

Changes in soil physical properties and organic carbon status at the topsoil horizon of a vertisol of central India after 28 years of continuous cropping, fertilization and manuring

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Abstract

Balanced application of inorganic fertilizer and organic amendments greatly influence the accumulation of organic matter in soil and also influence the soil physical environment. An investigation was carried out to study the long-term impact of fertilizer and manure application in a soybean–wheat–maize (fodder) crop rotation on soil organic carbon status and physical properties of a vertisol (Typic Haplustert or Pellic Vertisols) in sub-humid sub-tropical India. Five treatments namely, control (no fertilizer and manure), 100% of the optimum rate for nitrogen (100% N), 50% of the optimum rate for nitrogen, phosphorus and potassium (50% NPK), 100% of the optimum rate for NPK (100% NPK) and 100% NPK + farmyard manure at 15 Mg ha⁻¹ (100% NPK + FYM) from a long-term fertilizer experiment continuing at Jabalpur, India, were chosen for this study. Soil samples were collected from the topsoil horizon (0–15 cm) of all the four replications of the selected five treatments in April 2000 after 28 crop cycles and analyzed for physical and chemical properties. The results showed that the soil organic carbon (SOC) content in 100% NPK and 100% NPK + FYM treatments increased, respectively, by 22.5 and 56.3% over the initial level (1.14 kg m⁻²). The electrical conductivity, SOC content, aggregation, water retention, microporosity and available water capacity of the soil were increased while the bulk density was reduced significantly with the 100% NPK + FYM treatment over all other treatments. However, the use of imbalanced (100% N) and suboptimal rate of inorganic fertilizer (50% NPK) as compared to the unfertilized control showed no significant effect on the physical properties of the soil. The study indicates that application of balanced rate of fertilizers in combination with organic manure could sequester soil organic carbon in the surface layer, improve the soil physical environment and sustain higher crop productivity under this intensive cropping system.

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1. Introduction

Introduction of inorganic fertilizers along with the entry of high yielding and fertilizer responsive cultivars have largely replaced traditional practices, such as recycling of organic materials and application of organic manures in India. This has raised concerns about the potential long-

term adverse impacts on soil productivity and environmental quality, particularly in systems where imbalanced fertilization is practiced over a long period. Higher rate of subsidy on nitrogenous fertilizers artificially reduced their cost compared to P and K fertilizers in India, which encouraged farmers to use only nitrogenous fertilizers in many parts of the country. Besides this, the poor and marginal farmers often use suboptimal rates of NPK fertilizers due to scarcity of resources available to them (Nambiar and Abrol, 1989). In long-term fertility experiments in India, decline in soil organic matter is generally

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implicated as one of the causes for yield stagnation, particularly where N is the only fertilizer, irrespective of cropping system and soil type (Swarup et al., 2000). This eventually leads to deterioration of soil aggregation and net release of carbon from agricultural field to atmosphere. Losses and gains of soil organic matter could be influenced by land management practices such as cropping frequency, tillage, fertilizer application, manure application and also by cultivation of perennial legumes and grasses (Manna et al., 2005). Reports have indicated that loss of organic matter is generally associated with decline in soil porosity and wet aggregate stability and an increase in soil strength indices like bulk density (Dormaar, 1979; Skidmore et al., 1986). Maintenance of optimum soil physical conditions is an important component of soil fertility management. Breakdown of soil aggregates, and attendant poor soil structural condition, often restricts crop root growth and consequently limit their ability to explore the soil profile for water and nutrient (Haynes and Naidu, 1998). Organic matter affects crop growth and yield, either directly by supplying nutrients, or indirectly by modifying soil physical properties that can improve the root environment and stimulate plant growth (Kononova, 1961). Soil physical degradation is often associated with a decline in the organic matter content. However, the relation of organic matter to soil physical properties is not always clearly defined (Darwish et al., 1995). Mbagwu and Bazzoffi (1989) reported that organic carbon could account for about 70–90% of the variability of soil aggregate stability of a clay loam soil. On a silt loam soil, Pikul et al. (1993) found a significant correlation of bulk density and organic carbon with cone index. However, Mulla et al. (1992) could not establish a relation between the organic matter and physical properties of a silt loam soil under conventional and alternative farming.

In the face of regional energy crisis, increase in the cost of fertilizers and growing concern about deterioration of soil health and environmental quality, recycling of organic material is gaining significance in India. However, its availability is limited because of other competitive uses like fuel and fodder purposes. Under this situation integrated use of both organic manures and chemical fertilizers has emerged as a promising option not only for maintaining higher productivity but also for providing maximum stability to crop production in intensive farming systems (Swarup, 1998). Since soil fertility management practices may influence soil physical environment, it is important to determine the effect of manure and fertilizer application on soil physical properties such as aggregation, porosity, bulk density and water holding capacity. Most of the studies in the past evaluated only the short-term effects of separately applied organic matter on soil properties. In deed, little is known about the long-term impact of intensive cropping with chemical fertilization and organic manuring on soil physical properties particularly for high clay soil (Nambiar and Abrol, 1989). Long-term experiments provide the best

possible means for studying changes in soil properties and processes and thus, for obtaining valuable information required for formulating future strategies for maintaining soil health.

Against this background, the present study was undertaken to quantify the long-term changes in soil organic carbon, aggregation, porosity and water holding capacity of a vertisol as a result of continuous intensive cropping with different soil fertility management practices.

2. Materials and methods

2.1. Experimental site

A long-term fertilizer experiment continuing since 1972 at the experimental farm of the Jawaharlal Nehru Agricultural University, Jabalpur, India (23°12'N, 79°57'E and 393 m above mean sea level) was chosen for this study. This experiment has been under the supervision of the All India Co-ordinated Research Project on Long-term Fertilizer Experiments (AICRP-LTFE) of the Indian Council of Agricultural Research. The soil of the experimental site is clayey in texture with a cation exchange capacity of 46 cmol_c kg⁻¹ and is classified as Typic Haplustert (Pellic Vertisols). The clay content varied between 60.4 and 57.3%, while sand content ranged from 13.3 to 15.9%.

The experiment was continued with an annual three crop rotation of soybean (*Glycine max* L.), wheat (*Triticum aestivum* L.) and fodder maize (*Zea mays* L.) up to 1994. In the rotation, soybean was grown as a rainfed crop in the rainy season (June–September). Wheat was grown in the winter season (December–March) with three irrigations applied during crown root initiation, maximum tillering and flowering stage of the crop, while fodder maize was grown in the summer seasons (April–June) with one or two irrigations based on the crops need. Fodder maize was harvested at about 65 days after sowing. After 1994, fodder maize was discontinued due to the unavailability of irrigation water during the summer season and only a two crop soybean–wheat rotation has been continuing since then. Conventional tillage practices (two preparatory tillage operations by duck-foot cultivator) were applied to each crop for preparation of seed beds. Recommended weed control and plant protection measures were adopted in all the crops throughout the period of experimentation. The climate of the experimental site is sub-tropical sub-humid, with dry hot summer and cold winters. The mean monthly minimum temperature varies from 9.8° in January to 26.4 °C in May and monthly mean maximum temperatures varies from 26.1 °C in January to 41.9 °C in May, with wide diurnal variations. The average annual precipitation is about 1253 mm of which more than 80% is normally received during the rainy season (June–September). The experiment was laid out in a randomized block design with ten

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