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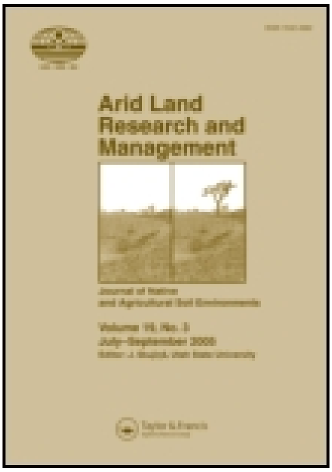

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Potential Contribution of *Retama raetam* (Forssk.) Webb & Berthel as a Forage Shrub in Sinai, Egypt

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The shortage of forage in arid areas is an important concern and it leads us to explore alternative options as nonconventional feed resources. Among potential forage species, samples of Retama raetam (R. raetam) *were collected from six different locations representing four habitat types in two diverse phytogeographical regions in Egypt during the summer and winter seasons. Soil characteristics, growth performance, and nutritional traits of* R. raetam *were evaluated to assess the potential value of this legume as an alternative forage source in the Mediterranean ecosystem. Data showed that soil texture across the study sites had sandy, loamy, and clayey textures, whereas pH ranged from neutral to alkaline and organic carbon was low at all sites. Growth and production of* R. raetam *were significantly affected by seasonal variation in rainfall and, based on our study results, this effect was more important than specific site property variations such as soil texture and organic matter contents. Moreover, data indicate that* R. raetam *had wide ecological amplitude and growth performance as a function of site and season. Nutritional value of* R. raetam *was high enough to meet the nutrient requirements of several different grazing animals. Comparing the* R. raetam *nutritional value with those of the other wild plants, it can be concluded that* R. raetam *has strong potential as forage crop with valuable nutritional quality for browsing animals. Moreover,* R. raetam *may represent an alternative feedstuff to the conventional forage and a promising substitute fodder in Mediterranean ecosystem.*

Keywords dryland, forage, Mediterranean ecosystem, nutrition, *R. raetam*

Introduction

Arid lands are defined as areas where rainfall is insufficient to sustain suitable pasture and forage production. The scarce rainfall has a critical effect on vegetation yield and composition (FAO, 2000). In fact, edaphic properties such as soil nutrient

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contents and moisture availability, soil reaction, microorganisms, and pollutants, as well as climatic factors such as rainfall quantities and annual distributions, solar radiation amounts, and winds significantly affect plant growth. A stress factor commonly encountered by plants in dryland regions is water deficiency and this is the primary factor resulting in low forage production (Khan & Ansari, 2008).

In arid lands, animal feed shortages are a severe problem, having a negative impact on animal production. Under these adverse environmental conditions, low soil organic matter contents and low soil water availability result in deficiency and low annual forage productivity due primarily to the long summer dry season. Therefore, the utilization of local feed resources for animals is necessary (Vasta et al., 2008), and some xerophytic plants with adequate forage potential offer the opportunity to reduce feed shortages to livestock (Khan & Ansari, 2008).

Among xerophytic shrubs, *Retama raetam* (Forssk.) Webb & Berthel (Fabaceae) (*R. raetam*) has a potential economic importance. It plays a significant role in soil protection and stabilization against wind or water erosion and provides an important dietary source for livestock species such as camels, goats, and sheep (Laudadio, 2009b). Additionally, this species represents viable fuel source for humans (Cheriti et al., 2009). It also has medicinal and potential industrial values since its roots are used to treat diarrhea, the leaves are used to help aching joints back pain and eye troubles (Said et al., 2002). This shrub grows under unfavorable dry conditions, common in the arid desert ecosystems, and it is widely distributed in the Mediterranean coastal desert of Egypt (Mittler et al., 2001; El-Bahri et al., 1999). Shrublands dominated by Fabaceae species are one of the most important ecosystems under Mediterranean-type climate. Shrubs are key components in these ecosystems as they influence both biotic and abiotic conditions. Woody species may create "islands of fertility" by improving availability of water and nutrients (Moro et al., 1997a) or by protecting against direct irradiance and overheating (Moro et al., 1997b; López-Pintor et al., 2000). In addition, legume species can increase soil fertility due to N enriched litter deposition or direct release of N from roots (Dart, 1998). Recently, researchers have become interested in woody legumes due to their ecological importance (Ndiaye & Ganry, 1997; Dart, 1998; El-Shaer 2000).

Information on the nutritive values of forage could help range management by selecting suitable grazing sites to sustain animal life without inflicting vegetation damage (Arzani et al., 2004). Many factors influence the chemical characteristics of growing plants such as mineral element concentration. Transfer of minerals from the soil to plant may however be influenced by environmental conditions such as temperature, rainfall, soil pH, texture, and organic matter (Shaltout et al., 2008; Shaltout et al., 2010). Due to the high palatability of *R. raetam* (Laudadio, 2009a), this legume may represent an important forage resource for livestock species, especially during the dry season when shortages of pasture commonly occur in this Mediterranean region. However, very little attention has been given regarding the forage potential of wild leguminous species, especially trees and shrubs (Dart, 1998). So, the ecological potentiality of *R. raetam* can contribute to reduce fodder shortages in the arid areas of Mediterranean ecosystem. Therefore, the aim of this study was to determine the nutritive value of *R. raetam* as a forage plant in Sinai (Egypt) in terms of morphological traits and chemical composition in order to assess the suitability of this species for animal nutrition under arid environmental conditions.

Materials and Methods

Study Area

The climate in the study area is typical Mediterranean arid with wet winters and dry summers. Precipitation ranges from 250 mm at the northern boundary to 10–20 mm in the Southern part of Sinai, with high summer temperatures and low winter temperatures (mean temperature of 10–20°C in the coldest months and 20–30°C in the warmest months) (El-Ghani & Amer, 2003).

Six sites were studied (Table 1) representing the common habitats in two different phytogeographical regions, namely Mediterranean region (north Sinai) and Sinai proper (south Sinai). The soils are mostly dominated by fine sand, sometimes mixed with clay and silt. The study sites are generally characterized by sparse vegetation ground cover, high sand contents at the ground surface and low soil organic matter contents.

Soil Physicochemical Characters

Soil physicochemical properties influencing *R. raetam* growth were evaluated. A total of 36 samples (3 replicates × 2 depths × 6 sites) were collected to determine: soil particle-size class (% sand, silt, and clay), soil reaction (pH), electrical conductivity (dSm^{-1}), and organic matter content (%). Soil particle-size class characteristics were evaluated separately at two soil depths (0–20 and 20–40 cm) according to the USDA soil textural triangle system (Liebens, 2001) at six different sites. In addition, the soil

Table 1. Description of the six sites in Sinai Peninsula where *R. raetam* is grown

Site name	Coordinates	Habitat type	USDA texture class
		North Sinai	
Zaranig Protectorate	31° 06’ N 33° 27’ E	Sand dune	Sandy
Gebel Halal	30° 59’ N 33° 35’ E	Sandy plain, with sandy/loamy and deep fine sand deposits.	Sandy-Loamy
Um-Shehan Village	30° 49’ N 34° 10’ E	Sandy plain mixed with clay, with deep very fine alluvial deposits.	Clayey
		South Sinai	
Ras Sudr	29° 35’ N 32° 44’ E	Coastal plain, drainage lines of the plain covered with alluvial deposits.	Sandy
El-Tur	28° 14’ N 33° 52’ E	Wadi bed, mouth of the Wadi covered with alluvial coarse deposit mainly boulders and gravels.	Sandy-Clayey-Loamy
Nuwbea	28° 58’ N 34° 39’ E	Wadi bed, mouth of the Wadi covered with alluvial coarse deposit mainly boulders and fine gravels.	Loamy-Sandy

moisture content was determined (Black, 1965) in each of the two depths during both summer and winter seasons at the different sites, with a total of 72 soil samples (3 replicates × 2 depths × 6 sites × 2 seasons) collected for analysis.

Growth Performance

Plants were observed to determine the growth patterns including: plant height (m), number of main branches per plant, number of lateral branches per plant, area of crown cover (m^2), number of leaves per plant, leaf area (cm^2), leaf length (cm), number of flowers per plant, and flower buds to plant ratios. These properties were measured for three individual shrubs in the six selected sites during the summer. Furthermore, the sampled plants were tagged for repeated measurements during the winter. Thus, the growth parameters were measured and/or calculated on three replicates from the six sites in the two seasons (summer and winter).

Nutritive Variables

Shoots of *R. raetam* shrubs were collected at each site during the summer and winter seasons. The plant samples then weighed and oven dried for 24 h at 65°C to determine moisture content (index of succulence). Samples were ground in a hammer mill, passed through a 1 mm sieve, and analyzed in triplicate for dry matter content, ash, crude protein (CP, Kjeldahl N × 6.25) content and crude fiber (CF) content according to the procedures outlined by the AOAC (2000). Digestible CP was estimated according to Le Houérou (1980). Total digestible nutrient (TDN) content was estimated according to the equation of Adams et al. (1964) as follow: $\text{TDN} = 74.4 + (0.35 \times \text{CP}) - (0.73 \times \text{CF})$. Nutritive value was determined as suggested by Abu-El-Naga and El-Shazly (1971) equation: Nutritive value (NV, % in DM) = TDN/CP, where TDN is the total digestible nutrient content. Net energy (NE) was estimated according to Riviere (1977) as follows: Net energy (MJ/kg DM) $= [(\text{TDN}\,\% \times 3.65 - 100)/188.3] \times 6.9$.

The nutritional ratio (NR) was estimated following the procedure of Le Houérou (1980), where NR = DCP (g/kg DM)/NE (FU/kg DM), where DCP is digestible CP, NE is the net energy, and FU is the forage unit. Metabolized energy (ME) was determined as: $\text{ME} = 0.82 \times \text{DE}$, where DE is the digestible energy (Garrett, 1980). A 1:1 soil:water suspension and glass electrode were used to measure soil pH (Sikora, 2006) and the electrical conductivity using a pocket meter (Smith & Doran, 1996).

Statistical Analysis

All statistical analyses were performed using the SPSS Statistical Package (version 16.0). Soil and plant data were previously tested for normality. For soil properties, two-way analysis of variance (ANOVA-2) was used to test for significant differences among soil depth, site location, and their interactions. For plant chemical composition, the ANOVA-2 was used to test the effects of season, site location, and their interactions. When significant differences were detected, means were separated using Duncan's multiple-range test at $p < 0.05$ (LSR). Simple linear correlation and regression coefficients were calculated to assess the relationship between the soil and plant characters.

Table 2. Mean of the two soil depth characters for *R. raetam* sites with two-way ANOVA testing the significance of variation in relation to site, soil depth, and their interaction

	Site								
	North Sinai			South Sinai			Two-way ANOVA		
Soil parameter	S1_ZR	S2_GHL	S3_UM_SH	S4_RS	S5_TOR	S6_NB	Site	Depth	Site × Depth
Sand (%)	91.5^a	79.5^b	41.3^d	91.3^a	57.3^c	78.4^b	$p < 0.001$	$p < 0.001$	$p < 0.001$
Silt (%)	4.7^e	7.4^d	17.8^a	5.4^e	13.0^c	14.6^b	$p < 0.001$	$p < 0.001$	$p < 0.05$
Clay (%)	3.9^e	13.2^c	42.4^a	4.5^e	29.8^b	7.3^d	$p < 0.001$	$p < 0.01$	$p < 0.001$
Winter moisture (%)	11.2^a	7.4^b	6.0^c	1.4^e	2.6^d	2.6^d	$p < 0.001$	NS	$p < 0.001$
Summer moisture (%)	4.5^a	1.5^b	0.27^d	0.93^c	0.74^c	0.95^c	$p < 0.001$	$p < 0.001$	$p < 0.01$
Organic carbon (%)	0.05^b	0.13^a	0.08^b	0.08^b	0.08^b	0.09^b	$p < 0.01$	NS	$p < 0.001$
Electrical conductivity (dSm^{-1})	21.8^a	10.6^{bc}	2.0^e	6.0^d	11.1^b	9.7^c	$p < 0.001$	$p < 0.001$	$p < 0.001$
pH	7.38^b	7.88^{ab}	7.98^a	7.67^{ab}	7.77^{ab}	8.22^a	NS	NS	NS

S1_ZR: Zaranig protectorate; S2_GHL: Gebel Halal; S3_UM_SH: Shehan; S4_RS: Ras Sudr; S5_TR: El Tur; S6_NB: Newbie.
NS, not significant.
Values within the same row with same letters are not significantly different.

Table 3. Mean of growth assessment and nutritive variables of *R. raetam* during two seasons at different sites with two-way ANOVA testing the significance of variation in site, season, and their interaction

		Site								
		North Sinai			South Sinai			Two-way ANOVA		
Parameter		S1_ZR	S2_GHL	S3_ UM_SH	S4_RS	S5_TOR	S6_NB	Season	Site	Season × Site
Growth variable	Plant height (m)	2.24^{a}	2.25^{a}	1.88^{b}	1.31^{c}	2.22^{a}	2.30^{a}	NS	NS	NS
	Main branch plant^{-1}	20.0^{b}	22.0^{a}	12.0^{c}	21.0^{a}	20.0^{b}	21.0^{ab}	$p < 0.001$	$p < 0.001$	NS
	Lateral branch plant^{-1}	110.0^{d}	1422.0^{a}	58.0^{d}	197.0^{c}	839.0^{b}	1417.0^{a}	$p < 0.001$	$p < 0.001$	$p < 0.001$
	Crown cover (m^{2})	2.67^{b}	2.71^{b}	1.72^{c}	3.06^{a}	1.84^{c}	2.69^{b}	NS	NS	NS
	Leaf plant^{-1}	28.0^{c}	117.0^{b}	–	–	302.0^{a}	117.0^{b}	$p < 0.001$	$p < 0.001$	$p < 0.001$
	Leaf area (cm^{2})	2.97^{a}	1.92c	–	–	2.32^{b}	1.17^{d}	$p < 0.001$	$p < 0.01$	$p < 0.001$
	Leaf length (cm)	0.95^{a}	0.90^{a}	–	–	0.95^{a}	0.80^{b}	$p < 0.001$	$p < 0.001$	$p < 0.001$
	Flower bud plant^{-1}	2920^{d}	3650^{c}	7920^{a}	1570^{e}	4830^{b}	3650^{c}	$p < 0.001$	$p < 0.001$	$p < 0.001$
	Flower plant^{-1}	347.0^{e}	2022^{a}	980^{f}	765^{c}	1815^{b}	702^{d}	$p < 0.001$	$p < 0.001$	$p < 0.001$
Nutritive variable	Ash (%)	27.50^{b}	40.00^{a}	40.20^{a}	46.00^{a}	28.00^{b}	22.00^{b}	$p < 0.001$	$p < 0.001$	$p < 0.01$
	Crude fiber (%)	14.45^{e}	28.50^{a}	22.00^{c}	15.00^{e}	19.50^{d}	25.95^{b}	$p < 0.001$	$p < 0.001$	NS
	Succulence	10.00^{d}	31.40^{a}	16.90^{c}	20.30^{b}	10.85^{d}	31.85^{a}	NS	$p < 0.001$	NS
	Nitrogen (N)	6.35^{a}	6.50^{a}	6.65^{a}	6.70^{a}	5.85^{a}	5.80^{a}	NS	NS	NS
	Crude Protein (%)	3.23^{b}	3.43^{a}	3.24^{b}	3.26^{b}	3.24^{b}	3.22^{b}	NS	NS	NS
	Digestible Crude Protein (DCP)	25.35^{bc}	27.05^{a}	25.55^{abc}	26.60^{ab}	24.95^{c}	26.45^{abc}	NS	NS	NS
	Total Digestible Nutrients (TDN)	74.85^{ab}	72.30^{b}	76.75^{a}	73.45^{b}	73.55^{b}	71.65^{b}	$p < 0.001$	$p < 0.001$	$p < 0.01$
	Net energy (Mcal kg^{-1})	6.70^{a}	6.60^{a}	7.05^{a}	6.25^{a}	6.60^{a}	5.95^{a}	NS	NS	NS
	Metabolizable energy (MJ kg^{-1})	12.35^{ab}	10.85^{b}	12.20^{ab}	12.85^{a}	12.15^{ab}	10.60^{b}	NS	NS	NS
	Nutritional ratio	5.35^{a}	5.95^{a}	5.95^{a}	5.50^{a}	5.35^{a}	4.80^{a}	NS	NS	NS
	Nutritive value (%)	2.49^{ab}	1.95^{b}	3.15^{a}	2.05^{b}	1.87^{b}	2.11^{b}	NS	NS	NS

S1_ZR: Zaranig protectorate; S2_GHL: Gebel Halal; S3_UM_SH: Shehan; S4_RS: Ras Sudr; S5_TR: El Tur; S6_NB: Newbie.
NS, not significant.
Values within the same row followed by the same letters are not significantly different.

Table 4. Mean (±standard error) of some growth variables of *R. raetam* measured during two seasons at different sites

	Summer						Winter					
	North Sinai			South Sinai			North Sinai			South Sinai		
Parameter	Site 1_ZR	Site 2_GHL	Site 3_UM_SH	Site 4_RS	Site 5_TR	Site 6_NB	Site 1_ZR	Site 2_GHL	Site 3_UM_SH	Site 4_RS	Site 5_TR	Site 6_NB
Plant height (m)	2.31 ± 0.15	2.31 ± 0.05	1.93 ± 0.1	1.36 ± 0.21	2.22 ± 0.07	2.3 ± 0.1	2.23 ± 0.1	2.23 ± 0.1	1.85 ± 0.05	1.31 ± 0.15	2.15 ± 0.2	2.2 ± 0.1
Main branch plant^{-1}	21 ± 1.0	24 ± 1.0	13 ± 1.0	23 ± 1.0	21 ± 1.53	23 ± 1.0	19 ± 1.0	20 ± 1.0	10 ± 1.0	20 ± 1.0	18 ± 1.0	20 ± 1.0
Lateral branch plant^{-1}	121 ± 1.0	1503 ± 174	65 ± 1.0	158 ± 3.0	933 ± 2.25	1494 ± 5.03	99 ± 2.52	1341 ± 2.1	52 ± 2.0	137 ± 2.08	746 ± 5.0	1341 ± 5.5
Crown cover (m^2)	2.76 ± 0.61	2.73 ± 0.15	1.8 ± 0.1	3.11 ± 0.3	1.83 ± 0.18	2.74 ± 0.2	2.66 ± 1.0	2.65 ± 0.05	1.76 ± 0.05	3.06 ± 0.08	1.95 ± 0.1	2.65 ± 0.1
Leaf plant^{-1}	–	–	–	–	–	–	56.0 ± 0.1	237 ± 5.1	–	–	604 ± 5.0	235 ± 5.0
Leaf area (cm^2)	–	–	–	–	–	–	6.03 ± 0.13	3.83 ± 0.05	–	–	4.65 ± 0.05	2.37 ± 0.05
Leaf length (cm)	–	–	–	–	–	–	1.9 ± 0.1	1.7 ± 0.1	–	–	1.9 ± 0.1	1.7 ± 0.1
Flower bud plant^{-1}	–	–	–	–	–	–	585 ± 5.0	730 ± 30.0	1585 ± 5.0	315 ± 5.0	968 ± 5.3	730 ± 30.0
Flower plant^{-1}	–	–	–	–	–	–	697 ± 5.13	4063 ± 29.8	196 ± 7.02	1531 ± 30.0	3634 ± 30.0	1406 ± 5.0

S1_ZR: Zaranig protectorate; S2_GHL: Gebel Halal; S3_UM_SH: Shehan; S4_RS: Ras Sudr; S5_TR: El Tur; S6_NB: Newbie.

Table 5. Simple correlation coefficients between some soil parameters, growth and nutritive variables of *R. raetam* shoots

		Soil			
	Plant	Sand	pH	EC	OC
Growth variable	Plant height	−0.09	0.01	−0.09	−0.06
	Crown cover	0.70**	−0.25	0.22	−0.50**
	Leaf	0.09	0.63	−0.07	0.22
	Flower	0.24	0.04	−0.04	−0.02
Nutritive variable	Ash	0.23	0.17	0.11	0.02
	CF	−0.01	0.23	−0.08	−0.37*
	CP	0.09	0.04	0.36*	−0.39*
	DCP	0.46**	−0.05	0.41*	0.08
	ME	−0.09	0.43**	0.11	−0.12
	NR	0.13	0.29	0.46**	0.13

EC, electrical conductivity; OC, organic carbon; CF, crude fiber; CP, crude protein; DCP, digestible crude protein; ME, metabolizable energy; NR, nutritional ratio.

Significance level: $^{*}p < 0.05$; $^{**}p < 0.01$ and $^{***}p < 0.001$.

Results

Habitat Characteristics

Soil textures in all sites varied from sandy, loamy-sandy, clayey, to sandy-clayey (Table 1). Most of the soil parameters studied differed significantly as a function of the site and depth ($p < 0.001$). At both soil depths, soil moisture content was higher in winter compared with summer. The maximum soil moisture content (11.2%) was recorded during the winter and the minimum (0.27%) during the summer in the subsurface soil at the S4_RS site (Table 2). Organic carbon content and pH were shown to be slightly different among the sites and soil depths, with pH

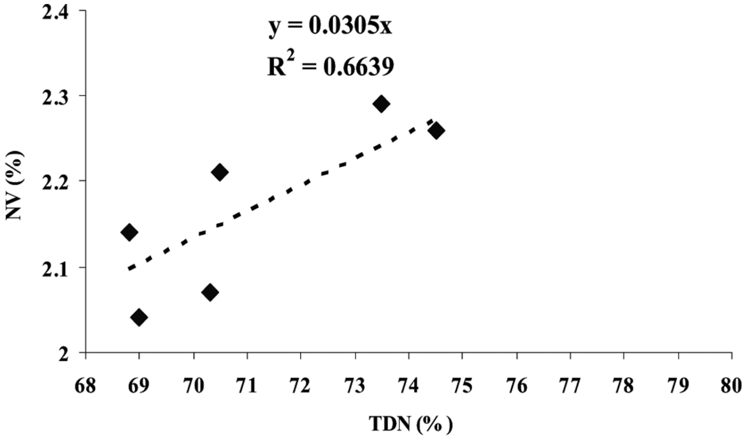

Figure 1. Relationship between the Total Digestible Nutrients (TDN) and Nutritive Values (NV) of *R. raetam* during summer season.

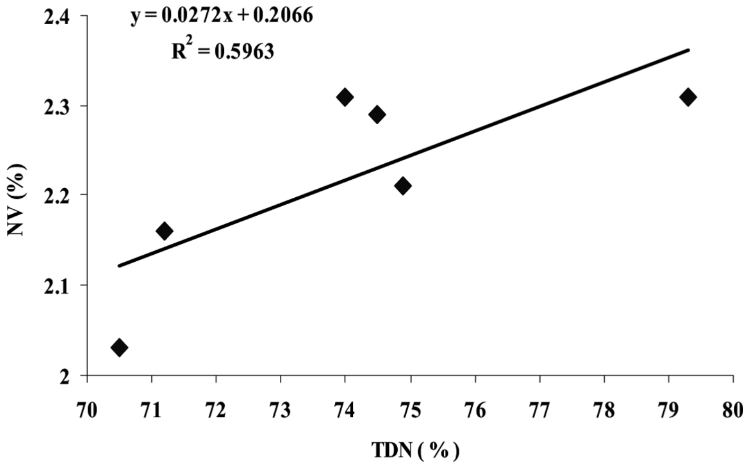

Figure 2. Relationship between the Total Digestible Nutrients (TDN) and Nutritive Values (NV) of *R. raetam* during winter season.

ranging from neutral to alkaline (7.38–8.22). The highest electrical conductivity value was recorded at the S1_ZR site and the lowest at the S3_UM_SH site.

Growth Performance

Data showed that the site and season significantly affected most of the plant growth indices (Table 3). In particular, the interactions between main factors influenced all measurements, except for plant height, main branches, and crown cover (Table 3). Seasonal variation was found to influence plant leaf number, area and length as well as flower number and flower bud/plant ratio. Significant differences were found

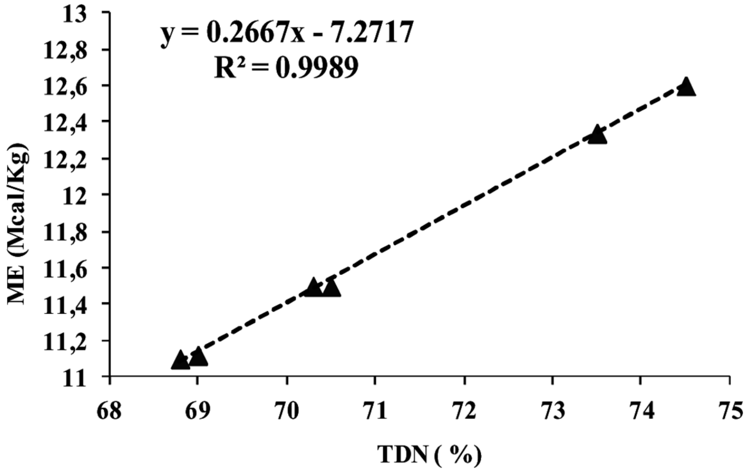

Figure 3. Relationship between the Total Digestible Nutrients (TDN) and Metabolized Energy (ME) of *R. raetam* during summer.

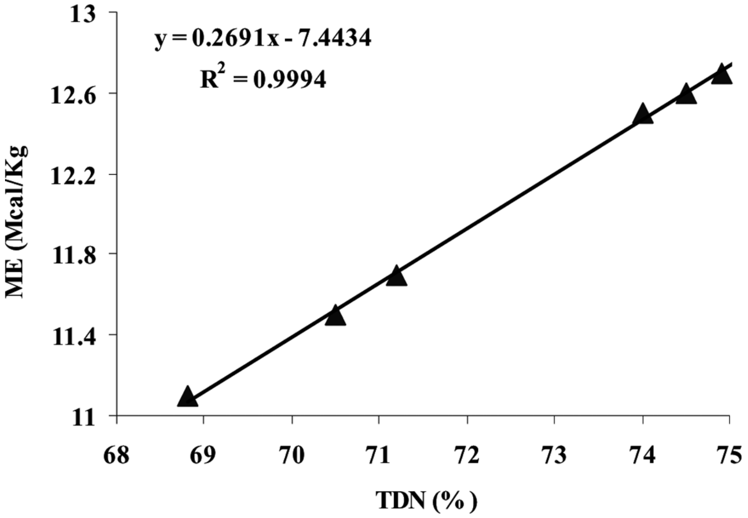

Figure 4. Relationship between the Total Digestible Nutrients (TDN) and Metabolized Energy (ME) of *R. raetam* during winter.

in leaf number, which ranged from 56.0 (S1_ZR) to 604 (S5_TR) during the winter season (Table 4).

Nutritive Variables

The season significantly affected ash, CF, and TDN content, whereas it had no effect on the other parameters (Table 3). Ash, CF content, and succulence varied significantly among sites, but TDN did not. Site location was found to be the main factor influencing plant succulence compared with seasonal effects and their interactions (Table 3). The nutritional variables of plants collected during the summer season varied significantly when compared with those collected in winter season. In the winter season, the site S2_GHL showed the highest values for most measured parameters. On the other hand, site S3_UM_SH had highest percentage of TDN, NE, and ME. The correlation analysis among the growth aspects, nutritive variables, and soil parameters revealed positive significant correlation between conductivity and CP (Table 5). On the other hand, organic carbon content had negative significant correlation with CF and CP, as well as with crown cover. The sand texture of soil had significant positive correlation with crown cover and nutritive variables.

The regression analysis between TDN and NV of *R. raetam* (Figures 1 and 2) indicate linear relationships ($R^2 = 0.6769$ and 0.5963 in summer and winter seasons, respectively). The same is true between TDN and ME (Figures 3 and 4) and indicate strong linear relationships for sites ($R^2 = 0.9989$ and 0.9994 at summer and winter, respectively).

Discussion

In the present study, the soil properties supporting the growth of *R. raetam* were found to vary among the different study sites, which, in turn, strongly influenced the phenological traits and nutritive variables of the plant. The soil characteristics in sites S3_UM_SH and S5_TR provided good water retention and enhanced potential for plant growth. This may explain the high growth performance of *R. raetam* grown at site S5_TR during the the winter. The low soil organic carbon content in most sites (0.05–0.13%) was in agreement with Zayed (1983) who studied soil-plant relationships of the same species in Sinai (Table 6). This may be due to sandy textured soils, wherein soil organic matter decay is accelerated (El-Khouly & Barakat, 2004). The results of the present work were in agreement with those found by Debussche and Thompson (2003) and El-Khouly and Barakat (2004). Higher soil water content was reported in sites located in Northern Sinai when compared with sites in Southern Sinai, especially during the winter season. Our data agreed with the findings of El-Khouly and Barakat (2004) on lavender (*Lavandula coronopifilia*) collected from Sinai. These authors reported that water limitations inhibited leaf and stem growth of lavender. The inhibition of leaf production resulted from a massive expansion of small daughter cells produced by meristematic division, and the growth inhibition is therefore related to the inhibition of cells' expansion. Reduced rates of new cell production may be an additional contribution to inhibition of plant growth (Lecoeur et al. 1995). In a previous study, Crawely (1997) found that water loss reduced the leaf length. In our work, *R. raetam* leaves were completely absent during the summer season at all sites, and they senesced and fell off the branches in S3_UM_SH and S4_RS sites during the winter season.

In the present study, the nutritional values of *R. raetam* were assessed according to the plant tissue chemical composition. Results on fiber content were in agreement with El-Shaer (2000), and the low to moderate fiber level in forage could positively influence plant nutrient uptake and assimilation (Bakshi & Wadhwa, 2004). Crude protein levels of *R. raetam* measured in our study under Egyptian conditions were two times higher than those observed for the same species in Tunisia (Laudadio, Tufarelli, et al., 2009). The levels of crude protein, observed as a function of site and season in this study, suggest that the crude protein levels of *R. raetam* appeared to be adequate to cover the maintenance requirements of protein for ruminants. These levels are sustained over the range of site and seasonal conditions evaluated in this study. Regarding N levels, the results of this study were consistent with those of other studies conducted on C^3 plants (Edwards et al., 2006). The small differences in *R. raetam* N content in response to habitat diversity and/or seasonality is probably determined by atmospheric nitrogen fixation through symbiotic association with *Rhizobium* bacterium (Gleadow et al., 2009). The present study indicates that the protein content in *R. raetam* is enough to maintain dietary animal maintenance requirements.

The TDN in plants varied among sites and seasons, and these values were higher than those reported by Heneidy (1996) in some common plants collected from the Sinai Peninsula. Our results meet nutrient requirements for sheep and cattle recommended by NRC (1984); and they were higher than those reported for common fodder crop such as clover and barley (Soliman & El-Shazly, 1978). Therefore, the TDN of *R. raetam* in locations evaluated through this study could be considered high enough to sustain grazing animal requirements. The NRC (1985) indicated that sheep are known to require an average 9% dietary protein for maintenance in *R. raetam*, the protein content exceeds this value. Compared with other fodder species, the protein percentage was higher than that of beerseem clover (*Trifolium alexandrinum*) (16.2% CP; Chauhan et al., 1980). It appears that the nutritive value of *R. raetam* meets or exceeds the nutritive value requirement for sheep (NRC, 1975), dairy cows (NRC, 1978), goats (NRC, 1981), and beef cattle (NRC, 1984).

Table 6. Nutritive variables of *R. raetam* compared with the other published works on some rangeland species and fodder crops

		%				
Species and/or Region	Reference	Ash	Fiber	Protein	DCP	TDN
White broom (*R. raetam*)	Present work	25–60	13.5–31	32–35	26–29	69–79
White broom (*R. raetam*)	Laudadio et al. (2009a)	8.5	–	14.7	–	–
Bunchgrass (*Panicum turgidum*)	Heneidy and Halmy (2009)	8.8	36.7	6.7	2.7	64.
Common plants in Sinai	Heneidy (1996)	9.1	39.9	6.6	2.65	65.7
UAE	Shaltout et al. (2008)	2.2–40	7.2–45	3.4–33	–	–
Raudhas in KSA	Madi (1993)	22–46	4.8–45	6–7.7		
Range ecosystem	El Kady (1987)	5.5–36	14.6–36	2.6–10	–	–
El Omyed, Mediterranean coast	Abdel-Razek, Ayyad, and Heneidy (1988)	–	–	–	4.9	72
Barley (*Hordeum vulgare*)	Soliman and El-Shazly (1978)	4.38	–	9.92	–	64
Corn (*Zea mays*)	Soliman and El-Shazly (1978)	3.21	–	8.06	–	68
Beerseem clover (*Trifolium alexandrinum*)	Soliman and El-Shazly (1978)	4.73	–	9.5	–	56

DCP, total digestible protein; TDN, total digestible nutrients.

Based on our findings, *R. raetam* appears to represent a valuable candidate as forage resource in the studied region. This fodder species should be considered valuable nonconventional forage in the Mediterranean arid ecosystem. However, further research is needed to assess the effects of climatic changes on the nutritional value of *R. raetam* in order to assess the plant's nutrient status under extreme dry conditions.

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