PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.6179

HORIZON
e-Publishing Group
HePG

RESEARCH ARTICLE

Effect of soil breeding and soil amendments on soil physical properties, rice yield and economics in crusted *Alfisol*

S Mohandas[1], V Dhanushkodi[2]*, V Karunakaran[2]*, R Nageswari[3]*, K Venkatalakshmi[4], K Parameswari[4], D Janaki[4], S Thenmozhi[5] & D Periyar Ramasamy[2]

[1]Agricultural College and Research Institute, Thanjavur 614 902, Tamil Nadu, India
[2]ICAR-Krishi Vigyan Kendra, Needamangalam 614 404, Tamil Nadu, India
[3]Tamil Nadu Rice Research Institute, Tanjore 612 101, Tamil Nadu, India
[4]Agricultural College and Research Institute, Pudukkottai 622 104, Tamil Nadu, India
[5]ICAR-Krishi Vigyan Kendra, Nilgris 643 002, Tamil Nadu, India

*Email: nageswari.r@tnau.ac.in ; karunakaran.v@tnau.ac.in; dhanushkodi@tnau.ac.in

OPEN ACCESS

ARTICLE HISTORY

Received: 20 November 2024
Accepted: 30 November 2024

Available online
Version 1.0 : 07 March 2025

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE

Mohandas S, Dhanushkodi V, Karunakaran V, Nageswari R, Venkatalakshmi K, Parameswari K, Janaki D, Thenmozhi S, Ramasamy D P. Effect of soil breeding and soil amendments on soil physical properties, rice yield and economics in crusted *Alfisol* . Plant Science Today (Early Access). https://doi.org/10.14719/pst.6179

Abstract

The impact of soil breeding and soil amendments on soil physical properties, rice yield, and economics under crusted Alfisols (red soil) was investigated in a field experiment at the Agricultural College and Research Institute, Tanjore, Tamil Nadu, India. The study was conducted for three consequetive years (2020–2023). There were totally nine treatments, comprising of clay, sand, and manure alone and their combinations and lime were replicated thrise. In the first year of the experiment, the treatments were imposed as per schedule and thoroughly mixed with surface soil. Every year, *sunnhemp* was raised as the first-season crop and incorporated *in-situ* at flowering prior to transplanting of rice. The results indicated that application of FYM 12.5 t ha^{-1}+ clay 100.0 t ha^{-1}+ coarse sand 100.0 t ha^{-1} (T_8) recorded highest growth and yield attributes, *viz*., plant height (94.26 cm), number of productive tillers (16.53), grain yield (3.981 t ha^{-1}), and straw yield (5.250 t ha^{-1}) of rice and B:C ratio of 1.66. Further, application of FYM 12.5 t ha^{-1}+ clay 100.0 t ha^{-1}+ coarse sand 100.0 t ha^{-1} reduced soil bulk density (1.31 Mg m^{-3}), increase in pore volume (45.40 %), soil infiltration rate (3.62 cm h^{-1}) and hydraulic conductivity (3.02 cm h^{-1}). However, this was on par with application of FYM 12.5 t ha^{-1}+ clay 50.0 t ha^{-1}+ coarse sand 50.0 t ha^{-1} (T_7).

Keywords

clay soil; constraints; manure; rice; sand addition; yield

Introduction

Soil degradation poses a significant challenge in rain-fed and irrigated agriculture, leading to substantial decreases in yield and economic losses. Higher bulk density, inadequate water infiltration, low water retention, erosion, unfavorable soil reactions, and nutrient deficiencies all contribute to this issue. The ideal soil physical environment is crucial for optimizing crop production (1). For realizing the genetic full potential of a crop, maintenance of the soil physical environment at its best is essential. Once soil physical health deteriorates, it takes a considerable amount of time to recover, impacting soil processes and ultimately reducing crop yields. It creates a favorable environment for optimal plant growth through root development to utilize the soil for water, nutrients, and plant anchorage effectively (2).

Various physical restrictions on the soil affect over 90 million hectares in India. The primary limitations of the soil are weak soil structure, sluggish and high permeability, crusting, hardening, compaction, and inadequate water openness, retention, and transmission. In *Alfisols*, the movement of water and air into deeper layers is hindered due to surface sealing by soil crusting and hard pans (3). Additionally, the limited clay and low organic matter content in the soil matrix restrict water transmission. The subsoil hard pan in red soil is caused by the eluviation of clay into the subsoil, increasing soil bulk density over 1.8 mg/m^3. Due to lesser porosity and soil compaction brought on by the higher bulk density in these soils, the infiltration rate is decreased, limiting water entry and causing more water to remain on the soil surface, hence hindering the development of healthy roots (4). The experimental farm's soil falls into the category of *Alfisols*, and it is generally known for its poor physical properties due to its texture composition and light texture. Various factors influence the formation of soil crust, such as the parent material, clay minerals, fine sand and silt, cationic composition, sesquioxide content, and aggregate stability (5). These soils tend to have lower surface roughness, quickly seal after rainfall, and form a crust due to the lower clay content and organic matter in the surface horizon, as well as the absence of stable aggregation. The lack of natural soil structure in *Alfisols* is due to low clay content in the surface horizon, dominance of 1:1-type soil minerals, and agricultural practices that introduce small amounts of organic matter. Upon irrigation, the soil becomes loose, but it forms a hard mass when it dries. Soil acidity is a major challenge in agriculture and has a detrimental impact on crop productivity and yield (6). Once the soil becomes acidic, applying lime to the surface can start to counteract the pH effect (7).

Amending soil with clay, coarse river sand, and manure may be an effective way to improve soil aggregation by facilitating the organization of soil particles and enhancing porosity. Moreover, this approach can help retain more water and nutrients by minimizing percolation losses (8). Furthermore, the incorporation of clay in soil amendments can bind soil particles together, leading to notable improvements in soil aggregation and enhancing water movement (6). Liming is a farming method that can change the soil's physical, chemical, and biological characteristics. Plants are better able to absorb the nutrients and water from the soil because it encourages better root system formation and increases the development of soil microorganisms. Moreover, liming alters the soil's physical attributes along with its biochemical and biological content (9). Adding soil can accelerate the restoration of damaged soil by changing its physicochemical characteristics and biodiversity (10). Likewise, the addition of clay can lead to increased crop yield (11). To address this issue, a soil breeding experiment was carried out as a one-time solution, altering the soil's textural composition to improve its texture, structure, and other physical properties for better crop production.

Materials and Methods

Details of the experimental site

The objective of this experiment is to alleviate soil physical constraints of *Alfisol, viz.,* soil crusting, poor water retention, poor soil aggregation, water transmission, etc. Its inappropriate texture is the primary problem with this soil. Its sandy surface, which contains different proportions of silt, clay, fine and coarse sand, and sand, causes several physical limitations, including crusting and restricted water absorption and soil structure. The dirt gets fluffy after irrigation, but it gets harder after it dries. The soil breed experiment was carried out as a one-time fix to address this and enhance the physical, structural and textural characteristics of the soil.

Soil management

To prevent surface crust formation, it is essential to enhance aggregate stability through the application of clay, lime, gypsum, or manure. This is because clay soils primarily consist of a high clay fraction, which contributes to inadequate permeability and nutrient retention. In India, a common practice involves adding 25 tons per hectare annually of tank silt or black soil, along with 25 tons per hectare of farmyard manure, composted coir pith, or pressmud. Nevertheless, it is crucial to conduct region-specific research that thoroughly evaluates the effects of soil improvement using organic materials and soil particles, which is necessary for reaping the benefits in major cropping systems within various ecological regions. Therefore, two specific levels of clay soil, both at 25 tons per hectare, were utilized in this study.

The land was deeply ploughed and pulverized by implements. Then, it was demarcated into 25 m × 50 m plots for every treatment under three replications. Furthermore, each plot was subdivided with a measure of 5m × 4m. The treatments involved using various soil amendments such as heavy clay, coarse river sand, different levels of FYM, and lime based on the lime requirement. These amendments were used in different combinations. The experiment schedule consists of 9 treatments as furnished Table 1. The treatments were imposed as per schedule and thoroughly mixed with surface soil. Sunnhemp (*Crotalaria juncea*) as green manure was raised as the first season (*kharif*) crop and incorporated *in-situ* at flowering before transplanting of rice. Rice (White Ponni) was planted for the first year (2020) of experimentation, followed by TKM-13 in the second and third years (2021 and 2022) of experiments after the *in-situ* incorporation of *Sunnhemp*. The configuration for experimentation employed in this study is outlined below (Fig. 1*).*

Table 1. Details of the treatments

S. No.	Treatment details
T_1	Control
T_2	Farm Yard Manure(FYM) @ 12.5 t ha^{-1}
T_3	Clay @ 50.0 t ha^{-1}
T_4	Clay@100.0 t ha^{-1}
T_5	Coarse sand @ 50.0 t ha^{-1}
T_6	Coarse sand @100.0 t ha^{-1}
T_7	FYM @12.5 t + Clay @ 50.0 t + Coarse sand @ 50.0 t ha^{-1}
T_8	FYM @12.5 t + Clay @100.0 t + Coarse sand @ 100.0 t ha^{-1}
T_9	Lime (as per Lime Requirement- 4.8 t ha^{-1})

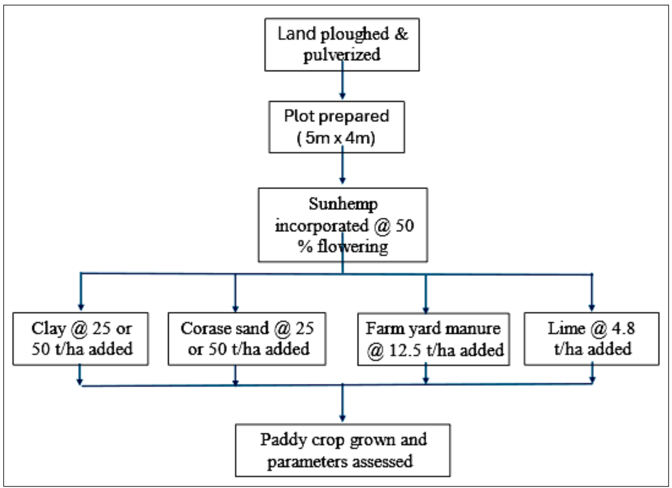

Fig. 1. Experimental setup.

Methodologies adopted in the study

The location of the soil profile at the experimental site is 10° 66 N and 79° 16' E. The elevation of the land is 58 m from mean sea level, and it dips gently towards the sea. The average annual temperature in this region is 28.3 °C, while the average annual rainfall is 920 mm. Following rice harvesting and before the application of any treatments, a mixed soil sample (0–15 cm) was taken from the experimental location. The physical characteristics of this sample, including the density of the bulk, soil porosity, hydraulic conductivity, and particle size distribution, were then treated and examined. The hydraulic conductivity of the material was assessed using the fixed heads hydraulic conductivity assembly method, while the bulk density, particle density, and analysis of pore space were determined through the cylinder method (12). Additionally, the soil infiltration rate was measured by employing the double-ring infiltrometer method. The mean weight diameter (MWD) of aggregates: MWD = ∑ Xi. Wi, where Xi is the mean diameter of a class (mm) and Wi is the percentage of aggregates that were returned and sieved relative to the total (13). The separation of macro- and microaggregates usually occurs at 0.25 mm (14).

Statistical analysis

For statistical analysis of data, on-farm data were collected from each treatment that had been evaluated for three consecutive years during 2020, 2021 and 2022. Simple correlation studies were carried out with analytical data on various physical properties to establish the relationship between different parameters using standard methods. The data collected on various soil characteristics of field experiments were analyzed. When there were significant variations in the treatment, critical distinctions were established at a 5 % probability level as per Panse and Sukhatme (15).

Results and Discussion

Effects of soil breeding and soil amendments on soil physical properties

The study examined the soil's physical properties, such as bulk density, soil pore volume, soil infiltration rate, and hydraulic conductivity, before and after implementing treatments (Table 2). Over a three-year period, heavy clay, coarse river sand, and FYM were individually and collectively added to the soil to address soil physical constraints. The FYM (@12.5 t ha^{-1})+ clay (@100.0 t ha^{-1}) + coarse sand (@ 100.0 t ha^{-1}) resulted in the most significant reduction in soil bulk density (1.31 mg m^{-3}) from the initial level (1.59 mg m^{-3}) and the highest improvements in soil pore volume (45.50%), soil infiltration rate (3.62 cm h^{-1}), and hydraulic conductivity (3.02 cm h^{-1}). Similarly, the results obtained under FYM (@12.5 t ha^{-1}) + clay (@50.0 t ha^{-1}) + coarse sand (@50.0 t ha^{-1}) showed significantly lower soil bulk density and the greatest improvements in pore volume, infiltration rate, and hydraulic conductivity (1.32 Mg m^{-3}, 44.6%, 3.53 cm h^{-1}, and 2.80 cm h^{-1}, respectively). The control demonstrated the highest soil bulk density (1.51 Mg m^{-3}), lowest pore volume (31.8%), infiltration rate (1.98 cm h^{-1}), and hydraulic conductivity (1.17 cm h^{-1}). The application of FYM (12.5 t ha^{-1}), clay (100.0 t ha^{-1}), and coarse sand (100.0 t ha^{-1}) resulted in the most substantial reduction in mean weight diameter and grand mean diameter (0.287 mm) from the initial level of 0.211 mm, and the highest enhancement in micro- and macroaggregate stability (20.8 mm) was achieved by the application of clay (100.0 t ha^{-1}).

Soil texture is one of the key characteristics influencing the physical and chemical characteristics of soil

Table 2. Effect of soil breeding and soil amendments on soil physical properties

S. No.	Treatment details	Bulk density (Mg m-^{3})	Particle density (Mg m-^{3})	Pore space (%)	Infiltration rate (cm h^{-1})	Hydraulic conductivity (cm h^{-1})
T1	Control	1.51	2.3	31.8	1.98	1.17
T_2	FYM @ 12.5 t ha^{-1}	1.38	2.26	41.4	2.92	2.53
T_3	Clay @ 50.0 t ha^{-1}	1.39	2.32	37.1	3.1	1.86
T_4	Clay@100.0 t ha^{-1}	1.4	2.39	39.2	3.43	1.87
T_5	Coarse sand @ 50.0 t ha^{-1}	1.45	2.3	37.4	4.3	2.56
T_6	Coarse sand @100.0 t ha^{-1}	1.44	2.37	37.3	4.75	3.01
T_7	FYM @12.5 t + Clay @ 50.0 t + Coarse sand @ 50.0 t ha^{-1}	1.32	2.45	44.4	3.53	2.8
T_8	FYM @12.5 t + Clay @100.0 t + Coarse sand @ 100.0 t ha^{-1}	1.31	2.42	45.4	3.62	3.02
T_9	Lime (as per Lime Requirement- 4.8 t ha^{-1})	1.42	2.41	34.7	2.85	1.71
S. Ed		0.06	0.08	1.02	0.32	0.28
CD (p=0.05)		0.14	NS	2.25	0.64	0.37

(16). Soil breeding with heavy clay and coarse river sand with farmyard manure reduced the bulk density of soil by up to 16.00%. This might be due to the significant positive effect of soil breeding with clay, coarse river sand, and farmyard manure on soil enhancing soil aggregation, better organization of soil particles, and increased porosity. Formation of soil aggregates in light soil helps in retaining soil water and nutrients by dropping the percolation losses due to the addition of clay and coarse river sand. The relationship between soil density and porosity is interlinked (17). Additionally, soil breeding with the application of clay can bind soil particles together, resulting in significant changes in soil aggregation and improving water movement (6). In the same way, the red *Alfisol* soil experiences an increase in water holding capacity due to the application of 60.00 t ha^{-1} of tank silt in Andhra Pradesh (18, 19). The available water content and moisture retention capacity were enhanced by applying tank silt and clay. After mixing 2% clay, four passes by an iron roller (500 kg) increased the moisture retention capacity and infiltration rate of loamy sand (8). The lime application helps in correcting soil pH, and it can alter the flocculation and formation, stabilizing stable aggregates. Further, it improves soil aeration, root growth, and microbial growth (9, 10). Increased clay content and the addition of farmyard manure can help to prevent the formation of crust because the clay particles link to soil aggregates, shielding them from the damaging effects of raindrop impact (10).

Application of FYM (12.5 t ha^{-1}) + clay and coarse sand (100.0 t ha^{-1} each) recorded higher mean weight diameter, micro and macro soil aggregates (Table 3). Wetting and drying cycles that occur naturally and frequently in soil can promote better aggregation and result in a stable soil structure. The stabilization of soil aggregates was enhanced by the application of compost (20). Furthermore, the application of organic matter significantly raised the quantities of microbial biomass carbon (MBC) in aggregates (21). The higher organic carbon and soil nitrogen were related to enhanced soil structure, as demonstrated by the positive correlations with MWD and macroaggregates. Additionally, a correlation analysis revealed a positive relationship between macroaggregate and stability, the pace at which soil organic carbon and soil nitrogen contributed to them. As a result, aggregate size had an impact on the sequestration of carbon and nitrogen in the soil. The findings showed that manure-enriched fertilizer enhanced soil fertility and structure more than fertilizer alone in improving crop output (22). Compared to the application of manure or fertilizer alone, a combination of the two improved soil nitrogen, aggregation, and organic carbon status. This indicated that the use of both fertilizers and manure was a suitable strategy for increasing carbon sequestration in agro-ecosystems (23). For improved agro-ecosystem functioning, the stability of soil aggregates and related carbon (C) is a crucial indication for evaluating overall soil health (24). Similar outcomes of enhanced soil nutrient availability due to the incorporation of clay in sandy soil were observed by (25) and by the addition of animal manure in sandy soil in Northern china (26). Similarly improvement of aeolian sandy soil in Mu Us, China with soft montmorillonite clay stone was noticed by (27). Utilizing natural clay deposits together with finely sized wheat straw could serve as an efficient approach to enhance plant growth in areas with limited water resources (28).

Effects of soil breeding and soil amendments on growth and yield of rice

The experiments involving soil breeding with heavy clay, coarse sand, and soil amendments resulted in increased plant height, productive tillers, rice grain yield, and straw yield (Table 4 and Fig. 2). The treatment FYM (@12.5 t ha^{-1}) + clay (@100.0 t ha^{-1}) + coarse sand (@ 100.0 t ha^{-1}) resulted in the highest growth and yield attributes for rice, including plant height (94.26 cm), productive tillers (16.53), rice grain (3.981 t ha^{-1}), and straw yield (5.250 t ha^{-1}).

Table 3. Effect of soil breeding and soil amendments on soil aggregates at various depths

S.No	Treatments details	Mean weight Diameter (MWD) (mm)			Grand mean Diameter (MWD) (mm)			Percentage of micro aggregates (<0.25m)			Percentage of macro aggregates (>0.25m)		
		0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm	0-10 cm	10-20 cm	20-30 cm
T_1	Control	0.385	0.307	0.211	0.334	0.411	0.335	80.25	84.5	87.55	19.75	15.5	12.45
T_2	FYM @ 12.5 t ha^{-1}	0.785	0.381	0.269	0.574	0.478	0.381	65.5	73.5	80.1	34.5	26.5	19.9
T_3	Clay @ 50.0 t ha^{-1}	0.641	0.25	0.214	0.43	0.349	0.345	66.3	76.6	79.2	33.7	23.4	20.8
T_4	Clay@100.0 t ha^{-1}	0.781	0.384	0.271	0.57	0.481	0.382	67.55	77.75	83	32.45	22.25	17
T_5	Coarse sand @ 50.0 t ha^{-1}	0.652	0.264	0.24	0.441	0.355	0.364	71.4	75.8	85.25	28.6	24.2	14.75
T_6	Coarse sand @100.0 t ha^{-1}	0.621	0.392	0.28	0.412	0.49	0.389	72.4	74.55	83	27.6	25.45	17
T_7	FYM @12.5 t + Clay @ 50.0 t + Coarse sand @ 50.0 t ha^{-1}	0.652	0.264	0.24	0.445	0.363	0.365	68.05	74.1	80.6	31.95	25.9	19.4
T_8	FYM @12.5 t+Clay @100.0 t + Coarse sand @ 100.0 t ha^{-1}	0.792	0.396	0.287	0.582	0.494	0.412	69.6	74.6	81.45	30.4	25.4	18.55
T_9	Lime (as per Lime Requirement- 4.8 t ha^{-1})	0.4	0.31	0.218	0.348	0.415	0.323	78.25	81.6	85.75	21.75	18.4	14.25
S. Ed		0.016	0.007	0.006	0.011	0.01	0.01	1.767	1.912	2.073	0.74	0.587	0.427
CD (p=0.05)		0.035	0.015	0.014	0.024	0.021	0.021	3.747	4.053	4.394	1.57	1.245	0.905

Table 4. Effect of soil amendments on rice growth, yield attributes, and economics

S.No.	Treatment details	Plant height (cm)				Productive tillers (Nos. hill^{-1})				B:C ratio
		2021	2022	2023	Mean	2021	2022	2023	Mean	
T_1	Control	72.60	86.31	90.25	83.05	15.00	6.67	10.62	10.76	1.34
T_2	FYM @ 12.5 t ha^{-1}	76.20	94.33	95.61	88.71	17.33	9.00	14.75	13.69	1.40
T_3	Clay @ 50.0 t ha^{-1}	78.60	92.13	101.44	90.72	18.00	9.00	14.50	13.83	1.31
T_4	Clay@100.0 t ha^{-1}	75.47	95.06	96.52	89.02	17.33	9.53	15.00	13.95	1.29
T_5	Coarse sand @ 50.0 t ha^{-1}	77.20	90.31	97.46	88.32	16.33	8.66	14.80	13.26	1.28
T_6	Coarse sand @100.0 t ha^{-1}	79.47	91.33	94.51	88.44	16.67	10.00	16.75	14.47	1.30
T_7	FYM @12.5 t + Clay @ 50.0 t + Coarse sand @ 50.0 t ha^{-1}	80.93	94.27	106.20	93.80	18.00	10.33	21.04	16.46	1.66
T_8	FYM @12.5 t + Clay @100.0 t + Coarse sand @ 100.0 t ha^{-1}	78.20	95.46	109.12	94.26	18.67	11.66	19.25	16.53	1.41
T_9	Lime (as per Lime Requirement- 4.8 t ha^{-1})	74.67	92.66	94.25	87.19	16.33	8.90	16.25	13.83	1.55
S. Ed		-	-	-	2.12	-	-	-	0.22	1.34
CD (p=0.05)		-	-	-	4.48	-	-	-	0.48	1.40

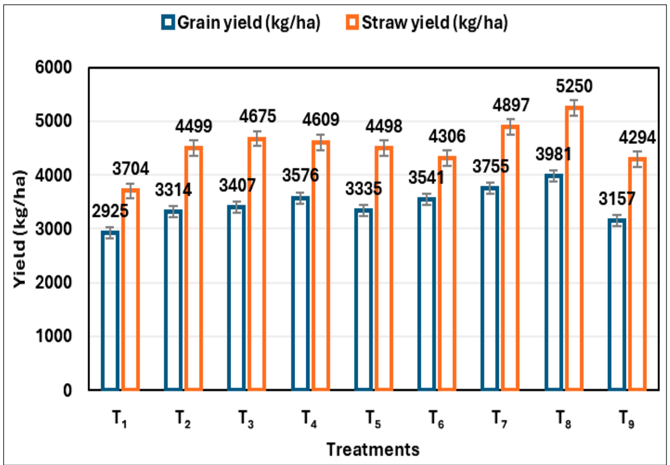

Fig. 2. Effect of soil amendments on rice yield.

This treatment was comparable to FYM (@12.5 t ha^{-1}) + clay (@50.0 t ha^{-1}) + coarse sand (@50.0 t ha^{-1}), which also showed significant growth and yield attributes, such as plant height (93.80 cm), number of productive tillers (16.46), mean rice grain yield (3.755 t ha^{-1}), and straw yield (4.897 t ha^{-1}). The grain yield was 28.00% higher than that of the control (Fig. 2). The control treatment without any soil amendments exhibited the lowest growth and yield attributes for rice, including plant height (83.05 cm), number of productive tillers (10.76), mean rice grain yield (2.925 t ha^{-1}), and straw yield (3.704 t ha^{-1}). Furthermore, the treatment FYM (@12.5 t ha^{-1}) + clay (@50.0 t ha^{-1}) + coarse sand (@50.0 t ha^{-1}) showed the highest B:C ratio of 1:1.66, while the control had the lowest B:C ratio of 1:1.28. The lime requirement treatment Lime (4.8 t ha^{-1}) had registered the rice growth, yield attributes *viz.*, plant height (87.19 cm) and productive tillers (13.83 no.s), rice yield (3.157 t ha^{-1}), which was 8.0% higher over control, and a straw yield (4.294 t ha^{-1}). Soil breeding with amendments strongly influenced crop growth and subsequently, the yield of rice, which might be due to the favorable influence of these practices on soil properties. The increase in yield resulting from the addition of clay and coarse river sand might be due to an increase in soil properties, which ultimately promoted crop growth and yield (4, 29, 30).

Conclusion

The current soil breeding experiment utilized various soil amendments, including heavy clay, coarse river sand, and FYM, either individually or in combination, to address soil physical limitations. Based on the results, it is recommended that a combination of FYM (12.5 t ha^{-1}), clay (50.0 t ha^{-1}), and coarse sand (50.0 t ha^{-1}) can be used to significantly reduce soil bulk density and improve soil pore space, infiltration rate, and hydraulic conductivity in soils with severe physical constraints. According to the expreimental results, this approach can also lead to enhanced rice yield and profitability of farmers. These results will act as an essential resource for upcoming studies and farming methods aimed at enhancing the crop's effectiveness.

Acknowledgements

The authors are grateful to the Tamil Nadu Agricultural University and Agricultural College and Research Institute, Tanjore District in Tamil Nadu, India for providing financial support and lab facilities.

Authors' contributions

SM carried out the field trial and research work, VD and VK helped and participated in editing, KV, DJ, KP, ST, DP and RN remaining authors suggested the final editing and suggestions for the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare no conflicts of interest relevant to this article

Ethical issues: None

References

1. Wang L, Zhang Q, Niu XW, Yang ZP , Zhang JJ. Effects of different land uses on soil physical and chemical properties in the Loess Plateau of Shanxi Province. Chin J Ecol Agric. 2007;15:53-56.

2. Indoria AK, Sharma KL, Sammi RK, Srinivasa RC. Role of soil physical properties in soil health management and crop productivity in rainfed systems-I: Soil physical constraints and scope. Curr Sci. 2016;3:320-28. https://doi.org/10.18520/cs/v110/i3/320-328

3. Ben-Hur M. Seal formation effects on soil infiltration and run-off in arid and semiarid regions under rainfall and sprinkler irrigation conditions. In: Zerein F, Jaescheke W, editors. Climate changes and water resources in the Middle East and North Africa. New York: Springer Verlag; 2008:429-52 https://doi.org/10.1007/978-3-540-85047-2_26

4. Seble G, Wubayehu K. Soil acidity and its managements: A review. International J Adv Res Biol Sci. 2021;8(3):70-79.

5. Alen M, Courage B, Jephita G, Lawrence M, Emmanuel C. Characteristics and management options of crusting soils in a smallholder farming area of the Zambezi metamorphic belt in northern Zimbabwe. S Afr J Plant Soil. 2015;32(3):157-64. https://doi.org/10.1080/02571862.2015.1018355

6. Kabango F, John B, Onesimus S, Lenssen AW, Majaliwa MJG, Stewart K. Effect of applying low rates of agricultural lime and chicken manure on selected soil properties on Ferralsols of Lake Victoria Agro-Ecological Zone, Uganda. J Agric Chem Environ. 2022;11:240-57. https://doi.org/10.4236/jacen.2022.114017

7. Anderson GC, Pathan S, Easton J, Hall DJM, Sharma R. Short-and long-term effects of lime and gypsum application on acid soils in a water-limited environment: 1. Grain yield response and nutrient concentration. Agronomy. 2020;10:1-15. https://doi.org/10.3390/agronomy10081213

8. Elio CJ, Affonso CG Jr, Edleusa PS, Guilherme LZ, Juliano Z, Vinícius HDO, et al. Effects of liming on soil physical attributes: A review. J Agric Sci. 2020;12:278-86. https://doi.org/10.5539/jas.v12n10p278

9. Riberiya ST, Petra M. Clay addition to sandy soil-influence of clay type and size on nutrient availability in sandy soils amended with residues differing in C/N ratio. Pedosphere. 2017;27(2):293-305. https://doi.org/10.1016/S1002-0160(17)60317-5

10. Li Y, Xu H, Li B, Li Y, Dua X, Sun Y, et al. Soil addition improves multifunctionality of degraded grasslands through increasing fungal richness and network complexity. Geoderma. 2023;437:116607. https://doi.org/10.1016/j.geoderma.2023.116607

11. Hall DJM, Davies SL, Bell RW, Edwards TJ. Soil management systems to overcome multiple constraints for dryland crops on deep sands in a water limited environment on the South coast of western Australia. Agronomy. 2020;10:1881. https://doi.org/10.3390/agronomy10121881

12. Hao YH, Ye TQ, Han BP, Xiang JW, Zhu F, Ni CF. The fracture zone of the aquifer is imaged by hydraulic tomography. *Hydrogeology* and *Engineering Geology.* 2008;35(6):6e11.

13. Kemper WD, Rosenau RC. Aggreagate stability and size distribution. In: Klute A, editors. Methods of soil analysis. Part I. Physical and mineralogical methods. Agronomy Monograph.1986;9:425-42. https://doi.org/10.2136/sssabookser5.1.2ed.c17

14. Oades JM, Waters AG. Aggregate hierarchy in soils. Aust J Soil Res. 1991;29:815–28. https://doi.org/10.1071/SR9910815

15. Panse VG, Sukhatme PV. Statistical method for agricultural workers, ICAR New Delhi, India. 1978:145.

16. Opeyemi AO, Adewunmi BI, Oluwaseyi AI. Physical and chemical properties of soils in gambari forest reserve near Ibadan, South western Nigeria. J Bioresour Manag. 2020;7. https://doi.org/10.35691/JBM.0202.0132

17. Panos P, Daniele DR, Leonidas L, Maeva L, Pasquale B, Cristiano B. Soil bulk density assessment in Europe. Agric Ecosyst Environ. 2024;364:108907. https://doi.org/10.1016/j.agee.2024.108907.

18. Rao CS, Rao V, Chary K, Vittal GR, Sahrawat KPR, Sumanta K. Water retention characteristics of various soil types under diverse rainfed production systems of India. Indian J Dryland Agric Res Dev. 2009;24:1-7. http://oar.icrisat.org/id/eprint/408

19. Shermeen T, Petra M. Clay addition to sandy soil reduces nutrient leaching-effect of clay concentration and ped size. Commun Soil Sci Plant Anal. 48(15):1813-21. https://doi.org/10.1080/00103624.2017.1395454

20. Rezacova V, Czakó A, Stehlík M. Organic fertilization improves soil aggregation through increases in abundance of eubacteria and products of arbuscular mycorrhizal fungi. Sci Rep. 2021;11:12548. https://doi.org/10.1038/s41598-021-91653-x

21. Zhao Z, Mao Y, Gao S. Organic carbon accumulation and aggregate formation in soils under organic and inorganic fertilizer management practices in a rice–wheat cropping system. Sci Rep. 2023;13:3665. https://doi.org/10.1038/s41598-023-30541-y

22. Yang C, Upendra MS, Chao L, Xin F, Fazhu Z, Jun W. Long-term chemical and organic fertilization differently affect soil aggregates and associated carbon and nitrogen in the loess plateau of China. *Agronomy.* 2023;13,6:1466. https://doi.org/10.3390/agronomy13061466

23. Abdalla K, Gaiser T, Seidel SJ, Pausch J. Soil organic carbon and nitrogen in aggregates in response to over seven decades of farm yard manure application. J Plant Nutr Soil Sci. 2023;186:253-58. https://doi.org/10.1002/jpln.202300062.

24. Rieke EL, Bagnall DK, Morgan CLS, Flynn KD, Howe JA, Greub KLH, et al. Evaluation of aggregate stability methods for soil health. Geoderma. 2022;428:116156. https://doi.org/10.1016/j.geoderma.2022.116156.

25. Riaz M, Marschner P. Sandy soil amended with clay soil: Effect of clay soil properties on soil respiration, microbial biomass and water extractable organic. Can J Soil Sci Plant Nutr. 2020;20:2465-70. https://doi.org/10.1007/s42729-020-00312-z

26. Zhao Y, Chen Y, Dai H, Cui J, Wang L, Sui P. Effects of organic amendments on the improvement of soil nutrients and crop yield in sandy soils during a 4-year field experiment in Huang-Huai-Hai Plain, northern China. Agronomy. 2021;11:157. https://doi.org/10.3390/agronomy11010157

27. Zhang H, Guo Z, Li J, Lu Y, Xu Y. Improvement of aeolian sandy soil in Mu Us, China with soft montmorillonite clay stone. Agron J. 2021;113:820-28. https://doi.org/10.1002/agj2.20492

28. Alghamdi AG, Majrashi MA, Ibrahim HM. Improving the physical properties and water retention of sandy soils by the synergistic utilization of natural clay deposits and wheat straw. Sustainability. 2024;16:46. https://doi.org/10.3390/su16010046

29. Welyou M, Kemal A, Isreal Z. Review on role of lime on soil acidity and soil chemical properties. JoCC. 2021;8:33-41. https://doi.org/10.37591/JoCC

30. Oliver YM, Gazey C, Fisher J. Dissection of the contributing factors to the variable response of crop yield to surface applied lime in Australia. Agronomy. 2021;11:829. https://doi.org/10.3390/agronomy11050829