International Journal of Environment and Climate Change

Volume 13, Issue 11, Page 4143-4152, 2023; Article no.IJECC.109586
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Long Term Effect of Organic and Inorganic Manures on Rice Productivity and Major Nutrient Dynamics in 33 Years Old Rice-Rice Cropping System of Godavari Delta

B. E. N. V. V. D. N. Raju [a++], Ch. Sreenivas [b#*], I. Usha Rani [a†], M. D. M. Kadiyala [c#] and T. V. Sridhar [a‡]

[a] Department of Soil Science, Agricultural College, Acharya N. G. Ranga Agricultural University, Bapatla- 522 101, India.
[b] Department of Soil Science, Regional Agricultural Research Station, Maruteru- 534 122, India.
[c] Department of Agronomy, Regional Agricultural Research Station, Maruteru- 534 122, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i113594

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/109586

Original Research Article

Received: 24/09/2023
Accepted: 28/11/2023
Published: 02/12/2023

[++] PG Scholar;
[#] Principal Scientist and Head;
[†] Assistant Professor;
[‡]Professor and Head;
**Corresponding author: E-mail: ch.sreenivas@angrau.ac.in;*

ABSTRACT

Aim: To study the "Long Term Effect of Organic and Inorganic Manures on Rice Productivity and Major nutrient dynamics in 33 years old Rice- Rice Cropping System of Godavari Delta".

Place and Duration of Study: A field experiment was carried out during *kharif* 2022 at Regional Agricultural Research Station, Maruteru, West Godavari district in the ongoing All India Coordinated Rice Improvement Project (AICRIP) on Long term soil fertility management in low land rice soils of Godavari delta under rice-rice cropping system.

Study Design and Methodology: Treatments imposed in this study were T_1: Control, T_2: 50 % NPK, T_3: 50% NPK + 50 % N-FYM, T_4: 50 % NPK + 50% N-Green Manure, T_5: 50 % NPK + 50 % N-*Azospirillum,* T_6: FYM @ 10t/ha, T_7: 100 % NPK+Zn+S, T_8: 100 % NPK +Zn+S+FYM @ 5 t ha^{-1}. All together 8 treatments laid out in RBD with three Replications. The application of fertiliser was carried out in accordance with the treatments. The prescribed fertiliser dose (90:60:60) was administered in the following forms: urea (46% N), single superphosphate (16% P_2O_5), muriate of potash (60% K_2O), and zinc sulphate ($ZnSO_4.7H_2O$) @ 50 kg ha^{-1}. The total dosage of phosphorus, potassium, and zinc were applied as basal. Three equally divided applications of nitrogen were made: one at the basal, one at the tillering stage, and one at the panicle initiation stage. Well decomposed farmyard manure (FYM) manure and Pheltophorum (green leaf manure) were applied one week before transplanting. Popular cultivar of Kharif rice MTU 1064 (Amara) was used for the study.

Results: Long-term application of organic and inorganic fertilizers and their combination didn't show any marked difference on physico-chemical properties of soil (pH and EC). Bulk density was recorded lowest in FYM @ 10 t ha^{-1} and it was on par with (T_8, T_3, T_4, T_5). Organic carbon was observed highest in FYM @ 10 t ha^{-1} and it was on par with (T_8 and T_3). There was a significant impact of long-term application of organic and inorganic fertilizers and their combination on soil chemical properties, highest available N, P, K, S and Zn was observed highest in conjunctive treatment (T_8) 100 % NPK + Zn + S + FYM @ 5 t ha^{-1} whereas, lowest was recorded in control. There was a significant impact on grain and straw yields. Highest grain and straw yields were recorded in (T_8) 100 % NPK + Zn + S +FYM @ 5 t ha^{-1} and it was on par with (T_7) 100 % NPK + Zn + S.

Conclusions: After the investigation, present study concludes that conjunctive and combined application of organics with inorganics improve soil physical, physico-chemical and chemical properties of the soil.

Keywords: Long term effect of manures; rice; rice cropping system; bulk density; organic carbon; nutrient dynamics; grain yield; straw yield.

1. INTRODUCTION

One of the most popular cereal food crops is Rice (*Oryza sativa L.*), which feeds roughly 40 nations and nearly two-thirds of the world's population. Rice cultivation is an essential aspect of the Asian economy; it accounts for more than 90% of the world's rice farming and consumption. In India, paddy is produced over an area of 45.07 million hectares, with a total yield of 122.7 million tonnes and a productivity of 2713 kg ha^{-1} [1]. In Andhra Pradesh, during the *kharif* season, rice is grown over an area of 2.32 million hectares with an annual yield of 7.89 million tonnes and a productivity of 3395 kg ha^{-1}. Due to intense rice monoculture, unbalanced fertilization, excessive irrigation water consumption, the Godavari delta's soil fertility and productivity are expected to be impacted. Continuous application of high quantities of chemical fertilisers had resulted in soil degradation issues, which were also detrimental to soil health. In India, long-term fertilizer studies revealed that, on average, during the wet season, rice removed 20.7 kg N, 5.17 kg P, and 35.5 kg K for every tonne of grain output [2]. Some countries, such as India, have agricultural soils with very low levels of SOM, often falling below the critical limit of 2% in the root zone due to the widespread use of extractive farming practises, the application of small amounts of organic fertilisers and the prevalence of soil degradation due to erosion, salinization and other processes [3].

To increase and maintain production, it is required to apply fertilizer components, particularly N, P and K from both organic and inorganic sources in proper quantities. Numerous studies conducted at research institutes and on farmer fields have shown the value of organic manures and biofertilizers in completing the nutritional requirements of crops and ensuring production stability [4]. To maintain agricultural productivity, it is important to identify such systems or practises. The long-term fertilizer tests carried out by AICRIP demonstrated and revealed that the simultaneous application of fertilizers and manures would not only add sustainability to production and improve soil health, but would also improve use efficiency of applied nutrients.

2. MATERIALS AND METHODS

Field experiment was conducted in Godavari medium black soil developed from alluvium at Regional Agricultural Research Station, Maruteru in West Godavari. Soil samples from 0 to 15 cm depth in each plot were collected and examined for different physical, physicochemical and chemical parameter using established procedures prior to preparatory cultivation of the experimental site. According to the preliminary soil analysis data, the experimental soil has a clay loam texture, slightly acidic in response, high in organic carbon, low in available nitrogen, medium in available phosphorus, and medium in potassium.

2.1 Experimental Details

2.1.1 Experimental design and layout

Field experiment was started in Godavari alluvial soil at Regional Agricultural Research Station, Maruteru in Andhra Pradesh during kharif, 1989. The experimental site has been under rice cultivation since kharif, 1989 onwards.

The experiment was laid out in a randomized block design with eight treatments replicated three times for rice crop (variety: MTU-1064 Amara) with spacing of 20x15 cm during *kharif* season. The organic manures were incorporated one week before rice transplanting in the treatments.

2.1.2 Treatments

T_1 - Control
T_2 - 50% NPK
T_3 - 50% NPK + 50% FYM-N
T_4 - 50% NPK + 50% GM-N
T_5 - 50% NP K + *Azospirillum*
T_6 - FYM@ 10 t ha^{-1}
T_7 - 100% NPK+Zn+S
T_8 - 100% NPK+Zn+S + FYM @ 5t ha^{-1}
RDF for *Kharif* rice: 90:60:60 (kg/ha)

2.2 Cultivation Details of Rice

Organic manures used in different treatment combinations were Peltophorum(green leaf manure) with nutrient composition (1.6%, 0.3% and 0.45 % N, P and K) and farmyard manure (0.62%, 0.29% and 0.72 % N, P and K). These manures were applied one week before transplanting. The prescribed fertiliser dose (90:60:60) was administered in the following forms: urea (46% N), single

Table 1. General characteristics of initial composite soil sample

PARTICULARS	Value	Method of Analysis	References
I. Mechanical analysis 1. Sand (%) 2. Silt (%) 3.Clay (%) Textural class	43 26 31 Clay loam	Bouyoucos hydrometer method	Piper, [5]
Bulk density (Mg m^{-3})	1.2	Core sampler method	Black, [6]
pH (1:2.5)	6.3	Glass electrode pH meter	Jackson, [7]
EC (dS m^{-1})	0.65	Conductivity meter	Jackson, [8]
Organic carbon (%)	1.21	Wet digestion method	Walkley and Black, [9]
Available N (kg ha^{-1})	180.7	Alkaline potassium permanganate method	Subbiah and Asija, [10]
Available P_2O_5 (kg ha^{-1})	47.2	Olsen's method	Olsen et al., [11]
Available K_2O (kg ha^{-1})	271	Flame photometry	Muhr et al., [12]
Available sulphur (mg kg^{-1})	31.25	0.15% $Cacl_2$ extraction, Turbidimetry	Chesnin and yien [13]
Avialable Zinc (mg kg^{-1})	1.22	DTPA extractable method	Lindsay and Norvell, [14]

superphosphate (16% P_2O_5), muriate of potash (60% K_2O), and zinc sulphate ($ZnSO_4.7H_2O$) @ 50 kg ha^{-1}. The total dosage of phosphorus, potassium, and zinc were applied as basal. Three equally divided applications of nitrogen were made: one at the basal, one at the tillering stage, and one at the panicle initiation stage.

2.2.1 Land preparation

The nursery area was properly ploughed and levelled. With a tractor-drawn disc plough, each field plot was tilled under dry conditions. Then, 15 days prior to transplantation, water was applied to each plot, and a power tiller was used to puddle the soil. Each plot was levelled with a wooden plank after the last puddling. The plots were set up according to the experimental design and the field was surrounded by irrigation and drainage systems.

2.3 Soil Analysis

2.3.1 Collection and processing of soil samples

Soil samples were collected from each treatment plot after harvest. Soil samples were drawn from 0-15 cm depth for estimation of soil physical, physico-chemical and chemical properties. After properly mixing the soil, the quartering procedure was used to generate samples weighing approximately 1/2 kg. The samples were crushed, sieved through a 2 mm sieve, and kept in a neatly marked polythene bag for soil analysis using normal procedures after air drying in the shade. For the purpose of estimating the amount of organic carbon, these sieved samples were further run through a 0.5 mm sieve.

2.3.2 Statistical analysis

The data from the observations were statistically analysed using the analysis of variance for a randomised block design approach proposed by Panse and Sukhatme [15]. The statistical significance was examined using the F-test at a 5% level of probability, and if the "F" value was determined to be significant, the critical difference (CD) was calculated to test the significance

2.3.3 Yield data

2.3.3.1 Grain yield

Each net plot's harvested crop was bagged separately, left to dry in the sun, and then threshed using a paddy thresher according to each plot's harvest. Following threshing, the grain was cleaned, dried in the sun to a consistent weight, and then weighed again to determine the final yield. Before expressing the total grain yield in kg ha^{-1}, grain yields from the labelled hills were added to those corresponding plot yields.

2.3.3.2 Straw yield

Each treatment's net plot straw was sun-dried to a consistent weight. Before expressing the total straw yield in kg ha-1, the straw from the five marked hills was added to their respective net plot yields.

3. RESULTS AND DISCUSSION

3.1 Long-Term Effect of Organic and Inorganic Fertilizers on Soil Physical, Physico-Chemical and Chemical Properties

3.1.1 Bulk density

The highest bulk density (1.15) was recorded under the treatment control, whereas lowest bulk density (0.95) was recorded in the treatment T_6 received FYM @ 10 t ha^{-1} and it was on par with T_8 :100 % NPK + Zn + S + FYM @ 5 t ha^{-1} (0.98), T_3 :50% NPK + 50% N-FYM (1.02), T_4 :50% NPK + 50% N-Green Manure (1.01), T_5 :50% NPK + 50% N-*Azospirillum* (1.04). There was a decrease in bulk density from initial soil sample to post harvest soil in all the treatment plots. The improved aggregation, higher porosity and improvement in soil structure brought about by the increase in soil organic matter are the causes of the reduction in bulk density of soil under integrated nutrition management. The findings made it very evident that combining organic sources with inorganic fertilisers lowers soil bulk density. These findings were similar to the findings reported by Kharche *et al*. [16] reported that the integration of chemical fertilisers with organics resulted in a considerable reduction in bulk density from an initial value of 1.32 to 1.20 Mg m^{-3}, which was much lower than that of the control and solely chemical fertilisers. Numerous scientists have noted that the by-products of organic material decomposition typically aid in the granulation of soil particles and so enhance the soil's porosity, which naturally lowers the bulk density of the soil.

3.1.2 pH & Electrical Conductivity (EC)

The results revealed that there was no significant difference in the pH and electrical conductivity values among all the treatments.

3.1.3 Organic carbon (%)

The highest soil organic carbon content was recorded in the organic treatment *i.e.*, T_6 which received FYM @ 10 t ha^{-1}(1.52 %). However, it was on par with treatments T_8- 100 % NPK + Zn + S + FYM @ 5 t ha^{-1}(1.48 %), T_3-50% NPK + 50% N-FYM (1.37 %) and lowest soil organic content was observed in control (1.06 %). Increased OC content with integrated usage of chemical fertilisers and organic manure treatments might be attributable to direct synergistic effect of combined application of organics and inorganics resulted in improved root growth, and the addition of additional plant residues. Similar findings were obtained by Sowmya *et al*., [17]. The FYM-treated plots had the highest levels of organic carbon due to the direct addition of organic matter to the soil and the stimulating effects of organics on boosting growth and the activity of microorganisms. The direct incorporation of organic matter in the soil is attributed to the rise in soil organic carbon in the manure treatment combinations. Following the breakdown of these components, the soil's organic carbon content may have increased [18,19].

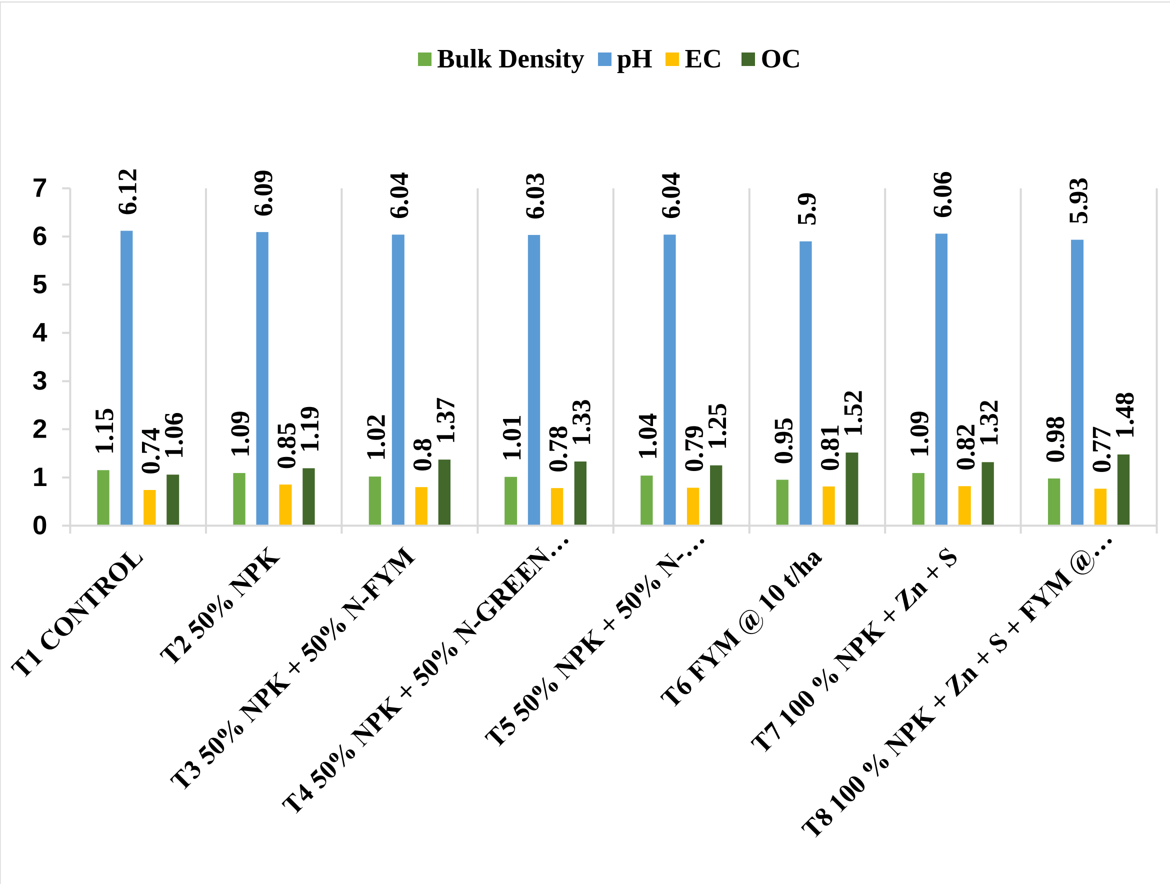

Fig. 1. Long-term effect of organic and inorganic fertilizers on soil physical & physico-chemical properties

3.1.4 Available nitrogen

Significantly higher available nitrogen (261 kg N ha^{-1}) was recorded in the treatment T_8 *i.e.*, (100 % NPK + Zn + S + FYM @ 5 t ha^{-1}) and it was on par with treatments that received 50 % NPK + *Azospirillum* (T_5-249 kg ha^{-1}), 100 % NPK + Zn + S (T_7- 249kg ha^{-1}), 50 % NPK + 50 % GM-N (T_4- 246kg ha^{-1}), 50 % NPK + 50 % FYM-N (T_3- 245kg ha^{-1}). Lowest available nitrogen was recorded in Control (T_1- 212 kg ha^{-1}). The maximum nitrogen concentration was found when organic and inorganic materials were applied together. This may be caused by the beneficial effects of manuring with inorganic fertilisers on soil nitrogen status, and it may also be brought about by the retention of nitrogen in the labile microbial pool due to shifting microbial flushes or by N mineralization from organic sources. Further, the wet soil conditions may have aided in the mineralization of soil nitrogen and increased soil microbial growth, which might have converted organically bound nitrogen into a form that was more easily available and resulted in the accumulation of more readily available nitrogen. The low nitrogen availability in FYM might be attributed to the fact that the nutrient releasing pattern of FYM is sluggish and the nutrient content is also low [20].

3.1.5 Available phosphorus

The highest phosphorus content (55.5 kg P_2O_5 ha^{-1}) recorded in the treatment T_8 *i.e.*, (100 % NPK + Zn + S + FYM @ 5 t ha^{-1}) and it was on par with treatments that received 100 % NPK + Zn + S (T_7- 43 kg ha^{-1}), 50 % NPK + 50 % FYM-N (T_3- 49.9 kg ha^{-1}), 50 % NPK + 50% GM-N (T_4- 48.4 kg ha^{-1}), FYM @ 10 t ha^{-1} (T_6- 48.8 kg ha^{-1}). Lowest available Phosphorus was recorded in Control (T_1- 25.6 kg ha^{-1}). In treatment T_8, additional usage of FYM, a direct source of phosphorus, contributed to the improvement in the status of available phosphorus. It might have also solubilized the native phosphorus in the soil by releasing several organic acids that have a chelating action decreased the fixation of phosphorus. Similar results agree with those of verma *et al* [21]. Increased available P status with FYM and green manure treatment might be attributed to P mobilisation in the soil. This rise in P might also be related to the breakdown of organic manures, which results in the release of significant amounts of CO_2 and organic acids and these organic manures provide a protective layer on sesquioxides, allowing the soil's phosphate-fixing ability to be reduced [22,23].

3.1.6 Available potassium

The highest potassium content (411 kg K ha^{-1}) recorded in the treatment T_8 *i.e.*,100% NPK + Zn + S+ FYM @ 5 t ha^{-1} (411kg ha^{-1}) and it was on par with treatments that received 100 % NPK + Zn + S (T_7, 407 kg ha^{-1}). Lowest available Potassium was recorded in Control (T_1, 337 kg ha^{-1}). Numerous researches have noted that organic manure has a favourable impact on the amount of K that is accessible [24,25] The findings of the experiment revealed that the highest accessible nutrient status was seen in the combination of organic and inorganic treatments. Long-term use of chemical

Table 2. Long-term effect of organic and inorganic fertilizers on soil chemical properties and rice grain & straw yield

Treatments	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})	Zn (kg ha^{-1})	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})
T_1	212	25.6	337	29.25	0.79	2780	4795
T_2	231	41.2	354	30.57	1.03	3995	6399
T_3	245	49.9	360	32.96	1.35	4652	7592
T_4	246	48.4	373	31.34	1.22	4660	7387
T_5	249	43	355	31.22	1.31	4077	7248
T_6	224	48.8	365	35.63	1.54	4327	7427
T_7	249	52.5	407	37.28	1.59	5370	8592
T_8	261	55.5	411	38.69	1.71	6115	8887
SEm ±	9	2.75	12.82	1.16	0.07	257	370
CD @ 0.05	27.3	8.35	38.9	3.52	0.20	779	1122
CV (%)	6.5	10.47	6.01	6.02	8.76	9.89	8.79

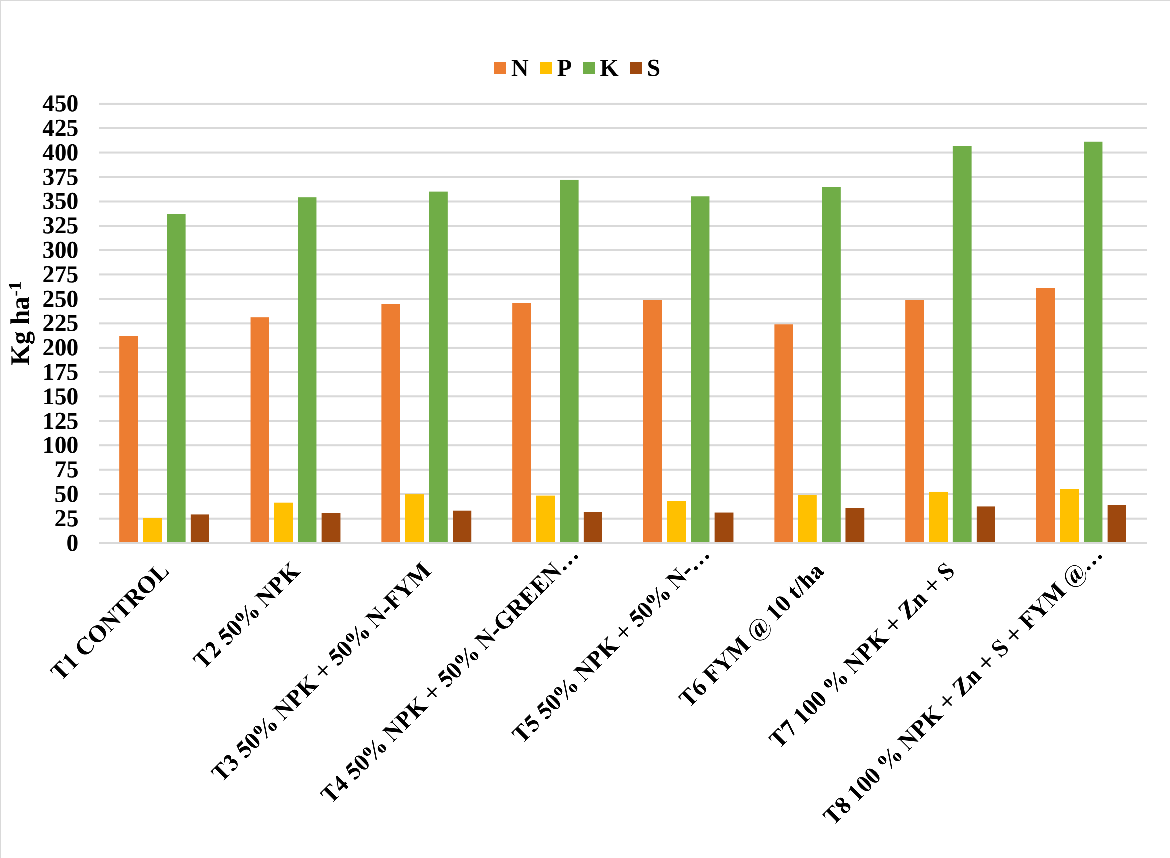

Fig. 2. Long-term effect of organic and inorganic fertilizers on soil chemical properties

fertilisers in combination with organic manures boosts the soil potassium content. The higher ability of organic colloids to retain K ions on the exchange sites may be responsible for this [26,27] also observed that continual usage of FYM and green manures improved the soil potassium status. The favourable effect of green leaf manuring and FYM on available potassium might be attributed to a decrease in potassium fixation, solubilization and release as a result of organic matter interaction with clay, in addition to direct potassium addition to the soil potassium pool.

3.1.7 Available sulphur

The highest available sulphur was recorded in the treatment T_8 *i.e.*, (100 % NPK + Zn + S + FYM @ 5 t ha^{-1}) and it was on par with T_7-(100 % NPK + Zn + S), T_6- FYM @ 10 t ha^{-1}. Lowest was recorded in T_1-Control. Because of the continuous cropping and manuring for 33 years, the soil nutrient status in terms of S increased in all plots treated with FYM and fertilisers. This was reportedly attributable to the provision of S from organic sources as well as that delivered in fertilisers. Mengyu *et al*. [28] observed that a long-term application of organic fertilization combined with chemical fertilization can enhance total sulphur and available sulphur.

3.1.8 Available zinc

Highest zinc content in the soil was recorded in the treatment T_8-100 % NPK + Zn + S + FYM @ 5 t ha^{-1} (1.71 mg kg^{-1}), it was on par with T_7-100 % NPK + Zn + S (1.59 mg kg^{-1}) & T- FYM @ 10 t ha^{-1} (1.54 mg kg^{-1}) and lowest was observed in Control (0.79 mg kg^{-1}). An increase in DTPA extractable zinc in inorganic treatment T_7 might be due to synergistic effect between nitrogen and zinc. The zinc-enriched treatments (T_7, T_8) showed increased Zn content in the soil, which was attributed to the enrichment of organic manure with the application of fertilizer zinc, which might have supplied additional Zn to the soil pool. This was in accordance with the findings of Sabeena *et al*. [29]. The rise in Zn availability owing to the use of FYM in conjunction with NPK may be attributed to mineralization of organically bound forms of Zn complexation in FYM [30]. This may be an impact of the synthesis of organic chelates, which reduced the susceptibility of Zn adsorption, fixing, and precipitation, increasing its availability in soil [31,32].

3.2 Long-Term Effect of Organic and Inorganic Fertilizers on Yield Data

3.2.1 Grain yield

Results of the present investigation revealed that combined application of organic and inorganic manures recorded higher grain yields when compared to organic and inorganic manures applied alone. The grain yield of rice ranged from 2780 to 6115 kg ha^{-1}. Significantly higher grain yield was recorded in treatment T_8 and it was on par with T_7, whereas lowest was observed under Control.

The increase in production in integrated applied plots may be attributed to greater and continuous access to nutrients for plants, which eventually boosted grain output [33]. In addition to increasing N availability, manures also provide micronutrients that promote P and K usage efficiency, leading to better growth and production characteristics. The benefits of green manuring and FYM enhanced rice grain production considerably above the control) [34]. Increased root biomass may have enhanced nutrient absorption by using more soil, which would have improved physiology and metabolism within the plant, leading to increased yields [35,36].

3.2.2 Straw yield

The straw yield of rice ranged from 4795 to 8887 kgha^{-1}. It was observed that there was a significant difference in straw yields among the treatments. Significantly highest straw yield was recorded in the treatment T_8 (8887 kgha^{-1}) which received 100 % NPK + Zn + S + FYM @ 5t ha^{-1}, but it was on par with treatment T_7(8592 kg ha^{-1})- 100 % NPK + Zn + S whereas lowest was observed under Control (4792 kg ha^{-1}). The data revealed that there was an improvement in straw yield in all the treatments except control. This might be due to improved nutrient availability and, as a result, higher nutrient absorption by plants. Rice straw yields were shown to improve when FYM and inorganic fertilisers were applied together, according to Naing *et al*. [37]. This suggests that farmers might use less inorganic fertiliser while still boosting the yield of their straw by mixing FYM and inorganic fertilisers. According to Bodruzzaman *et al*. [38] plots treated with 10t ha^{-1} FYM with 75% NPKZn yielded as much rice straw more than plots treated with 100% NPKZn.

4. CONCLUSION

Continuous fertiliser and manure application affects the soil physical, physicochemical and chemical properties.After the investigation, present study concludes that conjunctive and combined application of organics with inorganics improve soil physical, physico-chemical and chemical properties of the soil. As a result, FYM may be utilised as an alternative source to minimise the consumption of inorganic fertiliser.This long-term study concludes that applying 100% RDF+ Zn+S+ FYM @ 5 t ha^{-1} is a superior alternative in terms of yield components, supplementing inorganics with organics is the optimal strategy for preserving soil quality and crop production.

ACKNOWLEDGEMENTS

Author gratefully acknowledge the Department of Soil Science, Regional Agricultural Research Station, Maruteru and Agriculture College, Bapatla for providing lab and research site for conducting the study. Author express sincere thanks to Acharya N G Ranga Agricultural University for providing financial help.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Anonymous. Agricultural statistics at a glance, Agricultural statistics Division, Directorate of Economics and Statistics. Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India, New Delhi; 2021.
2. Yoshida S. Fundamentals of Rice Crop Science. The international rice research

institute. Los Baños, Laguna. Philippines. 1981;269.
3. Lal R. Managing Organic Matter Content for Restoring Health and Ecosystem Services of Soils of India. Journal of the Indian Society of Soil Science. 2020;68(1):1-15.
4. Sharma KL, Kusuma Grace J, Mandal UK, Gajbhiye PN, Srinivas K, Korwar GR, Bindu VH, Ramesh V, Ram chandran K, Yadav SK. Evaluation of long term soil management practices using key indicators and soilquality indices in a semi and tropical alfisol. Australian Journal of Soil research. 2008;46(4):368-377.
5. Piper CS. Soil and plant analysis. Hans Publishers, Bombay. 1966;368-369.
6. Black CA. Methods of Soil Analysis. Volume 1. American Society of Agronomy. Madison. Wisconsin. USA; 1965.
7. Jackson ML. Soil chemical analysis, pentice hall of India private Limited., New Delhi, India. 1973;498:151-154.
8. Jackson ML. Soil chemical analysis. Prenties Hall Publication Pvt. Ltd., New Delhi, India; 1967.
9. Walkley AJ, Black IA. Estimation of organic carbon by the chromic acid titration method. Soil Science. 1934;37:29-34.
10. Subbiah BV, Asija CL. A rapid procedure for the estimation of available nitrogen in soils. Current Science. 1956;25:259-260.
11. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular of United States Department of Agriculture. 1954;939.
12. Muhr GR, Datta NP, Sankarasubramoney H, Leley VK, Dunabha RL. Soil testing in Indian. 2nd edition, USAID Mission to India, New Delhi. 1965:52-56.
13. Chesnin L, Yien CH. Turbidimetric determination of available sulfates. Soil Science Society of America Journal. 1951;15(C):149-151.
14. Lindsay WL, Norvell W. Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil science society of America journal. 1978;42(3):421-428.
15. Panse VG, Sukhatme PV. Indian Statistical Methods for Agricultural Workers. I.C.A.R., New Delhi; 1978.
16. Kharche VK, Patil SR, Kulakarni AA, Patil VS. Katkar RN. Longterm integrated nutrient management for enhancing soil quality and crop productivity under intensive cropping system on vertisols. Journal of the Indian Society of Soil Science. 2013;6(4):323-332.
17. Sowmya P, Surekha K, Reddy K, Latha PC. Studies on soil physico-chemical properties in rice based cropping systems of longterm fertilizer experiments. International Journal of Environment and Climate Change. 2022;12(5):116-121.
18. Dey A, Dwivedi BS, Bhattacharyya R, Datta SP, Meena MC, Jat RK, Gupta RK, Jat ML, Singh VK, Das D, Singh RG. Effect of conservation agriculture on soil organic and inorganic carbon sequestration and lability: A study from a rice–wheat cropping system on a calcareous soil of the eastern Indo-Gangetic Plains. Soil Use and Management. 2020;36(3):429-438.
19. Datta A, Choudhury M, Sharma PC, Jat HS, Jat ML, Kar S. Stability of humic acid carbon under conservation agriculture practices. Soil and Tillage Research. 2022;216:105240.
20. Balamurugan P, Hemalatha M, Joshph M, Prabina BJ. Influence of organic and inorganic fertilizer levels on growth and yield of dual purpose K12 sorghum (Sorghum bicolor) under irrigated condition. International Journal of Chemical Studies. 2020;8(5):50-53.
21. Verma G, Mathur AK, Verma A. Effect of continuous use of organics and inorganics on nutrient status of soil and yield under maize – wheat intensive cropping system in an inceptisol. Journal of Soils and Crops. 2012;22(2):280-286.
22. Sabeena MS, Sridevi G, Jayanthi D, Balachandar D, Dheebakaran G. Integrated effect of organic and inorganic manuring on crop yield and soil nutrient balance in the on-going century-old permanent manurial experiment. International Journal of Plant and Soil Science. 2022;34(20):645-658.
23. Sharma PK, Sharma SP, Jain PK. Nutrient mining in different agro-climatic zones of Himachal Pradesh. Fertilizer news. 2001;46(8):69-74.
24. Das S, Bhattacharyya R, Das TK, Sharma AR, Dwivedi BS, Meena MC, Dey A, Biswas S, Aditya K, Aggarwal P, Biswas AK. Soil quality indices in a conservation agriculture based rice-mustard cropping system in

North-western Indo-Gangetic Plains. Soil and Tillage Research. 2021;208:104914.
25. Biswas S, Singh P, Rahaman R, Patil KV, De N. Soil quality and crop productivity under 34 years old long-term rainfed rice based cropping system in an inceptisol of sub-tropical India. Frontiers in Soil Science. 2023;3:1155712.
26. Rajashekarappa KS, Basavarajappa BE, Puttaiah ET. Effect of different organic mulches and in situ green manuring on soil properties and yield and economics of maize in dryzone of Karnataka. Green Farming. 2014;5(1):61-64.
27. Verma TS, Suri VK, Paul J. Prescription based fertilizer recommendations for rice, maize and wheat in different agro-climatic zones of Himachal Pradesh. Journal of the Indian Society of Soil Science. 2002;50(3):272-277.
28. Mengyu G, Lu X, Huang Y, Liu N, Yang J. Impact of long-term application fertilizer on soil total sulphur and valid sulphur. In IOP Conference Series: Materials Science and Engineering. 2017;207(1):012068.
29. Sabeena MS, Sridevi G, Jayanthi D, Balachandar D, Dheebakaran G. Integrated effect of organic and inorganic manuring on crop yield and soil nutrient balance in the on-going century-old permanent manurial experiment. International Journal of Plant and Soil Science. 2022;34(20):645-658.
30. Shambhavi S, Kumar R, Sharma SP, Verma G, Sharma SK, Sharma RP. Effect of 36 years of continuous cropping and fertilization on productivity, micro and secondary nutrient status and uptake by maize-wheat cropping system in western Himalayas. International Journal of Bio-resource and Stress Management. 2018;9(2):197-202.
31. Sabeena MS, Sridevi G, Jayanthi D, Balachandar D, Dheebakaran G. Integrated effect of organic and inorganic manuring on crop yield and soil nutrient balance in the on-going century-old permanent manurial experiment. International Journal of Plant and Soil Science. 2022;34(20):645-658.
32. Babu R, Reddy VC, Reddy RT. Effect of nutrient sources on growth and yield of direct seeded rice (*Oryza sativa* L.). Crop Research. 2007;19(2):189-193.
33. Farhad W, Saleem MF, Cheema MA, Hammad HM. Effect of poultry manure levels on the productivity of spring maize (*Zea mays* L.). The Journal of Animal and Plant Sciences. 2009;19(3):122-125.
34. Ram M, Dawari MR, Sharma SN. Organic manures and fertilizers on basmati rice under organic farming of rice wheat cropping system. International Journal of Agricultural and Crop Sciences. 2011;3(3):76-84.
35. Rao AU, Murthy KM, Sridhar TV, Lakshmi DA. Optimization of fertilizer doses for Kharif rice (*Oryza sativa* L.) on deltaic soils of Andhra Pradesh. International Journal of Farm Sciences. 2014;4(1):16-20.
36. Sreenivas CH, Srinivas D, Sridar TV, Surekha K, Satyanarayana PV. Long term fertilization effect on soil organic carbon and productivity of rice crop under rice-rice cropping system in godavari delta, India. Journal of Rice Research. 2015;8(1): 57-62.
37. Naing A, Banterng P, Polthanee A, Treloges V. The effect of different fertilizers management strategies on growth and yield of upland black glutinous rice and soil property. Asian Journal of Plant Sciences. 2010;9(7):414-422.
38. Bodruzzaman M, Meisner CA, Sadat MA, Hossain MI. Long-term effects of applied organic manures and inorganic fertilizers on yield and soil fertility in a wheat-rice cropping pattern. 19th World Congress of Soil Science, Soil Solutions for a Changing World 1-6 August 2010. Brisbane, Australia. 2010;23-44.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/109586