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This study assessed: (a) the total aerial and browse biomass of Atriplex nummularia Lindl. (saltbush) on ungrazed 9, 21, and 33-month old shrubs; (b) some relevant nutritional parameters for browse; and (c) the economics benefits of saltbush plantations in terms of cost ratios of energy and protein of saltbush vs. alfalfa, Medicago sativa L., hay. Saltbush proved to be a highly productive species in areas that are marginal or unsuited for conventional crops such as alfalfa. The cost ratio saltbush/alfalfa hay for metabolizable energy and crude protein was lower than one for all the scenarios related to life-span and management systems of saltbush when saltbush yield was higher than 3.0 Mg DM ha^{-1} yr^{-1}. The overall mean cost ratio saltbush/alfalfa hay for crude protein and metabolizable energy for all the scenarios was 0.22, considerably lower than that considered in our hypothesis.

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Goat milk production for cheese making is an increasing economic activity in Mendoza Province, Argentina. Goat diet is usually based on alfalfa hay and concentrates. Several enterprises have been located in areas where soil salinity or the presence of a shallow and saline water table significantly reduces the alfalfa yield and/or the life-span of the crop. In these areas, alfalfa yields only 10 Mg DM ha^{-1} $year^{-1}$, and its life-span is no more than four years (J. A. Paez, pers. comm., 2001). This yield corresponded to alfalfa cultivated under irrigation applying about 10,000 m^3 of water ha^{-1} $year^{-1}$ from the Mendoza River having EC of 0.9 dS m^{-1}. In contrast, in deep soils with moderate salinity (i.e., EC lower than 5 dS m^{-1}), alfalfa yields range from 18 to 20 Mg DM ha^{-1} $year^{-1}$, and the life-span of the crop is usually 5–6 years or even longer (Romero et al., 1995; Ochoa & Fernández, 1998).

Atriplex nummularia Lindl. subsp. *nummularia* (old man saltbush or giant saltbush, referred to hereafter as saltbush) is an alternate phreatophyte species. It may be able to reach water tables as deep as 10 m below ground surface (Le Houérou, 1992a). Its salt tolerance is also fairly high with half maximum yields under an EC of soil saturated extract around 30 dS m^{-1} (Le Houérou, 2000).

Saltbush can withstand minimum winter temperatures of -10° to -12° C for a few hours (Le Houérou, 1992a). Frost hazard is assessed through the mean daily minimum under standard shelter temperature of the coldest month. This parameter Q1 is usually referred to as "m" in the pertinent literature (Le Houérou, 2002). Saltbush is a fairly frost-tolerant ("m" > 1°C) species (Le Houérou, 2002).

The major constraint of saltbush is its high sensitivity to long-standing overbrowsing (Le Houérou, 2000). However, the type of utilization obviously affects the life-span of the stand. There exists in South Africa a 5-ha plantation established in 1921 and still productive in 1993 (Le Houérou, 1994a) that was managed with one single browse period of one month per year and 11 months total rest period. This type of utilization allows for long survival of the stands along with high productivity (Le Houérou, 2002). The best management system would be a single browse period of one to two weeks per year (Le Houérou, pers. comm., 2002).

Little has been published on the yield of saltbush plantations in areas with shallow water tables. Le Houérou (2002) reported data on a plantation in Tunisia in an area similar to the study site and also yield information from an irrigated crop of saltbush near Migda, NW of Bersheva, Israel.

Nutrient composition of saltbush browse fraction have been reported in several studies (Franclet & Le Houérou, 1971; Le Houérou, 1981; Correal Castellanos et al., 1986; Silva Colomer et al., 1986; Le Houérou, 1992a,b, 1994a, 2004; Lailhacar et al., 1993; Lailhacar, 2000; Watson & O'Leary, 1993; Chriyaa & Boulanouar, 2000; Delgado & Muñoz, 2000; Koocheki, 2000; Mirreh et al., 2000; Ben Salem et al., 2002, 2004). However, the economic aspects of saltbush plantations have been assessed in only a few studies (Le Houérou, 1989, 2002; Mirza, 2000).

We postulated that (a) saltbush could be highly productive when it was established in areas with a shallow and moderately saline water table, and (b) the nutrient costs for saltbush browse were lower (about 50%) than those for alfalfa hay. This study was performed to assess the aerial biomass productivity, nutrient composition and economic benefits of *Atriplex nummularia* plantations in areas with shallow and moderately saline water tables.

Material and Methods

Study Site and Field Trial

Three-month old nursery-grown speedlings were hand transplanted into a furrow bottom at a spacing of 1×2 m in an area with shallow (1–1.1 m deep) and moderately saline (4.6 dS m^{-1}) water table. Seven rows of about 110 plants each were established. Linear regression equations of shrub volume on total and browse biomass were estimated. Nutritional parameters were determined for 33-month old shrubs. To estimate the cost of saltbush plantation, the following scenarios were considered: (a) poorly and adequately managed plantations (10- and 30-year life-span, respectively), (b) saltbush browse yields from 1.0 to 6.5 Mg DM ha^{-1} $year^{-1}$, and (c) two management systems (cut-and-carry for pen feeding and direct browsing). For alfalfa crop, cultivated under irrigation, the life-span was four years and the yield was 10 Mg DM ha^{-1} $year^{-1}$ from year two onward. Costs through the life-span of the two crops were discounted at present value using a 12.0% discount rate. Browse biomass was about 0.4, 0.8, and 1.4 kg DM $shrub^{-1}$ for 9-, 21-, and 33-month old shrubs, respectively, or 6.5 Mg DM ha^{-1} $year^{-1}$ for the oldest saltbush plants, corresponding with the surviving 4,665 shrubs ha^{-1}. Mean values of nutritional parameters were: organic matter, 74.7%; in vitro organic matter digestibility, 47.0%; ash, 25.3%; crude protein, 13.6%, Na, 5.6%; and Cl, 7.7%.

Following the recommendations by Le Houérou (1995, 1999) on the high potential of several areas of Mendoza for saltbush plantations, a field trial was conducted on a farm close to a private goat cheese manufacturing enterprise located 15.5 km east of Mendoza City (32° 53′ S, 68° 42′ W, elev. 687 m). The mean annual temperature (1961–1990) was 16.7°C with a range of the absolute minimum and maximum from –7.8°C (July) to 40.6°C (February). The mean daily minimum temperature of the coldest month is 2.2°C. Mean annual rainfall for 1961–1990 was 189 mm (S.D. = 78.8 mm) with nearly 80% occurring during the spring-summer period (October–March).

The soil profile to 1.0 m depth was classified as Inceptisols (Soil Survey Staff, 1999) with EC (dS m^{-1}) of soil water extract of 9.1 (0–25 cm), 4.2 (26–50 cm) and 2.6 (51–75 cm). The permanent water table was 1.0–1.1 m deep, with EC of 4.6 dS m^{-1}. In the vicinity of the study site there were some 34,500 ha with permanent water table at <2.5 m deep (Ortiz Maldonado & Gómez, 2001).

Three-month nursery-grown speedlings (i.e., small (5–10 cm) seedlings grown in microcontainers), of the high palatability grade Von Holdt strain of *A. nummularia*, introduced from South Africa, were hand transplanted into furrow bottoms with 2 m row spacing and 1 m spacing in the row in September 2001. This intensively stocked plantation was to make efficient use of the water table present at the study site. Seven rows of approximately 110 plants each were established. After planting, 10 L of water per speedling was applied. Rainfall during the spring-summer period was 209, 121, and 101 mm for years 2001–2002, 2002–2003 and 2003–2004, respectively.

Allometric Regression Equations

The use of regression equations to predict aerial biomass fodder for saltbush by means of allometric variables such as height, canopy diameter, or circumference and their products or combinations has been highly successful (Le Houérou, 1981, 1994b; Le Houérou et al., 1982; Acherkouk, 2000; Lailhacar, 2000).

Measurements of the maximum height and two diameters (the longest and the greatest perpendicular to the first) of 20 randomly selected plants located in the central three rows were taken in June 2002, June 2003, and June 2004 (i.e., at 9, 21, and 33 months after transplanting). A simple random sampling design was used to select the individuals to measure. All the plants within our sampling sites were numbered. The next step was to select among those numbers at random a plant, using a random number table. These plants were cut at ground level, separated into wood and browse (leaves plus succulent green twigs up to approximately 4–5 mm diameter, according to Valderrábano et al. (1996), weighted and oven-dried at 70°C to constant weight. Biovolume, estimated as a theoretical cylinder from height and mean diameter of each individual shrub, was regressed separately on total and browse dry matter biomass for each growing season (Passera, 1986). Least squares method was used for obtaining estimates of parameters in linear regression models. Based on data from these plants, the browse to total biomass ratio was calculated.

Another 80 plants were selected by the procedure described above and the same measurements taken. Total and browse biomass of each of these individuals was calculated from the estimated regression equations and the results averaged.

Plant survival was determined for all plants located in the central three rows in June 2002 and at the end of the third growing season. Root depth was monitored at 3-month intervals excavating various shrubs whose sizes were representative of those present in the field. Only the main roots were used in this assessment because rootlets were difficult to observe.

Nutrient Content Determination

For nutrient content determination, six browse samples were analyzed. Each sample was a composite from three plants randomly selected from the 20 plants harvested for estimating regression equations in June 2004. Crude protein (CP; $N \times 6.25$) was determined by the Kjeldahl method (Müller, 1961); ash and Na determinations were made according to Association of Official Analytical Chemists (1975) methods. Chlorine (Cl) was determined by Mohr method (Vogel, 1960), and in vitro organic matter digestibility (IVOMD) by the procedure of Tilley and Terry (1963). The mean ratio leaves/twigs, in terms of DM, was determined on the six analyzed samples.

Cost of Nutrients

Establishment and maintenance costs for saltbush were estimated based on data obtained by the authors during the establishment and monitoring of experimental saltbush plantations in the Mendoza plain. For soil preparation, the use of rented machinery was assumed. The same costs for alfalfa hay were estimated based on standard technological catalogs elaborated in the Agronomy Faculty of the Universidad Nacional de Cuyo. For hay making the use of rented machinery was also assumed. Costs were valued at September 2004 price levels and were expressed in U.S. dollars (US$). Money conversion rate used was 3 Argentina pesos = 1 US$.

Two scenarios were analyzed in relation to the life-span of the crop: 10 and 30 years. These scenarios corresponded to poorly and adequately managed plantations, respectively (H. N. Le Houérou, pers. comm., 2004). The life-span for the alfalfa crop was four years.

Costs of establishment and maintenance through the life-span of the two crops were discounted at a present value using a 12.0% discount rate, corresponding to the opportunity cost of capital in Argentina. For saltbush management, two systems were considered: cut-and-carry (CAC) for pen feeding and direct browsing (DB); hence a purchase of a gasoline powered brush cutter, with a 10-year life-span, was included as investment in the CAC system at years 3, 12, and 23, and the cross fence necessary for good utilization of browse was included in the DB system. The CAC method of exploitation may also prove mandatory, albeit more expensive, wherever there was poor control of the grazing animals (Le Houérou, 2000).

The cost per unit of metabolizable energy (ME) and crude protein provided by both crops was calculated based on costs, biomass production, and nutrient content. It was assumed that all the browse available could be utilized by goats in the DB system. In fact, utilization would be 100% or even more as goats may eat parts such as small branches that humans did not consider as browse (H. N. Le Houérou, pers. comm., 2004). The cost ratio saltbush/irrigated alfalfa for hay making was calculated.

The wood production in saltbush plantations is of a great importance in the study area where fuelwood was valued. Therefore, the monetary value of saltbush wood production was included as financial output in the economic analysis. The monetary value was estimated based on: (a) the ratio between forage and wood (50%) reported by Le Houérou (1986, 1992a,b); (b) the caloric content of saltbush wood; 3,400 kcal (0.8 J) kg^{-1} DM (Le Houérou, 1992a); (c) the caloric content of the most common wood used in the study area (*Prosopis* spp.): 4,650 kcal (1.1 J) kg^{-1} DM (Braun & Candia, 1980), and (d) the selling price of *Prosopis* wood at farm gate (US\$ 0.03 kg^{-1} DM). Assuming that the commercial value of saltbush wood was commensurate with its caloric value, we would have a wood production value of US\$ 0.022 kg^{-1} (3,400/4,650 kcal kg^{-1} $*$ US\$ 0.03 kg^{-1} DM or 0.8/1.1 J $*$ US\$ 0.03 kg^{-1} DM). This production value was deducted from the costs of saltbush in the different scenarios.

Results

Plant survival was 95.0% in June 2002 and 93.3% in June 2004. It implies that there were 4,665, 33-month old shrubs ha^{-1} (1×2 m spacing or a density of 5,000 shrubs ha^{-1} multiplied by 0.933). Shrub roots reached the water table between 12 and 15 months after transplanting. It is probable that the rootlets reached it earlier.

Mean height and diameter of the shrubs after one, two, and three growing seasons after transplanting are shown in Table 1. The final regression equations and statistics are shown in Table 2. Mean total and browse dry matter biomass per shrub, estimated from the regression equations are presented in Table 3. Browse to total biomass ratio (DM) was 0.63, 0.40, and 0.29 after one, two and three growing seasons, respectively.

Mean and standard deviations of the nutritional parameters determined for browse were: organic matter (OM), 74.7% $\pm$ 1.3; in vitro organic matter digestibility (IVOMD): 47.0% $\pm$ 5.7; ash, 25.3% $\pm$ 1.3; crude protein (CP), 13.6% $\pm$ 0.4; sodium (Na), 5.6% $\pm$ 0.3; and chorine (Cl), 7.7% $\pm$ 0.5. This browse was composed by 69.6% (S.D. = 3.6) of leaves and 30.4% (S.D. = 3.6) of twigs.

Table 1. Dimensions of *Atriplex nummularia* shrubs according to the growing season (n = 80 for each season)

Growing season	Height (cm) Mean ± S.D.	Height (cm) Coefficient of variation	Diameter (cm) Mean ± S.D.	Diameter (cm) Coefficient of variation
2001–2002	105 ± 22	21	75 ± 22	29
2002–2003	148 ± 37	25	97 ± 37	38
2003–2004	184 ± 32	17	130 ± 36	28

The establishment and maintenance discounted costs of saltbush for 6.5 Mg DM ha^{-1} year^{-1} were US$ 1,073 (CAC system; 10-year life span), US$ 1,344 (CAC; 30-year life-span), US$ 735 (DB; 10-yr life-span), and US$ 854 (DB; 30 yr life span). If the number of surviving shrubs was considered (4,665 ha^{-1}), the costs per shrub were: US$ 0.23 (CAC, 10-yr), US$ 0.29 (CAC, 30-yr), US$ 0.16 (DB, 10-yr), and US$ 0.18 (DB; 30-yr). The total cost for the alfalfa crop was US$ 903 ha^{-1}.

In spite of the limitations imposed by our experimental plot size (about 0.13 ha), the biomass per ha at the end of the third growing season was calculated by multiplying the mean shrub yield by the number of surviving plants (4,665): about 25.5 Mg DM ha^{-1} of total biomass, corresponding to three years accumulation of DM material, and 6.5 Mg DM ha^{-1} yr^{-1} of browse biomass. Thus, we assumed that production of saltbush was 6.5 Mg DM ha^{-1} yr^{-1} from year three onward. According to measurements carried out by the authors of this study, the production schedule for alfalfa crop was: 5.5 Mg DM ha^{-1} yr^{-1} for year one and 10 Mg DM ha^{-1} yr^{-1} from year two onward.

Crude protein content of saltbush was 136 g kg^{-1} DM through the life span of the crop. This assumption would be an underestimation of CP production because regrowth after grazing generally had higher CP content than that of ungrazed 33-month old plants (Le Houérou, 1986). Metabolizable energy for saltbush was

Table 2. Parameters and data statistics of the linear regression equations of volume on total and browse biomass per shrub for *Atriplex nummularia* for the three growing season (n = 20 for each season)

Growing season	Biomass	Parameter Intercept	Parameter Slope	Data statistics Adjusted R^2	Data statistics Level of significance
2001–2002	Total	170	0.98	0.83	$P < 0.0001$
	Browse	158	0.48	0.66	$P < 0.0001$
2002–2003	Total	787	1.02	0.71	$P = 0.0025$
	Browse	430	0.29	0.75	$P = 0.0072$
2003–2004	Total	329	1.90	0.67	$P < 0.0001$
	Browse	115	0.47	0.71	$P < 0.0001$

Regression equations: $y = a + b*x$, where y = total or browse biomass (g DM shrub^{-1}), a = intercept, b = slope, and x = volume (dm^3).

Table 3. Estimated total and browse biomass for *Atriplex nummularia* shrubs for the three growing seasons (n = 80 for each season)

	Biomass (g DM shrub^{-1})	
Growing season	Total mean ± S.D.	Browse mean ± S.D.
2001–2002	662 ± 300	398 ± 146
2002–2003	2,179 ± 1,294	828 ± 369
2003–2004	5,470 ± 3,059	1,386 ± 757

8.9 MJ kg^{-1} DM (Le Houérou, 1981). For alfalfa hay (early bloom), CP and ME contents were 184 g kg^{-1} DM and 8.6 MJ kg^{-1} DM, respectively (National Research Council, 1970).

The cost ratio saltbush/alfalfa hay for metabolizable energy (MJ ha^{-1}) and crude protein (kg ha^{-1}) for various yields of saltbush and the two management systems of this crop are presented in Figures 1 and 2.

For poorly managed saltbush plantations (10-yr life span) and the CAC management system (Figure 1) the cost ratio saltbush/alfalfa hay would be lower than one when saltbush yields were higher than about 3.0 Mg DM ha^{-1} year^{-1} for ME and 1.8 Mg DM ha^{-1} yr^{-1} for CP. If adequately managed plantations of saltbush were considered (30-yr life span) the saltbush plantations would be convenient from the economic point of view when saltbush yields were higher than about 1.0 and 0.6 (data not shown) Mg DM ha^{-1} yr^{-1} for ME and CP, respectively. Lower yields of

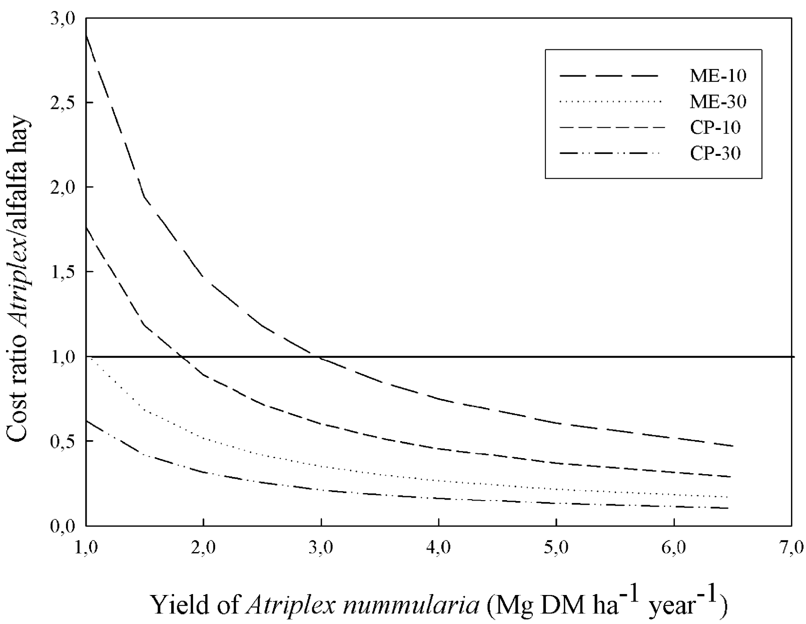

Figure 1. Cost ratios of saltbush/alfalfa hay for metabolizable energy (ME) and crude protein (CP) for different life spans (10 and 30 years), yields, and cut-and-carry management system of saltbush.

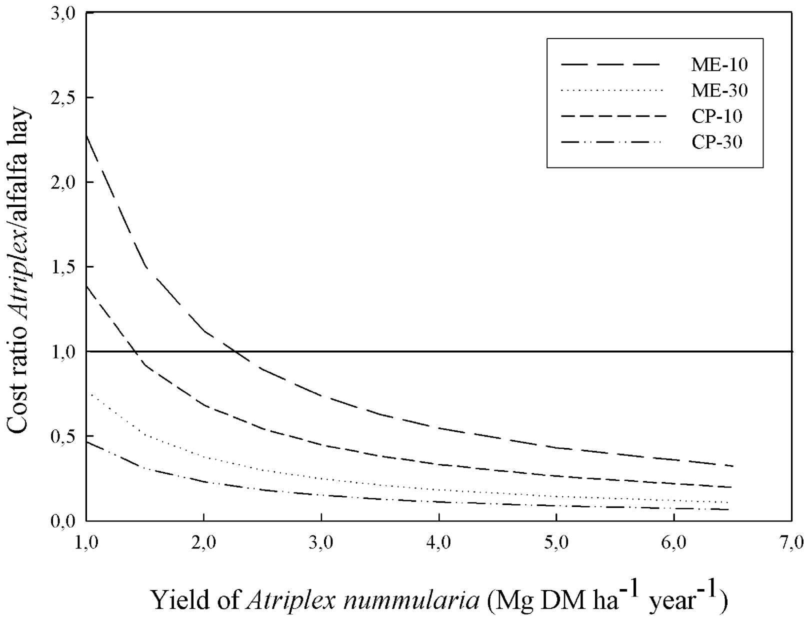

Figure 2. Cost ratios of saltbush/alfalfa hay for metabolizable energy (ME) and crude protein (CP) for different life spans (10 and 30 years), yields, and direct browsing management system of saltbush.

saltbush than those previously mentioned would be necessary for making saltbush cheaper than alfalfa when the DB management system was considered (Figure 2). Thus, saltbush yield in poorly managed plantations would be higher than 2.2 and 1.4 Mg DM ha^{-1} yr^{-1} for reaching a cost ratio of saltbush/alfalfa hay lower than 1 for ME and CP, respectively. The corresponding values for adequately managed saltbush plantations would be about 0.8 and 0.5 Mg DM ha^{-1} yr^{-1} (data not shown) for ME and CP, respectively.

At a saltbush yield of 6.5 Mg DM ha^{-1} yr^{-1} and under the CAC system, the cost ratio of saltbush/alfalfa hay for CP was 0.10 and 0.29 for saltbush plantations with life spans of 30 and 10 years, respectively (Figure 1). For ME, the cost ratio of saltbush/alfalfa hay was 0.17 and 0.47 for saltbush plantations with life span of 30 and 10 years, respectively. For the DB management system (Figure 2), the corresponding values were: 0.07 and 0.20 for CP for 30 and 10 yr, respectively, and 0.11 and 0.32 for ME for saltbush plantations with life spans of 30 and 10 yr, respectively.

Discussion

The comparison of our regression equations with that of Le Houérou et al. (1982) and Le Houérou (1994b), estimated on the basis of several thousand shrubs from several saltbush plantation in Libya: y (kg FM shrub^{-1}) = 124 $*$ 10^{-5}x, where x was the product of height by diameter in cm^2, indicated that the Le Houérou's equation gave, at the end of the third growing season, two and half times more total biomass per shrub than that of our equation, converted into DM. We assumed that the main causes of this difference could be:

1. a distinct plant density: 2,000 shrubs ha^{-1} in Libya vs. 5,000 in Mendoza,
2. distinct water availability: dry land cultivation in Libya vs. the presence of a shallow water table in Mendoza,
3. distinct seasons of harvesting: springtime in Libya vs. autumn in Mendoza; according to Le Houérou (pers. comm., 2004) spring production is usually ca. twice as high as fall production which implied higher density of biomass within shrubs in Libya,
4. distinct plant material: ours being a selected material from the Von Holdt strain from South Africa, while Le Houérou's was standard commercial material,
5. distinct weather conditions during the weeks and months that preceded the harvest.

The three first causes are likely to be the main reasons of the discrepancies observed but the others cannot be discarded. This showed the limits of the allometric relations method. According to Le Houérou (1994b),

> these relations were only valid for a given species and strains, in a given field, over a given season. The relation may be substantially altered depending on season and mainly on weather conditions and grazing pressure on the site for the previous weeks and months prior to the evaluation. With this restriction in mind it is possible to assess the total and Q2 forage biomass present in a "quick, cheap and fairly reliable way."

The browse biomass measured for 33-month old shrubs was 30% higher than that of a highly productive plantation of old man saltbush in Tunisia (mean annual rainfall = 260 mm; 'm' = 4.5°C) in an area with deep sandy alluvia over moderately saline clay and a deep brackish water table (ca. 5 m deep and ca. 10 dS m^{-1}), site unfit for conventional crops (Le Houérou, 2002). Total dry matter biomass (8.5 Mg DM ha^{-1} year^{-1}) was considerably higher than that predicted for the study area by Le Houérou (1995, 1999): 1.5–3.0 Mg DM ha^{-1} yr^{-1}. The irrigated saltbush plantation near Migda, NW Bersheva, Israel, did, however, exhibit, for a similar planting density (5,000 shrubs ha^{-1}), production data (Le Houérou, 2002) commensurate with ours. This seemed logical since our field experiment had a shallow, permanent, moderately saline water table. These conditions come close to permanent subirrigation.

The ratio between forage and wood, expressed in DM, for *A. nummularia* and other *Atriplex* sp. averaged 50%, but it can be considerably increased by appropriate management or substantially reduced via poor management or underutilization (Le Houérou, 1992a). Le Houérou (1986) reported that for 3-year-old uncut saltbush in Libya the browse to total biomass ratio, in terms of fresh matter, was 0.32, while this ratio was 1.0 for regrowth after one year. In our study, the browse to total biomass ratio, in terms of fresh matter, for almost 3-yr-old uncut plants was 34% higher than the ratio measured by Le Houérou (1986).

When comparing our results on nutritional value with those from other studies we consider our range Mean ± 1 S.D. The OM content of our saltbush (74.7%) was consistent with that reported by Ben Salem et al. (2002, 2004): 75.4 and 74.5%, respectively. It was slightly lower than that found by Silva et al. (1986): 76.4% and higher than that measured by Correal Castellanos et al. (1986): 71.4%.

The in vitro organic matter digestibility of the saltbush analyzed in this study (47.0%) was similar to that found by Correal Castellanos et al. (1986): 49.5%.

In contrast, Le Houérou (1981), Lailhacar (2000), and Koocheki (2000) reported higher values than those measured in the present study: 55.0, 61.6, and 68.8%, respectively.

The crude protein content of the saltbush in the present study (13.6%) was consistent with values reported by Chriyaa and Boulanouar (2000): 13.7% and Mirreh et al. (2000): 14.4%. This latter CP value corresponded to forage from 3-yr-old plants. Most of the studies reported CP contents higher than those measured in the present study: Franclet and Le Houérou (1971), 17.3–22.6% for South Africa and 21.3–23.2 for North Africa and Australia; Le Houérou (1981), 19.0%; Correal Castellanos et al. (1986), 16.7%; Silva et al. (1986), 17.0%; Le Houérou (1992a), 16–22%; Le Houérou (1992b), 15–20%; Delgado and Muñoz (2000), 19.9%; Koocheki (2000), 23.5%; and Ben Salem et al. (2002, 2004), 16.9 y 17.8%, respectively. Lower CP concentration than that measured in our study was found by Lailhacar (2000), 11.5%, and Watson and O'Leary (1993), 10.3%.

According to Le Houérou (1992b, 2004), Yaron et al. (1985), Benjamin et al. (1986), and Teifert (1989), about 45% of the saltbush N is nonprotein and therefore not retained by livestock. Of this nonprotein some 50% is glycinebetaine, a quaternary ammonium compound and ca. 0.5% proline, another nonretainable, nonprotein source of nitrogen. Both glycinebetaine and proline are known for playing an important role in drought and salt-tolerance mechanisms. These compounds are amenable to degradation by the rumen microflora when sufficient energy is available for the microorganisms to develop and the animals and their microflora have had time to adjust to the salt content of the diet. It would seem it takes up to 3–5 months for the animals and their rumen microflora to adjust to an *Atriplex*–rich diet. This assumption was supported by the results of a long-standing consumption trial involving 460 animals: the intake by sheep grew in a regular fashion from 800 to 2,500 g DM head^{-1} day^{-1} over a period of 4 months and then stabilized at the end of the 238-day experiment (Le Houérou, 1992a,b). Similar results have been reported by Correal Castellanos et al. (1990) in SE Spain.

Ash content of our saltbush (25.3%) was similar to that found by Franclet and Le Houérou (1971) for South Africa and Australia, 24.4%; Le Houérou (1981, 1992b), 25%; and Lailhacar (2000), 26.0%. It was lower than those measured by Le Houérou (1994a): 25–30%; Chriyaa and Boulanouar (2000), 30.8%; and Koockeki (2000), 28.5%. In contrast, it was higher than that reported by Franclet and Le Houérou (1971) for North Africa, 23.1%; Watson and O'Leary (1993), 23.0%; Delgado and Muñoz (2000), 19.5%; and Mirreh et al. (2000), 18.5%.

Sodium concentration for saltbush in this study (5.6%) was higher than that found by Delgado and Muñoz (2000), 3.9%; and Ben Salem et al. (2002, 2004), 4.2 and 4.7%, respectively. Sodium was lower than that measured by Franclet and Le Houérou (1971), 5.9% (average of samples taken through one year); and Watson and O'Leary (1993), 7.2%. Delgado and Muñoz (2000) measured chloride content (5.3%) which was lower than that found in our study (7.7%). Sodium plus Cl of our saltbush (13.3%) was higher than that reported by Franclet and Le Houérou (1971), 9.9%.

Since nutritive value is directly related to leafiness, the variability in the results of forage quality from various authors could be associated with changes in the stem and leaf components of the harvested material (Watson et al., 1987). In other words, the nutrient parameters differed very much between leaves and young stems (Mirreh et al., 2000). In the samples analyzed by these authors, CP, ash, and Na contents of leaves were about 140, 160, and 270% higher than those for stems, respectively, whereas leaves had only 82% of the OM content of the stems.

On the other hand, the observed variability could derive from the season of the year when the samples were taken. Thus, Correal Castellanos et al. (1986) found that saltbush varied according to the season and OM content ranged from 68.0 to 76.4%, CP content from 13.8 to 18.7% and IVOMD from 45 to 53%. Likewise, Franclet & Le Houérou (1971) reported that CP content ranged from 18.8 to 24.7%, ash content from 18.3 to 27.3% and Na content from 3.7 to 8.7%.

Furthermore, ash, Na, and Cl concentrations in *Atriplex* sp. may reflect the salinity level of the irrigation water and soil media (Watson et al., 1987). Thus, Miyamoto et al. (1996) found that ash content of *A. nummularia* tops (leaf plus stem) increased from 0.22 to 0.35 kg kg^{-1} of dry weight when the salinity of the irrigation water increased from 2.7 to 30 dS m^{-1}. Likewise, concentrations of Na and Cl in the plant tops increased sharply with increasing external salinity up to 30 dS m^{-1}, then leveled off or decreased. On the other hand, accumulation of salt is part of the adaptation process of halophytes to salinity (Glenn et al., 1994), hence Glenn et al. (1998) reported that ash content was significantly higher in plants irrigated with water having 4,100 mg of total dissolved solids (TDS) L^{-1} than that for plants irrigated using water with 1,149 mg TDS L^{-1}.

Another source of variation among the various studies could be the age of the leaves. Mirreh et al. (2000) reported that CP and other nutrient parameters (not included in our study) were higher in leaves of 1-yr-old plants than those for 3-yr-old shrubs.

The cut-and-carry or zero grazing management system was more expensive than the direct browsing system. Similar results were reported for *Opuntia* plantations for all the scenarios analyzed by Le Houérou (1989) in Tunisia and for most of the scenarios evaluated by Guevara et al. (1999) in Mendoza. Furthermore, the cost per shrub under the CAC management system was higher than that for the DB system for all the scenarios analyzed by Guevara et al. (1999).

Using another method for assessing the cost of browse (cost of maintenance plus amortization of establishment cost over 10 yr) and barley, *Hordeum vulgare* L., instead of alfalfa, Le Houérou (2002) found that cost ratios of Scandinavian Feed Units of saltbush vs. purchased unsubsidized barley was lower than 1 for all analyzed scenarios. They were: improved rangeland by overplanting of saltbush; saltbush fodder crop, clean cultivated and unfertilized; fertilized fodder crop of saltbush; alley cropping of saltbush and barley; and establishment of saltbush by direct seeding of pregerminated seeds. The cost ratio of saltbush/barley decreased from 0.9 to 0.003 from the first to the last scenario. This showed that the more intensive the production system was, the more profitable it became in terms of cost/benefit ratio per unit of feed produced. We obtained similar results when comparing poorly with adequately managed saltbush plantations.

The cost of establishment of saltbush (land preparation, nursery raising speedlings and planting costs) in our study was about US$ 300 ha^{-1}. A similar cost (US$ 317 ha^{-1}) was estimated in Pakistan by Mirza (2000). Le Houérou (2002) found in Northern Africa costs of establishment in the range US$ 200–400 ha^{-1} for four of the five scenarios envisaged. Our cost figures are in the middle of this range.

Conclusions

Atriplex nummularia proved to be a highly productive species in areas that are marginal for conventional crops such as alfalfa. The cost ratio saltbush/alfalfa hay for metabolizable energy and crude protein was lower than for all the analyzed scenarios related to the life-span and management system of saltbush when saltbush yield was higher than 3.0 Mg DM ha^{-1} yr^{-1}. The overall mean cost ratio saltbush/alfalfa hay for crude protein and metabolizable energy for all the analyzed scenarios was 0.22, considerably lower than that considered in our initial hypothesis.

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