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Properties and Classification of Some Oasis Soils* of Al-Ahsa, Saudi Arabia

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ABSTRACT. A field study utilized some soils under date palm cultivation (*Phoenix dactylifera* L.) in the oasis of Al-Ahsa, Saudi Arabia. Some of these soils have a mollic epipedon. The formation of this diagnostic epipedon could be attributed mainly to the frequent irrigation, natural drainage, and the addition of organic material from annual burning of weeds and other plant residues. It is, thus, suggested that these soils should not be classified as Typic Torripsamments as are the surrounding uncultivated soils. These soils best fit the criteria for Typic Haplaquolls and Typic Haplaquents which may be true of most of the oasis soils of Al-Ahsa under date palm cultivation.

The oasis of Al-Ahsa is situated in the Eastern Province of Saudi Arabia about 170 km southwest of Dammam on the Arabian Gulf (Fig. 1). The total cultivated land in the oasis is about 7000 hectares, where about 2 million date palms (*Phoenix dactylifera* L.) of 40 different varieties are grown (Homeyer 1978, Elprince *et al.* 1979). The irrigation water is supplied from about 36 natural springs fed from an artisian ground water reservoir (Homeyer 1978). The climate is continental with a mean annual precipitation of 6.9 cm which occurs mainly during the winter period. The mean annual temperature is 25.2°C (Ohlmeyer 1973). The soil moisture regime for the soils lacking a natural high water table is aridic while the soil temperature regime is hyperthermic. The area receives a high solar energy load which amounts to 176×10^3 LY per year and the annual evaporation reaches a total amount of 3310 mm (Asseed *et al.* 1982).

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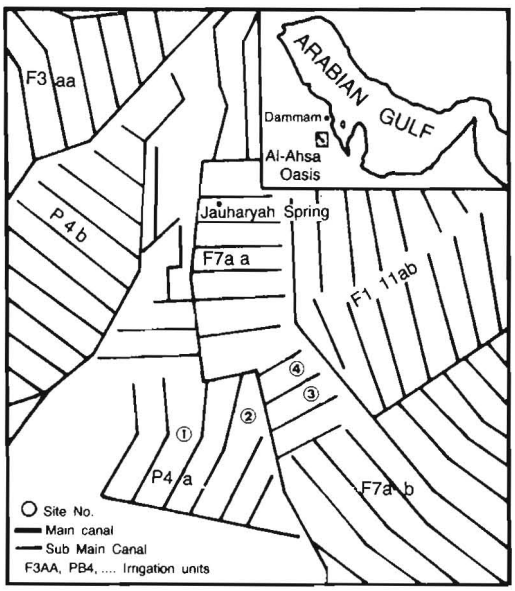

Fig. 1. Soil sampling sites and the irrigation and drainage network, Al-Ahsa, Saudi Arabia.

The natural drainage is an important factor in the formation of soils in the oasis of Al-Ahsa. Before, the completion of Al-Ahsa Irrigation and Drainage Project (HIDA) in 1977, the ground water level in most of the oasis soils was higher than today. This was mainly due to poor drainage which resulted from the obstruction of natural drainage to the north of the oasis by advancing sand dunes. A published record does not exist concerning the depth the project lowered the water table, but it is evident that many oasis soils have gained their agricultural potential as a result of the project completion (Aba-Husayn and Sayegh 1977). However, the farmers did not fully utilize the usefulness of HIDA due to many factors, such as lack of proper management, non adoption of the conservation practices and the general tendency among the farmers to over irrigate their crops (Hussain 1982).

In the oasis of Al-Ahsa, the soils vary greatly such as characteristics of the Ap horizon, soil structure and organic carbon content under date palm cultivation over varying periods of time. These soil characteristics fulfill the criteria for the mollic epipedon in some soils (Soil Survey Staff 1975). It has been reported also that the formation of a mollic epipedon is rather rapid and relatively complete within a period of 575 $\pm$ 80 years (Martel and Paul 1974). In addition, the date palm cultivation involves certain practices that might enhance mollic epipedon development under the local environmental conditions.

The purpose of this study was: (1) to determine the properties of some soils under the date palm cultivation in Al-Ahsa of different ages and (2) to establish a hypothesis for the formation of a mollic epipedon under the environmental conditions of the Al-Ahsa oasis.

Material and Methods

Four sites (Fig. 1) were selected in the study area to compare the changes in the properties of some soils under date palm cultivation for different periods of time. They also differ significantly in natural drainage. Site 1 is uncultivated and under natural vegetation [*Seidlitzia rosmarinus* (Ehrenb.) Solms-Laub] and (*Zygophyllum quatarense* Hadidi). It is about 1 km south of Al-Jauharyah spring. Site 2 has date palms which were planted 22 years ago and is located about 180 m east of site 1. The water table in the soils at sites 1 and 2 is very deep and the soil moisture regime is aridic. The soils at sites 1 and 2 are in one of the higher areas of the oasis that in the past was not practical to irrigate. Site 3 has date palms which were planted 42 years ago and is located about 300 m east of site 1. Site 4 has 82 year old palms and is located 250 m east of site 2 (Fig. 1). Most of the oasis soils of Al-Ahsa including the soils at sites 3 and 4 were poorly or somewhat poorly drained before the installation of Al-Ahsa Irrigation and Drainage Project in 1972 and are estimated to have an aquic soil moisture regime. Now, the level of ground water in the soils at sites 3 and 4 ranged from a depth of less than 50 cm in winter to a depth of 120 cm in summer. Although date palm cultivation has been practised for many centuries in the oasis, the ownership documents of the sites selected showed that the soils at sites 3 and 4 were under date palm cultivation for a period of three centuries or less, whereas the soil at site 2 came under cultivation for the first time approximately 22 years ago. The criteria for site selection were such that the pedons at sites 2,3 and 4 were free from sub-cultures except for a dense cover of weeds.

The soil profiles were exposed by digging a pit at each site. They were described according to the Soil Survey Manual (Soil Survey Staff 1951) and the May, 1962, supplement to the Soil Survey Manual (Soil Survey Staff 1962). Soil samples from each horizon were collected for laboratory analysis. Samples were air dried and sieved to remove coarse fragments (>2 mm). Soil pH for 1:1 soil-water ratio, electrical conductivity of the saturation extract (EC), soluble cations and anions, gypsum, cation-exchange capacity (CEC), extractable cations and calcium carbonate were determined by following methods given in U.S.D.A. Handbook No. 60 (U.S. Salinity Staff 1954). Organic carbon was determined by the Smith-Weldon modification of the Walkley-Black method (Jackson 1956). P was determined colorimetrically using $NaHCO_3$ and 1% citric acid as extractants (Watanabe and Olsen 1965). Particle size distribution was determined by the pipette method without removing $CaCO_3$ (Bascob 1974). The chemical composition of irrigation water used in the area is given in Table 1 (Asseed *et al.* 1982).

Table 1. The chemical composition of irrigation water used in the study area (Asseed *et al.* 1982).

EC mmhos/ cm	Soil Content (ppm)	Cations (Meq/1)				Anions (Meq/)				SAR	Water Type
		Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^{-2}	HCO_3^{-1}	Cl^-	SO_4^{-2}		
2.293	1531	13.02	0.2	7.47	4.18	0.0	3.11	14.65	7.42	5.40	C_2-S_2

Date Palm Cultivation Practices in the Study Area

Land preparation for date palm cultivation involves deep plowing (upto 1 m) for turning under the soil and breaking any hardpan material. After levelling and planting, the whole basin is covered with either cattle or poultry manure to a depth of 4 cm. The application of manure is repeated at the rate of 16 bushels per palm per year. The plant to plant and row to row distance is normally 4 m and it is often interplanted with citrus (*Citrus aurantifolia* Swingle), fig (*Ficus carica* L.), pomegranate (*Punica granatun* L.) and alfalfa (*Medicago sativa* L.) Flood irrigation is a common practice in the area with an interval of 7 days in the winter and 4 days in the summer. The dry fronds of palms are removed every two years. The weeds are eradicated annually. Moreover, some of the dry fronds, fruit bunch stalks, and weeds are burned annually and the ashes and unburned residue spread on the soil surface.

Geomorphology and Soil Parent Materials

Al-Ahsa oasis is situated on a plain which is about 8 km wide in the north and 25 km wide in the south. The plain slopes eastwards where it is bordered by a chain of hills with an average elevation of about 230 m above sea level. The area occupied by the oasis is L-shaped including the eastern oasis and the northern oasis. The main drainage directions are east for the eastern oasis and north for the northern oasis (Hotzl *et al.* 1978, Elprince *et al.* 1979).

Quarternary deposits cover most of the surface of the oasis. These deposits include mainly aeolian sand, sabkha sediments (saline flats or playas) and fluvial deposits including gravels with silt and associated fine grained sediments (Jenkins 1976). The underlying strata are composed of: (i) cemented calcareous materials (impure limestones), (ii) soft grey green marl which contains 10-50% $CaCO_3$, (iii) fragments of the first in a matrix of the second, and (iv) red beds (Jenkins 1976, Homeyer 1978, Elprince *et al.* 1979).

The red beds and the impure limestones are more likely upper members of the Miocene or Pliocene Hofuf Formation (Jenkins 1976, Elprince *et al.* 1979). According to Jenkins (1976), the grey green marl belongs to the Miocene Dam

Formation. He further states that the marl deposits vary from sandy loam to silty clay in texture and very often contain pale orange brown mottles. A recent study has placed the soils of Al-Ahsa into six great soil groups, namely, Torriorthents, Torripsaments, Calciorthids, Salorthids, Gypsiorthids, and Camborthids. (Soil Survey Staff 1981).

Results and Discussion

In general, the particle size distribution data indicates an increasing trend in clay content from site 1 to site 4 (Table 2). The clay distribution is uniform in each pedon except in the II C3 horizon at site 1 which resembles the marl stratum. The total silt content at both sites 3 and 4 decreases with depth and then shows an increase. This change could be the effect of soil pulverization by deep plowing and the presence of high $CaCO_3$ content at lower depths. However, the total sand content increases from site 1 to site 3. The changes in the properties of these irrigated soils (especially the particle size distribution) may be attributed to the application of animal manure containing about 90 percent sand which was used as livestock bedding (Homeyer 1978). Furthermore, the magnitude of change in the sand contents of these soils can not be quantify exactly because the farmers are adapted to different management practices (different amounts of manure, deep plowing, ... etc.). However, the overall magnitude of change in the four soil profiles varied from 1-10% (Table 2).

The parent material of all four pedons is dominantly aeolian sand with $CaCO_3$ contents ranging from 7.5% to 33.3% (Table 3). The presence of $CaCO_3$ and gypsum in the pedon at site 1 may indicate that both calcification and gypsification are taking place. In addition, a moderately high level of soil salinity is evident in the latter soil as well as in the lower horizons of the pedons at sites 3 and 4 (Table 3). The soil salinity at site 1 is probably due to salt accumulation under the present agro-climatic conditions. Low EC and soluble cations/anions are observed in the upper horizons of the pedons at sites 2 and 3. while site 4 has soil salinity comparable with that found at site 1. The low soil salinity level of the pedons at sites 2 and 3 may be due to more frequent irrigation and better soil drainage.

In all four pedons, the CEC parallels the distribution of clay and organic C with the highest CEC values in the Ap horizons of the pedons at sites 3 and 4 (Table 3). The soil pH ranges from 7.5 to 8.1 which is probably due to the presence of a high content of $CaCO_3$ in all the sites.

Organic C in the Ap horizon at site 4 is about 10 times the value found in the virgin soil at site 1 (Table 3). In general, the organic C in the surface horizons of the profiles at sites 2, 3 and 4 increases with the increase in the date palm cultivation period. Some of this increase in organic matter is believed to be due to the addition of ashes from the annual burning of weeds and plant residues along with the decomposition of dead weeds and palm roots. Also there is a significant difference

Table 2. Morphological properties and particle size distribution of pedons at the four sampling sites in Al-Ahsa Oasis

Horizon	Depth	Color (Moist)	Structure	Consistence (Moist)	Textural Class	Boundary	Very Coarse sand	Coarse sand	Medium sand	Fine sand	Very Fine sand	Coarse silt	Fine silt	Clay
	cm						%							
Site 1														
C 1	0–50	10YR6/3	sg	lo	s	ab	—	0.8	27.5	37.3	21.8	8.7	2.4	1.5
C 2	50–135	5Y5/2	m	fr	s	ab	0	1.6	13.9	33.2	28.0	15.7	6.1	1.5
IIC3	135+	5Y6/4	m	fi	sl		—	0.9	4.0	23.1	40.6	16.1	5.9	9.4
Site 2														
Ap	0–22	10YR4/3	sg	vfr	ls	ab	0.1	14.2	34.3	29.6	10.9	3.7	3.3	3.9
C	22–120	10Y7/4	sg	lo	s		0.1	10.3	32.9	32.3	16.6	3.4	2.2	2.2
Site 3														
Ap1	0–20	10YR3/3	1vfgr	vfr	sl	c	0.5	6.2	26.8	32.2	12.3	13.4	1.3	7.3
Ap2	20–30	2.5Y3/2	m	fr	ls	c	0.1	4.1	29.5	35.3	14.1	9.9	4.0	3.0
C 1	30–60	5Y4/1	m	fr	ls	g	0.3	8.8	31.0	32.2	11.8	10.7	2.1	3.1
C 2	60–120	2.5Y6/2	m	fr	ls	g	0.5	10.4	36.9	32.0	8.6	7.4	1.2	3.0
C 3	120–150	5Y4/2	m	fr	ls		0.6	8.2	32.4	27.3	13.5	10.8	4.1	3.1
Site 4														
Ap1	0–13	10YR3/1	1 fgr	vfr	ls	c	0.1	7.7	24.3	31.6	13.0	6.9	12.4	4.0
Ap2	13–28	10Y4/2	1 fgr	fr	sl	c	0.8	7.5	23.4	31.1	14.0	3.6	14.8	4.8
C 1	28–58	2.5Y4/2	m	fr	sl	g	0.5	9.9	30.6	28.1	11.9	5.8	6.4	6.8
C 2	58–81	2.5Y6/2	m	fr	ls	g	1.2	12.4	32.6	26.0	13.1	5.6	4.8	4.3
C 3	81–120	5Y5/1	m	fr	sl		0.1	12.1	31.2	23.2	13.5	5.4	9.5	5.0

Symbols used according to abbreviations given in Soil Survey Manual, USDA handbook No. 18, p. 139-140, 1951.

Table 3. Chemical properties of pedons at the four sampling sites in Al-Ahsa Oasis

Horizon	Depth	pH 1:1	Organic carbon	Extractable cations				Base saturation %	CEC Meq/100g	Citric acid extr. P_2O_5	$NaHCO_3$ ext P_2O_5	$CaCO_3$ %	EC mmho/ cm	Gypsum %	Soluble Cations and Anions						
				Ca^{++}	Mg^{++}	K^+	Na^+								Ca^{++}	Mg^{++}	K^+	Na^+	HCO_3^-	Cl^-	SO_4^{-2}
				Meq/100g						ppm					Meq/l						
										Site 1											
C 1	0–50	8.0	0.07	48	26.8	0.4	6.4	100+	3.1	1.7	1.2	12.4	5.6	7.5	23.2	8.0	1.1	12.3	1.4	27.0	25.2
C 2	50–135	7.7	0.08	59.2	20.0	0.4	4.7	100+	2.9	1.8	1.2	13.4	3.6	5.7	22.5	3.5	0.6	8.7	1.0	11.0	23.2
II C 3	135+	8.0	0.07	32.5	12.8	4.2	4.2	100+	5.1	6.9	1.2	33.3	11.0	Nil	41.6	24.0	3.2	53.0	3.0	71.7	47.1
		8.0																			
										Site 2											
Ap	0–22	7.5	0.12	6.8	12.0	0.3	3.2	100+	5.2	107.6	89.5	11.9	1.6	Nil	4.1	4.4	0.4	7.0	3.4	6.2	3.7
C	22–120	7.6	0.07	40.0	11.2	0.2	3.5	100+	2.8	3.4	9.2	7.5	1.5	Nil	4.5	5.5	0.3	7.0	3.3	6.9	7.1
										Site 3											
Ap1	0–20	7.5	0.62	12.0	4.0	0.3	4.0	100+	8.7	36.6	49.2	18.0	2.8	Nil	3.3	4.7	0.6	14.4	1.9	17.0	8.1
Ap2	20–30	7.6	0.55	8.4	12.8	0.3	4.8	100+	7.5	20.6	14.7	18.1	1.7	Nil	3.2	2.2	0.4	9.6	1.8	14.0	0.4
C 1	30–60	7.7	0.20	5.2	5.6	0.3	1.6	100+	5.2	1.9	9.2	16.1	2.0	Nil	4.5	2.7	0.4	10.2	2.0	13.0	13.0
C 2	60–120	7.7	0.12	9.6	6.4	0.5	4.6	100+	4.5	1.8	8.2	12.0	2.4	Nil	6.7	3.7	0.6	11.5	1.9	16.0	4.0
C 3	120–150	7.9	0.24	9.4	10.8	0.6	5.4	100+	6.1	2.3	1.2	18.8	3.8	Nil	9.1	5.3	1.4	20.4	1.4	23.0	11.8
										Site 4											
Ap1	0–13	8.1	0.81	8.0	14.4	0.6	4.6	100+	8.6	11.5	16.9	18.8	3.7	Nil	8.8	8.7	1.3	16.5	3.3	18.9	7.3
Ap2	13–28	8.1	0.54	12.8	13.6	0.5	5.1	100+	7.6	22.9	6.6	20.0	3.2	Nil	6.7	6.8	0.7	15.7	2.5	17.4	7.4
C 1	28–58	7.9	0.42	9.2	18.4	0.5	4.6	100+	6.5	32.1	3.9	17.3	2.9	Nil	6.1	4.4	0.7	15.7	3.6	14.2	7.3
C 2	58–81	7.9	0.17	6.0	16.4	0.5	3.2	100+	5.2	18.3	3.9	13.8	3.7	Nil	5.2	8.3	1.5	20.9	1.7	20.1	12.2
C 3	81–120	7.9	0.29	6.4	9.6	0.4	3.5	100+	5.4	17.9	1.2	11.9	8.7	Nil	24.1	19.9	2.4	42.6	1.0	59.0	27.1

in organic C content between the well drained sites and poorly drained site which may indicate an environment more favourable for organic C accumulation in the poorly drained sites. Apparently, the process of melanization responsible for mollic epipedon formation is taking place and the dark color of the upper horizons of the pedons at sites 3 and 4 could be related to this process.

Soil color (moist) in the surface horizons of the four pedons ranges from 10 YR 6/3 in the Cl horizon of the profile at site 1 to 10 YR 3/1 in the Ap1 horizon of the profile at site 4 (Table 2). This difference in soil color reflects differences in organic matter content. The high organic matter content in the pedons at sites 3 and 4 also correlates with improved soil structure in their Ap horizons (Table 2).

The surface horizon of the pedon at site 3 meets the requirements for a mollic epipedon in morphological, physical, and chemical properties, (Tables 2 and 3).

The amounts of phosphorus found in the Ap1 and Ap2 horizons of the pedon at site 3 were well below the 250 ppm P_2O_5 limit, which nullify the designation of these horizons as an anthropic epipedon.

It appears that a mollic epipedon can form in a relatively short period of time in that site 3 has been cultivated to date palms for only forty two years since it was last deep plowed. These results are similar to those found by Martel and Paul (1974). Apparently, the formation of the mollic epipedon in the oasis soils of Al-Ahsa could be related to two main variables. The first is the length of period under cultivation which may enhance the formation of a mollic epipedon and the second is the natural soil drainage.

A complete turnover of the soil profile is not performed until the old palms are replaced by new offshoots in the same field, then the mollic epipedon becomes the subject of destruction as a result of deep plowing. The natural soil wetness has an important role in the reformation of the mollic epipedon after the soil profile is disturbed by plowing. It is possible that the mollic epipedon reforms much sooner if the moisture regime is aquic as compared to udic.

Under the aquic moisture regime the soil conditions are mostly in reduced form due to an anaerobic condition. Hence, most of the elements such as iron, sulfur and manganese occur in reduced states. Furthermore, the presence of excess salts may decompose organic matter to humic acids. This destruction may change the soil color significantly (Bloomfield 1950, FitzPatrick 1980).

In general, soils that naturally had an aquic moisture regime, such as the soil at site 3, may have had a mollic epipedon before they were first cultivated but under date palm cultivation for several tens of years, its thickness may increase. Also a soil with an udic moisture regime under natural conditions may have a surface layer too thin to be mollic but under cultivation it may develop a mollic epipedon. It is unlikely, however, that a soil with an aridic moisture regime, such as the soils at sites 1 and 2, would ever form a mollic epipedon. Such relationships may indicate the presence or absence of the mollic epipedon in the studied soils.

The soils in this study area are classified according to their morphological, physical and chemical properties (Soil Survey Staff 1975). The pedons at sites 1 and 2 are classified as Typic Torripsamments although site 2 could be mapped as an irrigated phase. The classification of the soils at sites 3 and 4 is expected to change with time as they go through cycles of deep plowing, replanting, and manuring, however, based on their present characteristics they best fit the criteria for Typic Haplaquolls and Typic Haplaquents, respectively. In the schematic map of Saudi Arabia, most of the wet soils of Al-Ahsa were considered to be salorthids, but due to the large number of naturally flowing springs the soils probably remained leached so salorthids did not form.

It is estimated that these three sub-groups embrace a significant part of the soils under date palm cultivation in the oasis of Al-Ahsa in particular and many other oases of Saudi Arabia as a whole.

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خـواص وتـصنـيف بـعض أراضي واحـة الأحساء بالمملكة العربية السعودية

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قسم الأراضي والمياه ـ جامعة الملك فيصل
الهفوف ـ المملكة العربية السعودية

شملت الـدراسة الحقليـة بعض الأراضي المنزرعـة بـالنخيـل *(Phoenix dactylifera L.)* في واحة الأحساء، حيث تميزت بعض هذه الأراضي باحتـوائها عـلى الأفق التشخيصي Mollic والذي يعـزى تكـونـه بصـورة رئيسيـة إلى الـري المتكـرر والصرف الطبيعي وإلى إضافة المادة العضوية عن طريق الحرق السنوي للحشـائش والمخلفات النبـاتية الأخـرى. وعـلى هـذا، فقـد اقـترح أن هـذه الأراضي لا يـنبـغـي تـصـنـيـفـهـا (Typic Torripsamments) كما في الأراضي غير المزروعة المجاورة لها. بل إنها تتفق في خواصها مع الشروط المطلوبة لـTypic Haplaquents و Typic Haplaquolls والتي يمكن أن تشـمـل معـظم الأراضي الأخرى المنزرعة بالنخيل في واحة الأحساء.