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Comparative study on the impact of long-term fertilizer application on soil aggregate stability in inceptisol soils under rice-rice and finger millet-maize cropping systems

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Abstract
Integrated nutrient management (INM) is widely recognized as a valuable approach to ensure sustainable crop productivity while preserving soil fertility. The incorporation of organic manures into the soil has been shown to enhance soil characteristics and improve nutrient availability. In the 2020-21 agricultural year, soil samples were collected from the long-term fertilizer experiments conducted at the Regional Agricultural Research Station in Jagtial and the research farm of TNAU in Coimbatore. The samples represented six common treatment combinations involving chemical fertilizers and farmyard manure (FYM). The experimental design followed a randomized block design (RBD). The study aimed to investigate the impact of INM on the mean weight diameter (MWD) of soils under the rice-rice and finger millet-maize cropping systems. The long-term application of manure and fertilizer under the two different cropping systems in Jagtial and Coimbatore had a significant influence on the mean weight diameter of the soils. The MWD values ranged from 1.16 to 1.71 mm in Jagtial and from 0.56 to 1.07 mm in Coimbatore. Similarly, in the subsurface layer, the MWD varied from 0.73 to 1.31 mm in Jagtial and from 0.51 to 0.87 mm in Coimbatore. The experimental findings indicated that, in both cropping systems, the application of the 100% NPK+FYM treatment yielded the highest MWD values, indicating improved soil aggregate stability.

Keywords: Integrated nutrient management, organic, inorganic, mean weight diameter and cropping system

Introduction
Long-term fertilizer experiments (LTFE) have played a crucial role in advancing our understanding of nutrient management and sustainable agricultural practices in India. One notable cropping system in India is the rice-rice system, which possesses unique characteristics that differentiate it from other systems. In this system, rice fields are consistently irrigated or flooded throughout the entire growth period, capitalizing on rice's natural adaptation to waterlogged conditions. This flooding not only helps control weeds but also creates an ideal environment for rice plants to thrive. Additionally, the rice-rice system allows farmers to benefit from residual fertility and nutrient availability in the soil after the first rice crop, reducing the need for additional fertilizer application and maximizing resource efficiency. To enhance productivity and yield stability in the rice-rice system, various fertilizer treatments, including organic and inorganic sources, at different rates and combinations have been applied. The integrated use of organic manures and fertilizers has shown promise in maintaining higher productivity and achieving greater yield stability (Nambiar and Abrol, 1989) [8]. Another, significant cropping system observed in regions like Coimbatore is the Finger Millet-Maize system. This system involves the sequential cultivation of finger millet (*Eleusine coracana*) followed by maize (*Zea mays*). It is chosen based on the suitability of the climate, soil conditions, and the complementary growth requirements and yield potential of these crops. Finger millet, also known as ragi, is a resilient cereal crop well-adapted to diverse agro-climatic conditions, including marginal lands. It exhibits tolerance to drought, pests, and diseases. On the other hand, maize is a high-yielding cereal crop that requires relatively higher nutrient inputs and optimal growing conditions. By combining these two crops in a sequential cropping system, farmers can maximize resource utilization and diversify their crop production, thereby enhancing overall agricultural sustainability.

Material and Methods

The study encompassed long-term fertilizer experiments conducted in two distinct locations: Jagtial and Coimbatore. Each location was chosen based on its specific soil taxonomic class and the cropping system under investigation. Jagtial featured Typic Tropaquept soil and focused on studying the rice-rice cropping system. Coimbatore exhibited Vertic Ustopept soil and centered its research on the finger millet-maize cropping system. These locations and cropping systems were selected to provide a comprehensive understanding of the effects of long-term fertilizer application in different soil and agricultural contexts. A Randomized Block Design was employed to investigate the effects of Long-Term Fertilizer Experiment (LTFE) on six different cropping systems. The study focused on six common treatments, each with specific details: T_1: Control treatment, T_2: 100% nitrogen (N) application, T_3: 100% nitrogen-phosphorus (NP) application, T_4: 100% nitrogen-phosphorus-potassium (NPK) application, T_5: 150% nitrogen-phosphorus-potassium (NPK) application, T_6: 100% nitrogen-phosphorus-potassium (NPK) application along with 5 tons per hectare of farmyard manure (FYM). Soil samples were collected at two depths 0-20 and 20-40 cm from predetermined plots in the AICRP-LTFE experiments conducted in Jagtial and Coimbatore. The mean weight diameter of the soil was assessed using Yoder's apparatus method, as outlined in the study conducted by Kemper and Rosenau in 1986. The data obtained from the experiment were analyzed for analysis of variance (ANOVA) and the difference between treatment means was tested for their statistical significance with appropriate critical difference (CD) at 5% level of probability (Gomez and Gomez, 1984).

Result and Discussion

The mean weight diameter (MWD) of soil at both surface and subsurface depths was significantly influenced by different nutrient application treatments. The long-term application of manure and fertilizer under two different cropping systems in Jagtial and Coimbatore had a notable impact on the mean weight diameter of soils. Specifically, at the surface depth, the MWD ranged from 1.16 to 1.71 mm at Jagtial, and 0.56 to 1.07 mm at Coimbatore. Similarly, at the subsurface layer, the MWD varied from 0.73 to 1.31 mm at Jagtial, and 0.51 to 0.87 mm at Coimbatore. In both cropping systems, the application of 100% NPK+FYM treatment resulted in the highest mean weight diameter (MWD) values, indicating improved aggregate stability. On the other hand, the control treatment exhibited the lowest MWD values at both 0-20 cm and 20-40 cm soil depths. The ranking of treatments based on MWD was as follows: 100% NPK+FYM > 150% NPK > 100% NPK > 100% NP > 100% N > control.

The application of 100% NPK+FYM treatment resulted in a significant increase over all the treatments in the mean weight diameter (MWD) of soil aggregates in both the cropping systems and at both 0-20 cm and 20-40 cm soil depths. This indicates improved aggregate stability in the presence of balanced fertilization and organic manuring. In contrast, the control treatment exhibited smaller MWD values, indicating poorer aggregate stability. The observed increase in MWD in the 100% NPK+FYM treatment can be attributed to the binding capability of organic carbon and carbonates, which promote larger soil aggregation. In general, the mean weight diameter (MWD) of soil aggregates exhibited a decrease with increasing depth, indicating that surface soil had higher MWD values compared to subsurface soil in all treatments. This can be attributed to the higher organic content and secretion of organic acids in the surface soil, promoting better aggregate stability. This observation is consistent with the findings reported by Aulakh *et al.* (2013) [1].

The imbalanced fertilized treatments (100% N, 100% NP) resulted in a significant increase in MWD compared to the control treatment under both cropping systems. Similar trends were observed at the 20-40 cm depth. Additionally, the application of 100% NPK resulted in a significant increase in MWD compared to imbalanced fertilized treatments (100% N, 100% NP) and control under rice-rice cropping systems at the surface soil depth and at par at sub surface. However, a non-significant increase in MWD was observed for finger millet-maize systems at both depths over 100% NP. The addition of an extra 50% recommended dose of fertilizer (RDF) led to a continued significant increase in MWD under both cropping systems at the 0-20 and 20-40 cm soil depth. The highest percentage increase in mean weight diameter at the surface soil was observed in the 100% NPK+FYM treatment compared to the control treatment under the finger millet-maize cropping system compared to the rice-rice cropping systems. Similarly, at the subsurface soil, the highest percentage increase in MWD was recorded in the 100% NPK+FYM treatment compared to the control treatment under rice-rice compared to finger millet-maize cropping systems.

Table 1: Long-term effect of manuring and fertilization under rice-rice and finger millet-maize cropping systems on the mean weight diameter of soils

MWD 0-20 cm		
Location & cropping system Treatments	**Jagtial (Rice-Rice)**	**Coimbatore (Finger millet-Maize)**
Control	1.16	0.56
100% N	1.35	0.66
100% NP	1.39	0.70
100% NPK	1.48	0.71
150% NPK	1.59	0.76
100% NPK+FYM	1.71	1.07
SE m ±	0.02	0.01
CD at 5%	0.04	0.03
MWD 20-40 cm		
Location & cropping system Treatments	**Jagtial (Rice-Rice)**	**Coimbatore (Finger millet-Maize)**
Control	0.73	0.51
100% N	0.91	0.56
100% NP	0.96	0.61
100% NPK	1.03	0.64
150% NPK	1.16	0.70
100% NPK+FYM	1.31	0.87
SE m ±	0.03	0.01
CD at 5%	0.11	0.04

The increase in mean weight diameter (MWD) observed in plots where integrated nutrient management was applied can be attributed to the basal application of farmyard manure (FYM). This application significantly improved soil aggregation, leading to higher MWD values. The improvement in soil physical condition and increased organic carbon content due to FYM and inorganic fertilizer

application are responsible for the stabilization of aggregates and the subsequent increase in MWD (Selvi *et al.*, 2005; Hati *et al.*, 2007) [9, 6]. This finding aligns with the results reported by Bandyopadhyay *et al.* (2010) [2]. Organic matter plays a vital role in stabilizing aggregates by forming and strengthening bonds among quartz particles and clay domains (Bhattacharyya *et al.*, 2009; Chakraborthy *et al.*, 2010) [3, 4].

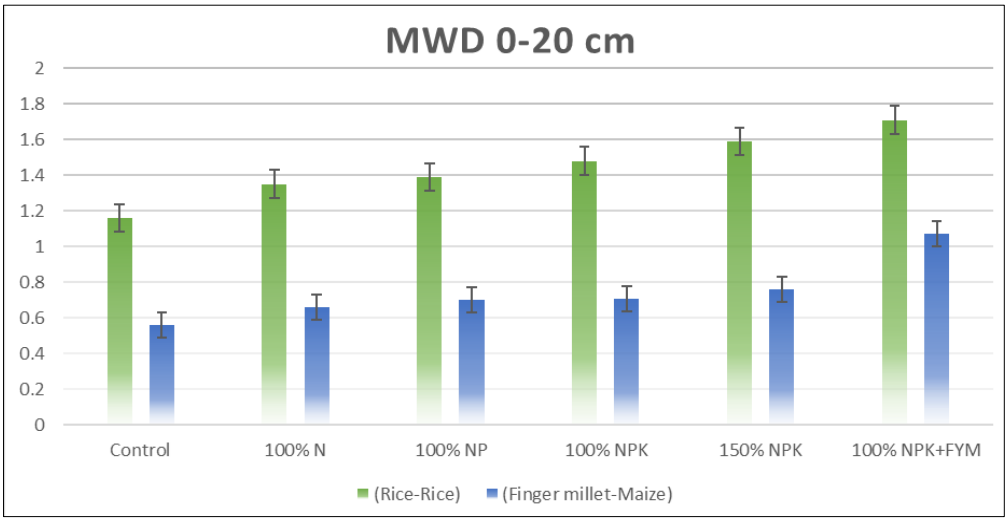

Fig 1: Long-term effect of manuring and fertilization under rice-rice and finger millet-maize cropping systems on the mean weight diameter of soils (0-20 cm)

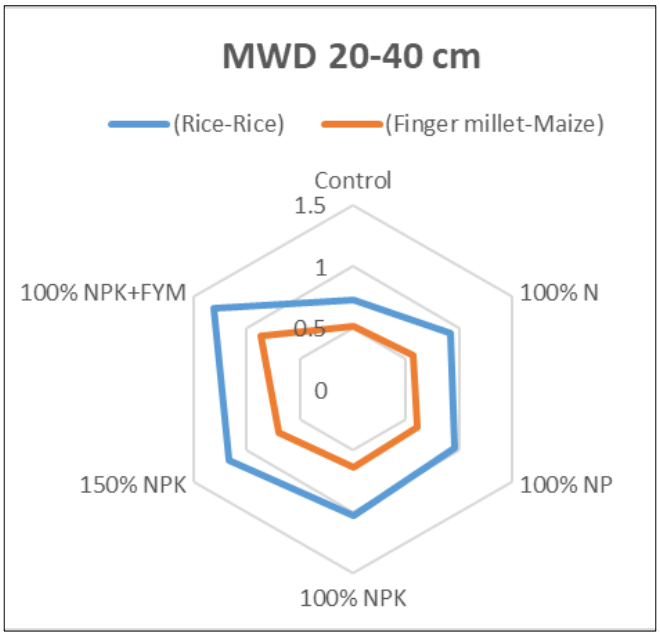

Fig 2: Long-term effect of manuring and fertilization under rice-rice and finger millet-maize cropping systems on the mean weight diameter of soils (20-40 cm)

Conclusion

Based on the findings of the above investigation it may be concluded that the application of balanced fertilization and organic manuring, particularly the treatment of 100% NPK+FYM, significantly improved the mean weight diameter (MWD) of soil aggregates in rice-rice and finger millet-maize cropping systems and at both soil depths. This indicates enhanced aggregate stability and soil physical properties.

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