Assessment of some chemical element contents in *Traganum nudatum* Del shrub using instrumental neutron activation analysis*

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Instrumental neutron activation analysis (INAA) has been used to determine some chemical element contents (K, Ca, Na, Fe, Zn, Co, Eu, Sb, and Sc) in *Traganum nudatum* Del (Chenopodiaceae family) consumed in North African rangelands by sheep livestock. Samples were collected from the area of Djelfa in an arid steppe of Algeria. Results show that pasture halophyte had sufficient levels of K, Ca, Zn, and Co to meet the requirements of ruminants. However, it seems that this halophyte shrub had substantial amounts of Na, higher than the critical level established by the National Research Council (NRC). Eu, Sb, and Sc were within the safety baseline of all the assayed elements recommended by the NRC. The high Na content ($\sim$ 10 g/kg) in this halophytic species requires elevated intake of water by livestock.

Keywords: Instrumental neutron activation analysis, Halophyte, Forage, Livestock, *Traganum nudatum*, Steppe

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I. INTRODUCTION

Halophytes are among the most salt-tolerant plants. These species can tolerate extreme conditions of aridity, salinity, and high temperatures [1]. In many areas of the world, halophytes are indispensable sources of animal feed, particularly in arid and semiarid climates. Such species can alleviate feed shortages, or even fill feed gaps during dearth periods, when annual grassland growth is limited or dormant due to unfavourable weather conditions [2, 3].

Livestock production practice in Algerian steppes is mainly based on grazing natural vegetation. The native rangelands of the country are greatly affected by annual precipitation, which is irregular and poorly distributed. The rangelands are characterized by a short rainy season, usually not more than three to four months per year [4]. Halophyte species are an important source for providing minerals to grazing livestock in extensive dearth situations. At the same time, mineral deficiencies can inhibit forage digestibility and herbage intake and ultimately decreases livestock production efficiency [5].

In Algeria, animal production is the main source of income for nomads. It relies mostly on natural vegetation for feeding sheep and goats [4]. In 2010, there were 18 million sheep in the Algerian steppe, which represents more than 86% of the total livestock population [6].

Feed sources of minerals are generally divided into various base feedstuffs, such as range or pasture plants, harvested forages, concentrates, and mineral supplements. However, efforts to minimize the cost of mineral supplementation in livestock production require a thorough knowledge of the supply and availability of mineral nutrients in feed and forages [7].

The instrumental neutron activation analysis (INAA) occupies a prominent position among various analytical methods due to its advantages of low detection limit, multi-elemental capability, a non-destructive method, and no sample preparation is required for analysis [8].

Traganum nudatum Del (Chenopodiaceae) is a native halophytic shrub in arid zones of the Mediterranean basin [9, 10]. To our knowledge, there are no published studies focusing on the chemical composition of *T. nudatum*, despite its forage value and importance in North African steppes. Therefore, the purpose of the present study was to assess chemical element contents in *T. nudatum*, mostly grazed by livestock in arid steppe of Algeria. This information may be used for the development of efficient chemical element supplementation regimes for grazing livestock.

II. MATERIALS AND METHODS

A. Study area

Foliage samples of *T. nudatum* were collected from the area of Mesrane in the province of Djelfa (3°3′E longitude, 34°36′N latitude and 830 m elevation) covered by a plant community, including *Atriplex halimus*, *Suaeda fruticosa*, and *Salsola vermicular* found in the Northern steppe of Algeria. The climate is typically Mediterranean, characterized by wet winters and hot dry summers with a mean annual precipitation of 250 mm/year. The average minimum winter and maximum summer temperatures are 5 °C in January and 26 °C in July, respectively. According to Halitim [11] the principal types of soil in the *Mesrane* zone are the calcimagnesic solontchak and isohumic soils.

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TABLE 1. Experimental conditions and nuclear data used in this study

Elements	Radionuclide	Half life[a]	γ-peaks used (keV)	Possible interferences
Ca	^{47}Ca	4.536 d	1297.06	No interferences
K	^{42}K	12.36 h	1524.7	No interferences
Na	^{24}Na	14.96 h	1368.63	^{77}Ge (1367.4)
Zn	^{69}Zn	13.76 h	438.63	^{147}Nd (439.40)
Fe	^{59}Fe	44.503 d	1099.25	^{116}In (1097.33)
			1291.6	^{116}In (1293.56)
Co	^{60}Co	5.27 y	1173.24	No interferences
			1332.5	No interferences
Eu	^{154}Eu	8.59 y	123.07	^{171}Er (124.02)
			1274.4	^{29}Al (1273.37)
Sb	^{122}Sb	2.72 d	564.12	134Cs (563.25)
	^{124}Sb	60.2 d	602.73	No interferences
Sc	^{46}Sc	83.79 d	889.28	No interferences
	^{46}Sc		1120.54	^{182}Ta (1121.3)
	^{48}Sc	43.67 h	983.52	No interferences
	^{48}Sc		1312.1	^{160}Tb (1312.14)

[a] h represents hours; and d, days; and y, years

B. Plant collection and sample preparation

Three 100 m transects were laid across the population of *T. nudatum*. These transects were further divided into three random blocks. Ten plants from each block were randomly harvested to measure chemical element content. Plant samples were clipped with stainless steel scissors with Teflon coated blades and, consequently, these samples were packed into paper bags. The samples were brought to the laboratory and were washed with distilled de-ionized water to remove any surface contamination and dried for 48 h in an oven at 60 °C. The dried samples were ground to a fine powder in a high speed mill (IKA® + A11 basic) to a particle size fraction of $< 200\,\mu$m. In order to minimize the contamination of Fe, Co, and Zn, dismountable Teflon coated blades were used for grinding.

Powdered plant samples were then stored in sterilized labeled polyethylene bottles and screw capped tightly to avoid absorption of moisture and any external contamination.

C. Instrumental Neutron Activation Analysis

The method used for the determination of chemical element mass fractions was a comparative (relative) neutron activation analysis, where both samples and standards were analyzed (irradiated and measured) under the same conditions. About 100 mg of the sample were sealed in quartz vials packed in aluminum containers and irradiated in the core of the reactor. For homogeneity, each sample was included in the mixture of 30 sample plants (i.e., 30 plants per transect). Three samples of plant material, together with triplicate CRM-GBW 07605 (GSV-4 tea leaves), were irradiated in the vertical channel of a multi-purpose, heavy-water research reactor (MHWRR) at a power of 5 MW, with a thermal neutron flux of $4.5 \times 10^{13}\,\mathrm{cm}^{-1}\,\mathrm{s}^{-1}$ for 6 h, to carry out irradiation enough to activate the middle- and partially long-lived radionuclides in the samples. Before collecting data, a decay of 4 days and 4 weeks for the middle-lived and long-lived nuclides, respectively, was necessary. The powder was then put into new polypropylene capsules and reweighed. Both long and middle lived radionuclides were measured using a CANBERRA (HPGe *p*-type) coaxial detector and a CANBERRA inspector 2k. The system has a resolution (FWHM) of 1.87 keV for 1332.5 keV γ-peaks of ^{60}Co and a relative efficiency of 35% when operated by Genie 2k software, with a low dead time ($< 5\%$). The data transferred from the inspector to the computer were processed using the Genie 2000 software. Middle-lived radionuclides (Na, K, and Zn) were measured after 4 days; the collection time was 3600 s for each sample and each standard. Whereas, the long-lived radionuclides (Ca, Fe, Co, Eu, Sb, and Sc) were measured after 4 weeks for a collection time of 7200 s. Table 1 presents radionuclides, possible interferences, and gamma-energy used in this study.

III. RESULTS AND DISCUSSION

A. Chemical element contents

This investigation was conducted to determine the chemical element contents of *T. nudatum* used for animal gazing in the arid steppe of Algeria, in order to gain information on the deficiency and/or excess of mineral levels for ruminants grazing therein, fed mainly with this halophytic species.

Nine chemical elements were characterized in *T. nudatum* using INAA. Table 2 represents a comparison of our results for the reference materials to their certified values. For most of the elements, no significant discrepancy was observed between the measured concentrations and reference values. In order to evaluate the laboratory performance, we have deter-

TABLE 2. Comparison of measured values of chemical element mass fraction (mg/kg on dry mass basis) with certified values in CRM-GBW 07605 (GSV-4 tea leaves). Values represent mean ± standard error of mean ($n = 3$)

Elements	CRM-GBW 07605 (GSV-4 tea leaves)			
	Certified value	Measured value	Relative difference (%)	U-Score
Ca	4300 ± 200	3850 ± 700	90	0.62
Co	0.18 ± 0.02	0.18 ± 0.01	100	0.01
Eu	0.018 ± 0.002	0.015 ± 0.003	83	0.83
Fe	264 ± 10	254 ± 12	96	0.63
K	16600 ± 600	16726 ± 1839	100	0.07
Na	44 ± 4	61 ± 8	139	1.90
Sb	0.06 ± 0.01	0.06 ± 0.01	100	0.01
Sc	0.085 ± 0.009	0.096 ± 0.002	113	1.19
Zn	26.3 ± 0.9	28.8 ± 1.03	109	1.85

mined the U-score test. This parameter is calculated according to the following equation

$$|U - \text{score}| = \frac{(x_{\text{lab}} - x_{\text{ref}})}{\sqrt{\sigma^2_{\text{lab}} + \sigma^2_{\text{ref}}}}, \tag{1}$$

where x_{lab} and σ_{lab} are the laboratory measured value and the standard uncertainty of the laboratory measured value, respectively; x_{ref} and σ_{ref} are the certified value and the standard uncertainty of the certified value, respectively.

A $U-$score $\leq$ 1 is satisfactory (the result is in agreement with the certified value); and unsatisfactory (the result and certified value are not in agreement) if the $U-$score > 3.29 [12]. This evaluation shows the good quality of the results obtained in this investigation (Table 2).

The results are presented in Table 3 where all mass fractions are reported on dry mass basis as the averages of at least three independent determinations with standard errors of mean (SEM). The chemical element contents quantified in *T. nudatum* follow the trend in a descending order: Na > K > Ca > Fe > Zn > Co > Sb > Sc > Eu.

Na and K have an electrochemical function in ruminants and are associated with maintenance of acid–base equilibrium, membrane permeability and the osmotic control of water in the body [13]. Mass fractions of K were high and adequate for ruminants, exceeding the critical level of 0.65% of diet dry matter, as recommended by the National Research Council (NRC) [14]. These results were in agreement with those found previously by Del Valle and Rosell [15] in shrubs growing in Northeastern Patagonia.

T. nudatum had Na contents well above the needs of a growing adult range ruminant (0.1 g of Na kg^{-1} of diet dry matter for sheep). As stated by Masters *et al.* [16], small ruminants can tolerate a soluble salts intake in forage of about 100–150 g/day, provided that they have accessed to abundant water. High salt content is perhaps the major negative component in halophytic species. Therefore, mixing some halophytes with glycophyte forages is recommended for better utilization of saltbushes [5].

The Ca requirement for ruminants is 0.51% of diet dry matter, according to the NRC [14]. The results showed that the Ca mass fractions were higher than this requirement, therefore Ca deficiency would not be expected. Similar high for-

TABLE 3. Mean values of chemical element mass fractions on dry mass basis determined in leaves of *Traganum nudatum* growing in Algerian arid steppe. Values represent mean ± standard error of mean ($n = 3$)

Elements	Mass fraction on dry mass basis
Ca (g/kg)	1.00 ± 0.30
K (g/kg)	1.10 ± 0.40
Na (g/kg)	10.25 ± 1.95
Zn (mg/kg)	15.30 ± 0.60
Fe (mg/kg)	793 ± 38
Co (mg/kg)	0.31 ± 0.04
Eu (mg/kg)	0.033 ± 0.005
Sb (mg/kg)	0.034 ± 0.007
Sc (mg/kg)	0.170 ± 0.02

age Ca mass fractions were reported by Towhidi *et al.* [17] in other halophytes growing in a central arid zone of Iran.

T. nudatum contained Fe levels in substantial amounts to meet adult range ruminant requirements (45 mg of Fe kg^{-1} of diet dry matter for sheep). Similar findings were reported by Ogebe and McDowell [18] and Khan *et al.* [19], who evaluated the Fe contained in native forages that grow respectively in semiarid regions of Nigeria and Pakistan.

It has been suggested that forage crops containing more than 27 mg of Zn kg^{-1} of diet dry matter will protect livestock from Zn deficiency disorders [14]. In the present investigation, Zn mass fractions were sufficiently adequate for ruminant requirements. Other studies have found that browse halophytes from northern Brazil [20], arid regions of Jordan [21], and southern Tunisia [22] had sufficient amounts of Zn to meet requirements of adult range ruminants.

Co is often the most severe element deficiency of grazing livestock [13]. However in this study, *T. nudatum* had Co contents that were sufficient to meet adult range ruminant requirements (0.1 mg of Co kg^{-1} of diet dry matter for sheep). These results were in sharp contrast to those reported by Chelliah *et al.* [23] who found poor forage Co mass fractions (< 0.1 mg/kg) in North Florida.

The Sc, Sb, and Eu elements in *T. nudatum* are present in the descending mass fractions as Sc > Sb > Eu (Table 3). This halophyte is quantified with the lowest Sc, Sb, and Eu contents, with respective values of 0.17, 0.033 and

TABLE 4. Potential chemical element intakes by sheep from leaves of *Traganum nudatum* growing in Algerian arid steppe. Values represent mean ± standard error of mean ($n = 3$)

Elements	Potential chemical element intakes per day [a]	Daily chemical element requirements [b]
Ca	(2.00 ± 0.62) g/kg	0.51 g/kg
K	(2.20 ± 0.82) g/kg	0.65 g/kg
Na	(20.25 ± 1.22) g/kg	0.10 g/kg
Zn	(30.6 ± 1.2) mg/kg	27.00 mg/kg
Fe	(1586 ± 76) mg/kg	45.00 mg/kg
Co	(0.62 ± 0.08) mg/kg	0.10 mg/kg

[a] Assumed sheep body weight: 50 kg; daily dry matter intake: 2.0 kg.
[b] Recommended average requirements by National Research Council [14].

0.034 mg/kg, and were far below the tolerable weekly intake recommended by the NRC [14]. Therefore, its toxic effects will be negligible. Similar low Sc, Sb, and Eu mass fractions were reported recently by Nordløkken *et al.* [24] in native species growing in southwest Norway.

B. Potential of ruminant mineral intake

Table 4 shows the potential of chemical element intakes and daily chemical element requirements by ruminants from the leaves of *T. nudatum*. It seems that a sheep weighing about 50 kg and consuming 2.0 kg per day DM of this halophytic species could eat substantial amounts of Ca, K, Fe, Zn, and Co to meet their requirements.

IV. CONCLUSION

Based on the present investigation, it is concluded that the *T. nudatum* saltbush contains adequate amount of chemical elements for livestock grazing in the arid steppes of Algeria. As a result, there is no urgent need for supplementation, as these elements are sufficient for ruminant requirements. However, offering fresh drinking water to animals fed *T. nudatum* saltbush would reduce Na intake and also enhance halophyte consumption and nutrients utilization.

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[1] Le Houérou H N. Utilization of fodder trees and shrubs in the arid and semiarid zones of West Asia and North Africa. Arid Soil Res Rehab, 2000, **14**: 101–135. DOI: 10.1080/089030600263058

[2] Flowers T J, Galal H K and Bromham L. Evolution of halophytes: multiple origins of salt tolerance in land plants. Func Plant Biol, 2010, **37**: 604–612. DOI: 10.1071/FP09269

[3] Nedjimi B and Daoud Y. Effects of calcium chloride on growth, membrane permeability and root hydraulic conductivity in two *Atriplex* species grown at high (sodium chloride) salinity. J Plant Nutr, 2009, **32**: 1818–1830. DOI: 10.1080/01904160903242342

[4] Nedjimi B. Rangeland improvement and management options in the arid steppes of Algeria. In: Denise GM. (Ed.) Steppe ecosystems : Dynamics, land use and conservation. New York (USA): Nova Science Publishers, Inc., 2012, 157–170.

[5] El Shaer H M. Halophytes and salt-tolerant plants as potential forage for ruminants in the Near East region. Small Rum Res, 2010, **91**: 3–12. DOI: 10.1016/j.smallrumres.2010.01.010

[6] DSASI. Direction of statistic agriculture and system information, agricultural census results. Algerian ministry for agriculture and of rural development, 2010, 125.

[7] McDowell L R. Minerals in animals and human nutrition. 2nd Ed. Netherlands: Elsevier Science, Amsterdam, 2003.

[8] Yuan X D, Chapman R L and Wu Z Q. Analytical methods for heavy metals in herbal medicines. Phytoch Anal, 2011, **22**: 189–198. DOI: 10.1002/pca.1287

[9] Quézel P and Santa S. Nouvelle flore de l'Algérie et des régions désertiques méridionales. Ed. CNRS, Paris, 1963.

[10] Nedjimi B, Beladel B and Guit B. Biodiversity of halophytic vegetation in Chott *Zehrez* lake of Djelfa (Algeria). AmerJ Plant Sci, 2012, **3**: 1527–1534. DOI: 10.4236/ajps.2012.311184

[11] Halitim A. Arid soils in Algeria. Ed. OPU, Algiers, 1988.

[12] Dung H M, Freitas M C, Blaauw M, *et al*. Quality control and performance evaluation of k_0-based neutron activation analysis at the Portuguese research reactor. Nucl Instrum Meth Phys Res A, 2010, **622**: 392–398. DOI: 10.1016/j.nima.2010.04.003

[13] Underwood E J and Suttle N F. The mineral nutrition of livestock. Third edition, Wallingford (USA): CAB International, 1999.

[14] National Research Council (NRC). Nutrient requirements of small ruminants: sheep, goats, cervids, and new world camelids. Washington DC (USA): National Academy Press, 2007.

[15] Del Valle H F and Rosell R A. Mineral composition of perennial vegetation of shrub patches in Northeastern Patagonia. Arid Soil Res Rehab, 2000, **14**: 15–25. DOI: 10.1080/089030600263148

[16] Masters D G, Benes S E and Norman H C. Biosaline agriculture for forage and livestock production. Agri Ecosys Environ, 2007, **119**: 234–248. DOI: 10.1016/j.agee.2006.08.003

[17] Towhidi A, Saberifar T and Dirandeh E. Nutritive value of some herbage for dromedary camels in the central arid zone of Iran. Trop Animal Health Prod, 2011, **43**: 617–622. DOI: 10.1007/s11250-010-9741-9

[18] Ogebe P O and McDowell L R. Mineral concentrations of forages grazed by small ruminants in the wet season in benue state, Nigeria. II. Trace minerals and forage crude protein. Comm Soil Sci Plant Anal, 1998, **29**: 1211–1220. DOI: 10.1080/00103629809370021

[19] Khan Z I, Ashraf M, Hussain A, *et al.* A study on seasonal variability of trace elemental status of forages for grazing ruminants. J Plant Nutr, 2008, **31**: 1345–1354. DOI:

10.1080/01904160802224425

[20] Armelin M J A, Piasentin R M and Primavesi O. Neutron activation analysis of zinc in forages used in intensive dairy cattle production systems. J Radioanal Nucl Chem, 2002, **252**: 585–587. DOI: 10.1023/A:1015875309037

[21] Abu-Zanat M M, Al-Hassanat F M, Alawi M, *et al*. Mineral assessment in*Atriplex halimus* L. and *Atriplex nummularia* L. in the arid region of Jordan. Afr J Range Forage Sci, 2003, **20**: 247–251. DOI: 10.2989/10220110309485822

[22] Laudadio V, Tufarelli V, Dario M, *et al*. A survey of chemical and nutritional characteristics of halophytes plants used by camels in Southern Tunisia. Trop Animal Health Prod, 2009, **41**: 209–215. DOI: 10.1007/s11250-008-9177-7

[23] Chelliah G, Myer R O, Carter J N, *et al*. Mineral concentrations of cool season pasture forages in North Florida during the winter-spring grazing season: II. trace minerals. J Plant Nutr, 2008, **31**: 1774–1788. DOI: 10.1080/01904160802324902

[24] Nordløkken M, Berg T, Flaten T P, *et al*. Essential and non-essential elements in natural vegetation in southern Norway: Contribution from different sources. Sci Total Environ, 2015, **502**: 391–399. DOI: 10.1016/j.scitotenv.2014.09.038