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Morphology and Composition of Some Soils Under Date Palm Cultivation in Al-Hassa Oasis, Saudi Arabia

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ABSTRACT. Three soil profiles from different date palm orchards in Al-Hassa were described and sampled by horizons. Some chemical and physical properties of the samples were determined.

The three profiles were classified in the Entisol order of the American Taxonomy and are considered to be Orthents.

All of the profiles had light texture in the topsoil and heavier texture in the substratum. The soils were calcareous and had low contents of organic matter, available P and DTPA soluble Fe. The contents of Cu, Mn and Zn were higher than the critical levels below which deficiencies are to be expected.

A brief description of the location, climate, water resources and soil resources of Al-Hassa oasis is given by Elprince (1985) and Al-Barrak (1986). The agricultural area (8200 ha) is irrigated and drained by an irrigation and drainage network managed by Al-Hassa Irrigation and Drainage Authority (HIDA).

The soils of the oasis were investigated by a limited number of researchers (Jenkins 1976, Homeyer 1978 and Al-Barrak 1986) but they still need more research to classify them in the whole oasis and to estimate their agricultural potential. Also the nutrient status, especially of micronutrients, of these soils is still unknown and needs further investigation.

The objective of this study was to investigate the morphology and composition of three soils which have been cultivated for more than a hundred years.

Materials and Methods

Three soil pits were dug (Fig. 1) in three old date palm farms (100-200 years). Site 1 (25° 21′ 59″ N Lat and 49° 41′ 81″ E Long) has 38-year-old palm trees and its ground water was at a depth of 108 cm in January, 1985. Site 2 (25° 21′ 59″ N Lat

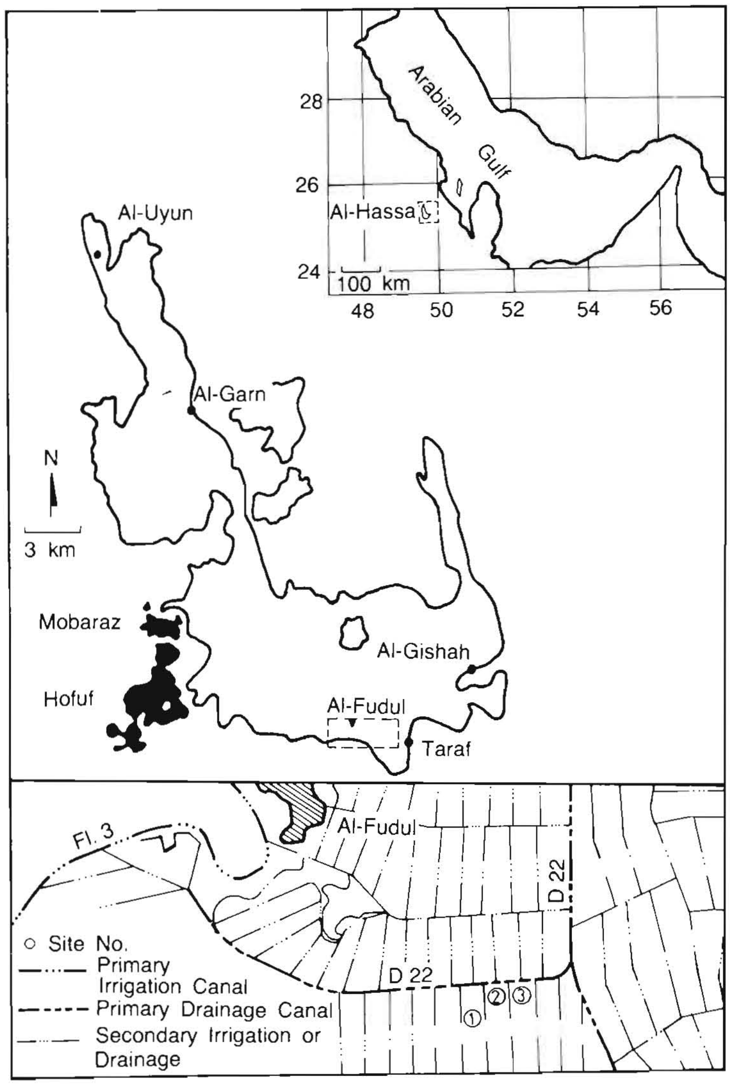

Fig. 1. Soil pit locations and the irrigation and drainage network.

and 49° 41′ 74″ E Long) and Site 3 (25° 21′ 48″ N Lat and 49° 41′ 66″ E Long) have date palms which were planted about 30 years ago, and ground water levels were at a depth of 125 cm (Site 2) and 133 cm (Site 3) in January, 1985. The ground water levels are generally expected to be much lower in the summer because of the heavy evapotranspiration in the oasis. The sites are at an elevation of 127.5 m above sea level.

In all the orchards, date palm trees were intercropped with a few citrus trees and grape vines which were showing iron deficiency chlorosis. The fertilization program on the farms was more or less the same, namely, 100 kg farmyard manure/tree/year mixed with ash of burned field residues.

The soil profiles were described using standards and terminology of the U.S. Soil Survey Manual (Soil Survey Staff 1951). A soil sample from each horizon was taken, air dried and sieved (< 2mm).

Soil pH (0.01 M $CaCl_2$), carbonate (volumetric calcimeter method), organic matter (colorimetrically after wet digestion with H_2SO_4 + $K_2Cr_2O_7$), EC and soluble ions (saturation extract) and mechanical analysis of the untreated sample (hydrometer) were carried out according to Black (1965). Available phosphorous was extracted with 0.5 M $NaHCO_3$ (Olsen *et al.* 1954) and was determined according to the method of Watanabe and Olsen (1965). Micronutrients (Fe, Cu, Mn and Zn) were extracted with DTPA (Lindsay and Norvell 1978) and determined by atomic absorption using background corrector (Abo-Rady 1979).

Fe and Mn oxides were extracted with boiling oxalate (0.4 N ammonium oxalate/oxalic acid) according to Abo-Rady (1985). Quantities extracted by this method are similar to those extracted by the method of Mehra and Jackson (1960). The advantages of the oxalate method used in this work were: faster, less in matrix (salts) and does not lead to the precipitation of metals in form of sulfides.

Results and Discussion

Morphological Properties

The morphological characteristics of the profile samples are presented in Table 1. The soils formed in a moderately coarse-textured sediment. According to Jenkins (1976) the Quaternary deposits of the oasis consist mainly of aeolian sand, fluvial deposits and sabkha sediments. The profiles are underlain by a layer of tertiary sand-clay marl at a depth varying between 82 cm and 125 cm. These soft gray-green marl strata belong to the Miocene Dam Formation and are of marine origin (Jenkins 1976). The parent materials of the layers in all sites under study

Table 1. Morphological properties and particle size distribution of the soil profiles

Horizon	Depth (cm)	Munsell color (moist)	Structure	Consistency (moist)	Boundary	Texture	Sand %	Silt %	Clay %
Site 1: Torriorthent, hyperthermic									
Ap1	0-21	10YR4/2	1fgr	vfr	c	sl	69.1	22.4	8.5
Ap2	21-36	10YR3/2	1fgr	fr	c	sl	75.1	12.4	12.5
C1	36-115	10YR5/2	m	fr	g	ls	85.1	2.4	12.5
2C2	115-175	10YR6/4	m	fr		scl	51.2	19.2	29.6
Site 2: Torriorthent, hyperthermic									
Ap1	0-21	10YR5/3	1fgr	vfr	c	sl	73.5	12.0	14.5
Ap2	21-68	10YR5/2	1fgr	fr	c	sl	78.5	7.0	14.5
C1	68-82	10YR5/4	m	fr	g	sl	69.5	11.2	19.3
2C2	82-143	10YR6/6	m	fr	g	scl	54.5	21.2	24.3
2C3	143-182	10YR6/4	m	fr		scl	63.5	16.2	20.3
Site 3: Torriorthent, hyperthermic									
Ap1	0-25	10YR4/3	1fgr	vfr	c	sl	82.3	2.2	15.5
Ap2	25-98	10YR4/3	1fgr	fr	c	sl	82.2	3.3	14.5
C1	98-125	10YR6/4	m	fr	g	sl	70.3	11.2	18.5
2C2	125-173	10YR6/4	m	fr		scl	58.5	20.2	21.3

Abbreviations for structure: (1) Strength: 1 = weak; (2) size: f = fine, (3) kind: gr = granular, m = massive.
Abbreviations for consistency: fr = friable, vfr = very friable.

were found to be quite similar; therefore, there were no big differences among the three profiles.

The deep Ap2 horizons, especially in Sites 2 and 3, are the result of date palm cultivation practices in the oasis which is deep plowed (up to 1 m) each time when old palms are replaced by new offshoots.

The difference in color between Ap1 and Ap2 at sites 1 and 2 resulted apparently from the added manure and ash and their mixture in the soil, or may have resulted from other agricultural practices like burning of residues at different spots in the farm, addition of sand to raise the level of the soil, and plowing.

According to the morphological, physical and chemical properties (Tables 1 and 2) the three soils can be classified in the Entisol order of the American Taxonomy and considered to be Orthents (Soil Survey Staff 1975).

Table 2. Chemical properties of the soil profiles

Horizon	Depth cm	pH	$CaCO_3$ %	EC mS/cm	Soluble Ions me/L							Org. Matt. %	Avail P ppm	Oxides ppm		DTPA Soluble ppm			
					Ca	Mg	K	Na	CO_3+ HCO_3	Cl	SO_4^*			Fe	Mn	Fe	Cu	Mn	Zn
Site 1																			
Ap1	0-21	7.8	15.4	6.15	21.0	15.0	1.3	30.0	0.5	33.5	33.3	0.93	5.7	58	9.0	2.2	0.20	9.0	1.46
Ap2	21-36	7.8	13.8	4.90	18.9	16.5	0.5	16.0	0.8	21.5	29.6	0.35	5.1	73	6.0	1.8	0.14	5.0	0.38
C1	36-115	7.8	9.5	4.60	14.0	9.0	0.7	25.0	0.5	35.7	12.5	0.20	5.0	179	10.0	3.0	0.21	4.0	0.49
2C2	115-175	7.9	19.0	4.50	15.8	10.3	0.6	21.7	0.7	27.5	20.2	0.08	4.1	53	7.0	3.2	0.29	7.2	0.72
Site 2																			
Ap1	0-21	7.9	9.0	3.00	5.5	6.0	0.5	19.1	2.5	20.5	8.1	0.96	4.9	92	12.5	5.2	0.30	13.0	1.64
Ap2	21-68	7.9	10.2	2.10	6.5	4.5	0.4	12.5	1.2	13.8	8.9	0.42	3.6	139	9.5	2.3	0.14	5.4	0.38
C1	68-82	7.9	14.0	2.80	6.0	5.4	0.5	17.0	1.0	21.0	6.9	0.30	3.0	75	14.0	3.8	0.18	6.0	0.36
2C2	82-143	7.9	15.4	2.50	6.8	5.1	0.5	18.0	0.5	23.0	6.9	0.08	2.9	41	16.0	3.2	0.26	7.2	0.46
2C3	143-182	8.0	23.0	4.00	9.0	8.0	0.5	25.2	0.9	13.4	10.4	0.05	2.7	30	5.0	3.2	0.26	5.4	0.42
Site 3																			
Ap1	0-25	7.9	8.3	2.05	4.4	3.2	0.4	13.0	1.3	12.9	6.8	0.92	4.8	145	13.0	4.0	0.28	9.2	1.98
Ap2	25-98	7.9	8.5	2.70	5.4	3.4	0.5	14.5	1.0	17.7	5.1	0.34	3.8	183	13.0	2.9	0.18	6.2	0.39
C1	98-125	7.9	13.8	3.60	9.6	6.2	0.5	20.7	0.8	10.0	26.2	0.09	3.2	73	15.0	2.2	0.18	6.0	0.32
2C2	125-173	8.0	21.5	4.90	11.7	9.3	0.6	24.9	1.1	33.7	11.7	0.04	2.8	25	11.5	1.6	0.18	4.8	0.32

* SO_4 = Total soluble cations - measured anions

Physico-chemical Properties

Table 2 shows that the soil profiles are calcareous, mildly and moderately alkaline in reaction and, due to irrigation, they contain moderate quantities of soluble salts, mainly NaCl and $CaSO_4$. The topsoil is enriched with organic matter but it decreases with increasing depth in the profile. Phosphorus extractable with sodium bicarbonate ranges from 2.7 to 5.7 ppm and highest amounts are, together with organic matter, in the surface layer.

Contents of iron and manganese oxides range from 25-183 and 5-16 ppm respectively. Compared with aridic calcareous soils (Randhawa *et al.* 1961, Mital and Roy 1963, and Joshi *et al.* 1981), the studied soils are poor in Fe and Mn oxides. The highest content of iron oxides is in the Ap2 horizons at Sites 2 and 3, but in the C1 horizon at Site 1. These higher contents are not associated with high contents of organic matter or clay but seem to occur through leaching and enrichment of iron in these horizons. Such leaching would be possible when it is taken into account that more than 10 mm of water are added daily in date palm farms in Al-Hassa area. Iron contents of the subsoils (influenced by ground water) are especially low. Iron is expected to be reduced and removed under such conditions. Manganese oxides are more mobile and they were leached to greater depths (C1 or C2). The vertical distribution of the Fe and Mn oxides is mainly influenced by soil-forming processes.

Contents of Fe, Cu, Mn and Zn extractable by DTPA range from 1.6-5.2, 0.14-0.30, 4.0-13.0 and 0.32-1.98 ppm respectively. The vertical distribution of these elements (Fig. 2) show that their contents are higher in the topsoil (effect of organic matter) and generally decrease with increasing depth, but they get higher in the 2C2-horizons in Sites 1 and 2 (probably because of the effect of ground water) To explain the reasons for such vertical distribution, correlation coefficients between DTPA extractable micronutrients and different soil parameters were calculated (Table 3). Generally, the correlation coefficients show significant influence of organic matter on Mn and Zn. Cu is positively influenced by organic matter, clay and clay + silt. This element is adsorbed in different amounts on the mentioned soil components. There is a negative influence of $CaCO_3$ on the DTPA extractable Fe and Mn, and of clay on the DTPA extractable Mn and Zn. The DTPA extractable amounts of Cu and Mn are negatively influenced by the content of Fe oxides. These results are in line with those reported by Joshi *et al.* (1983) and Awad *et al.* (1985) in aridic soils. The negative influence of $CaCO_3$ is possibly due to the oxidation of iron to ferric oxides (Mishra and Pande 1975). Knezek and Ellis (1980) found that high pH leads to the oxidation of Fe and Mn and to a decrease in their extractability with DTPA.

Critical levels of nutrient elements below which deficiencies would be expected are presented in Table 4. However, those levels were established for

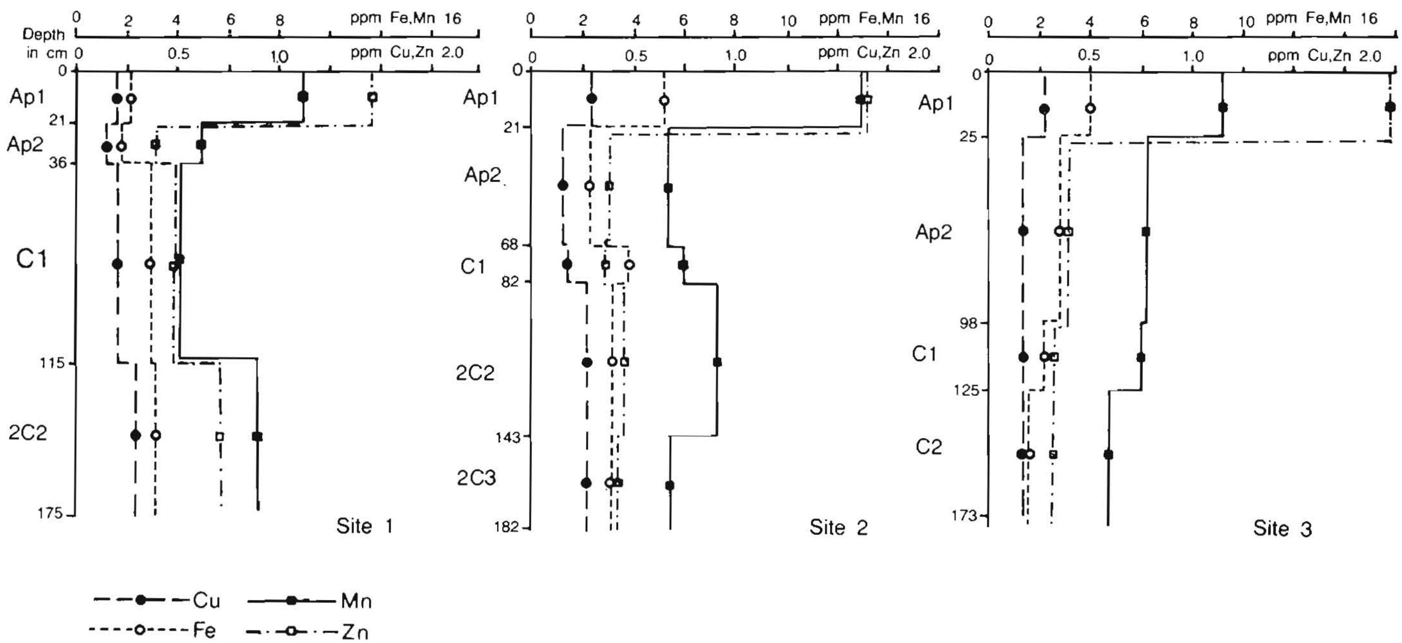

Fig. 2. The vertical distribution of DTPA extractable Fe, Cu, Mn and Zn in the soil profiles.

Table 3. Simple correlation coefficients of soil parameters with DTPA extractable micronutrients (n = 13)

Soil parameter	DTPA Extractable			
	Fe	Cu	Mn	Zn
Organic matter	0.444	0.221	0.774**	0.883**
pH	0.101	0.244	0.054	−0.196
$CaCO_3$	0.371	0.087	−0.316	0.443
Clay	0.099	0.420	−0.125	−0.315
Clay + silt	−0.115	0.328	0.009	−0.221
Fe oxides	0.194	−0.169	−0.041	0.201
Mn oxides	0.272	0.044	0.251	0.050

** Significant at 1% level.

Table 4. Critical levels of nutrient elements in calcareous soils (P=extractable by $NaHCO_3$; Fe, Cu, Mn, Zn = extractable by DTPA)

PPM					Reference
P	Fe	Cu	Mn	Zn	
10					Kamprath and Watson (1980)
12					Bowman *et al.* (1978)
	6.95				Sakal *et al.* (1984)
	4.5	0.2	1.0	0.8	Lindsay and Norvell (1978)
				0.6-0.8	Singh *et al.* (1980)

different crops under different conditions; therefore, they can be considered only for the purpose of comparison. The surface layers of the three sites contain higher amounts of Cu, Mn and Zn than the critical levels. The available amounts of Fe and P are below the critical levels and must be raised through fertilization. The low iron level is responsible for the mentioned iron deficiency symptoms in the citrus and grape plants growing on these farms.

Available nutrient elements in the soils of the orchards are higher than those found in uncultivated soils of Al-Hassa oasis (unpublished data) and similar to what was reported by other investiators in Saudi Arabia (Stewart-Jones and Kelso 1977, Bashour *et al.* 1983 and Devi Prasad *et al.* 1984).

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مورفولوجيا وتركيب بعض الأراضي المزروعة بالنخيل في واحة الأحساء، المملكة العربية السعودية

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تم وصف ثلاثة قطاعات من مزارع نخيل مختلفة في منطقة الأحساء، وأخذت عينات من كل أفق، وتم تحليل بعض المواصفات الكيميائية والفيزيائية لهذه العينات. صنفت الثلاثة قطاعات بأنها تتبع رتبة Entisol وتحت رتبة Orthent من نظام التقسيم الأمريكي.

اتصفت الأرض في الثلاثة قطاعات بقوام خفيف في الجزء العلوي من القطاع، وقوام أثقل في الجزء السفلي منه، كما اتصفت بأنها جيرية وذات محتوى منخفض من المادة العضوية ومن الفوسفور المتاح والحديد الذائب في DTPA. وكان محتواها من النحاس والمنجنيز والزنك أعلى من الحد الحرج والذي دونه يكون من المتوقع ظهور أعراض نقص العنصر.