the crop.

2.4 Observations Recorded

After the harvest of post rainy season soil samples were collected every year from 0-20 cm and analyzed for various physico-chemical and chemical properties. Composite soil sampling procedure was followed and collected samples were mixed well together and a representative portion soil sample was air dried, powdered and passed through a 2 mm sieve for determination of soil properties. Soil pH was determined in 1: 2 soil water suspension and measured with pH meter [6]. The electrical conductivity was measured in 1: 2 soil water suspension using conductivity meter [7]. Organic carbon was determined by Walkley & Black's method [8]. Available soil N was determined by the alkaline-$KMnO_4$ method [9]. Available P was determined by sodium bicarbonate ($NaHCO_3$) extraction and subsequent colorimetric analysis [10]. Exchangeable K [11] was determined using an ammonium acetate extraction followed by emission spectrometry. Available sulphur was determined after extracting with $CaCl_2$ and was followed by spectrophotometry [12]. Cation exchange capacity (CEC) determined by procedure given by Chapman, 1965 [13].

2.5 Sustainability Yield Index (SYI)

Treatment average 17 years grain yield was taken for both rainy and post rainy season. SYI was a quantitative measure to assess sustainability of an agricultural practice. SYI of individual treatment was computed using the below equation [14].

$$SYI = (A-Y) / Ymax$$

Where, A = Mean yield of a particular treatment
Y =Standard deviation of a particular treatment
Y max =Maximum yield obtained of a particular treatment over the years

2.6 Statistical Analysis

Experimental data were subjected to analysis of variance (ANOVA), which was most suited to present experimental design [15]. To compare the treatment means, least significant difference (LSD 0.05) test was used. The yield trends were analyzed separately by ordinary least squares linear regression of yields against a time (years) trend variable over the period. The form of the linear regression was:

$$Y= a + b_x$$

Where: Y – grain yield (t/ha); a – constant; X – year; b – slope of the yield trend.

3. RESULTS AND DISCUSSION

3.1 Effects of Long Term use of Inorganic and Organic Fertilizers on Crop Yield

The data regarding variations in the pooled yield of 17 years of experimentation of grain due to different inorganic and organic ferilizer input treatments are presented in Table 3. The pooled yield data reveals that, the treatments which received the inputs recorded significant increase in grain yield compared to control in both seasons. Pooled yield data clearly showed that 150 % NPK treatment proved its superiority over other treatments and recorded highest grain yield in rainy and post rainy season (5.90 and 5.77 t/ha respectively). It was statistically onpar with NPK+FYM, NPK, NPK+HW, NPK+Zn, NP and NPK-S in rainy season. It was statistically onpar with NPK+FYM in post rainy season. The higher yield due to higher dose of inorganic alone and in combination with FYM might have increased due to sustained nutrient supply and also due to better utilization of applied nutrients through improved microbial activity that involved nutrient transformation and fixation due to organic manuring [16,17]. It indicates that there was no need to increase the fertilizer level above the recommended level in the rainy season to get optimum yield and there was a need to increase the fertilizer level above the recommended level in post rainy season to get optimum yields.

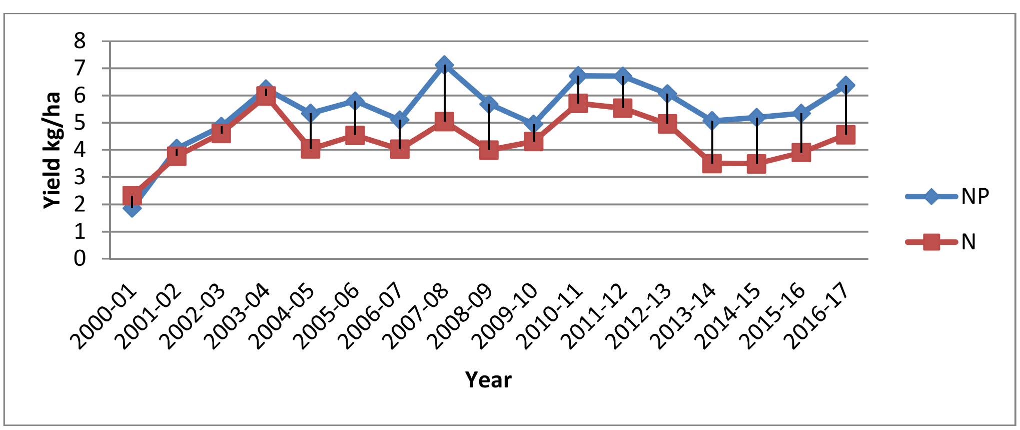
N alone treatment recorded low pooled grain yield in rainy and post rainy season (4.37 and 3.22 t/ha respectively) in comparsion with other treatments where nutrients were applied. Nitrogenous fertilizer application alone deteriorated the soil quality and resulted in drastic reduction of yield in compared with recommended dose of nutrients. This might be due to improper root growth and development that may be attributed to the absence of required quantity of P to the plants. Similar findings were also outlined by Mandal, et al. [18]; Santhy, et al. [19]; and Arulmozhiselvan, et al. [20].

Recommended dose of NPK through inorganics (100% NPK) recorded a pooled grain yield of 5.53 and 5.0 t/ha in rainy and post rainy season respectively. Where only FYM @ 15 t/ha was applied, the pooled grain yield of 4.40 and 3.58 t/ha was recorded in rainy and post rainy season (Table 3) which was onpar with 50% NPK treatment pooled grain yield (4.67 and 4.00 t/ha in rainy and post rainy season). Thus, it can be conclude that FYM @ 15 t/ha can substitute 50% of the nutrients. Similar findings were noticed by Katkar, et al. [21] in a 20 year old fertilizer experiment.

After N, P the most impact nutrient that effect crop growth and yield. To assess the P response, 100% NP and N alone treatments were compared. Because of addition of P to N, grain yield was maintained at 5.44 and 4.88 t/ha in rainy and post rainy season, which are onpar with NPK treatments (Table 3). When we compare the treatments 100% NP and 100% NPK it was observed that there was no significant increase in yield upon addition of K (Table 3). Which indicated that there was no response to applied potassium over 17 years of continues cropping (34 cropping cycles) in Inceptisols of South India.

3.2 Yield Trends (Time Series Analysis)

The 17 year yield trend of rice-rice vary significantly with different nutrient management practices and with season of crop. Positive yield trend was observed in all treatments in rainy season but in post rainy season negative yield trend was noticed in 100% N and control treatment. Graded dose of inorganic i.e., 50% NPK, 100% NPK and 150% NPK progressed the yield slope in rainy season (0.082, 0.103 and 0.132 respectively) but not in the post rainy season (0.044, 0.35 and 0.085 respectively) (Table 4).

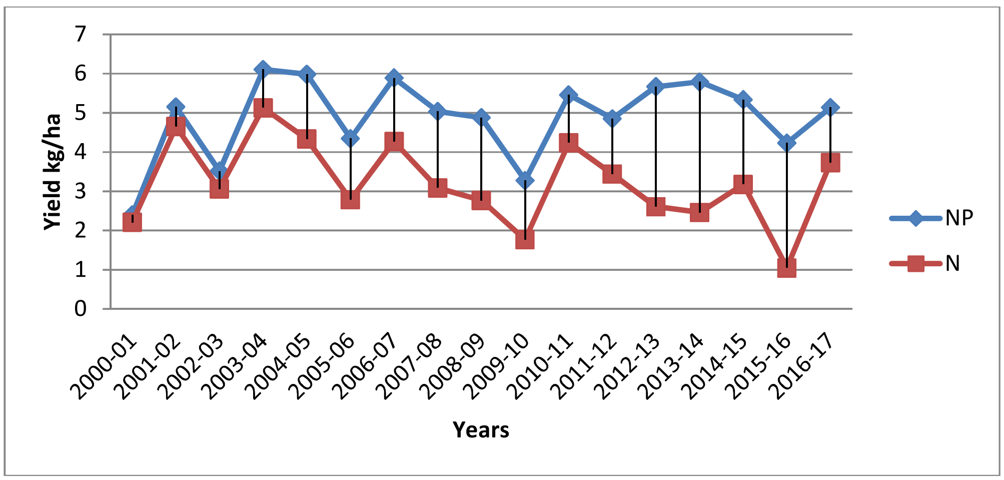


Graph 1. Rainy season NP vs N from 2000-17

Table 3. Effects of continuous inorganic and organic fertilizers on grain yield of rice (t/ha) (pooled yield in rainy and post rainy season from 2000-01 to 2016-17)

Treatment	Rainy season	Post rainy season
T1 - 50% NPK	4.67±0.19[b]	4.00±0.15[c]
T2 - 100% NPK	5.53±0.23[a]	5.00±0.16[b]
T3 - 150% NPK	5.90±0.35[a]	5.77±0.21[a]
T4 - 100% NPK + HW	5.59±0.58[a]	5.02±0.25[b]
T5 - 100% NPK + Zn	5.59±0.57[a]	5.10±0.25[b]
T6 - 100% NP	5.44±0.38[a]	4.88±0.19[b]
T7 - 100% N	4.37±0.21[b]	3.22±0.35[d]
T8 - 100% NPK + FYM	5.82±0.31[a]	5.41±0.52[ab]
T9 -100% NPK –S	5.52±0.35[a]	4.92±0.34[b]
T10-FYM	4.40±0.11[b]	3.58±0.16[cd]
T11- Control	3.14±0.36[c]	2.47±0.26[e]

**values in the same column followed by different letters are significantly different at P<0.001 according to Duncan's Multiple Range Test (DMRT) for separation of means, ± indicates the standard deviation values*



Graph 2. Post rainy season NP vs N from 2000-17

In rainy season the magnitude of yield slope was more positive in super optimum treatment and in post rainy season, the yield slope was more positive in integrated treatment. The positive yield slope was due to more addition of biomass to soil under super optimum dose of fertilizers and positive plant growth environment created by application of FYM as reported by Das, et al. [22]. There was no response to phosphorus application upto 4 years (8 cropping cycles). From 5th year onwards (9th cropping cycle) there was response to phosphorus when compared with the yields of 100% N treatment in rainy season but in post rainy season, the trend started at 8th cropping cycle (Graph 1 and 2). Similar conclusion was given by Bhandari, et al. [23]. Addition of P to soil, influenced the plant growth positively by increasing the crop yields. The increased P availability in soil increased exchangeable cation [24]. Inclusion of sulphur (T10) and zinc (T5) did not increase the grain yield to over sulphur free treatment (T2). In control treatment where no organic and inorganic inputs were supplemented, crop yields followed the retrogression over the period of 17 years.

3.3 Effects of Continuous use of Inorganic and Organic Fertilizers on Sustainability Yield Index

The SYI was computed with formula provided in materials and methods. The SYI is a useful tool to assess overall yield sustainability of system.

Long-term conjoint use of organic and inorganic fertilizers gave the utmost SYI i.e. 0.65 in rainy season. Similar finding was noted by Sathish, et al. [25]. In post rainy season, application of super optimum dose of inorganic fertilizers sustained greater SYI (0.65). This indicates the greatest

Table 4. Yield trends during 2000-01 to 2016-17 as affected by different nutrient management practices

Treatment	Rainy season				Post rainy season			
	a	b	R^2	Initial yield (t/ha)	a	b	R^2	Initial yield (t/ha)
T1 - 50% NPK	3.928	0.082	0.165	2.28	3.592	0.044	0.064	2.04
T2 - 100% NPK	4.604	0.103	0.198	2.42	4.681	0.035	0.028	2.45
T3 - 150% NPK	4.707	0.132	0.275	2.63	5.005	0.085	0.112	2.64
T4 - 100% NPK + HW	4.477	0.123	0.253	2.39	4.387	0.069	0.109	2.81
T5 - 100% NPK + Zn	4.523	0.118	0.25	2.59	4.538	0.062	0.081	2.58
T6 - 100% NP	4.373	0.117	0.237	1.86	4.39	0.054	0.071	2.40
T7 - 100% N	4.169	0.022	0.015	2.32	3.927	-0.078	0.135	2.21
T8- 100% NPK + FYM	4.823	0.111	0.22	3.24	4.593	0.09	0.141	2.52
T9 -100% NPK –S	4.553	0.107	0.221	2.97	4.303	0.068	0.098	2.41
T10-FYM	3.242	0.129	0.423	2.08	3.065	0.057	0.143	2.25
T11- Control	2.819	0.035	0.064	1.62	2.779	-0.034	0.061	1.72

sustainability of crop yield after 17 years of cropping (Table 5). In the initial four years, SYI for 100% N alone was onpar with other 100% NPK treatments, as the years progressed, the SYI lowered down. The lowest SYI (0.58) was recorded under the 50% NPK, 100% N and control treatments during rainy season. In post rainy season, lowest SYI (0.42) was recorded under the 100% N form 2000–2017 (Table 5). Ram, et al. [26] also reported that treatments which did not get ample supply of nutrients through inorganics resulted in lower SYI when compared with those treatments that received adequate supply of inorganics. 100% NP (T6) produced greater SYI (0.59 and 0.63) as compared with 100% N (T7) (0.58 and 0.42). To sustain crop production, optimum dose of P must be applied. Coming to the SYI of mean of both the seasons from 2000-17, highest SYI was observed in super optimum dose and integrated treatment (0.63) (Table 5), these results justify the work done by by Srinivasarao, et al. [27] and Yadav, et al. [28]. Integrated use of organics and inorganics proved positively for long-term productivity and sustainability, super optimum dose of inorganic fertilizers helps in the more biomass production, when the stubbles are incorporated into the soil. They were then converted into organics which increases the soil health. Lowest SYI was observed in 100% N (0.50). Whatever the nutrient management, the SYI value of rainy season was found to be substantially better than post rainy season. This concludes that rainy season yields were more sustainable than post rainy season. Greater value of SYI in rainy season may be due to good response for organic and inorganic fertilizers applied.

3.4 Effect of Long Term use of Inorganic and Organic Fertilizers on Soil Physio-chemical Properties

The long term supply of inorganic and organic fertilizers led to no notable change in the soil reaction (Table 6). Similar findings were given by Reddy, et al. [29] and Katkar, et al. [21] in 20 year old fertilizer experiment. This might be peculiar characteristics of clay soils that possessed inherent high buffering capacity and which not affected the soil reaction of soil due to fertilizer addition. The CEC ranged from 36.40 to 44.34 c mol (p+)/kg in control and organic fertilizer treatments, respectively (Table 6). Since long term fertilizer application and cultivation there has been increase in the CEC. Highest CEC was in the organic fertilizer treatment followed by integrated treatment. Tuyen, et al. [30] report also confirmed that treatment which received organic fertilizers continuously had higher CEC than the treatment which did not receive the organic fertilizers. This may be due the increase in organic carbon content in soil that receives the organic fertilizers in a permanent fertilizer experiment. There was decrease in trend in EC after 17 years of continuous cropping compared with the initial EC (0.47). Decrease in EC (-0.04) was less when compared with other treatments EC (0.47) was observed in the treatments receiving continuously super optimum dose of inorganic fertilizers (Table 6). This might be due to addition of salts through application of increased doses of inorganic fertilizers.

Organic carbon content (Table 6) varied from 7.4 g/kg in N alone to 10.3 g/kg in integrated treatment after 17 years of cropping.

Table 5. Effects of continuous fertilization and organics on sustainability yield index of rice from 2000-01 to 2016-17

Treatment	2000-04 Rainy season	2000-17 Rainy season	2000-04 Post rainy season	2000-17 Post rainy season	2000-17 Mean of both seasons
T1 - 50% NPK	0.43	0.58	0.42	0.61	0.59
T2 - 100% NPK	0.44	0.60	0.46	0.64	0.62
T3 - 150% NPK	0.43	0.61	0.43	0.65	0.63
T4 - 100% NPK + HW	0.41	0.59	0.45	0.62	0.61
T5 - 100% NPK + Zn	0.43	0.61	0.42	0.63	0.62
T6 - 100% NP	0.41	0.59	0.43	0.63	0.61
T7 - 100% N	0.44	0.58	0.47	0.42	0.50
T8 - 100% NPK + FYM	0.46	0.65	0.41	0.61	0.63
T9 -100% NPK –S	0.43	0.61	0.40	0.61	0.61
T10-FYM	0.42	0.60	0.38	0.62	0.61
T11- Control	0.40	0.58	0.44	0.49	0.54

Table 6. Effect of long term fertilizer and manure application on soil physico-chemical properties after 17 years of continuous cropping

Treatments	pH		EC(dS/m)		OC (g/kg)		CEC (c mol p^{+}/kg soil)	
	2017	Change	2017	Change over initial	2017	Change	2017	Change over initial
T1 - 50% NPK	8.24	+0.02	0.39±0.01^{ab}	-0.08	7.8±0.5^{c}	-0.1	37.00±1.2^{b}	+1.78
T2 - 100% NPK	8.33	+0.11	0.40±0.02^{ab}	-0.07	8.0±0.6^{bc}	+0.2	37.61±4.1^{b}	+2.39
T3 - 150% NPK	8.25	+0.03	0.43±0.02^{a}	-0.04	8.6±0.5^{b}	+0.7	38.48±2.8^{b}	+3.26
T4 - 100% NPK + HW	8.33	+0.11	0.38±0.05^{ab}	-0.09	7.9±0.6^{c}	0.0	36.47±2.9^{b}	+1.25
T5 - 100% NPK + Zn	8.29	+0.06	0.40±0.04^{a}	-0.07	7.9±0.1^{c}	0.0	38.06±0.9^{b}	+2.84
T6 - 100% NP	8.31	+0.09	0.37±0.01^{ab}	-0.10	7.9±0.9^{c}	0.0	37.28±1.5^{b}	+2.06
T7 - 100% N	8.26	+0.04	0.37±0.06^{ab}	-0.10	7.4±0.8^{c}	0.5	37.30±4.5^{b}	+2.08
T8 - 100% NPK + FYM	8.27	+0.05	0.36±0.08^{b}	-0.11	10.3±0.5^{a}	+2.4	42.30±4.2^{a}	+7.08
T9 -100% NPK –S	8.32	+0.10	0.39±0.05^{ab}	-0.08	8.1±0.9^{b}	+0.2	37.38±1.9^{b}	+2.16
T10-FYM	8.35	+0.13	0.36±0.04^{b}	-0.11	9.9±0.1^{a}	+2.0	44.34±4.8^{a}	+9.12
T11- Control	8.36	+0.14	0.34±0.05^{b}	-0.13	7.6±0.2^{c}	-0.3	36.40±2.8^{b}	+1.18
T12–Fallow	8.22	0.00	0.35±0.03^{b}	-0.12	7.5±0.5^{c}	-0.4	38.16±1.4^{b}	+2.94
Initial value	8.22		0.47		7.9		35.22	

**values in the same column followed by different letters are significantly different at P<0.001 according to Duncan's Multiple Range Test (DMRT) for separation of means, ± indicates the standard deviation values*

There was a precise increase or no change of organic carbon content of soil compared to initial content in all the treatments receiving 100% NPK and FYM. Highest buildup was observed in integrated treatment (2.4 g/kg), FYM (2.0 g/kg), 150% NPK (0.7 g/kg) treatments over initial. Similar findings were also given by Bharambe & Tomar [31] and Sharma, et al. [32]. They attributed that, positive influx of organic carbon content over the initial content was high in treatments where FYM was applied. This was partially due to addition of carbon and partially due to integration of organic and inorganic fertilizers, resulting in good crop growth, which in turn results in more plant residue addition. Walia, et al. [33] also finds that addition of stubbles to the soil after harvest of the crop helped in building the soil organic carbon. Treatments receiving super optimum dose of inorganic fertilizers and integration treatments, will produce more biomass, so more amount of stubbles are produced thereby resulting in increase in soil organic carbon after incorporation.

3.5 Effect of Long Term Use of Inorganic and Organic Fertilizers on Soil Chemical Properties

After 17 years, the available N content (Table 7) varies from 171 kg/ha in control to 219 kg/ha in T8 where combination of inorganic and organic fertilizers were applied. It was closely followed by the T10 (organic treatment) treatment at 214 kg/ha. Which was further, followed by other treatments which were receiving nitrogen. Avaliable N status increased in all treatments in comparison to the initial available N content (108 kg/ha). These results were in confirmatory with Sharma, et al. [34]. The maximum increase was recorded in treatments receiving recommended inorganics and organics as an additional dose followed by treatment receiving only organics then by treatment receiving super optimum dose of fertilizers. Sheeba & Chellamuthu [35]; Mairan, et al. [36] also reported similar findings. This might be due to N mineralization from FYM and direct inclusion of N through inorganics.

After 17 years, the available P varies from 16.5 kg/ha in N alone treatment to 43.0 kg/ha in 150% NPK and it is very closely followed by NPK + FYM (42.9 kg/ha) then followed by 100% NPK treatment (Table 7). There were significant increase in available P content in comparsion to initial P content in treatments which receives P fertilizers and FYM. N alone treatment showed decline in available P content compared to initial status. Maximum increase in P accumulation compared with initial P 19.6 kg/ha was observed in super optimum dose (23.4 kg/ha) closely followed by integrated treatment (23.3 kg/ha). Similar findings were given by Amruth, et al. [37]. This might be due to solubilisation and mobilization by ligand exchange reaction of negative charged organic acids with phosphate ions on aluminium and iron phosphate minerals which finally releases the phosphate ions into solution. In N alone and control treatments there was a decrease in P content compared with initial value by 3.1 and 2 kg/ha respectively.

Table 7. Effect of long term fertilizer and manure application on available nitrogen and phosphorus (kg/ha) after 17 years of continuous cropping

Treatments	Available N (kg/ha)		Available P (kg/ha)	
	2017	Change over initial	2017	Change over initial
T1 - 50% NPK	186±25^{bcde}	+78	29.4±1.2^{cd}	+9.8
T2 - 100% NPK	204±28^{abcd}	+96	30.9±1.5^{c}	+11.3
T3 - 150% NPK	211±27^{abc}	+103	43.0±1.8^{a}	+23.4
T4 - 100% NPK + HW	203±29^{abcd}	+95	30.9±1.5^{c}	+11.3
T5 - 100% NPK + Zn	207±31^{abcd}	+99	29.5±2.0^{c}	+9.9
T6 - 100% NP	196±24^{abcde}	+88	25.9±2.5^{d}	+6.3
T7 - 100% N	205±12^{abcd}	+97	16.5±1.1^{e}	-3.1
T8 - 100% NPK + FYM	219±19^{a}	+111	42.9±0.9^{ab}	+23.3
T9 -100% NPK –S	209±14^{abc}	+101	29.9±0.8^{c}	+10.3
T10-FYM	214±15^{ac}	+106	38.7±1.9^{b}	+19.1
T11- Control	171±25de	+63	17.6±1.2^{e}	-2.0
T12 –Fallow	181±09de	+73	25.4±1.5^{d}	+5.8
Initial value	108		19.6	

**values in the same column followed by different letters are significantly different at P<0.001 according to Duncan's Multiple Range Test (DMRT) for separation of means, ± indicates the standard deviation values*

Table 8. Effect of long term fertilizer and manure application on available potassium and sulphur (kg/ha) after 17 years of continuous cropping

Treatments	Available K (kg/ha)		Available S (mg/kg)	
	2017	Change over initial	2017	Change over initial
T1 - 50% NPK	315±22[ac]	-49	23.4±0.2[cd]	+9.4
T2 - 100% NPK	322±28[a]	-42	25.8±0.3[bc]	+11.8
T3 - 150% NPK	353±32[a]	-9	29.0±0.5[a]	+15.0
T4 - 100% NPK + HW	309±28[bcd]	-55	27.3±0.3[abc]	+13.3
T5 - 100% NPK + Zn	306±31[bcd]	-58	26.2±0.2[abc]	+12.2
T6 - 100% NP	271±26[d]	-93	25.4±0.3[bc]	+11.4
T7 - 100% N	263±22[d]	-101	20.3±0.1[cd]	+6.3
T8 - 100% NPK + FYM	325±41[ab]	-39	31.1±0.5[a]	+17.1
T9 -100% NPK –S	298±28[d]	-66	19.2±0.4[d]	+5.2
T10-FYM	314±26[abc]	-50	27.2±0.3[ab]	+13.2
T11- Control	281±30[cd]	-83	24.1±0.2[bcd]	+10.1
T12 –Fallow	294±25[bd]	-70	25.5±0.1[bc]	+11.5
Initial value	364.0		14.0	

**values in the same column followed by different letters are significantly different at P<0.001 according to Duncan's Multiple Range Test (DMRT) for separation of means, ± indicates the standard deviation values*

Data (Table 8) shows that there was a diminishing trend in available K status in all treatments. The decrease was utmost in N alone followed NP treatment. Sharma, et al. [38] also confirmed that maximum mining of native K occurs when no K fertilizers were supplied to soil for crop nutrition. The decrease was minimum in 150% NPK followed by integrated treatment. Integrated treatment (325 kg/ha) was found to be significantly superior to other treatments except 150% NPK (353 kg/ha) which recorded the highest available K content in soil. Manuja, et al. [39]; Mairan, et al. [36] reported similar results and they attributed that, organics aids resulted in reducing the leaching loss of K and it is also a direct source of K. Its favorable effect is evident in enhancing the solubility of insoluble K compounds during the decomposition process. There was a depletion in available K status, compared with initial status in all treatments. Verma, et al. [40] also reported similar findings in the long term fertilizer experiment.

The content of sulphur increased in all treatments in comparision to initial status (Table 8). The increase was maximum in treatment where SSP applied as P fertilizer. Increase in magnitude was highest in treatment receiving FYM in addition to recommended dose of fertilizers i.e., NPK followed by treatment receiving super optimum dose of fertilizer.

4. CONCLUSION

The long term fertilizer studies are essential to understand positive and negative impacts of inorganic and organic fertilizers on yield trends and soil quality. Long term integrate use of organic and inorganic fertilizers and super optimum dose of inorganic fertilizers gave higher yield sustainability in post rainy and rainy seasons respectively. Rainy season yields were onpar with treatments receiving the optimum dose, super optimum dose and integrated treatments. But post rainy season yields were highest in super optimum dose fertilizer treatment and integrated treatment. As the years progressed the response to integrated treatment increased compared with other treatments. From the data regarding the yield, it can be concluded that optimum dose of inorganic fertilizers are required to get higher yield in rainy season. In post rainy season, super optimum dose of inorganic fertilizers or integration of inorganic and organic fertilizers are required to get higher yields. Orgainc fertilizer have a potential to supply little quantities of nutrients to crops, there by increasing the soil productivity which in turn helps in maintaining the sustainability of crop yields. Integration of inorganic and organic fertilizers and super optimum dose of inorganic fertilizers (produces high biomass, leaf fall and stubbles act as source of organics) is therefore best viable option for sustaining soil quality and crop yields in rice-rice cropping sequence of semi arid tropics of India. Even the FYM improved the soil health, but the yields were low compared to optimum dose of fertilizers (they are onpar with 50% NPK, so it can be concluded that FYM 15 t/ha supplies the nutrients equal to 50% NPK). Findings of the present study also infer that inclusion of FYM alone or combination of

FYM and inorganic fertilizers and super optimum dose of inorganic fertilizers elevated the soil organic carbon, CEC Available N, Available P and Available S. These results are of greater importance to semi arid tropical climatic areas like India where there is no scope to increase land under cultivation due the increasing population. But the food grain production has to be increased to meet the rising population of the country.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Agricultural Statistics at a Glance. Government of India, Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare, Directorate of Economics and Statistics; 2015.
2. Prasad R. Rice-wheat cropping system. Advances in Agronomy. 2005;86:255–339.
3. Rudrappa L, Purakayastha TJ, Singh D, Bhadraray S. Long term manuring and fertilization effects on soil organic carbon pools in a Typic Haplusteps of semi-arid subtropical India. Soil Tillage and Research. 2006;88(1-2):180-192.
4. Swarup A. Lessons from long-term fertilizer experiments in improving fertilizer use efficiency and crop yield. Fertiliser News. 2002;37:71–73.
5. Reddy MD, Rama Lakshmi S, Rao CN, Rao KV, Sitaramaya M, Padmaja G, Rajalakshmi T. Effect of long-term integrated nutrient supply on soil chemical properties, nutrient uptake, and yield of rice. Indian Journal of Fertilizers. 2006;2: 25–28.
6. McLean EO. Soil pH and lime requirement. In Methods of soil analysis. Part 2-Chemical and microbiological properties, eds. Page AL, Miller RH, Keeney DR. 1982;9(2):199–223.
7. Rhoades JD. Soluble salts. In Methods of soil analysis, part 2: Chemical and microbiological properties, ed. Page AL, Miller RH, Keeney DR. 1982;2:635–655.
8. Jackson ML. Organic matter determinations for soils. In Soil Chemical Analysis. New Delhi, India: Prentice Hall. ed., Madison, Wisc: ASA and SSSA; 1967.
9. Subbaiah BV, Asija GL. A rapid procedure for estimation of available nitrogen in soils. Current Science. 1956;25(8):259–60.
10. Olsen SR, Cole CU, Watanabe FS, Deen LA. Estimation of available phosphorus in soil by extracting with sodium bicarbonate (USDA Circular 939). Washington, DC: US Government Printing Office; 1954.
11. Hanway JJ, Heidel H. Soil analyses methods as used in Iowa State College Soil Testing Laboratory. Iowa Agriculture. 1952;57:1–31.
12. Chesnin L, Vein CH. Turbidimetric determination of available sulphates. Soil Science Society of America Proceedings IS. 1951;149-157.
13. Chapman HD. Cation exchange capacity. In C. A. Black (ed.) Methods of soil analysis. Agronomy. Am. Soc. of Agron, Madison, Wis. 1965;9:894-899.
14. Singh RP, Das SK, Bhaskarrao UM, Reddy MN. Sustainability index under different management: Annual Report. Hyderabad, India: CRIDA; 1990.
15. Gomez KA, Gomez AA. Statistical procedure for agricultural Research. New York, USA: John Wiley & Sons. 1984;2: 25–105.
16. Arbad BK, Ismail S. Effect of integrated nutrient management on soybean (Glycine max)-safflower (Carthamus tinctorius) cropping system. Indian Journal of Agronomy. 2002;56(4):340-345.
17. Shirale ST, Kide DS, Meshram NA. Influence of INM on soil quality, yield and uptake by safflower in soybean-safflower crop sequence in vertisol. Journal of Soils and Crops. 2014;24(2):379-390.
18. Mandal BC, Saha MN, Adhikari M. Yield of rice and nutrient status of soil due to continuous cropping and manuring in a jute–rice–wheat sequence on Indo-Gangetic Alluvial soil. Journal of the Indian Society of Soil Science. 1991;39:689–692.
19. Santhy P, Selvi D, Dhakshinamoorthy M. Longterm fertilizer experiments an index of yield and soil sustainability. Madras Agriculture Journal. 2000;87:40-43.
20. Arulmozhiselvan K, Elayarajan M, Sathya S. Effect of long term fertilization and manuring on soil fertility, yield and uptake by finger millet on inceptisol. Madras Agriculture Journal. 2013;100(4-6):490-494.
21. Katkar RN, Kharche VK, Sonune BA, Wanjari RH, Muneshwar Singh. Long term effect of nutrient management on soil

quality and sustainable productivity under sorghum-wheat crop sequence in Vertisol of Akola, Maharashtra. Agropedology. 2012;22(2):103-114.

22. Das A, Sharma RP, Chattopadhyaya N, Rakshit R. Yield trends and nutrient budgeting under a long-term (28 years) nutrient management in rice-wheat cropping system under subtropical climatic condition. Plant Soil and Environment. 2014;60:351–357.
23. Bhandari AL, Ladha JK, Pathak H, Padre AT, Dawe D, Gupta RK. Yield and soil nutrient changes in a long-term rice-wheat rotation in India. Soil Science Society of America Journal. 2002;66(1):162–70.
24. Verma TS, Singh S. Effect of lime and gypsum on different forms of soil aluminium and acidity and crop yields in acid Alfisols of Himachal Pradesh. Journal of the Indian Society of Soil Science. 1996; 44:417–421.
25. Sathish A, Ramachandrappa BK, Shankar MA, Srikanth Babu PN, Srinivasarao CH, Sharma KL. Long-term effects of organic manure and manufactured fertilizer additions on soil quality and sustainable productivity of finger millet under a finger millet–groundnut cropping system in southern India. Soil Use and Management. 2016;32:311–321.
26. Ram S, Singh V, Sirari P. Effects of 41 years of application of inorganic fertilizers and farm yard manure on crop yields, soil quality, and sustainable yield index under a rice-wheat cropping system on Mollisols of North India. Communications in Soil Science and Plant Analysis. 2016;47(2): 179-193.
27. Srinivasarao CH, Venkateswarlu B, Lal R, Singh AK , Kundu S, Vittal KPR, Sharma SK, Sharma RA, Jain MP, Chary GR. Sustaining agronomic productivity and quality of a Vertisolic soil (Vertisol) under soybean-safflower cropping system in semi-arid central India. Canadian Journal of Soil Science. 2012;92:771-785.
28. Yadav RL, Dwivedi BS, Prasad K, Tomar OK, Shurpali NJ, Pandey PS. Yield trends and changes in soil organic-C and available NPK in a long-term rice-wheat system under integrated use of manures and fertilizers. Field Crops Research. 2000;68:219–246.
29. Reddy CV, Tiwari A, Tedia K, Verma A, Saxena RR. A brief review on effect of continuous application of fertilizers and manures on soil physical properties, nutrient uptake, growth and yield of rice on Chromustert. International Journal of Current Microbiology and Applied Sciences. 2017;6(11):91-103.
30. Tuyen TQ, Phung CV, Tinh TK. Influence of long term application of N, P, K fertilizer on soil pH, organic matter, CEC, exchangeable cations, and some trace elements. Omonrice Journal. 2006;14: 144–148.
31. Bharambe AP, Tomar A. Direct and residual effect of FYM and inorganic nutrients on rice-wheat cropping system in vertisol. PKV Research Journal. 2004;28: 47–52.
32. Sharma M, Mishra B, Singh R. Long-term effects of fertilizers and manure on physical and chemical properties of a mollisol. Journal of the Indian Society of Soil Science. 2007;55:523–524.
33. Walia MK, Walia SS, Dhaliwal SS. Long-term effect of integrated nutrient management of properties of typic ustochrept after 23 cycles of an irrigated rice (*Oryza sativa L.)* –Wheat (Triticum aestivum L.) System. Journal of Sustainable Agriculture. 2010;34:724–743.
34. Sharma U, Paliyal SS, Sharma SP, Sharma GD. Effects of continuous use of chemical fertilizers and manure on soil fertility and productivity of maize–wheat under rainfed conditions of the Western Himalayas. Communications in Soil Science and Plant Analysis. 2014;45(20): 2647-2659.
35. Sheeba S, Chellamuthu S. Long-term influence of organic and inorganic fertilization on the macronutrient status of inceptisols. Journal of the Indian Society of Soil Science. 1999;47:803–804.
36. Mairan NR, Patil SG, Kachhave KG. Physic-chemical properties under sorghum-sunflower cropping sequence in vertisols. Journal of Soils and Crops. 2005; 15(2):352-355.
37. Amruth B, Thippeshappa GN, Gurumurthy KT, Chidanandappa HM, Chandra Sheker B. Effect of phosphorus levels through integrated nutrient management (INM) packages on phosphorus availability and phosphorus fractions in soil under groundnut crop. International Journal of Current Microbiology and Applied Sciences. 2017;6(9):3398-3404.
38. Sharma SP, Singh MV, Subehia SK, Jain PK, Kaushal V, Verma TS. Long-term

effect of fertilizer, manure, and lime application on the changes in soil quality, crop productivity, and sustainability of maize–wheat system in alfisol of North Himalaya (Research Bulletin No. 2). Bhopal: AICRP on Long Term Fertilizer Experiments, IISS, and Department of Soils, CSK HPKV; 2005.

39. Manuja CV, Suma MR, Yogendra ND, Chandrashekar N, Gowda RC. Effect of long-term fertilizer experimentation on growth, yield and availability of nutrients in finger millet in alfisol soils of Bengaluru. Madras Agriculture Journal. 2013;100(7-9):703-708.

40. Verma G, Sharma RP, Sharma SP, Subehia SK, Shambhavi S. Changes in soil fertility status of maize-wheat system dueto long-term use of chemical fertilizers and amendmentsin an alfisol. Plant Soil and Environment. 2012;58(12):529–533.

Peer-review history:
The peer review history for this paper can be accessed here:
https://sdiarticle4.com/review-history/52242