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Mesquite (*Prosopis glandulosa* Torr.) dunes and interdunes in southern New Mexico: a study of soil properties and soil water relations*

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Soil properties and soil water relations were compared between soils of mesquite (*Prosopis glandulosa* Torr.) dunes and soils of adjacent interdune areas in southern New Mexico. Particle size, bulk density, organic matter content, electrical conductivity, pH, and temperature of dunal and interdunal soils were measured. Except for particle size and temperature, dunal and interdunal soils did not differ greatly. Soils of dunes had more sand and less silt and clay than did soils of interdunes. Soil temperatures were higher in interdunes than in vegetated dunes. Soil temperatures were similar in dunes with plant cover removed and in interdunes. Infiltration and runoff, hydraulic conductivity, and water retention measurements showed that although dune soils had greater infiltration and more rapid hydraulic conductivity, interdune soils retained more water above −1·5 MPa matric potential. Evaporative losses, as measured with atmometers 3 cm from the soil surfaces, were greater from interdunes than from vegetated dunes. Through two growing seasons, measured total soil water content at a depth of 30·5 cm was always greater for interdunes than for either vegetated or bare dunes. The dune soils stored water less efficiently than interdune soils and reached −1·5 MPa matric potential with much greater frequency.

Introduction

Since the late 1800s, honey mesquite (*Prosopis glandulosa* Torr.) has spread on the arid rangelands of the south-western U.S.A. On sandy soils in southern New Mexico, the establishment of mesquite allowed erosion by wind and the formation of coppice mesquite dunes. This process created an eroded interdunal soil and a deposited dune soil where formerly there had been one soil. Fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.], as well as mesquite, appear to flourish on the dunes but rarely grow on interdunes.

It is hypothesized that some factor, probably greater availability of soil water, was responsible for the growth of fourwing saltbush on dunes rather than on interdunes. We undertook this study to determine whether the soil–water relations differed between

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dunes and interdunes. Factors, both physical and chemical, affecting soil water availability were measured for both dunes and interdunes and compared.

It is generally thought that sand dunes store water efficiently, mostly because of a low evaporation rate from dune surfaces (Bagnold, 1941; Sharp, 1966; Pavlik, 1980). Due to their texture and structure, dunal soils reportedly offer ideal conditions for infiltration, deep penetration, low evaporation, and conservation of rain water (Petrov, 1971). Wood, Blackburn *et al.* (1978) found that coppice dune soils in Nevada have a deeper surface horizon, higher organic matter content, lower bulk density, and less silt than adjacent interdune soils. The deep sands of dune soils may hold more water available to plants than do interdune soils and this may account for the greater shrub density and vigor on dunes in Idaho (Chadwick & Dalke, 1965).

Dincer, Al-Mugrin *et al.* (1974) found dunes had almost no surface runoff, even under high intensity, short duration summer rains. Stuart, Fosberg *et al.* (1961) attributed the ease of infiltration on coppice dune soils in Nevada to their coarse texture and the large numbers of roots within the profile.

Evaporation from sands is a complex process, but Prill (1968) found that water below 30 cm (1 ft) on dunes usually continued moving downward in the profile. Evaporation at or near the soil surface is governed by climatic factors, vegetation structure and density as well as by soil factors such as texture and structure (Evans & Thames, 1981). Vegetation canopy affects the water status of the soil by influencing the air flow, relative humidity, radiation, and temperature above the soil surface as well as by direct interception of water (Horton, Namken *et al.*, 1970; Russell, 1973; Stark, 1970). Although about 99 per cent of the water actually taken up by plants is lost by transpiration (Osmond, Bjorkman *et al.*, 1980), no measurable difference in soil water content was found between vegetated and nonvegetated desert plots (Evans, Sammis *et al.*, 1981). Apparently, direct evaporation from the soil reduces soil water content as effectively as evapotranspiration (Evans & Thames, 1981), even though evapotranspiration is generally greater than evaporation from a pan (Taylor & Haddock, 1956). Possibly the higher soil temperatures associated with bare ground increase evaporation (Hide, 1954).

The availability of soil water to plants is determined predominantly by the texture, structure and organic matter content of the soil and by the depth and density of plant roots (Wiersma, 1959). However, Jamison (1956) found that, except in sandy soils, increases in organic matter did not increase the capacity of the soil to store water available to plants because organic matter holds much of the water very tightly. Electrical conductivity (EC) may also affect soil water availability, but EC values of less than 4 mmhos/cm are considered non-saline and have little effect on water in most soils (Bohn, *et al.*, 1979).

Caliche is characteristic of desert soils and in many places forms indurated layers. Caliche layers can prevent plant roots from obtaining water from the sub-caliche soil. Roots, physically impeded by a caliche layer, may extend horizontally along the top of the layer for several meters without penetrating the caliche (Shreve & Mallery, 1932).

Methods

We conducted this study on the Jornada Experimental Range, located 37 km north of Las Cruces, New Mexico. Elevation of the study site was 1340 m. The climate of the area is arid, with low relative humidity, high solar radiation and extremely variable precipitation. Mean annual precipitation is 230 mm with the most falling in August and the least in April. Evaporation averages 2350 mm per year from a free water surface; June accounts for 340 mm. The average frost-free growing season is 200 days.

Four, 1 ha study plots were established in 1980 on an area of mesquite duneland. The plots (A, B, C, and D) were randomly selected in a relatively uniform mesquite dunefield. The interdunal soils of plots A and B are coarse loamy, mixed, thermic Typic

Haplargids of the Onite series and the interdunal soils of plots C and D are coarse-loamy, mixed, thermic Typic Calciorthids of the Wink series. Dunes tall enough to qualify as pedons were classified as mixed Typic Torripsamments of the Pintura series. Soils on all of the plots contain petrocalcic layers, usually horizontally discontinuous and ranging from the surface to a meter or more in depth.

Four mesquite sand dunes were randomly selected within each plot. Vegetation was removed from one of the four dunes and this dune was kept in a denuded state throughout the study. Three interdune sites were randomly selected adjacent to each vegetated dune. A neutron probe access tube was installed in each of the four dunes and three interdune sites for a total of seven sites on each of the four study plots. Soil water content was determined at 30·5 cm intervals every 2 weeks during the 1980–81 growing seasons by the neutron probe method (Gardner, 1965). Water content in the top 15 cm of soil was determined gravimetrically on the same 2 week schedule. Dune access tubes varied in length, depending on dune height and distance to the caliche layer. Comparisons among sites were restricted to those holes where the caliche was below the depth for determining water content.

Thermocouples (one per 30·5 cm of depth) were buried within 150 cm of each of the 28 neutron access tubes. Soil temperatures and water contents were determined on the same date. Soil was sampled at each site from the upper 15 cm of each 30·5 cm depth increment. Each sample was analysed for organic matter content, particle size, pH, and electrical conductivity using the methods of Broadbent (1965), Day (1965), and Richards (1954), respectively. Water retention of the soil samples was determined at various matric potentials (Richards, 1965). Bulk density on the interdune areas was measured by the core method of Blake (1965). Bulk densities for both Wink and Onite soils agreed closely with those listed by Gile & Grossman (1979) for Onite soils; therefore, we used those published densities for interdune and dune soils.

Hydraulic conductivity ($K\theta$) of each soil sample was measured in the laboratory by the method of Richards (1954) and in the field by the method of Chiong, Green *et al.* (1981) as described by Kies (1982). Water content was measured at depths of 15, 30·5, 45, 61, and 76 cm on two mesquite dunes after water redistribution began on a flooded 1 m^2 plot on each dune. Water content determinations were made beginning immediately after flooding ceased, and ended 6 days later. Two interdune areas were similarly treated; on one, the soil was removed to expose the caliche layer before saturation of the plot.

Infiltration and runoff were measured with a portable rainfall simulator similar to the one described by Bertrand & Parr (1961). One dune and one interdune site were chosen near each of the test plots A, B, C, and D. On each dune the infiltration plot (1 m^2) was cleared of vegetation. During 1981, infiltration and runoff were determined for the four pairs of plots for both antecedent soil water and field capacity, with simulated rainfall being applied for 1 h. Simulated rainfall was applied at an average rate of 11·5 cm/h. The measured parameters for vegetated dunes, bare dunes, and interdunes were analysed by analysis of variance. Means were tested for least significant difference and differences with $P < 0{\cdot}05$ accepted as significant.

Results and discussion

Soil texture, organic matter, pH, and electrical conductivity

In the depth interval of 0–15 cm, sand content in the interdunes was significantly higher in Onite soils (81·5 per cent) than in Wink soils (77·3 per cent); no other differences in particle size classes were observed at depths of 0–15 and 30·5–45 cm. Organic matter, pH, and EC did not differ significantly between the two interdunal soils at either depth. At three depths (0–15, 30·5–45, and 61–76 cm), soil particle size classes in the dunes occurring on the two soils did not differ significantly. Because the Wink and Onite soils were similar, the data were combined and comparisons made between the interdune and dune soils.

Particle size determinations showed that dune soils had significantly more sand and less silt and clay than did interdune soils at depths of 0–15, 30·5–45, and 61–76 cm (Table 1). For interdune soils, sample size was restricted below 30·5 cm because of caliche. The texture of dune soils was uniform; percentages of sand, silt, and clay for the four depths sampled did not differ significantly. In the interdune soils, sand content was significantly greater at 0–15 cm than at 30·5–45 cm, silt content was significantly greater at 30·5–45 cm than at 0–15 cm and clay content did not differ among depths. Even though particle size differed, the bulk densities of the dune and interdune soils were the same (1·4 g/cm^3).

The organic matter content of the interdune and dune soils was low (0·24–0·59 per cent) and probably had little effect on the soil water status (Table 1). The mean EC values of the saturated paste extracts of both soils were below 4 mmhos/cm (Table 1) and would have little effect on water availability (Bohn, McNeal *et al.*, 1979). The pH was significantly higher in the interdune than in dune soils (Table 1). The pH values ranged from 7·4 to 8·1, indicating slight to moderate alkalinity. These pH values would have little effect on soil organisms, nutrients, or water status (Brady, 1974).

Soil temperature

Soil temperatures during 1980 at depths of 30·5 and 122 cm for vegetated dunes, bare dunes, and interdunes are plotted in Fig. 1. Comparisons of temperatures for each sample date showed that at the 30·5 cm depth, temperatures were similar among the areas until 30 July, when interdune soils were significantly warmer than bare dune soils. Interdune soils were significantly warmer than either vegetated dune or bare dune soils for the remainder of the season except on 26 September.

Differences in soil temperature were greater among vegetated dunes, bare dunes, and interdune soils at the 122 cm depth than at the 30·5 cm depth (Fig. 1). Interdune soils were significantly warmer than vegetated dune soils throughout most of the period of measurement. From 4 June until 10 October, bare dune soils were also significantly warmer than vegetated dune soils. Only at the time of maximum soil temperatures at the 122 cm depth (14 August) did soil temperatures differ significantly among all three sites. Soil temperatures in 1981 were similar to those of 1980 except that maximum temperatures at the 30·5 cm depth were recorded early in June rather than in July.

Infiltration rates

The water application rate did not exceed the infiltration rate for three of the four infiltration plots located on dunes with antecedent soil water conditions of < 2 per cent (dry run). Although the final infiltration rate could not be determined it was greater than 10·4 cm/h. The infiltration rate was 9·1 cm/h for the fourth dune where runoff occurred. Infiltration rates for the interdunes ranged from 8·7 to 11·1 cm/h with an average of 9·9 cm/h.

Using the same plots but with the soil water at field capacity (wet run), runoff occurred on two dunes with infiltration rates of 9·2 and 4·5 cm/h, respectively. On the other two dunes infiltration exceeded application rates of 11·8 and 12·7 cm/h. Infiltration rates on interdunes at field capacity ranged from 4·7 to 7·3 cm/h with an average of 5·7 cm/h. The higher infiltration rates on the vegetated dunes compared to the interdunes during the wet run may be attributable to the coarse texture of the dune soils. The high infiltration rates on vegetated dunes mean that few rainfall events would exceed the infiltration rate. Infiltration rates are more likely to be exceeded on interdunes than dunes; however, infiltration rates for interdunes still exceed the value for rainfall events of 1 h duration with a return period of 100 years (Hershfield, 1961).

Table 1. *Texture, organic matter, electrical conductivity, and pH of dune and interdune soils at various depths (mean and standard error): numbers of samples at each depth are shown*

Depth (cm)	Vegetated and bare dune soils			*n*	Interdune soils			*n*
Texture (per cent)								
	Sand	*Silt*	*Clay*		*Sand*	*Silt*	*Clay*	
0–15	86·6 ± 0·1[a]*	3·3 ± 0·4[a]	10·1 ± 0·3[a]	16	79·4 ± 0·9[b]	5·0 ± 0·8[b]	15·6 ± 0·4[b]	12
30·5–45	86·4 ± 1·0[a]	3·7 ± 0·9[a]	9·9 ± 0·3[a]	16	75·3 ± 1·6[b]	7·9 ± 0·8[b]	17·4 ± 1·2[b]	8
61–76	87·5 ± 0·7[a]	2·4 ± 0·6[a]	10·1 ± 0·3[a]	15	76·7 ± 1·8[b]	6·0 ± 0·6[b]	17·3 ± 1·2[b]	3
91–106	87·0 ± 0·9	2·8 ± 0·4	10·2 ± 0·4	11				
Organic matter (per cent)								
0–15		0·53 ± 0·05[a]		16		0·57 ± 0·05[a]		12
30·5–45		0·52 ± 0·06[a]		16		0·41 ± 0·04[a]		8
61–76		0·59 ± 0·06[a]		15		0·24 ± 0·12[b]		3
Electrical conductivity (mmhos/cm)								
0–15		1·14 ± 0·13[a]		16		0·47 ± 0·02[b]		11
30·5–45		2·34 ± 0·32[a]		16		0·55 ± 0·03[b]		8
61–76		3·05 ± 0·33[a]		16		0·50 ± 0·01[b]		3
91–106		2·50 ± 0·28		12				
pH								
0–15		7·5 ± 0·04[a]		16		8·1 ± 0·03[b]		11
30·5–45		7·4 ± 0·05[a]		16		8·0 ± 0·11[b]		8
61–76		7·4 ± 0·06[a]		16		7·8 ± 0·17[b]		3
91–106		7·5 ± 1·14		12				

* At each depth, means in corresponding columns for dune and interdune soils which are followed by the same letter are not significantly different ($P > 0{\cdot}05$).

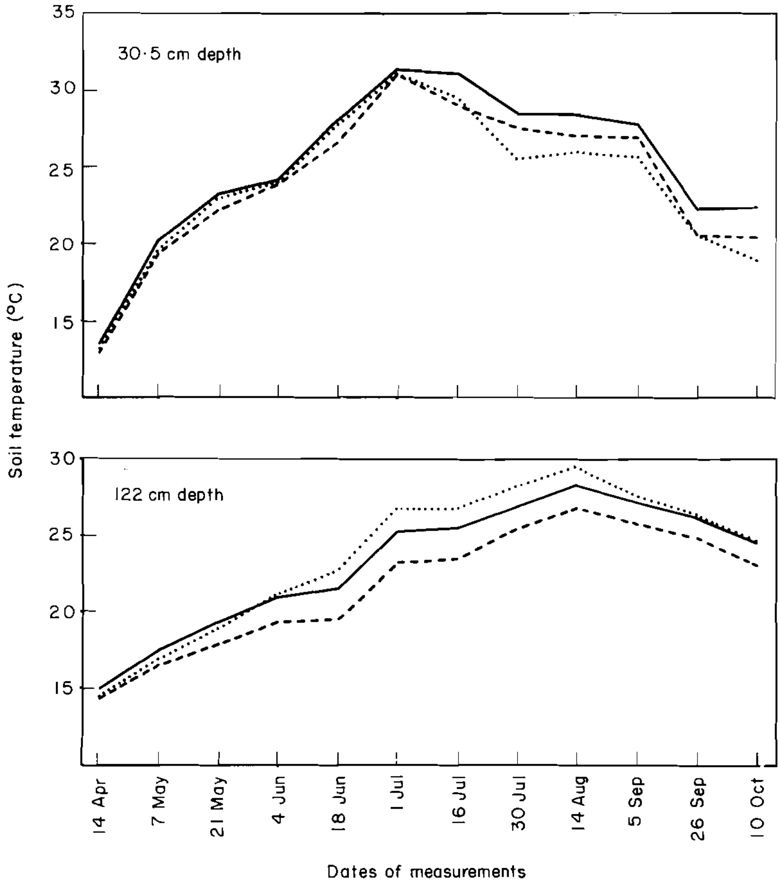

Figure 1. Average soil temperatures at depths of 30·5 and 122 cm on vegetated dunes ($n=12$), bare dunes ($n=4$) and interdune areas ($n=12$) during 1980. ---, vegetated dunes; ····., bare dunes; ——, interdunes.

Hydraulic conductivity

Laboratory measurements showed that hydraulic conductivity (Kθ) was greater for dune than interdune soils. At the 15 and 30·5 cm soil depth the mean $K\theta$ for the dune was 187·2 and 201·6 cm/day, respectively, and the mean $K\theta$ for the interdune at the same depths was 100·6 and 77·0 cm/day, respectively.

Field measurements of $K\theta$ on two vegetated dunes showed the rate of water movement to be slower than predicted by laboratory measurements. The average $K\theta$ was 53·4 and 135·8 cm/day at the 15 and 30·5 cm soil depth, respectively. On the interdune site Kθ was 23·7 cm/day at 15 cm soil depth and 29·6 cm/day at 30·5 soil depth. The values of $K\theta$ from the laboratory probably were higher because they were measured on disturbed soil samples. More importantly, both tests showed $K\theta$ to be much higher in dune than in interdune soils.

Evaporation

Evaporation, evaluated above the soil surface by Piche atmometers, was greatest from bare dunes. Evaporation differed significantly among bare dunes, interdunes and

Table 2. *Evaporation in grams per 24 h from atmometers located on vegetated dunes, interdunes and bare dunes on various dates in 1980 and 1981: number of observations* (n) *at each date are shown*

	Vegetated dunes		Interdunes		Bare dunes	
Date	*n*	$\bar{x}$ ± S.D.	*n*	$\bar{x}$ ± S.D.	*n*	$\bar{x}$ ± S.D
1980						
10 Jul	9	40·5 ± 7·0^{a*}	10	50·0 ± 4·7^{ab}	4	63·6 ± 4·3^{b}
22 Jul	12	20·3 ± 5·7^{a}	9	27·7 ± 1·2^{a}	4	38·4 ± 0·8^{c}
23 Jul	11	19·5 ± 1·2^{a}	8	26·9 ± 0·6^{b}	4	34·2 ± 1·1^{c}
1981						
10 Jun	12	32·4 ± 0·9^{a}	11	43·3 ± 1·0^{b}	4	53·6 ± 0·8^{c}
11 Jun	12	31·5 ± 1·1^{a}	12	45·6 ± 1·2^{b}	4	62·4 ± 1·2^{c}
22 Jun	12	40·0 ± 1·9^{a}	12	52·1 ± 2·1^{b}	4	69·0 ± 1·0^{c}
23 Jun	12	25·9 ± 0·7^{a}	12	35·2 ± 0·8^{b}	4	47·3 ± 0·9^{c}
6 Jul†	12	25·5 ± 1·3^{a}	12	34·8 ± 0·4^{b}	3	42·9 ± 1·1^{c}
21 Jul	12	30·4 ± 1·2^{a}	11	40·1 ± 0·7^{b}	4	49·5 ± 1·1^{c}
27 Jul	12	20·0 ± 0·9^{a}	12	27·7 ± 0·7^{b}	4	33·7 ± 0·7^{c}
11 Aug†	12	6·6 ± 0·5^{a}	12	11·7 ± 0·4^{b}	4	14·5 ± 2·2^{c}
17 Aug†	12	9·7 ± 0·5^{a}	11	15·0 ± 0·8^{b}	3	19·2 ± 0·8^{c}

* For each date separately, means followed by the same letter are not significantly different ($P > 0·05$).

†Readings made at end of 48 h and 24 h rate is average of 2 days.

vegetated dunes for all sampling dates (Table 2). Evaporation was lowest from vegetated dunes because of the mesquite canopy. We presume that evaporation was considerably higher from interdunes than from vegetated dunes because of extra heat reflected from the bare interdune soil and greater air movement. The bare dune soils were exposed to increased air movement compared to interdunal soils, resulting in greater evaporation from the bare dunes.

In deserts, evapotranspiration is about equal to evaporation from bare surfaces (Evans & Thames, 1981). Evaporation as measured with the atmometers was least on vegetated dunes, but the combined losses from transpiration and evaporation might approach the loss from evaporation on the sparsely vegetated interdunes.

Soil water

When gravimetric measurements were averaged across all sampling dates in 1980 and 1981, soil water content at a depth of 0–15 cm did not differ significantly among vegetated dunes, bare dunes, and interdunes. Water content of the surface soil was closely related to rainfall.

Caliche can absorb considerable amounts of water (Hennessy, 1982). Since water absorbed by caliche is unavailable to plants, only the four interdune sites, where caliche was well below the 30·5 cm depth, were used in comparisons of soil water content of dune and interdune soils at the 30·5 cm depth (Fig. 2). Soil water content in vegetated dune soils was probably even less than the measured soil water since water in the plant root mass within the range of the neutron probe was also measured. Interdunes had less root mass than dunes.

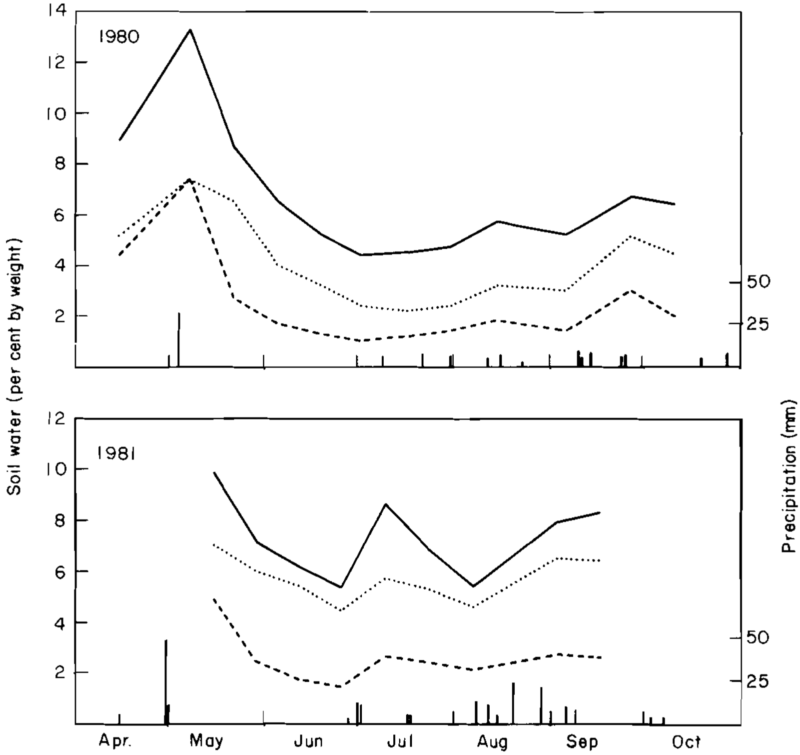

Figure 2. Average soil water content (per cent by weight) at the 30·5 cm depth for vegetated dunes (n=12), bare dunes (n=4) and interdune areas (n=4) in 1980 and 1981. Total daily precipitation greater than 2 mm is shown. ---, vegetated dunes; ·····, bare dunes; ——, interdunes.

In 1980, soil water content at the 30·5 depth was always significantly greater for interdunes than for vegetated dunes. With the exception of 7 May sampling date, soil water was significantly greater for interdunes than for the bare dunes and significantly greater for bare dunes than for vegetated dunes. In 1981, soil water at the 30·5 cm depth was always significantly greater for interdunes than for vegetated dunes and significantly greater for bare dunes than for vegetated dunes. Soil water at the 30·5 cm depth was greater for interdunes than for bare dunes in 1981 (Fig. 2), but the difference was significant only on 14 May, 9 July, and 16 September.

Samples taken at 2 week intervals showed the general trend for soil water content (Fig. 2). Rainfall amounts and patterns between the 2 years differed. In 1980 and 1981, rainfall totaled 116 and 213 mm, respectively, for April through November. Soil water content at the 30·5 cm depth followed the rainfall pattern.

Vegetated dunes, bare dunes, and interdunes were compared on the basis of the soil water that was available above −1·5 MPa matric potential at the 30·5 cm depth (Table 3). In 1980, significantly more water above −1·5 MPa was available in interdunes than in either vegetated dunes at all dates or bare dunes on six of the 12 sampling dates. In 1981, interdunes again had significantly more water available above −1·5 MPa than did vegetated dunes on all sampling dates. Bare dunes had significantly more water available above −1·5 MPa than did the vegetated dunes on all sampling dates except 14 May. Water available above −1·5 MPa differed significantly between interdunes and bare dunes only on 9 July.

Soil water at depths below 30·5 cm was not compared among all three sites because caliche was well below the 91·5 cm depth at only one interdune site. Soil water

Table 3. *Average soil water content (per cent by weight) above −1·5 MPa matric potential at the 30·5 cm depth on vegetated dunes, bare dunes and interdunes at sampling dates in 1980 and 1981 (mean ± standard error): number of observations (N) for each site are shown*

Date	Vegetated dunes ($N = 12$)	Bare dunes ($N = 4$)	Interdune ($N = 4$)
1980			
14 Apr	$2.6 \pm 0{\cdot}2^{a*}$	$2{\cdot}6 \pm 1{\cdot}0^{ab}$	$5{\cdot}4 \pm 0{\cdot}3^{c}$
7 May	$5{\cdot}7 \pm 0{\cdot}3^{a}$	$4{\cdot}8 \pm 1{\cdot}1^{ab}$	$9{\cdot}7 \pm 0{\cdot}3^{c}$
21 May	$0{\cdot}9 \pm 0{\cdot}2^{a}$	$4{\cdot}0 \pm 1{\cdot}0^{b}$	$5{\cdot}2 \pm 0{\cdot}3^{b}$
4 Jun	$0{\cdot}2 \pm 0{\cdot}1^{a}$	$1{\cdot}5 \pm 0{\cdot}8^{b}$	$2{\cdot}9 \pm 0{\cdot}2^{c}$
18 Jun	$0{\cdot}1 \pm 0{\cdot}1^{a}$	$0{\cdot}8 \pm 0{\cdot}7^{ab}$	$1{\cdot}6 \pm 0{\cdot}2^{c}$
1 Jul	$0{\cdot}1 \pm 0{\cdot}1^{a}$	$0{\cdot}5 \pm 0{\cdot}5^{ab}$	$0{\cdot}9 \pm 0{\cdot}3^{c}$
16 Jul	$0{\cdot}1 \pm 0{\cdot}1^{a}$	$0{\cdot}4 \pm 0{\cdot}4^{ab}$	$1{\cdot}0 \pm 0{\cdot}3^{b}$
30 Jul	$0{\cdot}1 \pm 0{\cdot}1^{a}$	$0{\cdot}4 \pm 0{\cdot}4^{ab}$	$1{\cdot}2 \pm 0{\cdot}4^{b}$
14 Aug	$0{\cdot}4 \pm 0{\cdot}2^{a}$	$0{\cdot}7 \pm 0{\cdot}4^{ab}$	$2{\cdot}2 \pm 0{\cdot}9^{c}$
5 Sep	$0{\cdot}2 \pm 0{\cdot}1^{a}$	$1{\cdot}2 \pm 0{\cdot}8^{ab}$	$1{\cdot}7 \pm 0{\cdot}9^{b}$
26 Sep	$1{\cdot}3 \pm 0{\cdot}3^{a}$	$2{\cdot}6 \pm 0{\cdot}8^{b}$	$3{\cdot}2 \pm 0{\cdot}4^{b}$
10 Oct	$0{\cdot}4 \pm 0{\cdot}2^{a}$	$1{\cdot}8 \pm 0{\cdot}7^{b}$	$2{\cdot}9 \pm 0{\cdot}4^{b}$
1981			
14 May	$3{\cdot}1 \pm 0{\cdot}4^{a}$	$4{\cdot}5 \pm 1{\cdot}1^{ab}$	$6{\cdot}4 \pm 0{\cdot}9^{b}$
28 May	$0{\cdot}7 \pm 0{\cdot}2^{a}$	$3{\cdot}5 \pm 1{\cdot}2^{b}$	$3{\cdot}6 \pm 0{\cdot}8^{b}$
11 Jun	$0{\cdot}3 \pm 0{\cdot}1^{a}$	$2{\cdot}9 \pm 0{\cdot}7^{b}$	$2{\cdot}6 \pm 1{\cdot}1^{b}$
25 Jun	$0{\cdot}2 \pm 0{\cdot}1^{a}$	$2{\cdot}0 \pm 0{\cdot}9^{b}$	$1{\cdot}9 \pm 0{\cdot}9^{b}$
9 Jul	$0{\cdot}9 \pm 0{\cdot}2^{a}$	$3{\cdot}1 \pm 0{\cdot}5^{b}$	$5{\cdot}1 \pm 0{\cdot}7^{c}$
23 Jul	$0{\cdot}8 \pm 0{\cdot}2^{a}$	$2{\cdot}8 \pm 0{\cdot}5^{b}$	$3{\cdot}2 \pm 0{\cdot}5^{b}$
6 Aug	$0{\cdot}5 \pm 0{\cdot}2^{a}$	$2{\cdot}1 \pm 0{\cdot}5^{b}$	$1{\cdot}7 \pm 0{\cdot}6^{b}$
2 Sep	$0{\cdot}9 \pm 0{\cdot}3^{a}$	$4{\cdot}0 \pm 0{\cdot}6^{b}$	$4{\cdot}3 \pm 1{\cdot}1^{b}$
16 Sep	$0{\cdot}9 \pm 0{\cdot}2^{a}$	$3{\cdot}9 \pm 0{\cdot}5^{b}$	$4{\cdot}8 \pm 0.7^{b}$

*For each date separately, means followed by the same letter are not significantly different ($P > 0{\cdot}05$).

determinations at this site indicated that interdune soils had more soil water at the 61 cm and 91 cm depths than did vegetated dunes or bare dunes; the difference was of the same magnitude as that at the 30·5 cm depth.

Water content in dune soils increased somewhat with depth. For five vegetated dunes with the caliche layer below 122 cm, water content (averaged across sampling dates) was 2·4, 2·6, 3·2, and 4·6 per cent by weight at the 30·5, 61, 91, and 122 cm depths, respectively. Water content was significantly greater at the 122 cm depth than at shallower depths in both 1980 and 1981. Variation in water content among sampling dates decreased with depth. At the 122 cm depth, gravimetric soil water content in 1980 ranged from 4·4 to 5·5 per cent. Comparisons by '*t*' tests of average water content at the 12 sampling dates in 1980 showed that bare dunes had significantly more soil water than did vegetated dunes at the 61 and 91 cm depths but not at the 122 cm depth. In 1981, the bare dunes had significantly more soil water than the vegetated dunes at depths of 61, 91, and 122 cm.

Interdune soils always had more total soil water and more available soil water above −1·5 MPa than dune soils despite higher hydraulic conductivity, higher infiltration, less evaporative stress, and lower soil temperatures for dune soils. During periods without rainfall, interdunes lost more water than bare dunes but still had more soil water after such periods. An untapped source of water exists under the caliche layer of the interdune areas. Soil water content was greater below than above the caliche and remained fairly constant (about 23 per cent by weight) during both years.

Data for various sampling dates in 1980 and 1981 were subjected to regression analyses with both soil particle size and temperature as independent variables (where an interaction term was possible). These data indicated that only a relatively small portion of the variation in soil water content could be explained by soil particle size and temperature. Contrary to the findings of Bagnold (1941), Pavlik (1980), and Sharp (1966) in sand dune studies, the dunes on this study site did not store water efficiently. Interdunes always had more available soil water than dunes. Even denuded dunes had less soil water than interdunes, although, presumably, they did not lose water through transpiration and their coarser soils should have been less subject to evaporation losses than were interdune soils.

The mesquite dunes were formed by wind erosion. During that process significant amounts of the silts and clays were lost (Hennessy, 1981). The lack of finer soil particles in the dunes would affect soil structure, soil aggregation, and water retention when compared to interdune soils. The lack of silts and clays in the dunes would also affect the supply of nutrients. The sparse growth of grasses and other plants on interdune soils is often attributed to the competition for soil water from widespreading mesquite roots (Paulsen & Ares, 1962; Wright & Van Dyne, 1981). That undoubtedly is a factor, but the soil water measurements from this study indicate that water availability is not the only factor involved. Competition should be less on interdune areas where the greatest amounts of soil water occur than on dunes. Other factors which may limit plant establishment on interdune areas are high soil surface temperatures, high evaporation rates, and the shearing of plants by blowing sand.

Brush control measures kill mesquite, and many of the resulting bare dunes may be slow in developing other plant cover, especially during periods of low rainfall. The elevated dune surfaces are more exposed to the erosive wind action than are interdunes. The desiccating effects of such winds, as illustrated by evaporation data, are substantial. Bare dunes will gradually erode away and the erosion process will remove more of the fine soil particles. Thus, even after successful mesquite control, soils in the dunes will be less favourable for water retention and plant growth.

Conclusions

Comparisons were made between soils of mesquite sand dunes and soils of adjacent interdune areas. Soil particle size, bulk density, organic matter content, electrical conductivity, pH, and temperature were measured. Of the soil properties measured, the greatest differences were observed in soil particle size and temperature. Soil temperatures were similar for bare dunes and interdunes but both had higher soil temperatures than vegetated dunes. Dune soils had more sand and less silt and clay than the interdune soils.

Infiltration and runoff, hydraulic conductivity, and water retention measurements indicated that dune soils had greater infiltration and more rapid hydraulic conductivity. Interdune soils retained more water above $-1{\cdot}5$ MPa matric tension. Through two growing seasons, soil water was generally greatest on the interdunes and least on the vegetated dunes, with the bare dunes having intermediate values. The dune soils stored water less efficiently than interdune soils and reached $-1{\cdot}5$ MPa matric potential with much greater frequency.

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