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Characteristics of some Soils under Date Palm in Al-Hassa Eastern Oasis, Saudi Arabia

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Abstract. In the eastern oasis of Al-Hassa, a 14 km transect was made from the north eastern part of Hofuf city to the south of Al-Jishah village. On this transect, twenty four sampling sites were taken at approximately 500m intervals. In the study area, irrigation water is supplied from seven main springs situated within the first 2.5 km distance from the western edge of the transect. The soils are mostly under date palm cultivation (*Phoenix dactylifera* L.) but some are uncultivated. In the Ap horizons of the cultivated soils, the average values of the properties soil depth, organic carbon, EC_e and clay are 51.0 cm, 0.71%, 4.4 mmho/cm and 15.6 respectively. The surface horizons of the uncultivated soils have lower contents of organic carbon, higher EC_e values, and slightly lower contents of clay than those in the cultivated soils. Both the $CaCO_3$ and the soil pH were lower in the surface horizons of the uncultivated soils than those in the cultivated soils. The data also indicated that there were no close relationships between most of the studied soil properties and the increase in distance from the western edge of the transect.

Introduction

The oasis of Al-Hassa is situated in the Eastern Province of Saudi Arabia about 170 km southeast of Dammam on the Arabian Gulf (Fig. 1). The irrigation water is supplied from 32 natural springs fed from an artesian ground water reservoir (Neogene aquifer complex). During the late 1960's, the 32 springs were integrated into the present Al-Ahsa Irrigation and Drainage Project, [1,2]. The climate is continental with a mean annual precipitation of 69 mm and a mean annual temperature of 25.2°C [3, p. 96]. According to Elprince *et al.* [4], the cultivated land in Al-Hassa oasis equals 7000 ha with 92% of land used to grow date palms (*Phoenix dactylifera* L.). The oasis is L-shaped and sloping slightly to the north and east. For convenience, the oasis is divided into the eastern and the northern oasis [5]. The main drainage directions are east for the eastern oasis and north for the northern oasis. [6, pp. 58-74, 7].

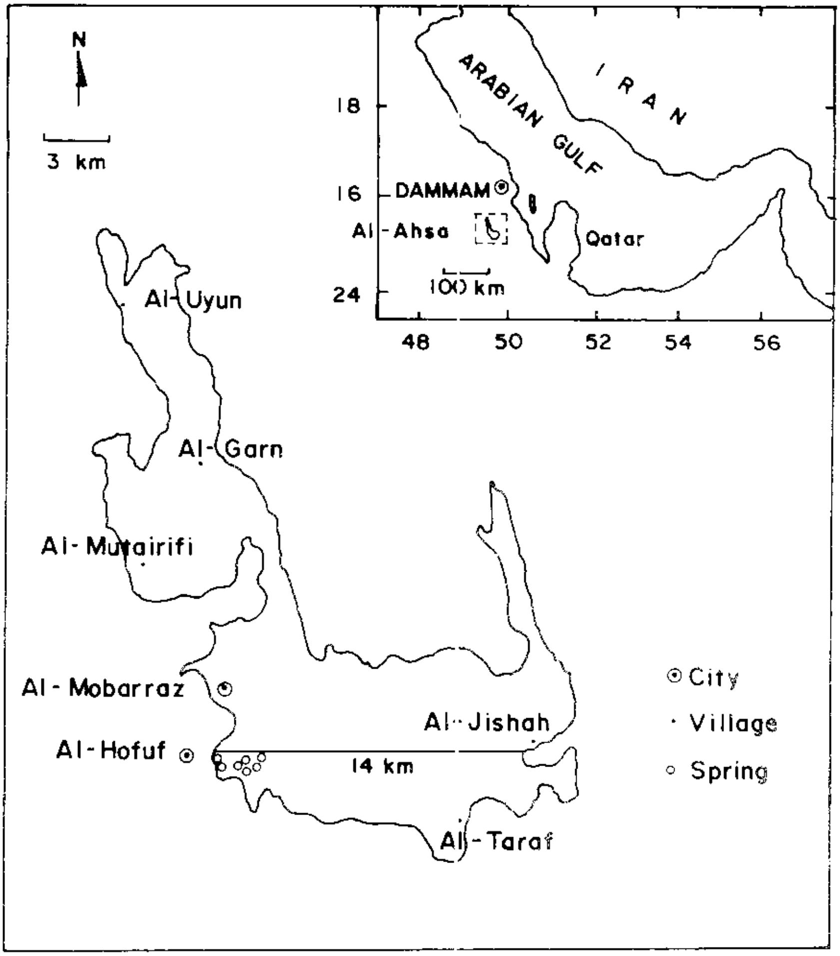

Fig. 1. Location of the study area in Al-Hassa, Saudi Arabia

The soils of Al-Hassa are of six great soil groups, namely, Torriorthents, Torripsamments, Calciorthids, Salorthids, Gypsiorthids and Camborthids but some of the oasis soils under date palm cultivation were classified as Typic Haplaquolls and Typic Haplaquents. [8, p. 41, 9].

It seems likely that the oasis of Al-Hassa was inhabited during early historic times and there had been a number of changes in the names by which both the oasis and the region as a whole were known.

It is assumed that agriculture started near some of the natural springs. In general, the springs are located in relatively high places where irrigation is possible by gravity flow. In addition, the soils near the springs were probably cultivated first because they were on high physiographic positions which enabled them to have better drainage than those far away from the springs (Fig. 1).

Before the completion of HIDA, the oasis of Al-Hassa has its old irrigation and drainage system. Most of the farms are irrigated without any mechanical devices where the water flows from the springs following the natural slope of the terrain. Water leaving the spring passes through irrigation canals and is diverted into farms. Many channels lead the surplus drainage water away from the farms along the two main natural drains until it reaches the edges of the cultivation district where it runs off into the desert or accumulates in the sabkhahs* that surround the palm belt. Soils are poorly drained with an aquic moisture regime [9]. Under the influence of such conditions, a high level of salinity has resulted in the soils of the eastern oasis [11,5].

Date palm has been cultivated in the oasis from centuries. In the study area, Date palm cultivation practices involve deep plowing (up to 1m) after breaking of hardpan, addition of manures and fertilizers, as well as some of the dry fronds, bunch stalks and weeds are burnt and the ashes are spread on the soil surface. These could influence and modify soil characteristics. A complete turnover of the soils is not performed until the old palms are replaced by new offshoots in the same field [9].

Although some of the soils in Al-Hassa oasis have been previously classified but, the present study was focused to cover more soils in Al-Hassa oasis. However, the specific objectives of this study were: (1) to determine the characteristics of some soils in Al-Hassa eastern oasis that have been under date palm cultivation and (2) to evaluate the effects of location and proximaty from the springs.

Materials and Methods

In this study a 1:10,000 map of Al-Hassa Irrigation and Drainage Project was used. A 14 km transect was made from the north eastern part of Hofuf city to the south of Al-Jishah village (Fig. 1). Twenty four sampling sites were established. The first site was located 70m west of Al-Hegil spring and the subsequent sites were situated at approximately 500m intervals. Most of the sampling sites occurred in cultivated fields. Seven springs namely Hagil, Khudud, Barabir, Luwaimi, Mahah,

*Sabkhah (playa) is an Arabic term for coastal and inland saline flat underlain by clay, silt and sand, and often encrusted with salt [10, pp. 84-86].

Ummalif and Buhadji are situated near the transect line (Fig. 1). The first four springs are considered as the main springs whereas the others are small springs. The distribution of these springs is such that one of these is situated near site 1, four near site 5, one near site 6 and none beyond site 6.

The soil profiles were exposed by digging a pit at each site and described according to the Revised Soil Survey Manual [12, pp. 173-188]. Soil samples from each horizon were collected for laboratory analysis. Samples were air dried and sieved to remove coarse fragments (> 2mm). Soil pH of the saturated paste, electrical conductivity of the saturation extract (EC_e), calcium carbonate, and gypsum content were determined [13]. Organic carbon was determined by the Smith-Weldon modification of the Walkley-Black method [14, pp. 219-221]. Particle size distribution was determined by the hydrometer method without removing $CaCO_3$ [15].

Results

Macromorphological, physical and chemical properties of the studied pedons are presented in Table 1. A dominant feature of the cultivated pedons in the study is the presence of an Ap horizon which is generally characterized by a dark color, very weak granular structure, sandy to loamy texture, clear boundary and very friable moist consistence. The surface horizons of the uncultivated pedons differ from the cultivated ones by having a light color, single grain structure and slightly hard to loose on dry.

The studied pedons were classified as:

Typic Halaquolls (Prof. No. 1,3,4,5,18 and 23)
Typic Haplaquents (Prof No. 5,6,8,10,13,14,15,16,19 and 20)
Aquic Torriorthents (Prof. No. 2 and 17)
Typic Torripsamments (Prof. No. 9,12 and 22)
Typic Salorthids (Prof. No. 24)
Typic Gypsiorthids (Prof. No. 11), and
Typic Torriorthents (Prof. No. 21) (Table 1).

The mean value of organic carbon in the Apl horizon of the cultivated soils is very high ranging from 0.28% to 2.2% (Table 2).

Particle size distribution results showed that sand (2000–50 um) is the dominant separate in the upper horizons at each site (Table 1). The percentages of sand in the Ap horizons of the studied pedons ranged between 41.1% in the Ap1 horizon at site 16, and 82.4 in the Ap horizon at site 9. The mean values of sand contents in the Ap1

Table 1. Morphological, Physical and Chemical properties of pedons at the twenty four sampling sites in the Eastern Oasis of Al-Hassa

Hori-zon	Depth cm	Color moist	Mottles	Struc-ture	Consist-ence	Textural class	Bound-ary	Sand	Silt %	Clay	pH Paste	Organic carbon	$CaCO_3$	Gypsum %	EC mmho/cm
						Site 1 (22 yrs palm) Typic Haplaquolls									
Ap	0-65	10YR 3/2		vflgr	mvfr	sl	c	57.1	27.7	15.2	8.2	0.68	38.3	0.2	2.4
AC	65-130	10YR 4/3		m	mfr	sl	a	57.6	22.7	19.7	8.1	0.43	41.5	0.8	3.0
C	130 +	2.5Y 7/4		m	mfr	ls		88.6	1.3	10.2	8.3	0.06	12.6	0.4	2.9
						Site 2 (40 yrs palm + rice) Aquick Torriorthents									
Ap	0-30	10YR 4/2		vflgr	mvfr	l	a	44.1	36.7	19.2	8.0	0.31	54.6	0.4	4.0
C	30-163	5Y 6/2		m	wss.wps	cl		46.1	25.7	28.2	8.1	0.18	52.6	0.5	5.2
						Site 3 (25 yrs palm) Typic Haplaquolls									
Ap	0-40	10YR 3/2		flgr	mfr	sil	g	45.6	52.2	2.2	8.3	0.83	30.6	1.5	3.3
AC	40-100	10YR 4/2		m	mfr	scl	a	53.6	26.7	19.7	8.3	0.38	44.4	0.6	4.1
C	100-117	7.5YR6/4	c2d10YR8/2	m	mfi	sic		3.3	53.8	42.9	8.1	0.00	62.8	0.5	4.7
						Site 4 (30 yrs palm) Typic Haplaquolls									
Ap1	0-24	10YR 3/2		vflgr	wss,wps	sl	g	45.6	30	15.4	8.4	0.62	39.4	0.7	1.6
Ap2	24-80	10YR 4/2		vfvlgr	ws,wp	sl	g	53.5	27.5	19	8.2	0.65	44.1	0.9	2.3
AC	80-116	10YR 5/2		m	ws,wp	l	c	34.6	43	22.4	7.5	0.32	60.0	0.2	3.1
2C	116 +	5Y 6/2	f2d7.5YR6/6	m	wvs,wvp	c		15	34	51	7.8	0.25	50.7	0.6	2.5
						Site 5 (60 yrs palm) Typical Haplaquents									
Ap1	0-15	10YR 3/2		flgr	mvfr	l	g	50.1	30.5	19.4	7.8	1.00	52.8	0.8	4.4
Ap2	15-75	10YR 4/2		m	mfr	l	c	47.1	31.5	21.4	7.6	0.68	56.3	0.6	3.3
AC	75-145	5Y 6/2	f1d10YR6/6	m	mfr	cl		37.6	29.0	33.4	7.8	0.65	49.6	0.6	3.5
C	145-170+	5Y 6/3		m	mfi	cl		34.1	27.0	38.9	7.8	0.34	46.5	2.2	5.1
						Site 6 (25 yrs palm) Typic Haplaquents									
Ap1	0-22	10YR 4/2		flg	mvfr	sl	c	67.4	20.1	12.5	8.4	1.30	34	0.5	2.3
Ap2	22-70	10YR 5/3		m	mfr	sl	c	56.6	27.5	15.9	8.2	0.68	44.1	0.3	2.9
C1	70-190	2.5Y 5/2		m	mfr	cl		37.6	32.5	29.9	8.1	0.46	59.0	0.8	2.6
C2	190 +	5T 7/2		m	mfr	cl		20.7	56.4	22.9	8.0	0.32	45.2	10.3	7.1

Table 1.Contd…

Hori-zon	Depth cm	Color moist	Mottles	Struc-ture	Consist-ence	Textural class	Bound-ary	Sand	Silt %	Clay	pH Paste	Organic carbon	$CaCO_3$	Gypsum %	EC mmho/cm
Site 7 (75 yrs palm, abandoned) Typic Haplaquolls															
Ap1	0-25	10YR 3/2		flgr	mvfr	sl	c	54.6	41	4.4	7.6	0.93	36.3	1.6	45
Ap2	25-70	10YR 6/2	fld10YR7/6	m	mfi	cl	c	42.6	24.5	32.9	7.8	0.53	47.6	0.6	10.4
C	70-90+	5Y 6/2	fld7.5YR6/6	m	mfi	cl		29.6	32	38.4	7.1	0.27	61.1	0.5	9.4
Site 8 (35 yrs palm) Typic Haplaquents															
Ap1	0-7	10YR 3/1		flgr	mvfr	sl	c	66.9	20.5	12.6	7.9	0.93	73.1	0.5	2.9
Ap2	7-55	10YR 4/2		flgr	mfr	1	g	46.4	31	22.6	8.0	1.20	52.2	0.6	2.9
C1	55-140	10YR 5/2		m	mfr	1	c	46.9	29.5	23.6	7.9	0.18	50.4	0.9	2.3
C2	140 +	5Y 6/2		m	mfi	cl		28.4	40	31.6	7.7	0.18	53.3	1.3	3.2
Site 9 (1 yr offshoots + alfalfa) Typic Torripsamments															
Ap	0-40	10YR 5/3		sg	ml	ls	c	82.4	10	7.6	7.9	0.46	18.7	0.4	2.2
Apb	40-65	2.5Y 4/2		m	mfr	sl	c	55.4	38	6.6	7.7	0.52	45.1	0.7	3.0
C	65-105	5Y 6/2		m	mfi	scl		55.6	25.5	18.1	7.7	0.32	40.4	0.8	3.6
Site 10 (7 yrs palm) Typic Haplaquents															
Ap	0-40	10YR 5/3		m	mfr	cl	c	44.4	48.5	7.1	7.7	0.80	40.7	0.8	7.2
C1	40-133	10YR 6/4		m	mfi	cl	c	54.4	40	5.6	7.6	0.34	34.4	21.3	8.4
C2	133-153+	5Y 6/2		m	mfi	1		49.4	48	2.6	7.7	0.10	37.6	2.1	9.7
Site 11 (Uncultivated) Typic Gypsiorthids															
C1	0-98	10YR 6/3		sg	dsh	scl	c	45.0	28.0	27.0	7.8	0.07	28.5	21.5	15.1
C2	98-140	2.5Y 7/4		m	dsh	sl	ab	50.0	44.0	6.0	7.9	0.02	33.2	0.6	4.5
Ab	140-145	10YR 3/1		sg	dsh	ls	ab	83.4	11.3	5.3	8.0	0.05	18.7	0.5	2.9
C	145-225+	2.5Y 7/4		m	dsh	sl		70.0	20.0	10.0	7.9	0.00	24.9	1.1	4.1
Site 12 (Uncultivated) Typic Torripsamments															
C1	0-70	10YR 6/4		sg	dl	ls	abs	80.0	14.0	6.0	7.9	0.20	20.9	3.2	3.5
2C2	70-200+	5Y 7/2	c2d7.5YR6/6	mlsbk	dh	sl		61.0	27.0	12.0	8.0	0.00	77.2	2.4	45.0
Ab	140-145	10YR 3/1		sg	dsh	ls	ab	83.4	11.3	5.3	8.0	0.05	18.7	0.5	2.9
C	145-225+	2.5Y 7/4		m	dsh	sl		70.0	20.0	10.0	7.9	0.00	24.9	1.1	4.1

Table 1.Contd...

Hori-zon	Depth cm	Color moist	Mottles	Struc-ture	Consist-ence	Textural class	Bound-ary	Sand	Silt %	Clay	pH Paste	Organic carbon	$CaCO_3$ %	Gypsum	EC mmho/cm
						Site 12 (Uncultivated) Typic Torripsamments									
C1	0-70	10YR 6/4		sg	d1	1s	abs	80.0	14.0	6.0	7.9	0.20	20.9	3.2	3.5
C2	70-200+	5Y 7/2	c2d7.5YR6/6	mlsbk	dh	s1		61.0	27.0	12.0	8.0	0.00	77.2	2.4	45.0
						Site 13 (10 yrs palm) Typic Haplaquents									
Ap1	0-8	10YR 4/2		fvlgr	mvfr	s1	c	55.4	27.5	17.1	8.1	0.88	46.8	0.5	1.7
Ap2	8-60	10YR 5/3		m	mfr	s1	c	54.4	28.0	17.6	8.0	0.70	44.0	0.7	1.8
C	60.82+	2.5Y 6/2		m	mfr	s1		70.4	14.0	15.6	8.0	0.37	40.0	0.3	1.7
						Site 14 (7 yrs palm) Typic Haplaquents									
Ap1	0-9	10YR 4/2		flgr	mfr	s1	c	63.9	22.5	13.6	7.9	0.89	37.5	0.5	6.5
Ap2	9-46	10YR 5/3		vfvlgr	mfr	s1	c	64.9	18.5	16.5	7.7	0.42	35.5	0.5	6.5
C1	46-85	10YR 6/2		m	mfi	s1	c	79.4	9.6	11.0	7.7	0.32	29.5	0.4	5.6
C2	85-111+	10YR 8/3		sg	ml	s		90.4	7.6	2.0	8.0	0.07	26.5	0.3	3.3
						Site 15 (3 + 40 yrs palm) Typic Haplaquents									
Ap1	0-7	10YR 4/2		flgr	mfr	s1	c	62.4	21.1	16.5	7.8	2.20	45.3	0.5	4.3
Ap2	7-74	10YR 5/3	m1f10YR5/2	m	mfr	sc1	c	59.4	15.6	25.0	7.9	0.52	43.8	0.9	1.8
C	74-89+	5Y 6/2		m	mfi	sc1		58.4	11.6	30.0	7.7	0.11	45.8	0.7	2.7
						Site 16 (28 yrs palm) Typic Haplaquents									
Ap1	0-13	10YR 3/2		flvgr	mfr	si1	c	41.1	55.7	3.2	7.5	0.48	64.6	0.7	9.2
Ap2	13-28	10YR 4/2		flgr	mfr	sc1	c	54.6	24.7	20.7	7.9	1.04	56.4	0.7	1.7
AC	28-106	10YR 5/2		m	mfr	1	gr	41.1	37.5	20.4	7.7	0.58	62.9	0.8	5.2
C	106-140	10YR 6/2		m	mfr	sl	gr	54.6	26.2	19.2	7.5	0.67	64.0	0.5	3.4
Apb	140-205	10YR 3/2		flgr	mfr	s1		69.6	19.2	10.2	7.4	0.63	82.6	0.4	6.1
C	205 +	2.5Y 6/4	f2d10YR5/6	m	mfr	1		44.6	35.7	19.7	8.0	0.89	69.0	0.7	2.2
						Site 17 (10 yrs palm) Aquic Torriorthents									
Ap	0-56	10YR 4/3		vfvlgr	mfr	s1	c	66.6	9.7	23.7	7.9	0.32	26.8	0.7	1.2
Apb	56-61	10YR3.5/2		vfvlgr	mfr	1s	c	72.1	16.7	11.2	7.8	0.41	21.2	0.6	1.5
C	61-86+	5Y 5/3		m	mfr	s1		74.6	13.2	12.2	7.8	0.15	25.8	0.5	1.3

Table 1.Contd...

Hori-zon	Depth cm	Color moist	Mottles	Struc-ture	Consist-ence	Textural class	Bound-ary	Sand %	Silt %	Clay %	pH Paste	Organic carbon %	$CaCO_3$ %	Gypsum %	EC mmho/cm
						Site 18 (28 yrs palm) Typic Haplaquolls									
Ap1	0-20	10YR3/2		flgr	wss,wps	sl	c	66.5	20.0	13.5	8.0	1.04	24.5	0.9	1.8
Ap2	20-75	2.5Y 4/2		fvlgr	wss,wps	sl	g	66.5	19.0	14.5	7.8	0.30	25.8	0.8	2.0
C1	75-245	2.5Y 4/2		m	wss,wps	sl		69.0	24.5	6.5	7.7	0.30	28.6	0.4	9.2
C2	245-300	5Y 5/2		m	wss,wps	sil		37.5	59.0	3.5	7.6	0.05	66.2	1.5	16.7
						Site 19 (7 yrs palm) Typic Haplaquents									
Ap	0-22	10YR 5/4		sg	mvfr	sl	g	72.0	24.5	3.5	7.9	0.28	14.8	7.4	3.5
C1	22-50	10YR 5/4		m	mfi	sl	c	62.0	34.5	3.5	7.8	0.22	16.9	14.7	5.9
C2	50-82	2.5Y 7/2		m	mfi	l		35.0	40.5	4.5	7.7	0.30	20.0	25.0	1.5
						Site 20 (1 yr offshoots + 20 yrs palm) Typic Haplaquents									
Ap	0-40	10YR 5/2		fvlgr	ds	sl	c	74.0	13.0	13.2	8.2	0.55	21.3	0.4	1.2
C1	40-55	10YR 6/3		m	ds	ls	c	83.0	11.0	6.0	8.0	0.14	13.8	1.3	1.6
C2	55-70+	10YR 7/4	f fine $CaCO_3$ concentra-tions	m	ds	sl		70.0	22.0	9.0	7.9	0.04	14.3	0.2	2.4
						Site 21 (10 yrs palm) Typic Torriorthents									
Ap	0-10	10YR 4/3		sg	mfr	sl	c	76.7	13.5	9.8	8.2	0.57	17.9	1.0	2.2
C	10-52	10YR 5/4		sg	mfr	ls	ab	80.2	11.0	8.8	8.1	0.12	18.7	0.3	1.7
Apb	52-100	2.5Y 4/2		m	mfr	ls	c	80.7	10.0	9.3	8.1	0.10	18.7	0.1	2.7
C1	100-114+	2.5Y 6/2		m	mfr	sl		79.2	6.0	16.8	7.9	0.01	18.3	0.1	4.5
						Site 22 (30 yrs dead palm, abandoned) Typic Torripsamments									
A11	0-6	10YR 5/3		f1pl	dh	sil	c	34.2	55.0	10.8	7.9	0.84	17.0	4.5	4.4
A12	6-50	10YR 3/2	c1p10YR8/1	m	dh	ls	ab	74.2	20.0	5.8	7.8	0.35	14.2	3.3	23.3
C1	50-66	10YR 6/3	c1p10YR8/1	m	ds	ls	ab	85.2	12.0	2.8	7.8	0.04	9.0	0.0	10.5
C2	66-80	5Y 6/2		m	dsh	sl		76.2	19.0	4.8	7.7	0.11	16.4	0.5	14.1

Table 1.Contd...

Hori-zon	Depth cm	Color moist	Mottles	Struc-ture	Consist-ence	Textural class	Bound-ary	Sand %	Silt %	Clay %	pH Paste	Organic carbon %	$CaCO_3$ %	Gypsum %	EC mmho/cm
						Site 23 (15 yrs palm) Typic Haplaquolls									
Ap1	0-27	10YR 3/2		flgr	mfr	sl	g	70.2	11.0	18.8	8.1	1.21	12.5	0.6	1.5
AC	27-96	10YR 5/2		m	mfr	sl	g	78.7	7.0	14.3	8.0	0.35	17.2	3.0	1.9
C1	96-166	5Y 5/3		m	mfr	sl		82.2	2.0	15.8	7.9	0.19	20.2	0.6	2.3
C2	166-200	10YR 7/3		m	mfr	ls		85.2	6.0	8.8	7.9	0.12	43.2	0.1	90.0
						Site 24 (Uncultivated) Typic Salorthids									
A11	0-18	10YR 4/3	c1d10YR8/1	f1pl	dsh	sl	c	60.4	29.6	10.0	7.5	0.24	29.2	17.1	97.0
A12	18-35	10YR 3/3	m1d10YR8/0	m	dsh	sl	c	63.4	23.1	13.5	7.8	0.05	12.0	10.5	60.0
C1	35-72	10YR 6/6	c1d10YR8/0	m	dsh	sl	ab	60.2	27.0	12.8	7.8	0.12	18.5	0.7	42.5
C2	72+	5Y 7/3	f1d10YR6/6 (10YR 3/2)	m	dh	l		40.7	45.5	13.8	7.7	0.14	19.3	0.7	105.0

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

Table 2. Ranges and means of some soil properties of the surface horizons of the studied profiles in the eastern oasis of Al-Hassa

Property	Cultivated soils: Ap1 horizons Min	Max	Mean	Ap2 horizons Min	Max	Mean	Ap1 + Ap2 Mean	Surface horizons Uncultivated soils Min	Max	Mean
pH (Paste)	7.5	8.4	8.0	7.6	8.2	7.9	7.9	7.5	7.9	7.7
Organic C %	0.28	2.2	0.82	0.3	1.2	0.61	0.71	0.07	0.24	0.17
$CaCO_3$ %	12.5	73.1	35.8	21.2	56.4	43.0	39.4	20.9	29.2	26.2
Gypsum %	0.2	7.4	1.04	0.3	0.9	0.66	0.85	3.2	21.5	13.9
EC (mmhos/cm)	1.2	45	5.4	1.5	10.4	3.3	4.4	3.5	97.0	38.5
Sand %	41.1	82.4	60.4	42.6	72.1	56.1	58.3	45.0	80.0	61.8
Clay %	2.2	23.7	12.4	6.6	32.9	18.7	15.6	6.0	27.0	14.3

Average depth of the plowed horizons (Ap1 + Ap2) = 51.6 cm and Ap2 horizons of the pedons were 66.4% and 56.2% respectively, whereas in the surface horizons of the uncultivated soils was 61.8% (Table 1 and 2). The clay contents of the surface horizons of the cultivated soils are low. The mean values of clay contents in the Ap1 and Ap2 horizons were 12.4% and 18.7% respectively, whereas that of the surface horizons of the uncultivated soils was 14.3% (Table 2).

Soil reaction, electrical conductivity, calcium carbonate equivalent and gypsum content of the soil at each site are presented in Table 1. In general, all the soil profiles have almost identical pH values being moderately alkaline. The highest and lowest pH values of the soil saturated paste were 8.4 and 7.1 in Ap1 horizon of the pedon at site 4 and C horizon of the pedon at site 7, respectively. The mean value of pH of the Ap1 horizon was 8.0 and 7.9 for Ap2 horizons, whereas that of the surface horizons of the uncultivated soils was 7.7 (Table 2). Electrical conductivity values of the Ap horizons of the pedons ranged between 1.2 mmhos/cm in the Ap horizon at site 17 and 45 mmhos/cm in the Ap1 horizon at site 7. Generally, the EC_e values for the C horizons are higher than those for their Ap horizons. However, the results further showed that the uncultivated sites 12, 22 and 24 have the highest EC_e values compared with those in the cultivated soils.

Calcium carbonate equivalent was high in most of the studied pedons. The highest value could be seen in the Apb horizon at site 16 which was 82.6% at a depth of 140-205 cm. The lowest value was 9.0% in the Cl horizon at site 22.

The gypsum contents were low in most of the pedons and ranged from 0% (Cl horizon at site 22) to 25% (C2 horizon at site 19). The pedons with relatively high percentages of gypsum were observed in the uncultivated or abandoned areas. The values of gypsum contents were 1.04 and 0.66 in the Ap1 and Ap2 horizons, respectively; whereas that of the surface horizons of the uncultivated soils was 13.9% (Table 2). Although, the gypsum contents did not show any trend with depth in most of the pedons, they showed a decrease with depth at sites 11, 12, 22 and 24, and an increase with depth at site 19.

Discussion

The soils of Al-Hassa eastern oasis vary in characteristics of the Ap horizon, soil structure and organic carbon content under date palm cultivation over varying periods of time (Table 1). Some of the Ap horizons of the cultivated soils meet the requirements for mollic epipedon in morphological, physical and chemical properties and the soils of the study area were classified according to their properties into the subgroups listed in Table 1 [16, p. 754].

In geneal, the mean values of both sand and clay fractions did not indicate an increasing trend from the uncultivated soils to the cultivated soils (Table 2). The reason that the mean value of sand percentages is slightly higher in the Ap1 horizons than that in the Ap2 horizons is due to the application of animal manure containing about 90% sand which was used as livestock bedding [1]. This probably contributed in minimizing the differences in particle size distribution between the cultivated and uncultivated soils.

Both Ap1 and Ap2 horizons of the cultivated soils in the study area have higher mean values of pH, organic carbon and calcium carbonate equivalent than those in the surface horizons of the uncultivated soils (Table 2). In contrast, the mean values of gypsum and EC_e were higher in the surface horizons of the uncultivated soils. This may be attributed to the effect of frequent flood irrigation which is a common practice in the oasis.

The data did not give significant correlation between distance and soil pH, organic carbon or EC_e values. Most of these EC_e values were lower than 5 mmhos/cm, with some exceptions especially in the uncultivated and abandoned soils in which the EC_e values were extremely high. This may indicate that the irrigation water was sufficient to reduce the EC_e hence most of the soils prior to irrigation might have had a higher salt concentration.

The $CaCO_3$ contents for both surface horizons and profile averages of the pedons showed a significant trend for a decrease with increased distance from site 1 ($r = -0.5^*$ and $r = -0.64)^{**}$, respectively (Fig. 2). The variations in $CaCO_3$ content throughout some of Al-Hassa soils were related to differences in the origin of the underlying strata [17].

All of the seven springs that exist in the study area are situated within the first 2.5 km distance from site 1. (Fig. 1). The soils near the springs have undergone more intensive cultivation than those far away from the springs and the quality of the springs water deteriorates progressively as the distance from the springs increases. The soils nearest the springs are more developed than those further away. This development is characterized by deeper profiles, higher values of organic carbon, better soil structure and lower values of EC_e and pH.

Five buried profiles with varying thickness were found underlying the studied pedons (Table 1). Most of these buried profiles seem to be buried by farmers recently, probably in the past ten years when the old date palms were replaced by new offshoots. It seems likely that the soil profile at site 16 was buried approximately 28 years ago. The buried profile at site 11 exists in uncultivated land and it seems to be quite old. The absence of such buried profiles underlying the pedons near the springs could not be taken as an evidence that agriculture started some distance from the springs, because most of the soils near the springs are on higher areas so they are

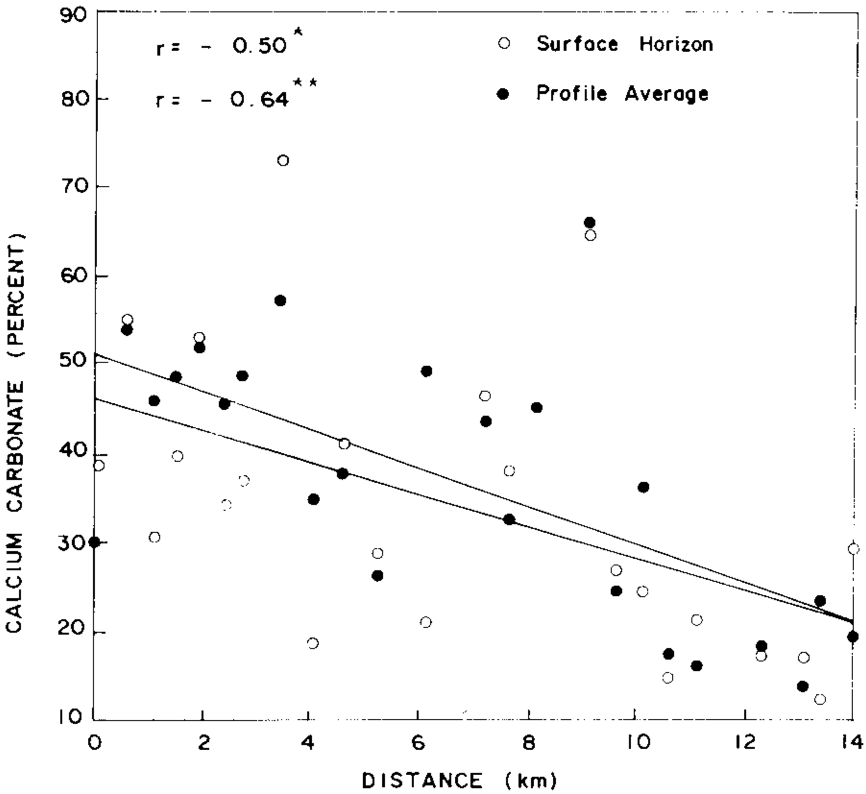

Fig. 2. Variation in $CaCO_3$ percentages along the transect with distance from the first site

less susceptible to burial activity by farmers. According to Vidal [5], the farms that are irrigated with mechanical devices are usually closer to the springs and much more common in the western part of the eastern oasis.

Soils at a distance of about 8.5 km have more organic carbon in their Ap horizons than some of the soils near the spring. The organic carbon in the surface horizons of the soils did not show any decrease with increased distance from the first site. But at a distance of 8 km from site 1, the percentage of organic carbon in the Ap horizons of the pedons showed a decrease with increased distance. No significant correlation was found between distance and organic carbon contents for both surface horizons and profile averages of the studied pedons ($r = -0.0017$ and $r = -0.2406$), respectively. Hence there appears to be no close relationship between the contents of organic carbon in the surface horizons.

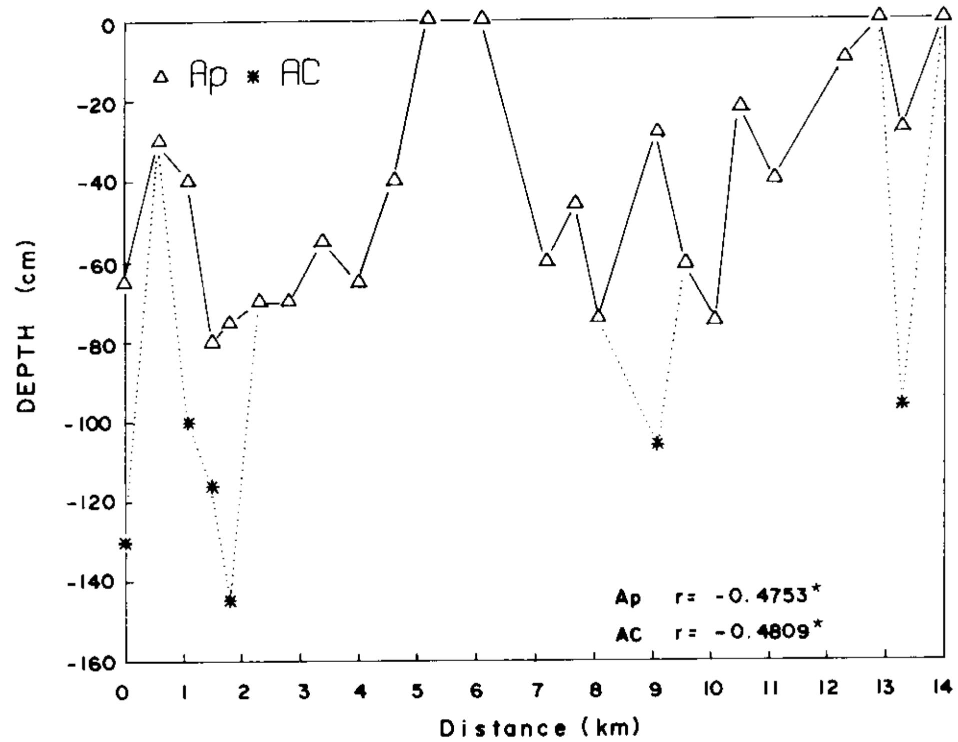

Fig. 3. Variation in depth of Ap and Ac horizons along the transect with distance from the first site

Average depth of the plowed horizons (Ap horizons) of the studied profiles is 51.6 cm (Table 2). The depth of the Ap horizons significantly decreased (r = -0.475*) with increased distance from the first site (Fig. 3). It seems that the soils near the springs had probably undergone more intensive cultivation than those further away.

The date palm cultivation caused some changes in the properties of the soils of the study area (Table 1).It appears that faunal pedoturbation which is a process of soil mixing by animals such as ants, earthworms, and man himself is the major soil forming process in the surface horizons of the oasis soils. Therefore, the variations in the depth of the Ap horizons of the pedons along the transect could be related to different intensities of date palm cultivation.

In the oasis soils of Al-Hassa, the gain in organic matter is believed to be due to the addition of ashes from the annual partial burning of weeds and plant residues along with the decomposition of dead weeds and palm roots [9].

The soils of the study area have high contents of $CaCO_3$ inherited from their parent materials (aeolian sand and/or alluvium). $CaCO_3$ tends to keep clay and organic matter flocculated and immobilized in the upper horizons of the cultivated pedons. The presence of this high content of $CaCO_3$ in the cultivated soils and its subsequent effect on pH may contribute to the rapid decomposition of the organic matter resulting in the formation of mollic epipedons. Therefore, the darkening of the surface horizons of the cultivated soils to certain depth may form in a relatively short period of time. Also, under the hyperthermic temperature regime of the soils of Al-Hassa, the dark color of the Ap horizon may disappear rather quickly if these soils were completely abandoned or fallow for long periods.

It was found that pH, EC_e and organic carbon in surface horizons and profile averages were not correlated with distance. In addition $CaCO_3$ contents and the depth of the Ap horizons were found to be correlated with distance but not strongly. Thus, it appears that there are no appreciable differences in the degree of development of the pedons along the transect.

One of the possible reasons for the absence of major differences in the development of the pedons along the transect is due to the presence of a slowly permeable stratum underlying most of the studied pedons [18, p. 30]. This stratum restricts the downward movement of water and may hinder the formation of any subsurface horizon.

It was reported that most of the oasis soil of Al-Hassa probably had poor drainage conditions before the installation of Al-Hassa Irrigation and Drainage Project [2,9]. Under the environmental conditions of Al-Hassa oasis with 69 mm of rain a year, the natural soil wetness may explain the previous finding that there were no close relationships between most of the studied soil properties and the increase in distance from the western edge of the transect. The elevation in the study area from 147 m at site 1 to 122 m at site 24 decreased. Therefore, the soils on lower positions probably have had udic or aquic moisture regimes before they were first cultivated. While those on higher positions had probably aridic or an udic moisture regimes. The aquic moisture regime is probably more favourable than the udic moisture regime for organic matter accumulation and darkening of the surface horizons. This natural soil drainage in the soils far away from the springs probably accelerated the formation of A horizons in these soils over those near the springs. Also, the presence of excess salts in the soils far away from the springs before cultivation, may enhance the decomposition of organic matter to form some humic substances which may contribute in darkening the surface horizons of these soils.

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خصائص بعض الأراضي في واحة الأحساء الشرقية

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ملخص البحث. تم عمل مقطع عرضي طوله ١٤ كم في واحة الأحساء الشرقية وذلك من الجزء الشمالي الشرقي لمدينة الهفوف وحتى جنوب قرية الجشه. ولقد أخذت عينات من أربعة وعشرين موقعًا على مسافات بينية قدرها ٥٠٠م تقريبًا وذلك على امتداد هذا المقطع العرضي. هذا وإن معظم الأراضي منزرعة بأشجار النخيل إلا أن بعضها غير مزروع.

ولقد بلغت معدلات بعض الخواص في الآفاق السطحية للأراضي المزروعة بالنخيل كعمق التربة والكربون العضوي والتوصيل الكهربائي والطين، القيم التالية: ٥١٫٦ سم، ٠٫٧١٪، ٤٫٤ مليموز/سم و١٥٫٦٪ على التوالي. إلا أن الآفاق السطحية للأراضي غير المزروعة تحتوي على محتويات أقل من الكربون العضوي وأعلى من التوصيل الكهربائي وأقل قليلاً من الطين وذلك عن مثيلاتها في الأراضي المزروعة. كما أن كلاً من كربونات الكالسيوم ورقم الحموضة كانا أقل في الآفاق السطحية للأراضي غير المزروعة عن مثيلاتها في الأراضي المزروعة.

هذا ولقد أشارت هذه الدراسة إلى عدم وجود علاقة مؤكدة بين خواص الآفاق السطحية المختلفة لهذه الأراضي مع الزيادة في المسافة من الحافة الغربية للمقطع العرضي.