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SEASONAL PREFERENCE OF AWASSI SHEEP FOR ATRIPLEX SHRUBS SUITABLE FOR MEDITERRANEAN RANGELANDS

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ABSTRACT

The relative preference of Awassi sheep for four promising Atriplex species, *A. halimus*, *A. nummularia*, *A. canescens* and *A. lentiformis* was tested in cafeteria trials. Atriplex species were offered to sixteen sheep in cafeteria-type experiments during two seasons, spring and autumn. After an adaptation period of 7 days, sheep were offered the species over eight consecutive days. The species were placed in troughs for two hours in the morning after overnight fasting. Sheep were housed individually in pens adjacent to each other. In both seasons, whole species and their botanical fractions were evaluated for chemical composition and *in vitro* digestibility. The variability of nutritive value among species was not dependent on season or botanical fraction. Time series analysis showed that intake levels and ranking of species did not change over the eight days. Average daily proportions (%) of whole shrub eaten were *A. halimus* (70.9) *A. nummularia* (70), *A. lentiformis* (65.3), *and A. canescens* (57.9). In autumn, the same order of consumption was maintained, though intake levels tended to be lower compared to spring. The behavioral pattern revealed that the number of return visits to troughs and time spent feeding on species did not influence intake levels. The botanical structure of species explained 20% of the variation in proportion of intake of whole species. The proportion of leaf was the major contributor to variation in proportion of intake of whole species. Relative preference of whole species was explained by intake, nutritive value and fractional proportions of the botanical fractions.

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1 Introduction

Most rangelands in West Asia and North Africa (WANA) are progressively degrading and producing less forage due to overgrazing by increasing livestock populations and frequent drought (Louhaichi, 2011). This has led to the examination of a large variety of trees and species, in particular legumes and halophytes as potential supplementary sources of fodder (Anon, 2009; El Shaer, 2010). Saltbush fodder species are often grown in dry areas because they can grow in arid zones between 200 and 400 mm isohyets of mean annual rainfall and they are drought and salt tolerant (ICBA, 2006; Osman et al., 2006). They are good for revegetating salt affected soils. In the WANA region, Atriplex is the most popular species introduced for rangeland rehabilitation because of its high tolerance to soil salinity and water scarcity (Mayberry et al., 2010). These salt tolerant plants are now gaining interest as ruminant feeds (Ben-Salem & Morand-Fehr, 2010). There being limited data on environmental adaptation, biomass production, proportion of intake and quality of most of the fodder species in the region, the International Center for Agricultural Research in the Dry Areas (ICARDA) established a pastoretum in 1998 which now contains forty two species and seventy ecotypes of fodder species collected from native and exotic species in 20 different countries around the world. Sixteen ecotypes of forty fodder species from the pastoretum were tested for dryland adaptation in three sites in the Syrian rangelands (steppe). Measurements of their fodder, wood and seed yield as well as vigor and survival percentage were documented (Larbi et al., 2007). However, fodder species vary greatly in proportion of intake by livestock. Preferred species tend to be grazed heavily, especially when animals are allowed to graze yearlong (Tastad et al., 2010; Ouled et al., 2011). Selective grazing can change the composition of the plant community and reduce productivity of primary forage species, thus affecting rangeland productivity (Louhaichi et al., 2009). Re-establishing vegetation is an expensive process, and policy makers need guidelines on the economic benefits of marginal and steppe land rehabilitation. One of the main challenges is how to manage plantations in the rangelands in a sustainable way. In view of this, four promising Atriplex species were selected from the pastoretum for a preference study in a cafeteria-type experiment with sheep. The selection of the Atriplex species was based on high adaptation of the species to drylands, drought and frost tolerance, high survival, high vigor, high fodder production and shrub size (Larbi et al., 2007). This study determined the relative preference of Atriplex species by Awassi sheep and related the preference ranking exhibited to fractional proportions and nutritive quality attributes of botanical fractions and intake of the shrubs.

2 Materials and methods

2.1. Study site

The experiments were conducted at the experimental farm of ICARDA in Tel Hadya (latitude 35° 55´ North, longitude 9° 35´ East, altitude 362 m), South of Aleppo, North West Syria. This region is characterized by a non-tropical dry climate with a mean annual rainfall of 150-300 mm.

2.2. Rangeland species

Four species of Atriplex; *A. halimus, A. canescens, A. nummularia and A. lentiformis*, all of the same maturity stage, were selected from promising varieties in the ICARDA pastoratum that are adapted to the rangelands of North West Syria (Larbi et al., 2007). The selection was based on species size, survival percentage, vigor, biomass yield as shown in Table 1. The four species were used for the trial during both spring and autumn. The species comprised of leaves, young shoots (green, growing shoots of the current year below 3 mm diameter) and woody shoots (old branches from previous years with diameter of 7-10 mm).

2.3. Animals

Sixteen castrated rams (10 - 12 months old, 45.3±2.92 kg BW in spring; 16 - 18 months old, 54.7±3.56 kg BW in autumn), were randomly distributed into 16 well-ventilated pens. Rams were housed individually in pens measuring 2m x 2.5m. Pens were adjacent but opaque to each other. The sheep were drenched before onset of the experiments.

Table 1 Plant characteristics of Atriplex species used for the cafeteria trial

Species	Origin	Shrub size (m)	Survival (%)	Vigor (1-10) 1 low, 10 high	Biomass kg/species
Atriplex canescens	USA	4.36	100	8	4.74
Atriplex halimus	Spain	7.82	100	10	6.48
Atriplex lentiformis	USA	4.64	98	8	1.99
Atriplex nummularia	Australia	4.50	89	9	2.68

Source: Larbi et al., 2007

2.4. Experimental design

Atriplex shrubs were offered in cafeteria trials that were carried out in two consecutive seasons, in the spring of April, 2013 and in the autumn of November, 2013. During each season, the trials were conducted over eight consecutive days. There was an adaptation period of seven days prior to the trials to allow the sheep to get familiar with the pens. During this period, a maintenance diet consisting of barley straw, wheat bran, salt and a mineral and vitamin mixture was offered. No shrubs were offered during this period. During the trial period, each of the Atriplex species was hand harvested each morning. Fresh shrub of each species was put in two troughs, each containing 500g of the shrub, and placed in each pen every morning during the 8 days of the trial. Eight feeding troughs were placed in each pen. It had been established through previous on-station studies (undocumented) in ICARDA station at Aleppo that sheep could not consume more than 1 kg of any Atriplex species per day. However, the sheep in this study had neither previous feeding nor exposure to Atriplex shrubs. The sheep were fasted for 12 h overnight before morning feeding. They were allowed to feed on the shrubs from 09.00 h to 11.00 h. The positions of the troughs containing the shrubs were randomly changed daily to avoid "habit reflex" of choice by the animals. Animals were watered *ad libitum*. After the morning feeding on the shrubs, each sheep received barley straw *ad libitum* and 500 g concentrate. The concentrate consisted of wheat bran (203 g/kg), salt (3.2 g/kg) and a mineral and vitamin mixture (4.6 g/kg) on a dry matter (DM) basis. It was offered twice daily in equal portions at 12 noon and 18.00 h. Use of sheep was assessed by the Environmental and Occupational Health and Safety unit of ICARDA.

2.5. Measurements of intake

Intake of both whole shrub and botanical fractions was determined. To determine intake of whole shrub intake, refusals corresponding to each species in each pen were pooled and recorded on a daily basis. To determine proportions of intake of individual fractions, amounts of botanical fractions offered and refusals of each fraction were determined. Before daily feeding, sub samples of freshly harvested whole species of each species were separated into botanical fractions (leaves, young shoots and woody shoots) and their DM proportions determined so as to estimate the quantity of each fraction that was offered to the sheep. At the end of feeding on each day, the refusals were proportionated and each fraction weighed and DM determined. The differences between before and after feeding were used to determine the proportion (%) of each fraction that was consumed by sheep in each pen each day. Tests of randomness in time-series analyses (Kendall, 1976) showed that repetitive trials over the 8 days had no effect on the intake of the sheep. Therefore, the average intake within each animal for each of the species was used for further analyses. Thus, relative preference was expressed as ranking based on average proportion (%) of each species that was consumed by sheep over the eight days.

2.6. Measurements of behavior

The feeding behavior in the context of this study will refer to the species the sheep preferentially selected to feed on based on the time spent feeding on individual species and the number of subsequent visits to each species. Feeding behavior was recorded by four observers on four randomly selected days during the experimental period of each season. On each day, individual observers selected a different pen and made observations for one hour. The observers stood at positions outside the pens that would not distract the feeding activities of the sheep. After 4 days, all sheep had been observed at least once.

2.7. Analysis of chemical composition

Before daily feeding, sub samples of freshly harvested whole species of each species were separated into botanical fractions (leaves, young shoots and woody shoots). Approximately 500 g of each of the botanical fractions were sub-sampled and ground to pass through a 1-mm sieve. All sub-samples were analyzed for DM and nitrogen (N) according to the methodology of the AOAC (2005). Dry matter was determined by oven drying at 105˚C overnight (method 934.01). Ash was determined by burning all organic matter of the samples using a muffle furnace at 500˚C overnight (method 942.05). Nitrogen content of the sample was determined by Kjeldahl method using Kjeldahl (protein/nitrogen) Model 1026 (Foss Technology Corp.), (method 954.01). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined as described by Van Soest & Robertson (1985). Neutral detergent fiber was not analyzed with a heat stable amylase and was expressed exclusive of residual ash. Acid detergent fiber was expressed without residual ash. Lignin was determined by solubilisation of cellulose with sulphuric acid. *In vitro* organic matter digestibility was measured in rumen microbial inoculum using *in vitro* gas production technique. The buffer solution was prepared according to the method described by Menke & Steingass (1988). Rumen fluid was collected prior to morning feeding using a vacuum pump from three ruminal fistulated castrated rams that were grazed for four hours, offered grass hay and water *ad libitum*. It was composited (1:1, v/v), filtered through four layers of cheesecloth and added to buffer solution (1:2, v/v) which was maintained in a water bath at 39^{o}C under continuous flushing with CO_2. The buffered rumen fluid (30 ml) was pipetted into 100 ml syringes containing 0.2 g of sample and immediately placed into a water bath at 39 °C. Gas production was recorded after 24 hours of incubation and used to calculate *in vitro* organic matter digestibility (IVOMD) according to the Menke et al. (1979) equation as follows:

$$IVOMD\ (g/kg) = 14.88 + 0.889GP + 0.45CP + 0.0651XA$$

Where GP: 24 h net gas production (ml/200 mg); CP: Crude protein (g/kg DM); XA: Ash content (g/kg DM)

Chemical analyses were undertaken at the ICARDA Animal Nutrition Laboratory in Aleppo, Syria.

2.8. Statistical analyses

Chemical analysis of shrubs and average proportion of whole shrubs eaten (%) was analyzed according to the following model:

$$Y_{ijk} = \mu + SH_i + SE_j + FR_k + SH \times SE_{ij} + SH \times FR_{ik} + SE \times FR_{jk} + SH \times SE \times FR_{ijk} + E_{ijk}$$

Where: Y_{ijk} is the response, μ is the overall mean, SH_i is the effect of the species, SE_j is the effect of the season, FR_k is the effect of fraction, $SH \times SE_{ij}$ is the interaction between shrub and season, $SH \times FR_{ik}$ is the interaction between shrub and fraction, $SE \times FR_{jk}$ is the interaction between season and fraction, and $SH \times SE \times FR_{ijk}$ is the shrub-season-fraction interaction and E_{ijk} is the error. Proportion of botanical fractions and sheep behavior was analyzed according to the following model:

$$Y_{ij} = \mu + SE_i + SH_j + SE \times SH_{ij} + E_{ij}$$

Y_{ij} is the response, μ is overall mean, SE_j is effect of season, SH_j is effect of shrubs, $SE \times SH_{ij}$ is effect of interaction between season and shrubs, E_{ij} is the experimental error. Means were compared using the least significant difference (LSD) test at 5% level of probability. All statistical analyses were done with SAS version 9.1.3 (SAS, 2003) statistical package. Univariate correlation was used to establish relationships between chemical analysis, proportions and intake for each fraction. Canonical correlation analysis was used to determine the relationship between intake of botanical fractions and their chemical composition and the intake of the whole shrub and its botanical structure.

3 Results

3.1. Nutrient composition of Atriplex species

Effect of Atriplex species, botanical structure and season on chemical composition and IVOMD of Atriplex shrubs is shown in Table 2. The effect of species was significant (P<0.05) in all parameters except ash. The content of ash was similar across the species. *A. halimus* had the highest (P<0.05) content of cell wall components among the species. *A. nummularia* had highest (P<0.05) IVOMD and content of N among the species. The effect

Table 2 Effect of Atriplex species, botanical structure and season on chemical composition and *in vitro* organic matter digestibility of Atriplex species

		DM	Ash	ADF	ADL	NDF	N	IVOMD
Species	AC	95.6	12	34.4[b]	9.22[c]	54.1[b]	1.83[ab]	28.2[b]
	AH	95.7	11.9	40.7[a]	13.6[a]	59.2[a]	1.69[b]	28.4[b]
	AL	94.9	13	35.5[b]	9.56[c]	55.8[ab]	1.69[b]	28.2[b]
	AN	95.2	14.1	34.9[b]	10.7[b]	54.7[b]	1.93[a]	31.3[a]
	SEM	1.78	1.55	1.99	0.66	1.86	0.089	0.89
Fraction	Leaves	94.8	23.1[a]	14.9[c]	5.7[c]	27.7[c]	2.89[a]	48.0[a]
	Y. Shoots	95.2	10.5[b]	40.2[b]	10.6[b]	61.2[b]	1.64[b]	30.0[b]
	W. Shoots	95.2	4.63[c]	54.1[a]	16[a]	78.9[a]	0.84[c]	13.4[c]
	SEM	0.885	2.66	3.99	1.78	1.68	0.177	5.3
Season	Spring	93.8	13.5	35.3	9.98	54.4[b]	2.16[a]	31.6
	Autumn	96.4	12	37.5	11.5	57.5[a]	1.42[b]	29.0
	SEM	1.67	1.70	1.33	0.79	1.77	0.22	0.8
P value								
Species		0.679	0.332	0.040	<0.001	<0.001	<0.001	<0.001
Fraction		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Season		0.567	0.570	0.566	0.670	<0.001	<0.001	0.770
Species*fraction		0.680	0.660	0.580	0.641	0.650	0.560	0.700
Species*season		0.650	0.640	0.600	0.690	0.685	0.630	0.650
Season*fraction		0.642	0.662	0.550	0.700	0.640	0.540	0.642
Species*season*fraction		0.600	0.598	0.220	0.440	0.060	0.610	0.430

AC: *A. canescens*; AH: *A. halimus*; AL: *A. lentiformis*; AN: *A. nummularia;* Y. shoots: Young shoots; W. shoots: Woody shoots. Means with different scripts are significantly different at *P*<0.05 in columns within species, fractions and seasons; SEM = standard error of mean.

Table 3 Effect of season and Atriplex species on the proportion of leaves, woody shoots and young shoots of the shrubs

Season	Species	Leaves	Woody shoots	Young shoots
Spring	AC	35.11bc	58.36a	41.64b
	AH	39.81^{ab}	48.48^{b}	51.52^{b}
	AL	32.35^{c}	58.57^{a}	41.43^{b}
	AN	42.68^{a}	30.71^{c}	69.29^{a}
Autumn	AC	26.53^{b}	27.73^{b}	72.28^{a}
	AH	28.5^{b}	36.29^{ab}	63.71^{ab}
	AL	15.52^{c}	41.90^{a}	58.09^{b}
	AN	46.44^{a}	30.38^{b}	69.62^{a}
Pooled SEM		2.17	3.47	2.58
			P value	
Species		0.960	<0.001	<0.001
Season		<0.001	<0.001	<0.001
Species*season		<0.001	<0.001	<0.001

Different scripts in columns within seasons are significantly different at *P*<0.05; SEM = standard error of mean; AC: *A. canescens*; AH: *A. halimus*; AL: *A. lentiformis*; AN: *A. nummularia.*

of botanical structure was significant (P<0.05). Season affected NDF and N significantly (P<0.05). The variation among species and botanical fractions did not depend on the season. The leaves had the highest (P<0.05) content of ash, N and IVOMD and the lowest (P<0.05) content of fiber components.

3.2. Proportions of botanical fractions

The relative proportions of botanical fractions of species were affected by season (Table 3). The proportion of woody shoots and young shoots was significantly different among species. The relative proportions of botanical fractions of species depended on the season. The proportions of leaves and woody shoots tended to be higher in spring, while the proportion of young shoots tended to be higher in autumn in all species except *A. nummularia* whose proportions of fractions remained consistent during both seasons. *A. nummularia* tended to have higher proportions of leaves compared to the other species during both seasons. *A. lentiformis* tended to have a higher proportion of woody shoots and lower proportion of young shoots compared to the other species during both seasons.

3.3. Effect of species, season and botanical structure on proportion of shrub eaten

The total intake of species within each pen during the 8 days of experiment remained consistent. The average daily proportions of species eaten did not depend on the proportions of botanical fractions or the season (Table 4). However, average proportions of individual botanical fractions eaten by sheep were affected by the season. Sheep ate significantly (P<0.05) higher proportions of *A. halimus* and *A. nummularia* during both seasons and lowest (P<0.05) proportions of *A. canescens*. Relative ranking based on intake from most to least consumed was *A. halimus*, *A. nummularia*, *A. lentiformis* and *A. canescens*. Average proportions of young shoots eaten by sheep were significantly (P<0.05) affected by the season. Intake was higher in spring. Proportions of leaves and woody shoots eaten also tended to be higher in spring.

3.4. Effect of shrubs and season on selection behavior

Number of return visits to the feeding troughs was not significantly different across the species, with return visits ranging from 8.2-9.5 (Table 5). The number of return visits to species was affected by the season. There were significantly (P<0.05) more visits to shrubs in spring compared to autumn. The time spent by the sheep feeding on the species was influenced by the season (Table 6). In autumn, significantly (P<0.05) more time was spent feeding on *A. halimus* and *A. lentiformis* compared to feeding on *A. canescens* and *A. nummularia*. In spring, sheep spent significantly (P<0.05) more time feeding on *A. canescens* compared to others. During both seasons, sheep tended to spend the least time feeding on *A. nummularia*. Pearson correlation of proportions of intake to return visits and time spent feeding is shown in Table 7. The correlation of proportion of shrub eaten to number of return visits was insignificant. Similarly, the correlation to time spent feeding was insignificant.

Table 4 Effect of season, Atriplex species and botanical structure on the proportion of shrubs eaten

Main effect of species		Average daily proportion of whole species eaten (%)
AC		57.9[c]
AH		70.9[a]
AL		65.3[b]
AN		70.0[a]
SEM		2.5
*Fraction*season interaction*		
Fraction	Season	Average daily proportion of fraction eaten (%)
Leaves	Autumn	82.4[a]
	Spring	89.4[a]
Young shoots	Autumn	50.5[b]
	Spring	79.5[a]
Woody shoots	Autumn	35.7[a]
	Spring	44.9[a]
P value		
Species		<0.001
Season		<0.001
Fraction		<0.001
Species*season		0.36
Species*fraction		0.12
Fraction*season		<0.001
Species*season*fraction		0.09

Within columns, means with different scripts are significantly different at *P*<0.05; SEM = standard error of mean; *AC: A. canescens; AH: A. halimus; AL: A. lentiformis; AN: A. nummularia.*

Table 5 Effect of Atriplex species and season on the number of return visits to feed on the shrubs

Main effect of species	Number of return visits per hour
AC	9.01
AH	9.50
AL	9.29
AN	8.24
SEM	0.620
Main effect of season	
Autumn	8.26[b]
Spring	10.1[a]
SEM	0.36[1]
P value	
Species	0.492
Season	0.020
Species*season	0.826

AC: A. canescens; AH: A. halimus; AL: A. lentiformis; AN: A. nummularia. Across seasons, means with different scripts are significantly different at *P*<0.05; SEM = standard error of mean.

Table 6 Effect of Atriplex species and season on the time spent feeding on the shrubs

Season	Species	Time spent feeding (seconds) per hour
Autumn	AC	422[b]
	AH	683[a]
	AL	688[a]
	AN	393[b]
Spring	AC	553[a]
	AH	451[ab]
	AL	445[ab]
	AN	325[b]
Pooled SEM		49.0
P value		
	Species	0.001
	Season	0.018
	Species*season	0.005

AC: A. canescens; AH: A. halimus; AL: A. lentiformis; AN: A. nummularia.
Across species, means with different scripts are significantly different at *P*<0.05;
SEM = standard error of mean.

Table 7 Pearson correlations between proportion of shrub eaten and number of return visits and time spent feeding

Season	Variables	statistics *r*	*P* value
Autumn	Number of return visit	0.213	0.146
	Time spent feeding	0.260	0.075
Spring	Number of return visit	0.358	0.174
	Time spent feeding	0.051	0.849

3.7. Canonical correlation

Canonical correlations between intake of botanical fractions and their chemical composition and between proportion of intake of each shrub and its botanical structure are shown in Table 8. The canonical correlations between the proportion of intake and the chemical composition of each fraction (leaf, young shoot, woody shoot) were moderate and highly significant (P<0.001). In leaf, the canonical correlation explained 28% of the variation in the intake of the leaves. Ash, N and IVOMD contributed positively to the variation. Ash contributed more compared to N and IVOMD. Chemical composition explained 32% of the variation in the proportion of intake of young shoots and nitrogen content contributed to the variation more than other variables. In woody shoots, the canonical correlation explained 31% of the variation of its intake. Nitrogen content and fiber components contributed positively to the variation in the proportion of intake.

The canonical correlation between the proportion of intake of whole shrub and the botanical structure of the species chemical composition of each fraction (leaf, young shoot, woody shoot) was moderate and highly significant (P<0.001). The botanical structure of species explained 20% of the variation in the proportion of intake of shrubs. Leaf was the major contributor to the variation in the proportion of intake of Atriplex species.

4. Discussion and conclusions

Atriplex species are the most popular among species introduced for rangeland rehabilitation in the West Asian and North African region (Mayberry et al., 2010) because of their high tolerance to soil salinity and water scarcity. This study has confirmed that intake levels of different Atriplex species by sheep may differ significantly; therefore, results in this study may have wide

Table 8 Canonical correlation between intake of botanical fractions and their chemical composition and the intake of shrub and their botanical structure

	Leaf	Young shoots	Woody shoots	Botanical structure
Variation explained	0.28	0.32	0.31	0.2
r *(P value)*	0.528 (<0.001)	0.564 (<0.001)	0.561 (<0.001)	0.444 (<0.001)
Wilks' Lambda *P* value	<0.001	<0.001	<0.001	<0.001
Coefficients				
Ash	0.44	0.199	-0.201	—
N	0.333	0.308	0.436	—
NDF	-0.137	-0.139	0.273	—
ADF	-0.191	-0.085	0.396	—
ADL	-0.098	0.06	0.319	—
IVOMD	0.340	0.084	-0.242	—
Leaf	—	—	—	0.442
Young shoots	—	—	—	-0.142
Woody shoots	—	—	—	-0.187

application, particularly in the WANA region. In the short term experimental periods of eight days, intake levels of individual species did not vary significantly across the days. This is in agreement with Ben-Salem et al. (2008), who carried out a proportion of intake assessment for nine days and concluded that one day of measurement may be sufficient for proportion of intake assessments. Tribe (1950) stated that "food selection of an animal today may be critically influenced by what it chose yesterday". This was qualified by Valderrabano et al. (1996) who reported that sheep fully adapted to *A. halimus* feeding by showing an increase in the level of intake only after 2 and 3 weeks. Therefore, it may be possible that animals are able to gradually adapt to consuming initially unpalatable feeds though this would be evident only in long-term trials.

Relative preference of whole species was linked to fractional proportions, nutritive value and intake levels of fractional proportions of the botanical fractions. Alicata et al. (2002) reported that the proportion of leaves in Atriplex species reduced and twigs increased during autumn, which is consistent with this study. Atriplex species are characteristic of plants with a C4 photosynthetic pathway whose biomass growth is higher in autumn and summer when ambient temperatures are higher than other seasons (Norman et al., 2010). The proportion of leaves was determined as the major contributor to intake. *Atriplex halimus* and *A. nummularia* were the most preferred species during both seasons and they tended to have higher proportions of leaves compared to *A. canescens* and *A. lentiformis* during both seasons. Therefore, information on proportions of botanical fractions of Atriplex species across seasons is useful to make proper comparisons of intake levels between species. Proportion of intake ranking of the morphological fractions followed the sequence of leaves, young shoots and then woody shoots. Atiq et al. (1994) reported that sheep may only eat branch material up to 2 mm, however, this trial revealed that sheep can eat woody shoots of up to 7-10 mm.

The comparison of intake of *A. lentiformis* and *A. canescens* highlighted the importance of selectivity and palatability of shrubs by sheep because the proportions of their morphological fractions were similar in spring, and those of *A. lentiformis* seemed inferior to *A. canescens* by having significantly ($P<0.05$) lesser proportions of leaves and young shoots and higher proportions of woody shoots in autumn, yet *A. lentiformis* was preferred ($P<0.05$) to *A. canescens*. It is important to take the selectivity by livestock into consideration which may be due to nutritive value of the shrubs among other factors. Nutritive value of Atriplex shrubs accounts for at least 30% of variation in the proportion of intake of botanical fractions. Seasonal changes in the nutritional value of leaves and shoots reported in this study were also reported by Alicata et al. (2002) who reported a tendency towards increase in fiber and reduction in ash content in *A. halimus* in autumn. Intake levels of the Atriplex species were positively correlated to leaf content. Ash content, N and IVOMD positively influence intake of leaves. Ash content in Atriplex species comprise mainly of sodium chloride and potassium chloride but also high concentrations of sulphur, magnesium, calcium and phosphorus (Ben-Salem et al., 2010). However, these minerals may not always be available due to complex interactions between minerals. According to Benjamin et al. (1995), A. *nummularia* has high digestibility due to the high salt concentration. Ben-Salem at al. (2010) reported that sheep and goats consuming more than one kg DM per day of *A. nummularia* could show toxicological signs. Therefore, feeding Atriplex species solely may predispose livestock to mineral imbalances (Masters et al., 2007). Although further analysis of the ash content was beyond the scope of this study, it is imperative to determine the levels of ash constitutes, including oxalates and other anti-nutritive factors so as to determine feeding levels that would avoid toxicity. The N content of the Atriplex species in this study ranged between 1.7-1.9% DM which could translate to CP content of 10.6-11.9% DM. This was in the range of results reported by Alicata et al. (2002) for *A. halimus* (13.6 - 19.3% DM), 12.5 - 25.2% DM as reviewed by Ben-Salem et al. (2010) for *A. nummularia* from various regions, and 16.4, 16.1 and 18.9 for *A. nummularia, A. halimus and A. canescens* respectively as reported by Degen et al. (2010). This is beyond the threshold level of 7% required by rumen microbes for efficient ruminal digestion (Van Soest, 1994), which would, therefore, make Atriplex species useful protein supplements, if palatable. However, high CP concentrations in Atriplex leaves can be misleading because up to 60% of this fraction can be non-protein nitrogen (Benjamin et al., 1992) and some N can be unavailable to the animal because of the presence of anti-nutritive agents such as tannins and oxalate (Abu-Zanat et al., 2003).

A. halimus and *A. nummularia* were preferred by sheep across seasons compared to *A. canescens* and *A. lentiformis* in this study. This is in agreement with a comparative study on palatability of Atriplex species from different origins that showed *A. halimus* was similar to *A. nummularia* and that palatability of *A. halimus* was better than any other of 14 Atriplex species tested (Elhamrouni & Sarson 1975). *A. halimus* and *A. nummularia* show good potential as sheep fodder and can be considered as promising forage plant for large-scale plantings in the Mediterranean rangelands. However, further studies need to determine the optimum grazing rates and susceptibility to damage of these species by livestock during grazing. An understanding of why sheep select certain species and which parts of the species they select would allow for the development of appropriate grazing management strategies for promising fodder species for use in the rehabilitation of degraded rangelands as well as offer commercial incentive to revegetate degraded lands. Adapted native and introduced fodder species can also be integrated into the smallholder crop-range-livestock production systems in Mediterranean rangelands to improve available feed and reduce pressure on the rangelands if properly managed.

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Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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