Original Research Article

An insight into the physico-chemical properties of soil under rice-based cropping systems

ABSTRACT

An experiment was conducted with seven cropping systems T_1 (Rice – Rice), T_2 (Rice – (Green gram / Black gram), T_3 (Rice - Cotton), T_4 (Rice – Sesame), T_5 (Rice – Maize), T_6 (Rice – Dhaincha), T_7 (Rice – Rice – Rice) during the *rabi* season (October to January), 2021-2022. At the post-harvest stage, samples were collected from several cropping systems in the experimental plot. In the Department of Soil Science and Agricultural Chemistry, Coimbatore, Tamil Nadu, India, cropping systems were examined for physico-chemical analysis. Cropping systems differed in physicochemical properties as a result of soil variance. Rice - (green gram/black gram) has better nutrient status than other farming systems. Rice-rice-rice was found to have lower nutrient status

Keywords: cropping systems; physico-chemical properties; rice

1. INTRODUCTION

Rice (*Oryza sativa*) is the world's most important food crop. Rice is an important staple meal for about 40% of the world's population. Rice output has increased globally, from 148 Mha in 2002 to 164 Mha in 2011 [1]. India is a major rice-growing country. Rice is farmed on 43.86 million ha in India, with an output level of 104.80 million tons and a productivity of roughly 2390 kg/ha [2]. Rice is cultivated in 28 districts of Tamil Nadu. The state has 2.2 million hectares of rice agriculture, which is mostly irrigated and partly rainfed. The average production in the state is around 2.8 tons/ha. Rice-based cropping system can be described as mix of farming practices that comprises of rice as the major crop followed by subsequent cultivation of other crops. Intercropping of rice and other compatible crops is also widely practised in many regions [3].

Due to the introduction of short and medium duration rice varieties, multiple cropping and the diversification of rice-based cropping systems were possible with inclusion of pulses, oilseeds and vegetables in summer/*pre-kharif* season. This has been found more beneficial, providing enhanced productivity of system and improved soil fertility status than cereal-cereal sequence [4]. Several intensive rice-based cropping methods have been identified and are being utilized by farmers. While Agriculture that is intensive and produces a lot of food. Variety of rice and other crops has resulted in heavy removal of minerals from the soil. Unbalanced and the selective application of chemical fertilizers has resulted in degradation of soil health [5]. Therefore, this system should have different sets of key indicators and their critical limits for maintaining normal functioning of soil and productivity of rice. Experiments on cropping systems are ultimate solution to overcome the drawbacks of mono cropping system. Hence, the present study was conducted to assess the impact of various cropping systems on Physico-chemical properties of soil.

2. MATERIALS AND METHODS

2.1 Study area

The present experiment was carried out and soil samples were collected from the Wetlands, Central Farm Unit, Tamil Nadu Agricultural University, Coimbatore, India during Dec 2021-March 2022, to study the physico-chemical properties of soil. The latitude was 11.00141° north, the longitude was 76.92571° east, and the elevation was 426.6 meters above mean sea level. The temperature in the study area ranges between 24 to 32.5^0 C, relative humidity is in the range of 73 to 88% and the average annual rainfall over the district varies from about 550 mm to 900 mm. The initial soil analysis revealed that soil is clay loamy in texture with 7 cropping systems replicated thrice in Randomized Block Design. The cropping systems were raised with recommended dosage of fertilizer. For all base crop *i.e.,* Rice 150:50:50 RDF had been adopted uniformly. The cropping system details are as follows (Table 1)

Table 1. List of treatments of present experiment

Treatment	Cropping system	variety	Recommended dosage of fertilizer (kg/ha)
T_1	Rice – Rice	Improved white ponni - ADT 45	150:50:50
T_2	Rice – (Green gram / Black gram)	Improved white ponni - Co 8	25:50:25
T_3	Rice - Cotton	Improved white ponni - Co 17	80:40:40
T_4	Rice – Sesame	Improved white ponni - Co 1	35:23:23
T_5	Rice – Maize	CR 1009 - CoMh 8	250:75:75
T_6	Rice – Dhaincha	CR 1009 - Local	Nill
T_7	Rice – Rice – Rice	ADT 37 - Improved white ponni - Co 51	150:50:50

Fig. 2 Experimental area and soil samples

2.2 Soil analysis

Geo-referenced wet soil samples (0-15 cm) were collected from the field from each treatment, soil was air dried, processed, pulverized and passed through a 2 mm sieve for chemical characteristics, while a part was used for physical soil analysis. A total of 63 representative soil samples were taken for analysis.

2.3 Soil physical properties
Bulk density, particle density and porosity were evaluated using soil from seven treatments by adopting cylindrical method [6]
2.4 Soil physicochemical properties
pH and EC were determined in 1:2.5 soil-water suspension using a pH and EC meter [7]
2.5 Soil chemical properties
The Alkaline potassium permanganate method [8], was used to determine soil available Nitrogen, Extractable soil phosphorus by 0.5M $NaHCO_3$ (pH-8.5) using Olsen method and the intensity of blue colour was measured by spectrophotometer [9], the available potassium in the soil was evaluated with the flame photometric technique [10], DTPA extraction method was used to assess soil accessible micronutrients like zinc, Fe, Mn and Cu [11], cation exchange capacity of soil was determined by using Neutral Normal Ammonium Acetate method [12], soil organic carbon was measured by using chromic acid wet digestion method [13].

3. RESULTS AND DISCUSSION

3.1 Bulk density, Particle density and Porosity

From table 2, it was observed that the values of bulk density of the soil ranged from 1.30 to 1.44 g/cm^3 with a mean value of 1.39 g/cm^3. The highest bulk density was recorded in Rice-Rice system while the lowest value was found in Rice – (Green gram / Black gram) system. It implies that if the soil has more organic matter, the bulk density will be lower. If soils are rich in organic matter, they become more friable, porous, and chemically active and tend to have a lower bulk density, all came to the same conclusions, demonstrating the universality of the inverse relationship between bulk density and soil organic matter [14] [15] [16] [17]. Particle density of the soil samples ranged from 2.35 to 2.56 g/cm^3 with a mean value of 2.44 g/cm^3. The maximum particle density was found in Rice-Dhaincha system and the minimum value was recorded in Rice – (Green gram / Black gram) system. With the constant application of inorganic and organic fertilisers, the soil particle density of surface soil samples remained mostly unaffected. In the plots where organic manure and inorganic fertilisers have been treated together, the density of the soil particles marginally reduced [18]. The porosity of the soil samples ranged from 39.98 to 46.07% with a mean value of 42.87%. The maximum porosity was found in Rice-Dhaincha system and the minimum value was recorded in Rice - Cotton system. Between the various cropping sequences, there was very little variation in porosity, and there was also no discernible difference between the sequences. Physical features cannot be changed in a short period of time since they are unique traits of a particular soil. Although organic matter may have a role, it is insufficient to affect transformation.

Table 2. Effect of various cropping systems on soil physical properties

Soil physical properties			
Cropping systems	**Bulk density (g/cm^3)**	**Particle density (g/cm^3)**	**Porosity (%)**
Rice – Rice	1.44	2.44	40.87
Rice – (Green gram / Black gram)	1.30	2.35	44.55
Rice - Cotton	1.49	2.48	39.98
Rice – Sesame	1.36	2.53	45.81
Rice – Maize	1.39	2.35	40.41
Rice – Dhaincha	1.38	2.56	46.07
Rice – Rice – Rice	1.40	2.44	42.44
Mean	1.39	2.45	42.87
SEd	0.02	0.07	1.59
CD (.05)	0.06	0.15	3.46

3.2 Soil pH, EC, CEC and Soil organic carbon

It was observed from the table 3, that the maximum pH value ranged from 7.24 to 8.23 with a mean value of 7.8. The maximum pH was found in Rice-rice-rice system and the minimum pH was recorded in Rice-Cotton samples. Significant pH fluctuation under various farming procedures was not seen. However, the overall *rab*i season crop was found to have a lower pH, which may be related to the cold weather's effect on the pace at which organic matter decomposes. From the analysis of soil sample for electrical conductivity, it was observed that the EC of the soil samples were normal in range. The EC of the samples ranged between 0.28 to 0.52 dS m^{-1} with a mean value of 0.40 dS m^{-1}. The lowest electrical conductivity was found in the Rice – (Green gram / Black gram) system and the highest value was recorded in Rice-Rice system. The soils in the research region were determined to be non-saline in character, with rice-rice cropping system having the greatest EC value and irrigated rice-pulse cropping system having the lowest EC value of 0.28, the lower EC in low/plain land may be the result of salts leaching rather than accumulating [19]. The CEC of the samples ranged between 35.31 c mol (p+) kg^{-1} to 48.5 c mol (p+) kg^{-1} with a mean value of 43 c mol (p+) kg^{-1}. The lowest CEC was found in the Rice - sesame system and the highest value was recorded in Rice – (Green gram / Black gram) system. A greater SOC achieved by a delayed decomposition rate may be the cause of the higher CEC. The C buildup was likewise favoured when rice was produced during the *rabi* season under submerged conditions. According to [20], the apple bean cropping system has a high CEC since it has the highest carbon stock. It was found that the maximum value of Soil Organic Carbon in the sample was 0.62% and the minimum value was 0.26% with a mean of 0.43%. The highest organic carbon content was recorded in Rice – (Green gram / Black gram) system whereas the lowest value was found in Rice-Rice cropping system. Pulses and grain legumes provide options for rice-based crop diversification or intensification, as well as for mitigating the drawbacks of a continuous rice-based cropping system. Sustainable crop management techniques are required in rice-based farming systems because to reduce growing concerns about ecological difficulties and raising SOC [21].

Table 3 Effect of various cropping systems on soil Physico-chemical properties

Soil physico-chemical properties				
Cropping systems	**pH**	**EC (ds m^{-1})**	**CEC (c mol (p+) kg^{-1})**	**Soil organic carbon (%)**
Rice – Rice	8.01	0.52	44.84	0.26
Rice – (Green gram / Black gram)	8.21	0.28	48.5	0.62
Rice - Cotton	7.24	0.35	46.67	0.27
Rice – Sesame	7.54	0.28	35.31	0.29
Rice – Maize	7.87	0.50	47.69	0.61
Rice – Dhaincha	8.01	0.41	41.86	0.47
Rice – Rice – Rice	8.23	0.49	40.88	0.38
Mean	7.87	0.40	43.68	0.43
SEd	0.16	0.02	2.59	0.074
CD (.05)	0.34	0.05	5.63	0.162

3.3 Soil available nitrogen, available phosphorus, available potassium

From the data (Table 4), it was found that the maximum value of nitrogen in the sample was 239 kg ha^{-1} and the minimum value was 130 kg ha^{-1} with a mean of 184 kg ha^{-1}. The highest nitrogen content was recorded in Rice – (Green gram / Black gram) system whereas the lowest value was found in Rice-Rice-Rice cropping system. With the addition of leguminous crops to the rotation, a gradual improvement in the condition of the available N was seen after each year [22]. Pertaining to the data, the maximum value of available phosphorus 28.3 Kg ha^{-1} and minimum of 14.1 kg ha^{-1} in with a mean value of 21 kg ha^{-1}. Rice – (Green gram / Black gram) system was found to record higher phosphorus value and Rice - sesame system recorded lower phosphorus value in the sample. The buildup of organic matter under Rice – (Green gram / Black gram) may have contributed to the higher quantity of phosphorus accessible, and additional decomposition may have generated organic acid, which would have converted the P from an unavailable form to an available form. In agreement with [23], the inclusion of legumes and leguminous green manure in the cropping sequences may be the cause of the increased phosphorus availability by transferring unavailable P to accessible P while fixing N. The available potassium content of the soil ranges from 301 to 388 kg ha^{-1} with a mean value of 335 kg ha^{-1}. Rice – Dhaincha system was found to record higher potassium value and the Rice – Sesame system recorded the lower potassium value in the given soil sample. It may be because of fact that green manure single crop was added in *rabi,* which would have boosted K by storing it in biomass and causing its biomass to degrade.

Table 4 Effect of various cropping systems on soil available nutrients

Soil available nutrients(kg ha^{-1})			
Cropping systems	**Nitrogen**	**Phosphorus**	**Potassium**
Rice – Rice	162	20	348
Rice – (Green gram / Black gram)	239	28.3	326
Rice - Cotton	186	19.9	307
Rice – Sesame	133	14.1	301
Rice – Maize	221	22.3	318
Rice – Dhaincha	204	21.9	388
Rice – Rice – Rice	130	21.4	361
Mean	184	22	335
SD	7.764	2.093	4.995
CD (.05)	16.92	4.56	10.88

3.4 Available Micro nutrients

From Fig.2, Extractable Zinc values in the cropping systems ranged from 0.23 to 1.67 mg kg^{-1} with a mean value of 0.78 mg $kg^{-1.}$ The highest value was seen in the treatment Rice – (Green gram / Black gram) system whereas the lowest value was found in Rice-Rice-Rice cropping system. The majority of the soil samples in the research region may lack zinc due to the basic soil reaction, overuse of phosphatic fertilizers by farmers who ignore the native nutrient status, and high iron concentration in these soils which causes zinc deficiency. According to [24] the presence of medium to heavy texture, which encourages zinc fixing in the octahedral layers substituting for magnesium, may be the cause of the lower zinc levels in black soils. Iron values in the samples ranged from 2.91 to 12.37 mg kg^{-1} with a mean value of 8.30 mg kg^{-1} in the sample. The highest value was seen in Rice – (Green gram / Black gram) system whereas the lowest value was found in Rice-sesame cropping system. It was noted that black soils produced results were quite comparable. Black soils had iron levels that were typical. Given that black soils have higher levels of alkalinity than sandy soils, the high availability of iron in black soils may be caused by the precipitation of insoluble iron compounds [25] and [26] reported similar outcomes. The soil samples were analysed for manganese, the values ranged from 0.15 to 0.57 mg kg^{-1} with a mean of 0.41 mg kg^{-1}. The highest value was seen in the treatment Rice – (Green gram / Black gram) system whereas the lowest value was found in Rice- rice cropping system. Rice is usually grown using floods, which moves the Mn in the soil layer below and lowers the Mn content [27]. The soil samples collected were analyzed for copper and the values of samples ranged from 1.21 to 2.30 mg kg^{-1} with a mean value of 1.71 mg kg^{-1}. The maximum copper was found in the treatment Rice – (Green gram / Black gram) system whereas the lowest value was found in Rice- rice cropping system. By providing a soluble chelating and complexing agent, the organic matter present in clay-textured soils may increase the availability of copper and prevent its loss through fixation and the creation of insoluble carbonates and hydroxides, [28] discovered equivalent outcomes.

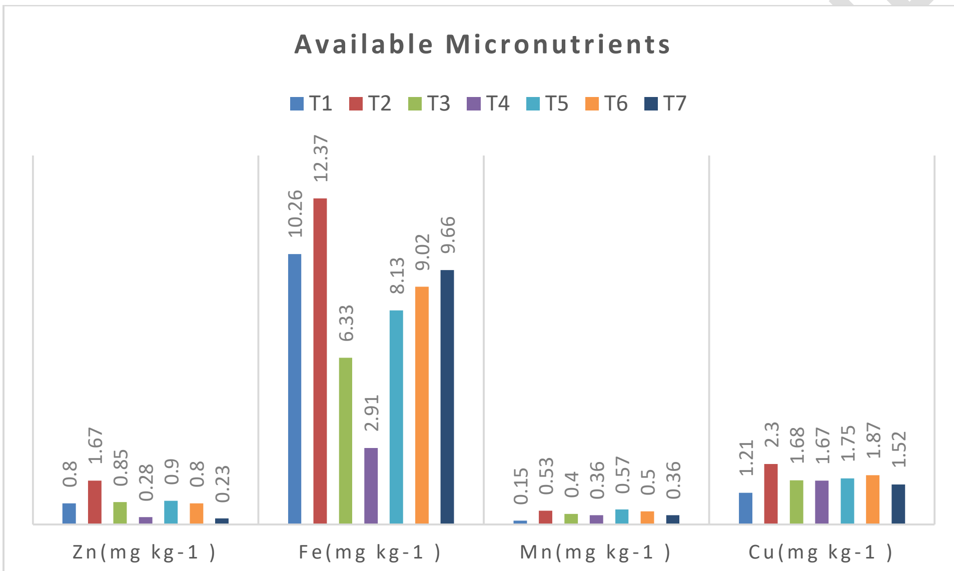

Fig. 2 Effect of various cropping systems on Soil Available Micronutrients

4. CONCLUSION

From the investigation, it was observed that physico-chemical properties significantly differ due to the effect of different cropping systems. Under various cropping systems taken for research work, rice-green gram/black gram cropping system shows higher fertility status than other cropping systems as it contains higher physico-chemical and better soil properties than others due to presence of legume crops. The cropping system rice – rice - rice system shows minimum value in most of the soil physico-chemical properties than other cropping systems. Since further more investigation is needed by including many other cropping systems to define a better land use system.

REFERENCES

1. FAOSTAT, 2013. Food and agricultural data. Available at: http://faostat .fao.org (accessed 29 May 2013).
2. Statistics, Agricultural. "Agricultural Statistics at a glance 2014. Government of India, Ministry of Agriculture, Department of Agriculture and Cooperation, Directorate of Economics and Statistics." (2015).
3. Deep, Mangal et al. “Rice-based cropping systems for enhancing productivity of food grains in India: decadal experience of AICRP.” (2018).
4. Sravan, Uppu, Murthy, Koti. "Enhancing Productivity in Rice-Based Cropping Systems". Plant Competition in Cropping Systems, edited by Daniel Dunea, IntechOpen, 2018. 10.5772/intechopen. 76904..

5. John PS, George M, Jacob R (2001). Nutrient mining in agro – climatic zones of Kerala. Fertilizer News, 46: 45 – 52, 55 – 57.
6. Gupta, R. P., & Dakshinamurthi, C. Procedures for physical Analysis of soils. 1981; *IARI, New Delhi*.
7. Jackson, M. "Soil chemical analysis, advanced course: publ. by the author, Dept." 1973; *Soil Science, Univ. Wisc., Madison, Wisconsin*
8. Subbiah B, and GL Asija. Alkaline permanganate method of available nitrogen determination. 1956:Current Science 25:259.
9. Olsen Sterling Robertson. Estimation of available phosphorus in soils by extraction with sodium bicarbonate: 1954. US Department of Agriculture
10. Stanford George, and Leah English. Use of the flame photometer in rapid soil tests for K and Ca.1949: Agronomy Journal 41 (9):446-447..
11. Lindsay, W. L., & Norvell, W. Development of a DTPA soil test for zinc, iron, manganese, and copper. 1978; *Soil science society of America journal*, *42*(3), 421-428.
12. Jackson,M.L.(1973) Soil Chemical Analysis, Prantice Hall of India Pvt. Ltd. New Delhi.
13. Walkley, A. and Black, T.A. 1934. An examination of the Degt. Jarett method for determination of soil organic matter and a proposed modification of cromic acid titration. Soil Sci. 37: 29-38.
14. Thomas Anken, Peter Weisskopf, Urs Zihlmann, Hansrudolf Forrer, Jan Jansa, Katarina Perhacova,
15. Sinha, N.K., Chopra, U.K., Singh, A.K. *et al.* Soil Physical Quality as Affected by Management Practices Under Maize–Wheat System. *Natl. Acad. Sci. Lett.* **37,** 13–18 (2014). https://doi.org/10.1007/s40009-013-0194-3
16. Jabro, J. D., et al. "Long-term tillage frequency effects on dryland soil physical and hydraulic properties." *International Soil Conservation Organization Conference Proceedings*. 2008.
17. Lampurlanés, J., and C. Cantero-Martínez. "Soil bulk density and penetration resistance under different tillage and crop management systems and their relationship with barley root growth." *Agronomy journal* 95.3 (2003): 526-536.
18. S. S. Dhaliwal, R. K. Naresh, Agniva Mandal, M. K. Walia, Raj K. Gupta, Rajveer Singh & M. K. Dhaliwal (2019): Effect of manures and fertilizers on soil physical properties, build-up of macro and micronutrients and uptake in soil under different cropping systems: a review, Journal of Plant Nutrition, DOI: 10.1080/01904167.2019.1659337
19. Alemayehu, Kiflu, and Beyene Sheleme. "Effects of different land use systems on selected soil properties in South Ethiopia." *Journal of Soil Science and Environmental Management* 4.5 (2013): 100-107.
20. Sofi, J. A., et al. "Soil quality index as affected by different cropping systems in northwestern Himalayas." *Environmental monitoring and assessment* 188.3 (2016): 1-13.
21. Porpavai, S., et al. "Impact of various rice based cropping systems on soil fertility." *Journal of cereals and oilseeds* 2.3 (2011): 43-46.
22. Anwar, M., et al. "Effect of organic manures and inorganic fertilizer on growth, herb and oil yield, nutrient accumulation, and oil quality of French basil." *Communications in soil science and plant analysis* 36.13-14 (2005): 1737-1746.
23. Hazra, K. & Nath, Chaitanya & Ghosh, P. & Swain, Dillip. (2020). Inclusion of Legumes in Rice–Wheat Cropping System for Enhancing Carbon Sequestration. 10.1007/978-981-13-9628-1_2.
24. Revathi, D., Venkaiah, K., Naidu, M.V.S and Ramavatharam, N. 2005. Nutrient status of tomato (Lycopersicon esculentum Mill.) growing soils in Madanapalle division of Chittoor district of Andhra Pradesh. The Andhra Agricultural Journal. 52(1&2): 141-146.
25. Ramarao, S. 2003. Morphology, characterization and taxonomy of soils in Chirala mandal of Andhra Pradesh. M.Sc. (Ag.) thesis. ANGRAU, Rajendranagar.
26. Ramesh, K. 2000. Characterization and classification of some soils of Singarayakonda mandal of Prakasam district of Andhra Pradesh. M. Sc (Ag.) Thesis. Acharya N G Ranga Agricultural University, Hyderabad, India.
27. Fageria, N. K., et al. "Chemistry of lowland rice soils and nutrient availability." *Communications in Soil Science and Plant Analysis* 42.16 (2011): 1913-1933.

28. Venumadhav, M and Prasadarao, B.R.C. 2003. Major and micro nutrient status of rice- fallow blackgram grown in soils of Krishna western delta region of Andhra Pradesh. The Andhra Agricultural Journal. 50 (spl): 151-153.