

THE FORMATION OF BROWN-RED SANDY SOILS FROM SHIFTING SANDS ALONG THE MEDITERRANEAN COAST OF ISRAEL *

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Various views have been expressed as to the origin and formation of the brown-red sandy soils along the Mediterranean coast. The prevailing opinion is that they are formed from the calcareous sandstones known as "kurkar", which are prevalent in the coastal plain (2, 4, 10, 12, 17). Picard (7) suggested that erosional material from the terra rossa soils inter-mixed with the sand, and brought about the formation of the red sandy soil. Avnimelech (1) claimed that these soils were formed from "kurkar", with admixtures of erosional material transported from the mountains. Raczkowsky (8) assumed that the iron oxides coating the sand grains, which imparted its color, came from the weathering of marine deposits. Rim (13) states that the formation of red-sandy soils occurs in the lower layers of the shifting sand dunes of the coast, owing to the accumulation in these layers of grains of iron-containing minerals and their subsequent hydrolysis.

In a previous investigation on shifting sands which supported a continuous growth of vegetation (11), many changes were pointed out. These changes were expressed by the rise in organic matter and nitrogen content of the sands, increase of the finer fractions, aggregation of the sand, increase of field water capacity, retarded permeability, and the development of a large population of microorganism. In the wake of these changes the properties of the sands gradually approached those of the lighter types of the neighbouring brown-red sandy soils. In addition, the color of the sands also altered gradually, from a light yellow with a faint reddish tinge, to a light brown-red. This color is also typical of the sandy soils.

Microscopic studies of sand grains taken from uncropped plots and from plots after four years of cropping (with alfalfa and sown pasture) showed the

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changes which occurred on their surfaces. Prior to the growth of plants, the sand grains were largely bare, and only occasionally were colloid spots seen on them. With the years of plant growth the surface area of colloidal coating increased, colloids having been formed from the mineral compounds in the sand and from the organic remains of the vegetation.

According to Philippovitch (5) the process of adhesion of the organic colloids to the sand grains is accomplished by the colloidal iron compounds. The subject of the adsorption of clay and humus on quartz grains was studied by Sideri (14). According to him, after drying, the adsorbed colloids attain to a considerable extent, irreversible properties, and adhere to the silica grains. Repeated alternate wetting and drying cause adsorption of additional layers of clay and humus and bring about the accumulation of colloids on the grain surface.

In the experiment of sand dune reclamation with the aid of crops (11), it was supposed that the wetting and drying of the sand between successive irrigations, aided in the adherence and accumulation of the colloids on the sand grains. Along with this, the colloids gradually coated the grain surfaces and changed the color of the sand.

The colloidal coating of the quartz grains developed mainly in the upper layers of the sand, which is the zone of principal root spreading activity and colloidal and organic matter accumulation. The coating decreased with depth.

The degree of colloidal coating varied as to the plots. The most pronounced coating occurred in the sand of the perennial plots, i.e. alfalfa and sown pasture; the least, in sands bearing annual crops. In the latter, total organic matter content was lower than in the former. In nature the colloidal coating occurs in widespread areas. One may suppose that this process is enhanced by the specific climatic conditions of the region, i.e. rainy winters alternating with warm dry summers. The native vegetation on the sands acts in this direction, but the process is slow owing to the thinness of the vegetative cover. In the relatively young coastal sands, this process is just beginning. As the sands become stabilized and covered with vegetative growth, the faster becomes the rate of the coating process. The dense permanent vegetative cover on cultivated sands stimulated the process and hastened its rate.

The colloids formed under natural conditions in the sand are similar in composition to those formed with the aid of the vegetation in the experimental field. The chemical composition of the colloids, separated from the upper layer (0—15 cm) of the sand in the experimental plots both before and after growing of perennial plants, are presented in Table 1. Table 1 also shows the molecular ratio of $\frac{\text{SiO}_2}{\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3}$ in these colloids and in those of brown-red sandy soils. The ratios are nearly equal.

TABLE 1.

THE CHEMICAL COMPOSITION OF COLLOIDS IN THE SAND-DUNES
BEFORE AND AFTER PLANT GROWTH; THE RATIO OF $\frac{SiO_2}{Fe_2O_3 + Al_2O_3}$
IN THE SAND-DUNES AND BROWN-RED SANDY SOILS.

<i>Sources of colloids</i>	<i>Location</i>	SiO_2 %	Fe_2O_3 %	Al_2O_3 %	CO_2 %	<i>Organic Matter</i> %	$\frac{SiO_2}{Fe_2O_3 + Al_2O_3}$
Sand-dunes before plant growth	Mikhmoret	41.9	10.8	19.8	2.32	3.8	2.7
Sands after alfalfa growth	"	43.5	11.6	20.1	1.92	5.0	2.7
Sands after pasture growth	"	40.6	10.4	19.8	1.75	6.9	2.6
Brown-red sandy soil.	Rehovot*						2.6
"	Ness-Ziona*						2.6
"	Rehovot*						2.6

* (9)

The changes which occurred through the growth of plants in the chemical and mechanical composition of the sands, physical properties, degree of colloidal coating, and coloration, brought these soils nearer to the brown-red sandy soils. This led to the supposition that the brown-red sandy soils could have been formed directly from the shifting sands which predominate in the region, with the vegetation acting as a primary factor in their formation.

The colloids, which formed gradually in the upper layers of the sand were partly washed down by the winter rains into the deeper layers. The organic compounds aided the iron compounds in this migration by serving as protective colloids (15, 16). In this manner, the thickness of the brown-red soil layers increased.

Succeeding additions of shifting sands to those already stabilized, could also have possibly, with the aid of vegetation, increased the thickness of the brown-red soil layers. This was noticed in various locations in the region.

The supposition that the brown-red soils were formed from shifting sands does not contradict the opinion that these soils are also formed from "kurkar", but rather further explains it. The "kurkar" was presumably formed through the consolidation of coastal sands by lime which precipitated from solutions containing calcium bicarbonate (1, 2, 3, 6). During the weathering process the lime was gradually leached out of this porous rock by rains, and the loose sand which served as a basis for the formation of "kurkar" once again appeared. This liberated sand underwent the process of colloidal coating with an active role being played by the vegetation similar to that of shifting sands which were under continuous vegetative cover.

The process of colloidal formation in "kurkar" can be more rapid and on a greater scale, owing to the denser vegetation and the presence in it of more easily weathered materials. The brown-red sandy soils formed from "kurkar" may, therefore, be heavier than those formed directly from shifting sands.

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