It appears from the data presented that the low percentages in *Cenchrus* species are due to two causes: (1) the poor setting of grains in the spikelets (there are only 20 to 25% setting of well-developed grains) and (2) some mechanical obstruction caused by the involucre of bristles of the spikelets.

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A Review of the Soil Studies on Deccan Black Soils and the Effect of Irrigation on them

by

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Introduction: The black soils of India have received attention from all soil workers for a long time. Probably on account of its colour, and its importance in cotton cultivation the black soil type was one of the earliest to be subjected to intensive study.

Objective: In this paper an attempt is made to present in a compact, cogent form, the results of voluminous pieces of work which have been done by several Agricultural Chemists at Madras in succession for well over 40 years now. The work has had a marked pedological emphasis, and is fundamental in perspective. None the less, its importance as the starting point for the solution of all soil problems cannot be over-emphasised.

Studies on Deccan Black Soils: (1) INVESTIGATIONS ON ORIGIN OF BLACK COLOUR: (a) Annett: (1910) attributed the colour

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of black soils to the presence of titaniferous magnetite in the coarse fraction of the soil. But his work was mainly representative of black soils from Madya Pradesh and Bombay, and not of Madras. Moreover his investigation was primarily confined to the laboratory. (b) Harrison and Sivan: (1912) on the other hand, started their investigation with extensive tours of black soil areas, within Madras State, recording observations on the sub-soils and the underlying rocks. They divided the soils examined into five areas of which the Deccan was one. Laboratory examination revealed that, while the black soils were similar in properties, their origin was different in different tracts. It was also observed that the presence of titaniferous magnetite could account for black colour only in the case of Bombay soils, and not Madras soils. Thus they observed that the soils of Bombay and Madya Pradesh originated from trap rock while those of Madras traced their origin to diverse geological formations of local importance. Harrison and Sivan deduced, moreover, that the black colour of Madras soils was associated with a colloidal complex of organic matter and a double silicate of Iron and Aluminium.

The work of Harrison and Sivan made a distinct contribution to the then existing knowledge of the suject. It must however be mentioned, that their work related only to a study of surface soils with particular reference to the cause of the black colour. Although underlying rock formations were observed during the study, detailed correlation between the nature of the rocks and the soils arising therefrom had not been attempted. With the advent, two decades later, of the Russian concept of soil science, with main emphasis on the study of the soil as a unit by itself, the Chemistry Section of the Madras Agricultural Department fell in line with workers in other parts of the world, and commenced work on soil profiles opened up in representative tracts of the State.

(2) ORIGIN OF BLACK SOILS, TUNGABHADRA SOIL SURVEY: (a) *Juxta-position of Black and Red Soils:* The Tungabhadra Project area in the Ceded Districts was one of those examined elaborately by the Chemistry section. One hint that was offered by this examination was that a possible correlation could be worked out between the parent rock and the soil type it gave rise to. In a published report of this soil survey, Ramiah (1937) divided the soils of the area as black and red, deep and shallow, with and without gypsum, basing this division on criteria such as colour, depth and salt content. A striking feature observed during the

survey was the occurrence, side by side, of black and red soil patches, apparently as independent entities, with clear lines of demarcation.

This interesting phenomenon had been explained by observers in a number of ways. Some, probably under the influence of the Russian school of thought emphasizing the importance of climate, believed that topography was a determining factor; according to them, red soils were formed first and black soils were derived later from them by transportation. But during the Tungabhadra soil survey, black soils were encountered at altitudes of 1,500 feet, and vast stretches of red soils were found occurring at lower levels. Thus the topography theory was found unsatisfactory.

(b) *Conclusions from Tungabhadra Soil Survey:* The survey, with its elaborate data regarding a very considerable number (440) of soil profiles, was admirably suitable for throwing light on the associated occurrence of black and red soils, and their colour. It was deduced that, the black soil organic matter might be present in combination with calcium silicate complex of the clay. The country rocks in the area were mainly granites and gneisses; red soils were observed to be formed in the vicinity of rocks of predominant potash felspar content, while black soils were associated with other minor occurrences of hornblende schist, trap dykes, highly basic gabros, and also with limestones of Vindhyan age. Thus, it was evident that black soils were derived from rocks rich in calcium and magnesium, while red soils originated from rocks low in these elements, but high in potassium.

(3) COLOUR OF BLACK AND RED SOILS: Ramiah and Raghavendrachar (1937) observed that both the black and red soils contained almost the same amount of iron, while, ordinarily, one would expect red soils, on account of their colour, to contain more iron. They concluded that high silica sesquioxide ratios and high lime contents were not by themselves causes of the black colour, but that this composition gives clay of light grey colour, which, in combination with even small amounts of organic matter, develops the black colour.

(4) DETAILED INVESTIGATION ON ORIGIN AND GEOCHEMISTRY OF SOILS OF MADRAS DECCAN: Anantanarayanan (1941) investigated the origin of Madras Deccan soils elaborately and studied their geochemistry at length. Soil samples obtained during

the Tungabadra soil survey were utilised for the investigation. His work could be described under four broad heads.

(i) Morphology of Deccan soils, (ii) Dynamics of soils, (iii) Minerological composition of soils, (iv) Composition of clay minerals.

(i) *Morphology of Deccan Soils:* The study included a detailed analysis of the soil profile and several horizons. It was concluded that the Madras Deccan black soils were closely similar to the Chernozems of Russia and the Black Prairie soils of North America. The main difference was the dissimilarity of parent material granite for Madras soils and loess in the case of chernozems. According to the scheme of classification put forward by Sigmond at the International Congress of Soil Science, 1939, both black and red soils of Madras Deccan are soils of mixed origin, or "organic mineral soils", the former belonging to sub-group "Humic siallites" under calcium soils and main type "black soils", and the latter coming under the sub-group "Siallites", order "Red earth" and type "Red soil".

(ii) *Dynamics of Deccan soils:* The mechanism of soil formation was sought to be followed up by a study of the chemical and mechanical composition of soil types, and the parent rock responsible for their formation. It was observed that black soils had a lower free silica content and a higher combined silica content than red soils. Black soils had a higher silica-sesquioxide content than the red. They had a high content of calcium both as silicate and as carbonate as also of magnesium and sodium. Moreover, black soils had a high percentage of fine fractions, high water-holding capacity, and a low distribution of water-soluble salts in the top three feet.

Similarities noticed were (1) higher free silica content at surface, (2) increasing amount of combined silica with depth (3) constancy of silica sesquioxide ratio within the profile. These similarities point to a similarity in the extent of influence of external factors like rainfall, temperature and topography. The formation of two soil types in close contiguity may, therefore, be due to differences in the mineral composition of the parent rock, and not to external features.

(iii) *Minerological Composition of soils:* As was done earlier by Harrison and Sivan, the minerals in the course fractions of the soil were separated, employing heavy liquid separation technique, into 3 groups of specific gravities, (1) above 2·96, (2) Between 2·96 and 2·50 and (3) below 2·50. This was combined with a detailed minerological study of the rocks underlying the soils, for gathering information regarding the influence of the mineralogical composition of parent rock on that of the soil. Minerals present in each density group were identified by their petrological characteristics. Fusion analysis was performed with the different density groups.

Striking differences were observed between minerological composition of black soil high density group, which was found to contain amphibole and pyroxene groups, and that of the red soil high density group, which contained ilmenite, biotite, epidote and garnet.

These observations lend weight to the assumption that, in the Madras Deccan area, Black and Red soils have not evolved from the same kind of rocks. Black soils appear to have been derived from from rocks rich in amphiboles and pyroxenes, characterized by presence of large amounts of hornblende and plagioclase. Red soils, on the other hand, are derived from rocks containing mica and orthoclase felspar.

(iv) *Composition of clay minerals:* Clay colloids from the two types of soil were separated by differential sedimentation, and examined elaborately. Chemical analysis showed that silicate A (completely decomposed by HCl) was present in black soil colloids, while silicate B (resistant to HCl decomposition) was present in red soil colloids. Moreover, the silica-sesquioxide ratio of the black soil colloid was about 3, while the corresponding figure for the red soil colloid was only 2. This indicates that the predominant clay mineral of black soils is Montmorillonite and that of red soils, Kaolinite.

Thus, it was proved unequivocally that parent rock was the determining factor in the case of Madras Deccan soils. While Russian pedologists emphazised the influence of climate and environment in soil formation, the mass of useful soil data collected by Madras Agricultural Chemists indicated that the climatalogical theory of the Russians need not be accepted without modifications.

Irrigability of Black Soils of Madras Deccan: (1) GENERAL CONSIDERATIONS: The emphasis on the laboratory study of black and red soils outlined above should not lead one to suppose erroneously that the practical aspect of the problem has been overlooked. The Tungabhadra Soil Survey is a monumental attempt at translating fundamental studies into practical applications.

It was the general local belief that black soils would not respond so well and so economically to irrigation as red soils. The object of the Tungabhadra Soil Survey was to verify this assumption, and to forecast and prevent, if possible, any evil effects attendant upon black soil irrigation. Fundamental work on these soils had established their general similarity to the Russian Chernozems, which had themselves been found suitable for irrigation. But, as the horizons, and the distribution of calcium carbonate and gypsum were different from those of the Chernozems, more detailed investigations seemed to be called for.

(2) Classification of profiles on basis of distribution of calcium salts: Shiva Rau and Kasinathan (1951) paid attention to these differences between the Madras black soils and the chernozems and tried to determine the place of Madras Deccan black soils in a general system of classification. The Tungabhadra Soil Survey had revealed the existence of two obvious profiles, the gypseous and non-gypseous. A more detailed investigation brought out two main types of the gypseous profile itself. In one (Type I) gypsum was at the top, and calcium carbonate (or kankar) below, while in type II the relative positions of these calcium salts were reversed. This difference is indicative of a difference in the direction of eluviation.

Laboratory analysis for soluble salts showed that there was generally a higher concentration of soluble salts in layers near the surface in the case of type I. Moreover, it was observed that the two types were distributed over well-defined and significant areas, Type I, being absent in tracts under tank irrigation, while type II was present in such cases. These considerations hint at the difference in pedogenic factors for the two types.

(3) Probable effects of Irrigation on soils, of Gypseous Profiles: It could be reasonably inferred that the introduction of irrigation would, in the case of type II, accentuate the already existing natural trend, that is, of washing down of salts. On the otherhand, in type I the increased supply of water at the surface would result in a restoration of a typical chernozem process, or result in the concentration of alkali in the upper horizons, simulating conditions prevailing in brown steppe soils.

(4) STUDY OF CONDITIONS LIKELY TO PREVAIL ON INTRODUCTION OF IRRIGATION: The foregoing considerations indicate that the problem of irrigating Black soils of Madras Deccan is complicated, and that extreme caution is to be exercised in arriving at conclusions or offering recommendations. Therefore a detailed study of this problem was undertaken for gathering more exact information. This study consisted of two aspects: (a) complete analysis of soil samples drawn during soil survey (b) actual field experiments in a locality representative of the area. The former aspect is dealt with in the following pages. Emphasis was placed on the study of soil properties in relation to the effect of irrigation.

(a) *Mechanical Composition:* All four types of black soils (deep, shallow, with and without gypsum) were similar in containing more than 60% of fine fractions (Clay and silt) and in showing an increase in the fine fractions with depth. Further, gypseous layers possessed less of fine fractions.

(b) *Single value Constants:* Hygroscopic coefficient, maximum water-holding capacity, pore-space and absolute specific gravity, which represent single properties influenced by groups of other properties, were determined. Black soils were observed to have a moisture retaining power varying from 65–85%. Percolation and permeability were observed to be dependent upon clay content and presence of gypsum.

(c) *Total Soluble Salt Content:* This determination, which was one of the most important ones undertaken, revealed the fact that salt concentration increased up to the 4th or 5th foot, after which it began to decrease slightly. Ranges for the first three feet were (a) 0·1% (b) 0·1–0·3 and (c) 0·3–0·5% respectively, showing that at the root zone salt concentrations are well below toxic levels.

(d) *Nature of Soluble Salts:* It is well known that, more than the total soluble salt content, the quality of component salts is important in determining their effect on plants. Hilgrade and other American workers have set the limits of toxicity of sodium carbonate, sodium chloride and sodium sulphate, at 0·10%, 0·25% and 0·75% respectively.

Analytical data indicated that the limits set by Hilgrade were rarely exceeded; in the few cases where they were exceeded, the depth was well below that reached by roots of common crops.

In the gypseous profiles high concentration of salts was actually associated with the zone of gypsum concentration. Salts present at this zone were calcium and sodium sulphates, a little sodium chloride and magnesium salts, and traces of bicarbonates, carbonates being absent. In non-gypseous profiles, the gypsum was found replaced by sodium chloride, which, however, was well within toxic limits, or counter-balanced by calcium salts.

(e) *Exchangeable Bases:* The importance of exchangeable bases will be apparent when it is stated that they govern such diverse soil conditions as absorption and retention of moisture, availability of plant nutrients, formation of tilth, facility for good cultivation and range of possible crops. With the development of existing knowledge on mechanism of surface phenomena, the importance of base exchange on soil properties has gained prominence.

Thus, exchangeable calcium ions develop a crumb structure, enable a soil to be cultivated over a wide moisture range to make it possible for a number of crops to be raised. Sodium ions, on the other hand, deflocculate the soil, render it impervious to water and to plant-roots, and bring about soil deterioration to a degree unfit for crop growth.

Deep black soils with gypsum showed an average capacity of 45 to 60 milliequivalents, a figure indicating sufficiency of exchangeable bases, those without gypsum giving 45 to 65, shallow black soils with and without gypsum from 25 to 35, while red soils had capacities lower than 20. In other words, the black soils had a high base status, while the red ones had a low one.

Among the individual bases, the sum of exchangeable Calcium and Magnesium was fairly uniform throughout the profile, the exchangeable Calcium decreasing, and the exchangeable Magnesium increasing with depth, Sodium increased with depth, the increase being characteristic of the soil type examined.

(f) *Degree of Alkalization:* Puri and others, working on Punjab soils, have fixed 25% as the tolerated limit for degree of alkalization. The figures obtained for the project soil samples indicated that nearly three fourths had less than 20%, well within tolerated limits.

(g) *pH value:* This value is a measure of the intensity of soil reaction. Generally it is due to hydrolysable salts present, and is closely associated with the degree of alkalization. Puri's observations on Punjab rice soils led him to conclude that pH values exceeding 8·5 decreased crop yields. In soils under Tungabhadra water irrigation, however, even at a pH of 9·5, the degree of alkalization was less than 25, and the yields were not affected. The reason for this difference in behaviour lies probably in the fact that Madras Deccan soils have a far higher lime status, which is responsible for increasing the pH, and, at the same, keeping down the degree of alkalization.

(h) *Examination of Soils from areas already under Irrigation:* The irrigated soils of the tract fall under three heads; black clays, loams, and sandy loams. The source of irrigation is either river or tank, the rivers being Tungabhabra and Pedda Hagari. More detailed information of the irrigability at the soils of the tract was sought from the chemical examination of soils from profile pits located in areas under irrigation.

The average total soluble salt content of Tungabhadra river waters was only 15 to 16 parts per 1,00,000, while for Pedda Hagari river and Chinna Hagari river the figures were 80 and 130 respectively. Water from the tanks of this area was also higher in salt content than the Tungabhadra. Moreover, Tungabhadra river water was free from carbonates, while the others and contained appreciable amounts of sodium and carbonates. This accounts for the fact that while wetland areas under Tungabhadra irrigation have maintained a high fertility status during the past several centuries, those under Hagari irrigation have already developed symptoms of alkalinity.

It is thus seen that the Black soils of Madras Deccan will give a very favourable reaction to irrigation with Tungabhadra water. The soil profile, with its gypseous and non-gypseous nature, the clayey condition of the soil which naturally impedes upward movement of salt solution, and above all, the high lime status and the low degree of alkalization are all points in favour of bringing the soils under irrigation. The only consideration is the quality of irrigation water, which must be free from carbonates and sodium. The Tungabhadra river water, with its low content of soluble salt, low sodium concentration and freedom from carbonate, ideally meets the situation.

Summary and Conclusions: A review of the work done by the Madras Agricultural Chemist's section on the colour, origin and properties of black and red soils, especially those of the Madras Deccan, is given. Enough data has been gathered and presented for assigning these soils a distinct place in the world group of soils. It has been pointed out that the Russian School of pedological thought is only of limited importance in the study of soil problems of the State. Results of elaborate analysis of different types of black soils and various sources of irrigation water have been presented, and their bearing on irrigability discussed in detail.

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