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EVALUATION OF FORAGE QUALITY AMONG COASTAL AND INLAND GRASSES FROM KARACHI

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Abstract

Four grasses (coastal: *Aeluropus lagopoides* & *Sporobolus tremulus*, and inland: *Paspalum paspalodes* and *Paspalidium geminatum*) were evaluated for biomass production, mineral composition and forage quality under optimal non-saline conditions. Vegetative shoots were collected from natural populations and allowed to grow under ambient environmental conditions for about six weeks. Forage quality parameters included neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein (CP), dry matter digestibility (DMD), and metabolizable energy (ME). Coastal species had higher ADF and crude protein values in comparison with inland species whereas, DMD were highest in *Paspalum paspalodes* followed by *Sporobolus tremulus*, *Paspalidium geminatum* and *Aeluropus lagopoides*. Estimated metabolizable energy (ME) was highest in *Paspalum paspalodes* with similar values in other test species. *Sporobolus tremulus* had the highest sulphur (1.42%) while the other three species had considerably lower values ($\leq$ 0.45) which are within acceptable fodder limits for ruminants. Inland grasses (particularly *Paspalum paspalodes*) appeared to be better forage species producing higher biomass, DMD, ME and crude protein and low ADF and S than the coastal ones. However, with careful rationing all test species could be used as supplementary fodder for livestock.

Introduction

Global population is expected to reach 9.3 billion by 2050 with about 4% or 335 million in Pakistan alone. However, crop production cannot keep pace at the same rate as increasing population, poverty and decreasing arable land (Anon., 2001). Cost of food items increased by 28% in 2009 with ~85% Pakistanis living on less than two dollars per day (Anon., 2004). Naturally occurring inland and coastal salt tolerant grasses have considerable potential as low cost non-conventional fodder crop particularly C_4 grasses with high nutritive value (Khan *et al*., 2009; El-Shaer, 2010). About 68 halophytic grasses occur in Pakistan with 18 species along the coast (Khan & Qaiser, 2006). Halophytic grasses exhibit considerable variation in growth (Chen *et al*., 2009; Gulzar & Khan, 2006) and appear to have high nutritive value even under stressful conditions (Grattan *et al*., 2004; Robinson *et al*., 2004). *Thinopyrum ponticum* showed higher (85%) relative yield than conventional forges such as alfalfa (43%) when irrigated with saline water (Suyama *et al*., 2007). *Panicum turgidum* was found to be a promising fodder alternative to maize and could produce considerable biomass with brackish (~10 dS/m) water irrigation. However, monitoring of anti-nutritive factors such as toxic levels of S, Mo and lignin (Arzani *et al*. 2006, Arzani, 2008; Abd El Rehman, 2008) in plant tissue and of Se, B and NO_3-N in irrigation water and soil (Suyama *et al*., 2007) also need to be considered. Since field studies on forage quality are difficult to manage laboratory studies have been carried out by many workers.

Nutritive value parameters of forage species such as metabolizable energy (ME) appear to depend strongly on plant maturity (Minson, 1990) and better ME values and digestibility of some salt tolerant forage grasses appeared to be linked to their potential for slower growth among young plants (McDonald *et al*., 1995). High ADL and ADF have been considered as the most important livestock constituents for the selection of forage plants for quality and digestibility (Van Soest & Jones, 1994; Le Houerou, 1993; 1994). Successful growth and biomass production of potential forage species on saline soils would depend on the regulation of salt balance, its ability of osmotic adjustment and maintenance of favorable water potential (Nedjimi, 2009). Little data is available on the comparative growth and nutritive value among coastal and inland grasses of Pakistan.

The present study aims to evaluate the growth and nutritive potential of two coastal [*Aeluropus lagopoides* (Linn.) Trin. Ex Thw. and *Sporobolus tremulus* (Willd.) Kunth.] and 2 inland [*Paspalum paspalodes* (Michx.) Scribner and *Paspalidium geminatum* (Forssk.) Stapf.] grasses under non-saline conditions. It was assumed that in the absence of salinity 1) coastal grasses will exhibit lesser growth than inland ones and 2) nutritive value of coastal grasses will also be better than the inland species due to slower growth.

Materials and Methods

Ramets of the inland grasses *Paspalum paspalodes* and *Paspalidium geminatum* were collected from Korangi industrial area (24^0 51'03.2 N; 67^0 05'60.4 E) and Malir River Karachi (24^0 49' 41.1N; 67^0 05' 54 E) respectively, and of the coastal grasses *Aeluropus lagopoides* and *Sporobolus tremulus* from Sandspit (24^o 49'06. 70" N; 66 ^{o} 56'06. 80" E). Plants were grown in plastic pots (26 x 20 cm) containing thoroughly washed coastal dune sand and placed in 2 L plastic trays for sub-irrigation with half strength Hoagland solution (Epstein, 1972). Pots were flushed with nutrient solution every week and trays were replenished with fresh nutrient solutions which were maintained to constant 2 L volume with tap water. Plants were cut at 15 cm above soil surface and initial biomass (fresh and dry) of five individual plants was recorded which were then allowed to grow for about 6 weeks. Plants were harvested and soil particles adhering to roots were thoroughly cleaned with the respective nutrient solution and then with tap water. Plant material was separated into above-ground and below-ground parts and dried to constant weight in a micro-wave oven alongside a half filled beaker of water for 15 to 20 min (Popp *et al*., 1996). Growth parameters such as height, fresh and dry biomass were also measured. Hot water extracts were prepared by boiling 0.5 g dry shoot and root in 10 ml of de-ionized water to determine Ca^{++} and Mg^{++} by atomic absorption spectrometry (Perkin Elmer, USA). Ash content was determined by AOAC 923.03 method after igniting dried plant material in a muffle furnace at 550°C for 3 h (Anon., 1990).

Nutritive value: Acid digestible fiber (ADF), Neutral digestible fiber (NDF) and Acid digestible lignin (ADL) were determined according to Van Soest *et al*., (1991). N and S were analyzed by CNS Analyzer (Elementar Vario EL III).

Crude protein (CP) was calculated as
CP = Total nitrogen (N) x 6.25 [Newman *et al*., 2003]

Dry matter digestibility (DMD) was estimated by and calculated as
DMD% = 83.58 – 0.824 ADF% + 2.626 N% [Oddy *et al*., 1983]

Digestible energy (DE) was estimated as follows:
DE (kcal / kg) = 0.27 + 0.0428 DMD% [Fonnesbeck *et al*., 1984]

Metabolizable energy (ME) was calculated as:
ME (Mcal / kg) = 0.821 x DE (Mcal / kg) [Khalil *et al*., 1986]

All values of proximate analysis and cations are expressed on percent dry biomass basis. Variation in growth and chemical composition among the four test species was subjected to one-way ANOVA while individual means compared by post-hoc Bonferroni test. Pearson's Rank Correlation was performed between ADF and DMD and between ADL and DMD. All statistical analyses were carried out by SPSS for Windows Ver. 11.0 (Anon., 2001).

Results

Growth parameters: A one-way ANOVA showed significant differences in plant biomass (F value = 40.3; $p<0.001$) and shoot height (F = 74.69; $p<0.001$) among the four test species with highest dry biomass in *Paspalum paspalodes* (35 g/pot). In general, inland grasses had higher dry biomass and shoot height (Figs. 1 a & b).

Fiber: NDF varied significantly (F = 4.77; $p<0.001$) among test species. *Aeluropus lagopoides* had the highest NDF (69%) followed by *S. tremulus* (63%) and *P. paspalodes* (61%) and lowest in *P. geminatum* (55%) (Table 1). ADF also varied significantly (F = 37.11; $p<0.01$) among test species with higher values in the coastal species *A. lagopoides* (34%) and *S. tremulus* (35%) than the inland *P. paspalodes* (24%) and *P. geminatum* (33%) (Table 1). Although ADL varied significantly (F = 21.70; $p<0.001$) among the test species but did not follow the same trend as that of ADF. *Paspalidium geminatum* had highest ADL (11%), followed by *A. lagopoides* (10%), *S. tremulus* (5%) and *P. paspalodes* (2%) (Table 1).

Chemical composition: Considerable (F = 40.73; $p<0.001$) variations were noted for CP among species with higher values in the coastal species *S. tremulus* (15%) and *A. lagopoides* (9%) than the inland *P. paspalodes* (5%) and *P. geminatum* (8%) (Table 1). DMD also varied significantly (F = 16.01; $p<0.001$) with highest values in *P. paspalodes* (66%) followed by *S. tremulus* (61%), *P. geminatum* (60%) and *A. lagopoides* (59%) (Table 1). One way ANOVA showed significant differences (F = 15.6; $p<0.001$) in ME with highest values in *Paspalum paspalodes* (2.53 Mcal Kg^{-1} dry biomass) (Table 1). A negative correlation was found between DMD and ADF (r^2 = 0.92) and also between ADL and DMD (r^2 = 0.72).

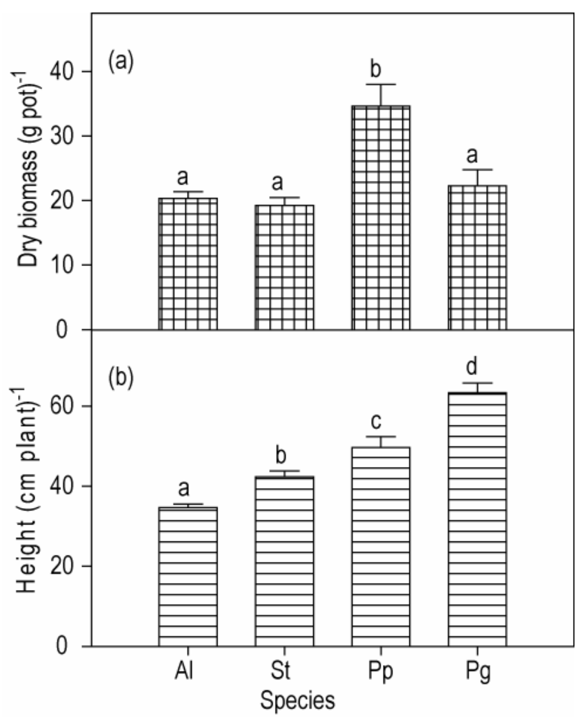

Fig. 1. Height (a) and dry biomass accumulation (b) among coastal (*Aeluropus lagopoides* = Al, *Sporobolus tremulus* = St) and inland (*Paspalum paspalodes* = Ps and *Paspalidium geminatum* = Pg) forage grasses. Bars represents means ± s.e. (n = 3). Similar letters show non-significant differences among species (Bonferoni test).

Table 1. Mean neutral detergent fiber (NDF), acid detergent fiber (ADF), acid digestible lignin (ADL), crude protein (CP), dry matter digestibility (DMD), metabolizable energy (ME) and ash among coastal (*Aeluropus lagopoides*, *Sporobolus tremulus*) and inland (*Paspalum paspalodes*, *Paspalidium geminatum*) forage grasses. Values are means (n = 3) on dry biomass basis. Similar letters show non-significant differences among species by one-way ANOVA.

Species	NDF (%)	ADF (%)	ADL (%)	CP (%)	DMD (%)	ME (Mcal/kg)	Ash (%)
A. lagopoides	69.03a	34.32a	10.00a	9.08a	59.11a	2.30a	5.51a
S. tremulus	62.46b	34.60a	5.39b	15.02b	61.38a	2.38a	5.91a
P. paspalodes	61.33b	24.33b	1.67c	5.38c	65.79b	2.53b	5.80a
P. geminatum	55.33c	32.67a	10.67a	8.19a	60.11a	2.33a	10.82b

Ash content: Significant (F = 22.74; p<0.001) differences occurred in ash content among test species with highest ash in *P. geminatum* (11%). In general, lower ash content was found among coastal grasses (Table 1).

Ca and Mg: A one way ANOVA showed significant differences (F = 4.45; p<0.001) in shoot Ca among all test species with higher values in coastal grasses *A. lagopoides* (0.91%) and *S. tremulus* (0.41%) in comparison with inland species *P. paspalodes* (0.20%) and *P. geminatum* (0.10%) (Fig. 2a). Shoot Mg varied significantly (F = 13.04; p<0.001) among all species. Higher Mg was found in coastal grasses *A. lagopoides* (0.40%) and *S. tremulus* (0.63%) in comparison with inland species *P. paspalodes* (0.19%) and *P. geminatum* (0.11%) (Fig. 2a).

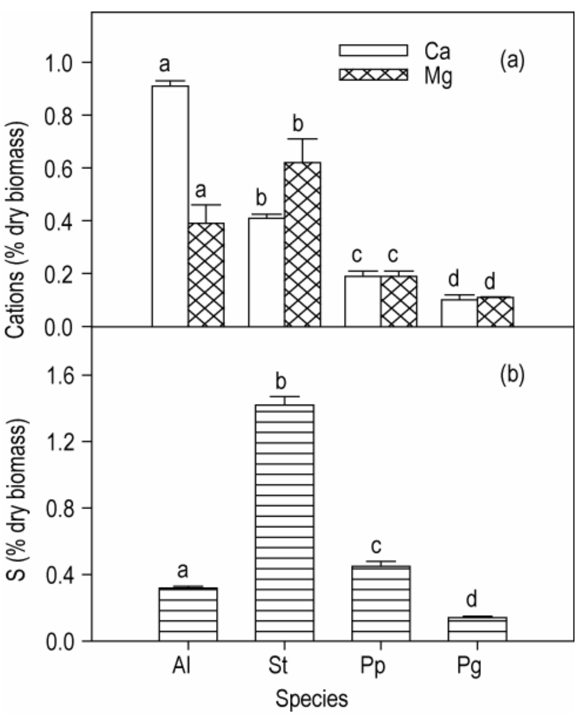

Fig. 2. Comparison of (a) calcium, magnesium and (b) sulfur accumulation among coastal (*Aeluropus lagopoides* = Al, *Sporobolus tremulus* = St) and inland (*Paspalum paspalodes* = Ps and *Paspalidium geminatum* = Pg) forage grasses. Bars represents mean ± s.e. (n = 3) on dry biomass basis. Similar letters show non-significant differences among species (Bonferoni test).

Sulphur: Sulfur also varied significantly (F = 408; p<0.001) among all test species with highest values in *S. tremulus* (1.4%), followed by *P. paspalodes* (0.45%), *A. lagopoides* (0.32%) and lowest values in *P. geminatum* (0.14%) (Fig. 2b).

Discussion

Growth: Considerable variation in biomass accumulation has been reported in salt tolerant forage grasses in controlled laboratory experiments and this variation could be species specific or an adaptive response to habitat conditions (Arzani *et al*., 2006; Masters *et al*., 2007; Yayneshet *et al*., 2009). Species which thrive in saline conditions have a competitive advantage over others in their natural habitats. In the present study the inland species were collected from soils having an $ECe_{1:5}$ up to 10 dS/m and coastal species up to 25 dS/m. The evaluation of these dominant grasses with specific adaptations in morphological, physiological and biochemical mechanisms would be helpful in selecting the right plant for a particular environment for instance decreased leaf surface area to maintain high water use efficiency (Larcher, 2003; Munns & Tester, 2008). This study compares inland and coastal grasses for their growth and nutritive potential under non-saline conditions. Inland species showed better growth in comparison with the coastal species with highest dry biomass accumulation in *Paspalum paspalodes* than the other three test species although *P. geminatum* was the tallest.

Fiber: Inland species had higher (> 60%) DMD values in comparison with the coastal species, much higher than the recommended level for animal maintenance (Arzani *et al*., 2006). A strong negative correlation was found between DMD and ADF and between DMD and ADL. Similar results were reported for forage grasses of Himalayan (Sultan *et al*., 2008) and Zagros (Arzani *et al.,* 2006) mountain rangelands. However, Van Soest (1994) found inconsistent association between ADL and DMD. Lignin is considered to be a major cell wall constituent (Abd El-Rehman, 2008) that may limit nutrient availability for ruminants (Casler & Jung, 2006). Similarly higher ME values (> 9–MJ/Kg ≈ 2 Mcal/Kg) in coastal grasses as well as *P. geminatum* appeared to be sufficient for maintenance of beef and cattle (Anon., 1996) while ME values > 10 MJ/Kg (2.53 Kcal/Kg) in *Paspalum paspalodes* were comparable to various cultivars of *P. vaginatum* (Robinson *et al*., 2004; Suyama *et al*., 2007) which could be suitable for dairy cattle.

Crude protein: Generally about 6-8 % CP is required for weight maintenance in various types of ruminants (Esmaeli & Ebrahimi, 2003; El-Shatnawi & Mohawesh, 2000; White, 1983). In the present study, *S. tremulus* had the highest CP values while those of other three species were within acceptable limits as part of maintenance diet for livestock.

Ash and mineral content: Ash levels were low among all four test species which would be expected for other grasses such as *Sporobolus* sp. and *Distichlis* sp. (Dakheel *et al*., 2008; Alhadrami *et al*., 2010) a favorable trait for forage crops. Mineral contents were also within the acceptable upper limits for K (2%), Ca (1.5%) and Mg (0.6%) (Anon., 2005) with higher Ca and Mg in coastal species.

Sulphur: High (> 0.4%) S could lead to loss of appetite and increased sulphide production by ruminant microorganism (Bird, 1972; Kandylis, 1984) leading to cerebro-cortical necrosis (Gould *et al*., 2002). Sulphur may also interact with Mo in rumen to reduce Cu availability (Suttle, 1991) causing anemia, fragile bones and reproductive disorders. In the present study only *Sporobolus tremulus* had undesirably high S levels.

Conclusions

Paspalum paspalodes proved to be the best forage candidate for biomass production, DMD, ME, and low S, NDF, ADF and ADL. *Aeluropus lagopoides* had somewhat higher NDF and ADL, while *Paspalidium geminatum* had high ash, Ca and ADL but within acceptable limits recommended for livestock. *Sporobolus tremulus* showed promising results for crude protein, DMD and ME but with contained high S. In general, inland grasses appeared to have better biomass and nutritive value, however with careful rationing all four species could be used as fodder.

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References

Abd El-Rehman, H.H. 2008. Improvement of the nutritive value of some unpalatable desert plants by ensiling treatment with palatable plants and molasses additives. *J. Agric, Sci*., *Mansoura Univ*. 3: 8001-8010.

Al Sherif, E.A. 2009. *Melilotus indicus* (L.) All: a salt-tolerant wild leguminous herb with high potential for use as a forage crop in salt-affected soils -168. *Flora*, 204: 737-746.

Alhadrami, G.A., S.A. Al-Shorepy and A.M. Yousef. 2010. Growth performance of indigenous sheep fed *Sporobolus virginicus* grass hay grown in saline desert lands and irrigated with high salt content ground water. *Tropical Animal Health and Production*, 42: 1837-1843.

Anonymous. 1990. Association of Official Analytical Chemists. *Official methods of analysis*, 15th ed. AOAC, Arlington, VA.

Anonymous. 1996. National Research Council. *Nutrient Requirements of Beef Cattle*, seventh ed. National Academy Press, Washington, D.C, USA.

Anonymous. 2001. SPSS for Windows, Release 11.0.0. SPSS Inc., Chicago USA.

Anonymous. 2001. UNFPA (www.unfpa.org/swp/2001/english/)

Anonymous. 2004. Agricultural Statistics of Pakistan. (www.statpak.gov.pk)

Anonymous. 2005. National Research Council. *Mineral Tolerance of Animals*. The National Academies Press, Washington.

Arzani, A. 2008. Improving salinity tolerance in crop plants: a biotechnological view. *In Vitro Cell. Dev. Biol.-Plant*., 44: 373-383.

Arzani, H., M. Basiri, F. Khatibi and G. Ghorbani. 2006. Nutritive value of some Zagros Mountain rangeland species. *Small Ruminant Research*, 65: 128-135.

Bird, P.R. 1972. Sulphur metabolism and excretion studies in ruminants. Sulphide toxicity in sheep. *Aust. J. Biol. Sci*., 25: 1087-1098.

Casler, M.D. and H.J. Jung. 2006. Relationships of fibre, lignin, and phenolics to in vitro fibre digestibility in three perennial grasses. *Anim. Feed Sci. Technol*., 125: 151-161.

Chen, J., J. Yan, Y. Qian, Y. Jiang, T. Zhang, H. Guo, A. Guo and J. Liu. 2009. Growth responses and ion regulation of four warm season turf grasses to long-term salinity stress. *Scientia Horticultare*, 122: 620-625.

Dakheel, A.A., G.A. Hadrami, S.A. Shoraby and G. Shabbir. 2008. The potential of salt-tolerant plants and marginal resources in developing an integrated forage-livestock production system: 2nd International Salinity Forum. Salinity, Water and Society–Global Issues, Local Action. 30 March–3 April 2008, Adelaide Convention Centre, Adelaide (www.internationalsalinityforum.org/.../al-dakheel_E6.pdf).

EL Shaer, H. 2010. Halophytes and salt-tolerant plants as potential forage for ruminants in the Near East region. *Small Ruminant Research*, 91: 3-12.

El-Shatnawi, M.K. and Y.M. Mohawesh. 2000. Seasonal chemical composition of saltbush in semiarid grasslands of *Jordan. J. Range Manage*., 53: 211-214.

Epstein, E., 1972. *Mineral Nutrition in Plants: Principles and Perspectives*. John Wiley and Sons, New York.

Esmaeli, N. and A. Ebrahimi. 2003. Necessity of determining animal unit requirement based on the quality of forage. *Iranian J. Nat. Resourc*., 55: 579-596.

Fonnesbeck, P.V., D.H. Clark, W.N. Garret and C.F. Speth. 1984. Predicting energy utilization from Alfalfa hay from the Western Region. *Proc. Am. Soc. Anim .Sci*., (Western Section) 35: 305-308.

Gould, D.H., D.A. Dargatz, F.B. Garry, D.W. Hamar and P.F. Ross. 2002. Potentially hazardous sulfur conditions on beef cattle ranches in the United States. *JAVMA*, 221: 673-677.

Grattan, S.R. C.M. Grieve, J.A. Poss, P.H. Robinson, D.L. Suarez and S.E. Benes. 2004. Evaluation of salt-tolerant forages or sequential water reuse systems, III. Potential implications for ruminant mineral nutrition. *Agric. Water Manage*., 70: 137-150.

Gulzar, S. and M.A. Khan. 2006. Comparative salt tolerance of perennial grasses. In: (Eds.): M.A. Khan and D.J. Weber. *Ecophysiology of High Salinity Tolerant Plants*. pp. 239-253. Springer, The Netherlands.

Kandylis, K. 1984. Toxicology of sulphur in ruminants: review. *J. Diary Sci*., 67: 2179-218.

Khalil, J.K., W.N. Sawaya and S.Z. Hyder, 1986. Nutrient composition of *Atriplex* leaves grown in Saudi Arabia. *J. Range Manage*., 39: 104-107.

Khan, M.A. and M. Qaiser. 2006. Halophytes of Pakistan: Characteristics, distribution and potential economic usages. In: *Sabkha Ecosystems*. (Eds.): M.A. Khan, H. Barth. G.C. Kust and B. Boer. Springer, The Netherlands. pp. 129-153.

Khan, M.A., R. Ansari, H. Ali, B. Gul and B.L. Nielson. 2009. *Panicum turgidum*, a potentially sustainable cattle feed alternative to maize for saline areas. *Agriculture, Ecosystems and Environment*, 129: 542-548.

Larcher, W. 2003. *Physiological Plant Ecology*. 4th Edition. Springer-New York. Pp. 513.

Le Houerou, H.N. 1993. Salt tolerant plants for the arid regions of the Mediterranean isoclimate zone. In: (Eds.): H. Lieth and A. El Masoom. *Towards the rational sse of high salinity-tolerant plants*. KLuwer Academic Publications, Dordrecht, The Netherlands, pp.405-411.

Le Houerou, H.N. 1994. Forage halophytes and salt-tolerant fodder crops in the Mediterranean Basin. In: (Eds.): V.R. Squires and A.T. Ayoub. *Halophytes as a resource for livestock and for rehabilitation of degarded lands*. Kluwer Academic Publishers, pp. 123-137.

Masters, D.G., S.E. Benes and H.C. Norman. 2007. Biosaline agriculture for forage and livestock production. Agriculture, *Ecosystem and Environment*. 119: 234-248.

McDonald, P., R.A. Edwards, J.F.D. Geenhalgh and C.A. Morgan. 1995. *Animal nutrition*. Logan Scientific and Technical Co. and Wiley, New York, 607 pp.

Minson, D.J. 1990. *Forage in ruminant nutrition*. Academic Press, New York, NY, USA.

Munns, R. and M. Tester, 2008. Mechanisms of salinity tolerance. *Annual Review of Plant Biology*, 59: 651-681.

Nedjimi, B. 2009. Salt tolerance strategies of *Lygeum spartum* L.: A new fodder crop for Algerian saline steppes. *Flora*, 204: 747-754.

Newman, J.A., M.L. Abner, R.G. Dado, D.J. Gibson, A. Brookings and A.J. Parsons. 2003. Effects of elevated CO2, nitrogen and fungal endophyte infection on tall fescue: growth, photosynthesis, chemical composition and digestibility. *Global Change Biol*., 9: 425-437.

Oddy, V.H., G.E. Robards and S.G. Low. 1983. Prediction of in vivo dry matter digestibility from the fiber nitrogen content of a feed. In: (Eds.): G.E. Robards, R.G. Pacham. *Feed Information and Animal Production*. Commonwealth Agriculture Bureaux, Farnham Royal, UK, pp. 395-398.

Popp, M., W. Lied, A.J. Meyer, A. Richter, P. Schiller and H. Schwitte. 1996. Sample preservation for determination of organic compounds: microwave versus freeze-drying. *J. Exp. Bot*., 47(303): 1469-1473.

Robinson, P.H., S.R. Grattan, G. Getachew, C.M. Grieve, J.A. Poss, D.L. Suarez and S.E. Benes. 2004. Biomass accumulation and potentioal nutritive value of some forages irrigated with saline-sodic drainage water. *Animal Feed Sci. and Technol*., 11: 175-189.

Sultan, J.I., Inam-Ur-Rahim, M. Yaqoob, H. Nawaz and M. Hameed. 2008. Nutritive value of free rangeland grasses of northern grasslands of Pakistan. *Pak. J. Bot*., 40: 249-258.

Suttle, N.F., 1991. The interaction between copper, molybdenum and sulphur in ruminant nutrition. *Annu. Rev. Nutr*., 11: 121-140.

Suyama, H., S.E. Benes, P.H. Robinson, S.R. Grattan, C.M. Grieve and G. Getachew. 2007. Forage yield and quality under irrigation with saline-sodic drainage water: Greenhouse evaluation. *Agricultural Water Management*, 88: 159-172.

Van Soest, P.J. 1994. *Nutritional Ecology of the Ruminant*. Second edition. Cornell University Press, New York.

Van Soest, P.J., J.B. Robertson and B.A. Lewis. 1991. Methods for dietry fiber, neutral detergent fiber and non starch polysaccharides in relation to animal nutrition. *J. Diary Sci*., 74: 3583-3597.

Wang, C., K.H. Dong, Q. Liu, W.Z. Yang, X. Zhao, S.Q. Liu, T.T. He and Z.Y. Liu. 2010. Effects of feeding salt-tolerant forages cultivated in salt-alkaline land on intake, average liveweight gain, physiological responses and slaughtering performance in lamb. *Livestock Science*, xxx: xxx–xxx. doi: 10.1016/j.livsci.2010.09.020.

White, L.M. 1983. Seasonal changes in yield, digestibility, and crude protein of vegetative and floral tillers of two grasses. *J. Range Manage*., 36: 402-405.

Yayneshet, T., L.O. Eik and Moe. 2009. Seasonal variations in the chemical composition and dry matter degradability of exclosure forages in the semi-arid region of northern Ethiopia. *Animal Feed Sci. Technol*., 148: 12-33.

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