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Origin, Properties, and Taxonomic Classification of Black Soils: A Comprehensive Overview

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Introduction

Black soils, also known as Regur soils or cotton soils, are characterized by their dark color and unique physical properties. When dry, these soils become extremely hard, and when wet, they become sticky and plastic in nature. They are primarily found in regions with monsoonal climates, and the name "black cotton soil" comes from their historical association with cotton cultivation. These soils, taxonomically classified as Vertisols, cover approximately 74 million hectares in India and are commonly found in states such as Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh, and Karnataka.

Black soils are considered highly productive, particularly under dryland farming as well as irrigated conditions. These soils are primarily derived from the weathering of basalt, granite, gneiss, and schist. They are rich in smectite, a type of clay mineral, and are typically neutral to alkaline in reaction, with high cation exchange capacity (CEC), dominated by calcium (Ca^{++}), magnesium (Mg^{++}), and sodium (Na^{+}). Due to the swelling and shrinking behavior of smectite clay minerals, these soils exhibit the formation of deep cracks, slickensides (polished soil faces), and gilgai microrelief, particularly in areas with seasonal wet and dry conditions.

Managing black soils can be challenging due to their susceptibility to erosion, low infiltration rates, and poor drainage under irrigation. A deep understanding of these soils' physical, chemical, and biological properties is essential to improve their management and optimize their agricultural potential.

Pedogenic models of vertisols

The formation of Vertisols can be explained by several pedogenic models, including the pedoturbation model, soil mechanics model, and differential loading model. The first two models are generally regarded as the most relevant for explaining Vertisol formation.

As the soil dries, particularly clayey soils rich in 2:1 smectitic minerals, surface cracks develop due to shrinkage. These cracks act as zones of weakness, and with recurring wetting and drying cycles, they tend to open and close repeatedly. When the cracks open, soil material from the surface falls into them, leading to the growth of wedge-shaped features within the soil. This cyclical drying and wetting cause internal pressures due to the expansion of clay minerals, leading to the formation of slickensides and the eventual development of microrelief, such as gilgai.

The process of internal soil movement, driven by swelling pressures, results in the formation of intersecting shear planes or slickensides, which create wedge-shaped structures within the soil profile. Over time, these features grow in both width and depth, often resulting in visible microtopography on the soil surface, such as circular mounds and linear ridges (gilgai). These characteristics are important for recognizing and understanding the dynamic processes occurring in Vertisolic soils.

Factors influencing black soil formation

Climate

Black soils are typically found in regions with a monsoonal climate, characterized by distinct wet and dry seasons. The annual rainfall range for the formation of black soils is between 300 to 900 mm, though higher rainfall of up to 1270 mm/year has also been recorded in some areas.

Parent Material

Black soils primarily form from the chemical weathering of mafic (basic) igneous rocks, including basalt, gabbro, diabase, and their metamorphic counterparts such as gneiss. They can also form over sedimentary materials like shales and limestones.

Topography

These soils are most commonly found in flat or gently sloping terrains with gradients less than 3%. Black cotton soils are typically located in alluvial plains, where the terrain is nearly level.

Age

Vertisols can be found on geomorphic surfaces as young as 550 years old. Over time, slickensides develop and reach equilibrium with the environment, typically within 100 to 1,000 years after formation.

Major surface characteristics of black soils

1. Gilgai (Microrelief)

The most distinctive surface feature of black soils is the undulating surface with sunk holes and ridges, forming a microrelief called gilgai. These features result from internal soil churning and swelling.

2. Wide and Deep Cracks

Black soils are known for developing deep, wide cracks that extend up to a meter or more in depth, especially during the dry season.

3. Slickensides

The formation of slickensides—polished and striated soil surfaces caused by internal soil movement—is a common feature in black soils, particularly in the subsurface horizons.

Physical properties of black soils

- Texture

Black soils are predominantly clayey, with the surface layer being lighter in texture, becoming increasingly clayey with depth.

- Structure

These soils possess a poor structure that is greatly influenced by water regimes. They typically form angular or blocky structures, which break down into irregular or prismatic shapes.

- Bulk Density

The bulk density of black soils ranges from 1.2 to 1.6 g/cm^3, depending on moisture content and soil depth.

- Clay Mineralogy

Black soils are rich in montmorillonite, a type of smectite clay mineral, which is responsible for their swelling and shrinking behavior.

- Consistency

These soils are hard when dry and very sticky or plastic when wet. This characteristic makes them challenging to manage, especially in areas prone to wetting and drying cycles.

- Water Retention

Black soils have a relatively high water storage capacity, making them suitable for dryland farming.

- Infiltration Rate

These soils have high infiltration rates initially, but as they become wetter, their infiltration rates decrease significantly due to the formation of cracks.

- Swelling and Shrinkage

The clay minerals in black soils cause them to swell when wet and shrink as they dry.

Chemical properties of black soils

- pH

Black soils are typically neutral to alkaline, with a pH range of 7.5 to 8.5. The presence of calcium carbonate (CaCO3) contributes to the higher pH levels.

- Calcium Carbonate ($CaCO_3$)

Black soils are often calcareous, with CaCO3 concentrations ranging from nil to 10% or more in some profiles.

- Cation Exchange Capacity (CEC)

The CEC of black soils varies between 47 and 65 meq/100 g, depending on the clay content. The dominant cations are calcium (Ca^{++}), magnesium (Mg^{++}), and sodium (Na^{+}).

- Organic Matter

Organic carbon content in black soils is generally low, rarely exceeding 1.0% in most Indian black cotton soils.

Soil classification

Based on the morphological, physical, and chemical properties of black soils in the study area, they are classified according to the Soil Taxonomy system (1975). The soils exhibit deep cracks (greater than 1 cm wide) up to 50 cm depth, contain more than 30% clay, and show gilgai microrelief and slickensides. These characteristics place the soils under the order Vertisols, sub-order Usterts, and great-group Chromusterts. The subgroup classification is Udic Chromusterts.

Conclusion

- Black soils display distinct features such as wide, deep cracks, gilgai microrelief, and slickensides in the subsurface.
- Argillipedoturbation is the key pedogenic process responsible for the development of the "vertic" horizon in black soils.
- The structure of black soils is predominantly angular to blocky, and they are clayey in texture.
- The soils have a dark grayish brown to very dark grayish brown color and exhibit a range of bulk densities from 1.2 to 1.6 Mg/m^3.
- The pH of black soils ranges from neutral to alkaline, and their organic carbon content is typically low.
- These soils are highly fertile and suitable for cotton cultivation, but they require careful management due to their swelling and shrinking characteristics and their susceptibility to erosion under certain conditions.

Reference

Gaddi, A, V. and Sarangamath, P, A., 2001, Physical and chemical properties of Vertisols of northern transitional tract of Karnataka. Karnataka J. Agric. Sci., 14(1): (41-46).

Kolhe, A, H., Chandran, P., Ray, S, K., Bhattacharyya, T., Pal, D, K. and Sarkar, D., 2011, Genesis of associated red and black shrink-swell soils of Maharashtra. Clay Research, 30(2): (1-11).

Pulakeshi, H, B., Patil, P, L. and Dasog, G, S., 2014, Characterization and classification of soil resources derived from chlorite schist in northern transition zone of Karnataka. Karnataka J. Agric. Sci., 27(1): (14-21).

Satyavathi, P, L, A. and Suryanarayana Reddy, M., 2003, Characterization and classification of shallow, medium deep and deep red and black soils of northern Telangana zone in Andhra Pradesh. J. Tropical Agril., 41: (23-29).

Srinivasa rao, ch., Subbaiah, G, V. and Tomar, K, P., 1995, Characterization and classification of black soils of Telugu Ganga project area in Nellore district of Andhra Pradesh. Proc. Indian natn. Sci. Acad., 61(3): (191-198).