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The Soils of Madras
Part-II — The Black Soils of Madras

by
Sri. P. K. R. MENON and Dr. A. MARIAKULANDAI
Agricultural College and Research Institute, Coimbatore

Introduction : In the preceding Section (Part-I) the distribution of the different soils in the districts and taluks of the districts was given. The soils were shown as belonging to four categories namely the black, red, alluvial and arenaceous soils. Nothing was said about the nature of each category. In the present and subsequent papers it is proposed to deal with each category in respect of mechanical and chemical composition and Physic-chemical properties.

Although revenue authorities have divided the soils of the State into the categories given above it would be more correct to classify them into (a) black (b) red (c) laterite (d) mixed (e) alluvial (f) saline and alkaline and (g) forest and organic soils according to their nature and properties. In these classes there are various types and the properties of the important types are discussed under each class.

The geological formations of Madras State : The oldest and the most extensive geological formations in Madras State are granites and gneisses of the Archean Period. These can be broadly subdivided into (a) the younger granites and granatoid gneisses and (b) the older gneisses. The granites and gneisses which cover the major portion of the State vary very much in mineralogical and chemical composition. The felspars present in them may be potash felspars, lime or sodalime felspars. The other minerals found in the rocks are quartz, muscovite, biotite, hornblende, augite and others. Accessory minerals found in these rocks vary very much and garnet, apatite, corundum etc. are sometimes met with. Acidic rocks generally give rise to red and sandy soils while basic rocks rich in soda-lime felspars are mainly responsible for the development of black soils.

The other rock formations of any importance in the State are the charnokites which contain hypersthene or enstatite. These occur in Nilgiris and in parts of Salem and Coimbatore districts. Khondolites occur in Northern Circars and along the east coast. Rocks of the Gondawana system are found in parts of the State from Madras to Tanjore. The main rocks of the system are grits,

sandstones, shales and limestones. Loose textured sandstones and pebbles known as Cuddalore formations or Cuddalore sandstones are found in parts of South Arcot and Tanjore districts. Laterite formations derived from various kinds of rocks occur in the West Coast and on the hills and in parts of the East Coast.

Rock formations which can grouped under granites and gneisses give rise to both black and red soils. The rocks responsible for the two soils, however, differ in their chemical composition as can be seen from the following table.

Chemical Analysis of typical rocks giving rise to Black and Red Soils in Madras State:

Heads of analysis	Rocks giving black soil		Rocks giving red soils		
	Trap rock	Hornblende Schist	Red granite	White granite	Mica granite
1. Moisture %	..	2·88	0·33	0·48	..
2. Loss on ignition %	0·07	0·14	..	..	..
3. Silica (SiO_2) %	52·69	50·48	71·37	73·36	72·15
4. Iron Oxide (Fe_2O_3) %	8·05	9·60	3·49	1·92	3 60
5. Alumina (Al_2O_3) %	23·04	20·13	14·54	14·12	14·31
6. Sesquioxides % (R_2O_3)	31·09	29·73	18·03	16·04	17·91
7. Lime (CaO) %	9·43	10·98	1·54	1 40	1·65
8. Magnesia (MgO) %	5·21	4·21	0·42	0 52	0·54
9. Potash (K_2O) %	1·08	0·14	3·83	4·34	4·41
10. Soda (Na_2O) %	2·74	2·23	3·54	3·69	4·21
11. *Silica* Sesquioxide ratio (Molecular)	3·17	3·26	7 24	8·36	7·72

From the above table it is seen that there is a considerable difference in the chemical composition of the rocks giving rise to black and red soils. Black soils originate from basic rocks containing 45–55% of silica while acidic rocks with over 65% of silica are mainly responsible for red soils. The trap and hornblende schist are richer in sesquioxides, lime and magnesia and poorer in Potash than the granites which form red soils. There is a considerable variation in the molecular silica/sesquioxide ratio of the two types. The felspars exist in the trap rock and the hornblende schists mainly as lime and soda–lime felspars while in the three granite types listed above they are present chiefly as alkali felspars (sodium and potassium felspars). It is believed that the nature of the felspars determines the type of soil which is obtained from the rock.

The Black Soil: The total area of black soil in Madras is about 67 lakhs of acres. It is found in all the districts of the State except in Nilgiris, Malabar and South Kanara. The non-occurrence of the of the black soil in these districts is due to the heavy rainfall received there. The black soil area is the greatest in the districts of Ramanathapuram and South Arcot where it forms 61% and 45% respectively of the total cultivable area. The black soil is generally formed under semi-arid conditions with an annual precipitation of 20–40 inches.

The depth of the soil varies considerably. Some are 4 to 5 feet in depth while others are 8 to 15 feet deep. In some places the top soil is black in colour while the lower depths may be grey, light yellow or light brown. The black soil cracks deeply in summer with the result that there is a common saying that the soil ploughs itself. The belief among the ryots is that the wider the cracks the more fertile is the soil. The cracks are some times so deep that it is dangerous for cattle to walk in the field. The power to develop cracks in summer generally possessed by black soils is due to two causes. First of all, the soils vary from clays to heavy clays (containing 30 – 50% and more of clay). Secondly the black soil clay belongs mainly to the montmorillonite group which possesses high expansion on the absorption of water and considerable shrinkage when it becomes dry. The soil has a high molecular silica/sesqui-oxide ratio of 2·7 to 3·5. Its base exchange capacity is high (30 to 70 milliequivalent per 100 gms. of soil) but varies considerably from tract to tract. There is a distinct correlation between the clay content of the soil and its cation exchange capacity, 1% of clay generally accounting for about one milliequivalent of base. The soil has a high lime status and 70 – 80% of the cations in the exchange complex consists of calcium. Free calcium carbonate is generally present in the soil in the form of Kankar and in some profiles the lower depth below 4 feet consist mainly of this constituent with small infiltration of the soil. The black soil may be divided into two classes according as it contains gypsum or not. Where gypsum occurs it is generally found below the third foot and it is always associated with a high concentration of soluble salts particularly sodium and magnesium sulphates. The black soil is generally fertile containing fair amounts of available phosphoric acid and adequate amounts of Potassium and lime. It is deficient in nitrogen. The limiting factor for its cultivation is insufficiency of water.

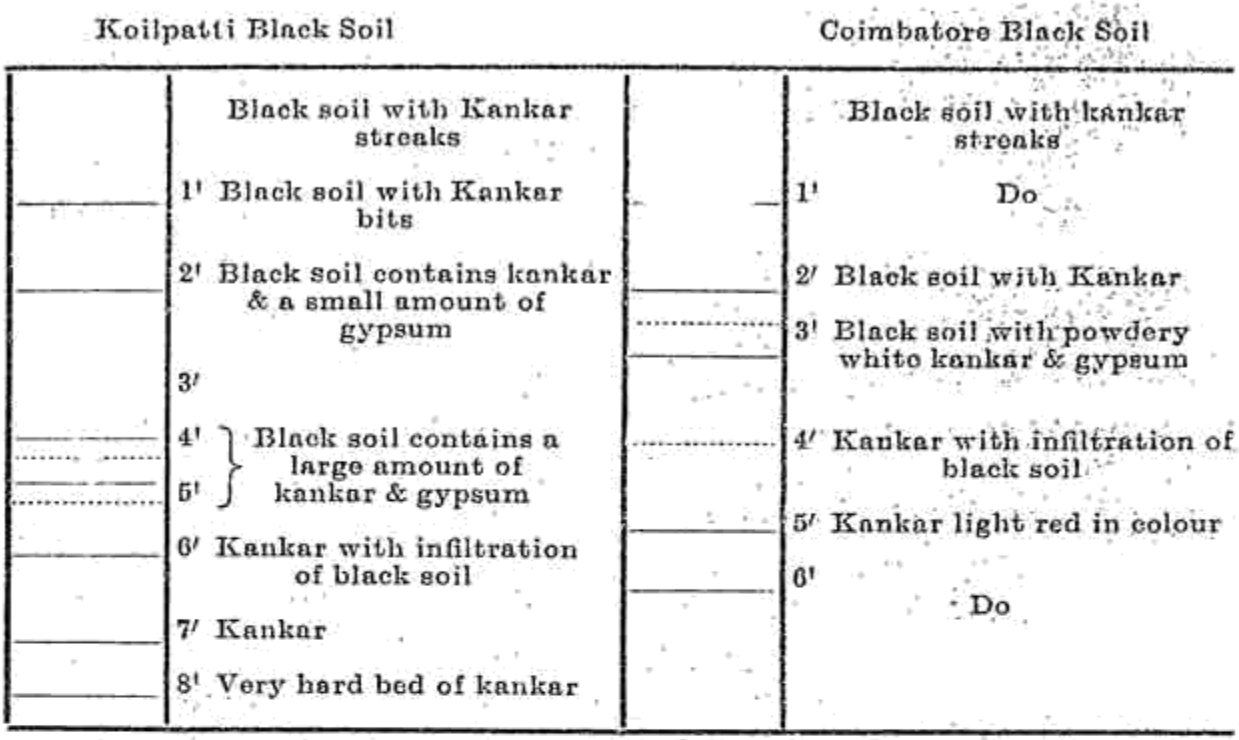
The black soils of Madras are derived from many geological formations such as granites, gneisses, schistose gneisses, chlorite, hornblende schists, traps and Dharwar formations, cretaceous lime stones of Trichinopoly and shales etc.

Colour of Black Soils: There has been much speculation about the colour of the black soil and various theories have been advanced to account for it. Some of these are: (1) the colour is due to the presence of large amounts of organic matter in the soil; (2) a black mineral containing titaniferous iron ore present in the coarse fractions is responsible for the colour; (3) complex humus compounds give the colour to the soil. All these hypotheses have been found to be incorrect or inadequate. The organic matter and humus content are less than 1% and titaniferous minerals, even if present, are not sufficient to give the black colour to the soil. C. Raghavendrachar (2) working at Coimbatore (unpublished records) has given a satisfactory explanation to account for the colour of the soil. He attributes the colour to a very thin coating of a small amount of black calcium humate on the colloidal complex of the soil just as ferric oxides give red and yellow colour to soils. The calcium humate is formed particularly on the surface soil from the decomposition of the organic matter of plant residues in the presence of abundance of lime. In support of this, it has been shown that many of the black soils are black only at the top (where calcium humate forms) and are light grey or dirty white below the surface even when the chemical composition is the same throughout the Profile. So, it is clear that the natural colour of the clay complex is light grey or dirty white and that the calcium humate which is formed on the surface is responsible for the black colour of the soil. A very small quantity of the substance is sufficient for giving the colour as it is present as a thin coating on the colloidal complex. This black coating of calcium humate is resistant to the action of hydrogen peroxide and so the colour of the black soil is not destroyed by boiling with hydrogen peroxide. However, when the combination between calcium and the humic material is broken up by treatment with dilute hydrocholoric acid (N/5) and the soil is then boiled with hydrogen peroxide the black colour disappears and the clay complex assumes its natural light grey or dirty white colour. It is therefore the peculiar combination of humic material with calcium and the coating of the resultant product that is responsible for the colour of the black soil. There is as much (or even more) iron in the black soil as in the red; but in the former it exists mainly as combined iron in the divalent condition as against at least a part as free ferric oxides in the red soil.

Occurrence of Black and Red Soils side by side in Madras State: In many localities in Madras State the black and red soils are found to occur side by side. Many Indian Scientists (4, 5) believe that the two soils have originated from the same kind of rock and the red soils are found at higher elevations and the black soils at lower levels. They also consider that the red soil washed down into the lower topography may change into black soil. Extensive field observations have, however, shown that the black soil does not always occupy a lower topography as compared with the adjacent red soil although in many places it does so. It cannot also be conceived how the red soil with low silica - sesquioxide ratio, base exchange capacity and entirely different mineralogical pattern can change into the black soil. Field observations and laboratory data indicate that both the types of soils are formed from rocks of different mineralogical and chemical composition although the rocks may be classified under the same group such as granites and gneisses. It is possible that different portions of the same rock formation (such as granites and gneisses) give rise to the two types of soil on weathering. Basic rocks rich in soda lime felspar give rise to black soil while granites and gneisses with a preponderance of alkali felspars form the red soil. The occurrence in many places, of the black soil at a lower topography than the red soil may be explained as being due to the greater mobility of montmorillonite clay. The particles of montmorillonite clay are very much smaller than the Kaolinitic clay of red soils. So when black and red soils are formed in a place the black soil clay has a greater tendency to wash down and accumulate in regions of lower topography leaving behind the larger particles of red soil clay.

Properties of the Black Soil: The black soils found in the various districts of the State are not identical. They vary in mechanical composition, base exchange properties and other characteristics. In texture they vary from clays (30% to 50% of clay) to heavy clay (over 50% of clay). For practical purposes the black soils of Madras State may be divided into two main types: (1) the heavier black soil exemplified by the Koilpatti black soil and (2) the lighter type found in Coimbatore. Intermediate between these are several other types differing in mechanical composition and other properties.

Profile Study: The profile characteristics of the two types are indicated diagramatically as below:



In both the profiles the first and second foot of soil are black in colour with Kankar streaks. In the lower depth Kankar is found in abundance. Below 4 feet considerable amounts of Kankar are found with small infiltrations of the soil. At greater depth especially in the Koilpatti area there is very little of soil and the material is mainly Kankar. Gypsum with associated salts is found in the profiles from $2\frac{1}{2}$ to 5 feet.

Mechanical Composition: The mechanical composition of the soil and sub-soil as determined by the International method are tabulated below:

Mechanical Composition:

Koilpatti type.				*Coimbatore type.*	
%	0–1'	1–2'	2–3¾'	0–1'	1–2'
Clay	53·2	58·1	72·8	34·2	65·0
Silt	15·6	16·0		11·4	
Fine sand	14·0	12·5	11·9	17·7	39·0
Coarse sand	11·5	8·5	4·6	30·1	
Matter soluble in N/5 HCl (By diff.)	5·7	4·9	10·7	7·5	6·0
Total	100·0	100·0	100·0	100·0	100·0

The Koilpatti soil is a heavy clay with over 50% of particles of 0·002 mm and less (clay). The finer fractions (clay + silt) make up about three fourth of the soil. The matter soluble in dilute hydrochloric acid (mainly calcium carbonate) increases with depth. The Coimbatore type of black soil is a clay soil containing about equal amounts of the finer and coarser fractions. The clay content of the soils is near about 30% and so it should be classified as a *clay soil*. The admixture of about equal proportions of the finer and coarse fractions make the Coimbatore black soil more suitable for crop production than the heavier Koilpatti type.

Water Soluble Salts: The soluble salts present in 1:5 water extract of the soils and sub-soils are presented below.

	Coimbatore type.			Koilpatti type.			
	0–1′	1–2′	2–3′	0–1′	1–2′	2–3¼′	3¼–4½′
Total soluble salts %	0·090	0·14	1·83	0·069	0 095	1·42	1·92
Calculated Salts:							
Calcium bicarbonate % $Ca(HCO_3)_2$	..	0·043	0·031	Soluble salts not calculated when the total salts are less than 0·1%		0·025	0·038
Calcium sulphate % ($CaSO_4$)	..	..	0·88			0·79	0·81
Magnesium sulphate % ($MgSO_4$)	..	..	0·10			0·18	0·26
Sodium bicarbonate % ($NaHCO_3$)	0·067	0·0094	...	..	..	..	..
Sodium carbonate % (Na_2CO_3)	0·0085	0·0085	..	..	..	..	..
Sodium sulphate % (Na_2SO_4)	0·0050	0·0022	0·33	..	....	0·32	0·69
Sodium chloride (NaCl)	0·0058	0·041	0·12	..	..	0·0099	0·012
pH	8·78	8·75	8·32	8·76	8·74	8·65	8·51

In both types the top soil and the sub-soil contain less than 0·1% of soluble salts. But lower down the salt concentration increases to 1% and more. This is the gypsum layer and the salts consist of calcium, magnesium and sodium sulphates. The layer extends from 2½–3 feet to 5–6 feet. It is noted that at the top of the gypseous layer sodium sulphate is much less in quantity than calcium sulphate while in the middle the two salts are present in nearly equal amounts and still lower down sodium sulphate exceeds calcium sulphate. For details of the salt distribution in the whole of the gypseous layer of the Koilpatti soil (8) may be referred to.

As the black soil contains considerable amounts of sodium salts its irrigation should be undertaken with caution. In certain parts of the country as in Nira valley in Bombay and the Irwin Canal area in Mysore indiscriminate irrigation of the soil with salt accumulation in the lower depth has lead to its alkalinisation and impoverishment. To prevent such damage irrigation water must be used judiciously, the water table should not be allowed to rise and the drainage must be kept efficient. Experiments carried out at Siruguppa in Bellary district have indicated that with or without crop the black soil can be given light, medium or heavy irrigation without any danger of the rise of salt from the lower depths. Irrigation only washes down the soluble salts and the danger of alkalinisation is remote. However it should not be forgotton that the area where the experiments are now conducted is situated in a land mass of dry soil, that the drainage is excellant and that the water table has not risen. What the position will be when the whole area becomes irrigated and the water table rises should be studied carefully. Irrigation of the black soil should therefore be undertaken with precautions.

Base Exchange properties of black Soils: The study of the base exchange properties of black soils presented considerable difficulties on account of the presence in them of free calcium carbonate and soluble salts including gypsum. One of the authors has worked out a suitable method for such soils (6). The results of the base exchange studies and the silica sesquioxide ratio of the soils are tabulated below.

Base exchange properties of Black soils.

	Coimbatore type			Koilpatti type			
	0—1′	1—2′	2—3′	0—6″	6—12″	1—2′	2—3′
Cation exchange capacity (Milliequivalents ..	32·3	34·4	27·4	61·38	65·85	67·22	65·85
Exchangeable Calcium (me) ..	23·46	21·4	19·6	49·54	53·16	52·97	50·46
,, magnesium (me) ..	6·9	7·6	6·8	9·93	11·11	12·73	13·62
,, Potassium (me) ..	0·61	0·57	0·42	1·29	0·76	0·81	0·89
,, Sodium (me) ..	0·65	0·43	0·41	0·62	0·62	0·71	0·88
Molecular silica/sesquioxide ratio of composite soil ..	—	2·7	—	—	3·5	3·7	—

The base exchange properties indicate that the two types differ considerably in their cation exchange capacity, the Coimbatore soil showing only half the value for the Koilpatti soil. However

in both types calcium forms more than 70—80% of the exchange capacity and the next important cation is magnesium. The monovalent cations, sodium and potassium are present only in small amounts and the degree of alkalinisation of the soil and sub-soil are low. Sodium was estimated directly by a modification of Kahane's (10) method standardized by one of the authors (7).

It is also noted that in both the soil types 1% of clay (0·002 mm and less) contributes to about 1 milliequivalent of cation exchange capacity to the soil. Facilities do not exist at Coimbatore for the identification of the clay minerals. But from the base exchange properties of the soil, the silica-sesquioxide ratio and the dehydration studies of the clay it has been deduced that the black soil contains montmorillonite clay with some admixed Kaolinite.

The fertility status of the black soils: The results of the chemical analysis of the black soil with the range of the nutrients from a number of estimations is tabulated below. The methods employed for the estimations are those usually adopted in the laboratories of the Government Agricultural Chemist, Coimbatore. Nitrogen was estimated by the reduced iron method using 1:1 sulphuric acid. Total phosphoric acid and potash calcium and magnesium were estimated in the hydrochloric acid extract and the available constituents by Dyer's 1% citric acid method.

	Coimbatore type	Koilpatti type
Nitrogen (N) % ..	0·02 — 0·05	0·30 — 0·50
Total phosphoric acid % (P_2O_5) ..	0·033 — 0·065	0·065 — 0·095
Total Potash % (K_2O) ..	0·17 — 0·45	0·20 — 0·35
Total Calcium % (CaO) ..	1·07 — 2·40	3·08 — 4·85
Total Magnesium % (MgO) ..	0·64 — 1·61	0·60 — 1·35
Available phosphoric acid (P_2O_5) ..	0·005 — 0·017	0 0060 — 0·025

Both the soil types are deficient in nitrogen, organic matter and available phosphoric acid. Total phosphoric acid and total and available Potash are, however, present in adequate amounts. There is abundance of lime in the soil especially in the lower depths. Low organic matter content is a common feature of tropical cultivated soils. During the major part of the year the temperature and the moisture content of the soil are conducive to vigorous microbial activity and the added organic matter undergoes active

decomposition. In summer when the moisture in the surface soil is too low for microorganic activity oxidative decomposition is vigorous. Both these causes operate to make the organic matter in the soil low.

Summary of the properties of Madras black soils: The black soils of Madras are derived from granites and gneisses containing soda lime felspar and generally range from clays to heavy clays the finer fractions (clay + silt) accounting for 40 — 70%. The clay minerals of the soil belong to the montmorillonite group. The soil has a high silica — sesquioxide ratio of 2·7 to 3·5 and a high cation exchange capacity of 30 — 70 milliequivalents per 100 gms. of the dry soil. Each gram of clay generally contributes to about 1 milliequivalent to base exchange capacity. Calcium forms 70 to 80% of the exchangeable cations and there is abundance of free calcium carbonate in the soil. Some of the black soils contain gypsum. The gypsum is generally associated with considerable quantities of sodium sulphate and magnesium sulphate. So the irrigation of the soil must be taken up with caution. The black soils are comparatively fertile. They are poor in nitrogen, organic matter and available phosphoric acid but contain adequate amounts of Potash and lime. Bumper crops can be raised on the soil with proper manuring.

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