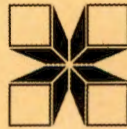


Fodder Shrub Development in Arid and Semi-arid Zones

Editors

Gustave Gintzburger
Mustapha Bounejmate
Ali Nefzaoui

VOLUME 2



About ICARDA and the CGIAR



Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is governed by an independent Board of Trustees. Based at Aleppo, Syria, it is one of 16 centers supported by the Consultative Group on International Agricultural Research (CGIAR).

ICARDA serves the entire developing world for the improvement of lentil, barley, and faba bean; all dry-area developing countries for the improvement of on-farm water-use efficiency, rangeland and small-ruminant production; and the West and Central Asia and North Africa region for the improvement of bread and durum wheats, chickpea, and farming systems. ICARDA's research provides global benefits of poverty alleviation through productivity improvements integrated with sustainable natural-resource management practices. ICARDA meets this challenge through research, training, and dissemination of information in partnership with the national agricultural research and development systems.

The results of research are transferred through ICARDA's cooperation with national and regional research institutions, with universities and ministries of agriculture, and through the technical assistance and training that the Center provides. A range of training programs is offered extending from residential courses for groups to advanced research opportunities for individuals. These efforts are supported by seminars, publications, and specialized information services.



The CGIAR is an international group of representatives of donor agencies, eminent agricultural scientists, and institutional administrators from developed and developing countries who guide and support its work. The CGIAR receives support from a wide variety of country and institutional members worldwide. Since its foundation in 1971, it has brought together many of the world's leading scientists and agricultural researchers in a unique South-North partnership to reduce poverty and hunger.

The mission of the CGIAR is to promote sustainable agriculture to alleviate poverty and hunger and achieve food security in developing countries. The CGIAR conducts strategic and applied research, with its products being international public goods, and focuses its research agenda on problem-solving through interdisciplinary programs implemented by one or more of its international centers, in collaboration with a full range of partners. Such programs concentrate on increasing productivity, protecting the environment, saving biodiversity, improving policies, and contributing to strengthening agricultural research in developing countries.

The World Bank, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP) are cosponsors of the CGIAR. The World Bank provides the CGIAR System with a Secretariat in Washington, DC. A Technical Advisory Committee, with its Secretariat at FAO in Rome, assists the System in the development of its research program.

© 2000 International Center for Agricultural Research in the Dry Areas (ICARDA)

All rights reserved.

ICARDA encourages the fair use of this material. Proper citation is requested.

Citation: Gintzburger G., M. Bounejmate and A. Nefzaoui (eds.). 2000. Fodder Shrub Development in Arid and Semi-arid Zones. Proceedings of the Workshop on Native and Exotic Fodder Shrubs in Arid and Semi-arid Zones, 27 Oct-2 Nov 1996, Hammamet, Tunisia. ICARDA, Aleppo, Syria. Vol II: viii + pp 293-679.

AGROVOC descriptors: Range, rangeland, range management, pasture, forage, arid zone, desertification, nomads, Bedouins, agro-pastoralists, animal feeding, feed calendar, nutritive value, small ruminants, sheep, goats, camels, land tenure, public policy, economic analysis, technology transfer, genetic resources, biodiversity, germplasm, fodder shrubs, shrubs plantation, fodder reserves, *Atriplex* spp., spineless cactus, crop residues, Spain, Morocco, Algeria, Tunisia, Libya, Egypt, Jordan, Syria, Lebanon, Iraq, Pakistan, Australia, South Africa, Sahel, Chili, Saudi Arabia, Turkey, Kazakstan, Uzbekistan, Central Asia.

ISBN: 92-9217-099-7

ICARDA

P.O. Box 5466, Aleppo, Syria

Phone: (963-21) 2213433/2213477/2225112/2221012

Fax: (963-21) 2213490/2225105/5744622

Telex: 331208/331263/331206 ICARDA SY

Website: <http://www.icarda.cgiar.org>

E-mail: ICARDA@cgiar.org

Acknowledgment: The workshop was organized by ICARDA and CGIAR Systemwide Livestock Program, with the support of the Tunisian Ministry of Agriculture (Institution pour la Recherche et l'Enseignement Supérieur Agricole, l'Élevage et des Pâturages, et la Direction des Forêts) and financial support from SDC (Swiss Agency for Development and Cooperation), CIHEAM (Centre International des Hautes Etudes Agronomiques Méditerranéennes, Instituto Agronomico Mediterraneo de Zaragoza), IPGRI (International Plant Genetic Resources Institute), IDRC (International Development Research Centre, Canada), FAO Regional Office for the Near East (Cairo, Egypt) and the Initiative for Collaboration to Control Natural Resource Degradation (Desertification) of Arid lands in the Middle East. The participation and contributions of all are gratefully acknowledged.

Fodder Shrub Development in Arid and Semi-arid Zones

**Proceedings of the Workshop on Native and Exotic Fodder
Shrubs in Arid and Semi-arid Zones
27 Oct-2 Nov 1996, Hammamet, Tunisia**

Volume II

Editors

Gustave Gintzburger

Former Leader, Pasture, Forage and Livestock Program, ICARDA

Mustapha Bounejmate

Forage and Pasture Scientist, ICARDA

Ali Nefzaoui

Livestock Scientist, INRA, Tunisia

Sponsors

International Center for Agricultural Research in the Dry Areas (ICARDA)

CGIAR Systemwide Livestock Program (SLP)

Ministry of Agriculture, Tunisia

Swiss Agency for Development and Cooperation (SDC)

International Center for Advanced Mediterranean Agronomic Studies (CIHEAM)

West Asia and North Africa Regional Office of the International Plant Genetic
Resources Institute (IPGRI)

International Development Research Centre (IDRC/Canada)

Near East Regional Office of the Food and Agriculture Organization of the United
Nations (FAO/RNE)

Initiative for Collaboration to Control Natural Resource Degradation
(Desertification) of Arid Lands in the Middle East



International Center for Agricultural Research in the Dry Areas (ICARDA)

Contents

Volume I

Foreword

A. El-Beltagy	1
---------------------	---

Introduction

G. Gintzburger, M. Bounejmate and A. Nefzaoui	3
---	---

International Experience with Fodder Shrubs

Use of Fodder Trees and Shrubs (Trubs) in the Arid and Semi-arid Zones of West Asia and North Africa: History and Perspectives

H.N. Le Houérou	9
-----------------------	---

Shrubland Management and Shrub Plantations in Southern Europe

V.P. Papanastasis	54
-------------------------	----

Management of Forage Shrub Plantations in Australia

C.V. Malcolm	67
--------------------	----

Shrub Introduction and Management in South America

S. Lailhacar	77
--------------------	----

Discussion: International Experience with Fodder Shrubs

	101
--	-----

National Experience with Fodder Shrubs

A Study on the Syrian Steppe and Forage Shrubs

N. Mourad	109
-----------------	-----

Fodder Shrubs in Jordan

K. Tadros	122
-----------------	-----

Moroccan Experience with Fodder Shrub Research and Development

B. Boulanouar, A. Chriyaa and A. Boutouba	134
---	-----

Fodder Shrubs and Trees in Pakistan

S.N. Mirza	153
------------------	-----

Potential of Saltbush (*Atriplex* spp.) as a Fodder Shrub for the Arid Lands of Iran

A. Koocheki	178
-------------------	-----

Economic Aspects of Fourwing Saltbush (*Atriplex canescens*) in Iran

A. Tork Nejad and A. Koocheki	184
-------------------------------------	-----

Utilisations des Arbres et Arbustes Fourragers en Zone Sahélienne du Sénégal

D. Macoumba et K.A. Mamadou	187
-----------------------------------	-----

Research on Fodder Shrubs and their Management in the Rangelands of East Anatolia

L. Tahtacioglu	193
----------------------	-----

Les Arbustes Fourragers Autochtones et Introduits dans les Parcours du Maroc Oriental <i>M. Fagouri, M. Elasraoui et H. Elhelafi</i>	197
Algerian Experience with Fodder Shrub Plantation <i>N. Redjel and J. Boukheloua</i>	203
Tunisian Experience with Fodder Shrubs <i>A. Nefzaoui, H. Ben Salem, M. Zaafouri and S. Chouki</i>	210
Discussion: National Experience	229
Farmers and NGO Experience	
Agro-pastoral Community Experiences with Fodder Shrubs in Syria <i>A.R. El-Fikiki, F.A. Ibn Nuri and A.M. Ibn Jassim</i>	239
People's Participation in Range Management: Ma'in Range, Jordan <i>J. Muhamed</i>	244
Rangeland Rehabilitation through Plantation of Fodder Shrubs in Kanak Valley, Balochistan, Pakistan: Community Participation <i>K. Nawaz</i>	253
Saltbush Propagation: Seed Handling from Picking to Planting <i>R. Von Holdt</i>	261
Profitable Saltland Farming: An Australian Farmer's Experience <i>M.J. Lloyd</i>	267
"Un Arbre pour Chaque Citoyen." Résultats d'un Essai Mené par une ONG pour la Reconstitution du Couvert Végétal dans le Sud Tunisien <i>A. Zammouri</i>	277
Technology Transfer of Fodder Shrubs: A Synthesis <i>N. Redjel</i>	279
Discussion: Farmer and NGO Forum	288

Volume II

Biology and Ecology of Fodder Shrubs

Evaluation of Six Halophytic Shrubs under Center-pivot Sprinkler Irrigation <i>M.M. Mirreh, A.A. Osman, M.D. Ismail, M.S. Al Daraan and M.M. Al Rowaili</i>	293
Agroforestry Plantations of Fodder Shrubs and Herbaceous Crops in Relation to their Individual and Chemical Nutritive Constituents <i>M.S. El-Hakeem</i>	309

Effectiveness of Hybridization for Improving Some Characters of <i>Atriplex canescens</i> : Germination and Survival Performance O.H. Soliman and J.R. Barrow.....	325
Contribution à la Définition d'une Méthode d'Estimation de la Biomasse d' <i>Atriplex nummularia</i> au Maroc Oriental M. Acherkoug.....	334
Improving Feed Resources and Quality in the Dryland Areas of Morocco by Introducing the Strip-Alley Cropping System E. El Mzouri, A. Chriyaa, M. El Mourid and A. Laamari.....	340
Saisonalité des Réponses des Ligneux Sahéliens à l'Aridité: Cas de <i>Acacia tortilis</i> (Forssk.) Hayne subsp. <i>raddiana</i> (Savi) Brenan dans la Zone Soudano-Sahélienne du Sénégal (Dahra-Djolloff) D. Macoumba et G. Michel.....	348
The Production of Indigenous and Exotic Shrubs in the Marginal Areas of the Western Cape J.M. Van Heerden, A.J. Heydenrych and J.C. Botha.....	360
The Influence of Spacing on the Production of Saltbush Species in the Little Karoo Region of the Western Cape J.M. Van Heerden, A.J. Heydenrych and J.C. Botha.....	368
The Production of Karoo Bitou (<i>Osteospermum sinuatum</i> DC) in the Ceres and Robertson Karoo J.M. Van Heerden, A.J. Heydenrych and J.C. Botha.....	375
Le Frêne (<i>Fraxinus</i> spp.) et Le Pistachier de L'Atlas (<i>Pistacia atlantica</i>) A. Abdeguerfi et M. Laouar.....	385
Biological Nitrogen Fixation and ¹⁵ N-Labeled Mineral Nitrogen Uptake by <i>Acacia cyanophylla</i> , <i>Acacia cyclops</i> and <i>Atriplex</i> spp. M. Ismaili, B. Saloua and M.P. Salema.....	390
Effects of Spacing and Grazing on Relative Growth Rate of Woody Fodder Plants in a Semi-arid Area of Northern Greece A.B. Ainalis and C.N. Tsiouvaras.....	395
Echanges Gazeux Instantanés, Efficacité de la Transpiration et Fluorescence de la Chlorophylle "A" Chez Différentes Espèces du Genre <i>Atriplex</i> R.Y.H. Silva et S. Lailhacar.....	403
Relations Hydriques Chez Huit Espèces ou Provenances d' <i>Atriplex</i> Installées dans la Zone Aride Méditerranéenne du Chili R.Y.H. Silva et S. Lailhacar.....	414
Efficacité Transpirationnelle au Niveau des Échanges Gazeux chez des Espèces du Genre <i>Atriplex</i> Installés dans la Zone Aride Méditerranéenne du Chili R.Y.H. Silva et S. Lailhacar.....	422

Distribution of Fodder Shrubs in the Arid and Saharan Zones of Morocco <i>M. Tazi, A. Birouk, B. Hafidi and M. Aghlabi</i>	426
The Ecology and Biology of Fodder Shrub and Undershrub Chenopodiaceae in Khorasan Province, Northeastern Iran <i>M.H. Rashed</i>	431
Intérêt des Plantes Spontanées des Zones Arides et Désertiques pour la Réhabilitation des Milieux Déggradés en Tunisie Présaharienne: Cas de <i>Periploca laevigata</i> Ait. et de <i>Rhus tripartitum</i> (Ucria) DC <i>M. Neffati</i>	439
Discussion: Ecology and Biology of Fodder Shrub	453
Plant-Animal Interface	
Nutritive Value of Fodder Shrubs Used in Mediterranean Sylvo-Pastoral Systems and their Use by Grazing Animals <i>T.G. Papachristou</i>	461
Etude du Pâturage de Caprins en Sous-bois de Chênes Liège dans les Pyrénées Orientales, France <i>J.J. Rochon et J.P. Goby</i>	469
Browse Foliage as a Supplement to Wheat Straw for Sheep <i>A. Chriyaa and B. Boulanouar</i>	476
Chemical Composition and <i>In Vitro</i> Digestibility of Browse Plants in a Semi-arid Region of Spain <i>F. Muñoz, J.D. Andueza, I. Delgado and M.J. Ochoa</i>	485
Forage Use of Native <i>Atriplex halimus</i> L. in the Rainfed Areas of Aragón, Spain <i>I. Delgado and F. Muñoz</i>	491
Développement Morphologique et Biomasse Apétable d' <i>Acacia cyanophylla</i> Lindl. en Réponse aux Différentes Modalités d'Exploitation Pastorale dans les Zones Arides en Tunisie <i>Y. Ammari et M.S. Lamhamedi</i>	500
Nitrogen Supplementation of Cactus-based Diets Fed to Barbarine Yearlings <i>A. Nefzaoui, H. Ben Salem and L. Ben Salem</i>	512
Nutritive Value of Spineless Cactus- (<i>Opuntia ficus indica</i> var. <i>Inermis</i>) and <i>Atriplex</i> - (<i>Atriplex nummularia</i>) based Diets for Sheep <i>A. Nefzaoui</i>	518
Palatability of Mediterranean Shrubs: Comparison between Browsing and Cafeteria Techniques using Goats <i>A. Nefzaoui, H. Ben Salem, H. Ferchichi and H. Abdouli</i>	524

Improvement of the Nutritive Value of Tannin-rich Fodder Trees: Effect of Air-drying and Polyethylene Glycol Treatment of <i>Acacia cyanophylla</i> Lindl. Foliage on Intake, Digestibility and Growth in Sheep H. Ben Salem, A. Nefzaoui, L. Ben Salem and H. Abdouli.....	531
Evolution de la Composition Chimique et de la Digestibilité <i>in vitro</i> de Quatre Arbustes Halophytes dans le Sud Tunisien T. Khorchani, M. Hammadi, H. Abdouli et H. Essid.....	540
Effect of Straw Supplementation on Intake and Browsing of <i>Atriplex nummularia</i> (Oldman Saltbush) by Segureña Ewes, under Pen-feeding and Free-grazing Conditions E. Correal and J.A. Sotomayor	551
Effect of Straw Supplementation on the <i>Atriplex halimus</i> (Saltbush) Diet Consumed by Segureña Ewes J.A. Sotomayor and E. Correal.....	558
Native Shrubs in Sheep Diets S.K. Hamadeh, M. Abi-Said, K. Faour and A.E. Osman	564
Pâturage de l' <i>Atriplex nummularia</i> dans la Zone Aride du Sud du Maroc M. Tazi, A. Birouk, B. Hafidi et M. Aghlabi.....	570
Les Arbres et Arbustes dans les Systèmes Fourragers Tropicale: Élaboration de Références Scientifiques et Techniques au Service d'une Meilleure Gestion de ces Ressources H. Guerin, A. Ickowicz et B. Mallet	580
Discussion: Plant-Animal Interface	592
Socioeconomics	
Economics of Pastoral Fodder Shrubs in Jordan K. Nesheiwat.....	599
<i>Atriplex halimus</i> L. Source de Bois de Feu et de Fourrage en Milieu Aride (Cas de la Région de Marrakech, Maroc) A. Benchaabane	610
Use of Seawater Irrigation for Halophyte Plantation on the Arabian Peninsula H. Wakabayashi.....	617
Socioeconomics of Shrub Plantations in Syria J. Rae, G. Arab, K. Jani, N. Murad, T. Ngaido, G. Gintzburger and T.L. Nordblom	627
Socioeconomic Assessment: Rapporteur's Report T.L. Nordblom.....	648
Discussion: Socioeconomics	655

Recommendations of the Workshop Participants

Recommendations661

List of Participants

List of Participants..... 667

Participants Photograph..... 679

Biology and Ecology of Fodder Shrubs

Evaluation of Six Halophytic Shrubs under Center-pivot Sprinkler Irrigation

M.M. Mirreh, A.A. Osman, M.D. Ismail,
M.S. Al Daraan and M.M. Al Rowaili
Range and Animal Development Research Centre
Al Jouf, Kingdom of Saudi Arabia

Abstract

In shallow rocky poor soils under approximately 400 mm irrigation, halophytic shrubs produced 6.6 tonnes of dry matter. Grazing sheep were highly selective on a halophytic shrub mixture. Native *Atriplex leucoclada* was the most often selected, while *Atriplex nummularia* was the least often selected. Sheep were also highly selective of plant part, removing more than 96% of the leaves from most selected species. Continuous stocking with sheep over three years encouraged more woody biomass, and a cut-back for rejuvenation was not achieved with sheep grazing. Halophytic shrubs were characterized by low organic matter (72% in leaves), low energy (1.85 Mcal/kg in young leaves and 1.68 Mcal/kg in old leaves), high mineral matter (28% in young leaves), and high crude protein (18% in young leaves). Sheep receiving saltbush as a sole diet could not maintain weight. Average daily losses over three consecutive years, with at least four months grazing per year, ranged from 23 g/hour per day to 61 g/hour per day. However, animals gained weight when grazing an *Atriplex* and barley-stubble mixture, or when supplemented with 400 g of barley. The difference between supplemented and non-supplemented diets was approximately 64 g/hour per day. Thus, if an energy supplement is supplied, halophyte shrubs may be integrated into a farming or feeding system that takes advantage of their retention of high crude protein and their high water-use efficiency. Because of the high salt content of halophytes, estimated free-water consumption was 69 mL/g of sodium chloride in the summer months. Thus, approximately 11 L/head per day of good-quality water should be available for sheep grazing halophyte shrubs during summer.

Introduction

Saltbush species occur in different parts of the world, predominantly in the arid and semi-arid areas. Large-scale plantations of *Atriplex* species were carried out in North Africa and Iran, along with small-scale projects in Jordan, Syria, Israel, South Africa, Mexico, Australia, and the United States. The most extensively used species were *Atriplex nummularia* in North Africa and *Atriplex canescens*, because of its frost tolerance, in Iran. In addition to these two species, species such as *A. halimus*, *A. lentiformis*, *A. glauca*, and *A. leucoclada* were introduced as potential forages (Draz 1989; Sankary 1986; and Malcolm 1989).

Fodder shrubs were introduced to fill a feed gap for grazing animals or as a protein supplement where availability was not a problem. Other methods of establishing saltbush are emerging as a result of the global increase in salinized soils and global warming. Interest in halophytic plant research for reclamation of salinized soils, for carbon dioxide fixation, as a fodder for livestock, and for landscaping is growing (UNEP 1993). A substantial proportion of the studies conducted on introduced shrubs was devoted to production and water-use efficiency under rainfed conditions. *Atriplex* species growing under 100–400 mm rainfall produced 1,000–3,000 kg DM/ha per year (Forti et al. 1987; and Sankary 1986).

Artificial plantations were established in areas with mean rainfall of 200–300 mm, but supplemental irrigation below 200–250 mm was recommended (Le Houérou 1992). High water-use efficiency of saltbush species has been reported in different parts of the world. Rain-use efficiency of 5–10 kg DM/ha per mm of forage and 10–20 kg DM/ha per mm/year above ground biomass were reported for *Atriplex nummularia*, *A. halimus*, and *A. canescens* (Correal et al. 1990; and Forti 1971).

In the Kingdom of Saudi Arabia, meat consumption is high and lamb prices are extremely high due to widespread affluence. This has resulted in the establishment of mega sheep production schemes. Large-scale projects were set up on the Buseita plain, which has less than 50 mm annual rainfall, high summer temperatures, high evapotranspiration, and soils with a relatively high solute of gypsum. Considerable investments have been made in these projects, but farmers may face problems with water depletion and soil salinization. Changes in government policy regarding grain subsidies may attract non-livestock farmers to produce fodder for livestock to utilize the sunk cost of their investment.

Considering the high water demand of traditional fodder crops and the fact that the major cost of livestock goes for maintenance feed, protein-rich shrubs with high water-use efficiency may be a more appropriate base feed for these projects. This study was part of extensive research on six halophytic shrubs being tested by the Range and Animal Development Research Center. The objectives were to evaluate production dynamics, forage value, and sheep performance on halophyte shrubs as a sole diet and when supplemented with barley grain.

Materials and Methods

In 1991, six halophytic species were established from seedlings and planted on a 2,025 ha area under center pivot irrigation with approximately 420 mm of water per year. The six species were three indigenous species, *Atriplex halimus*, *Salsola chaudharyi*, and *A. leucoclada*, and three exotic species, *A. nummularia*, *A. canescens*, and *A. lentiformis*. Soil at the site is shallow, gravelly, gypsiferous, and less than 40 cm deep above the bedrock.

For each species, a small enclosure was built to monitor production changes. Forage production was estimated by clipping individual plants and separating them into leaf and stem components before grazing in the spring and after grazing in the autumn. Similar clippings were made for the plants in the enclosures. Clippings of stemmy branches and leaves were collected for each species separately and analyzed. Total digestible nutrients (TDN) were calculated according to Warden (1981), and energy values were calculated according to IFI (1982). Naimi sheep grazed the halophytic shrubs for three consecutive years. In 1992, when plants were one year old, 25 adult sheep were grazed for 129 days. In 1993, 50 adult Naimi ewes grazed the 2.25 ha area for 160 days. In 1994, 48 ewes grazed the same area for 127 days, but half of the sheep were given 400 g barley/day from the start of grazing. Water intake was estimated using pre-measured troughs, with depth of water remaining used to estimate water consumed.

Grazing animals were given a 7–10 day adjustment period before regular weighing started. Animals were weighed bi-weekly to capture the effect of fluctuations due to changes in climate and vegetation composition on animal performance.

Results and Discussion

Production Dynamics

Dry matter changes

Dry matter production of individual shrubs is shown in Table 1. Average dry matter yield of one-year-old plants was 768 g/plant, ranging from 314 g/plant for *Salsola chaudharyi* to 1,227 g/plant for the fast-growing *A. leucoclada* species. Average dry matter yield of non-grazed shrubs increased to 2,137 g/shrub in the fourth year after establishment (Table 1). Production varied from 618 g/shrub for *A. leucoclada* to 2,844 g/shrub for *A. canescens*. Above-ground biomass from individual shrubs in the fourth year was approximately three times their biomass in the first year, except for *Atriplex leucoclada*, a species known to behave like an annual with fast growth the first growing season and seed produced the first year.

Table 1. Above-ground dry matter for six shrubby species and their first and fourth years after establishment.

Species	g DM/shrub	
	1st year	4th year
<i>Atriplex canescens</i>	408	2,843
<i>A. halimus</i>	2,370	2,370
<i>A. lentiformis</i>	1,117	2,787
<i>A. leucoclada</i>	1,227	617
<i>A. nummularia</i>	759	2,680
<i>Salsola chaudharyi</i>	314	1,521

Dry matter production of the shrub mixture in protected enclosures under center pivot irrigation averaged 3,290 kg/ha in the first year and increased to 6,579 kg/ha in the fourth year. In Western Australia, *Atriplex* spp. growing in areas receiving rainfall of 500 mm/year produced up to 5 tonnes DM/ha (Malcolm and Pol 1986). Studies of various species of *Atriplex*, including *A. nummularia*, *A. halimus*, *A. canescens*, *A. lentiformis*, *A. amnicola*, etc., in medium-textured soils with a shrub density of 1,000–3,000 shrubs/ha, produced above-ground biomass of 5–20 tonnes DM/ha and a production of 2–10 tonnes DM/ha per year (Franclet and le Houérou 1971; Forti 1971).

Yields for *A. nummularia*, *A. halimus*, and *A. canescens* of 2,000–4,000 kg DM/ha per year with 200–400 mm water were reported (Le Houérou 1992). This is similar to the results obtained in this study. Rain-use efficiency, measured as above-ground standing biomass in the first year per millimeter of water applied, was 7.8 kg DM/ha and 15.7 kg DM/ha per year in the fourth year. Rain-use efficiency of 5–10 kg DM/ha per mm per year was measured for species *A. nummularia*, *A. halimus* subsp. *halimus*, *Schweinfurthii*, and *A. canescens* subsp. *liners* in areas receiving 100–400 mm water/year, with yields of 2,000–4,000 kg DM/ha per year (Le Houérou 1992). This is similar to the results in this study, with an application of 420 mm/ha per year. Le Houérou (1992) reports that fodder shrubs are efficient rain and water users and produce twice as much fodder per unit of water used as barley and wheat, and 3–4 times as much as alfalfa.

Leaf-stem distribution dynamics

Table 2 shows the percentage of leaves determined as a proportion of dry matter of individual shrubs before the start of grazing in three consecutive years. Percentages for similar shrubs in a protected enclosure are also given.

Table 2. Percentage of leaves of six shrubs before grazing and in protected areas.

Species	Before grazing			Enclosure
	1992	1993	1994	1994
<i>Atriplex lentiformis</i>	32.9	36.5	30.0	17.0
<i>A. canescens</i>	49.1	45.2	41.0	41.1
<i>A. halimus</i>	47.3	37.8	31.0	18.5
<i>A. leucoclada</i>	58.9	29.7	41.1	24.1
<i>A. nummularia</i>	47.9	35.2	33.0	21.0
<i>Salsola chaudharyi</i> [†]	52.0	48.1	39.9	29.1
Mean	48.0	38.8	36.0	25.1

[†] Leaves and tendrils.

Leaves constituted 48% of the above-ground biomass one year after establishment, and declined to 36% in the fourth year.

Generally, the proportion of leaves declined from year to year, primarily because of the compounding effects of plant maturation and leaf-stripping by grazing

sheep. Only one species, *A. leucoclada*, had a higher proportion of leaves in the fourth year than in the third. This was attributed to new plants germinating from seed, since this plant is known to produce volunteer seedlings quickly. Non-grazed plants in the enclosure had significantly lower percentages of leaves than their grazed counterparts in the same year (Table 2). This difference was approximately 11% in favor of grazed plants. Over three years, the percentage of leaves from non-grazed plants declined by 23%. This indicates that productivity of the forage portion of shrubs declines with protection and favors production of more wood. Apparently, a cut-back of the woody parts not grazed by sheep allows for better rejuvenation of young vegetative parts that may be used as a fodder if camels are grazed after sheep. In clipping studies of the six species in this study, most species were able to recover from severe cut-back of the top 90% when followed by a short rest period (three months). A cut-back of 25–50 cm was recommended to rejuvenate forage components.

Chemical content of shrubs

The proximate components of six halophytic shrubs are shown in Table 3. Average organic matter content of the shrub leaves was 72%, ranging from 64% in *A. halimus* to 78% in *Salsola chaudhryi*. Organic matter of the stemmy branches averaged 87%, ranging from 81% in *A. halimus* to 91% in *A. canescens*. The low organic matter of the leaves was due to their high mineral matter, which averaged 28.0%, and ranged from 22% in *Salsola chaudhryi* to 36% in *A. halimus*. Ash content was found to be about 25% for *Atriplex* spp., 27% for *A. halimus* (ILCA 1980), 23.6% for *A. halimus* (Mirreh 1994), 27–39% for *A. nummularia*, and 18–27% for *A. lentiformis* (Wilson 1992). In this study, ash contents of 27.5% in *A. halimus*, 18.5% in *A. nummularia*, and 20.7% in *A. lentiformis* were found. This is comparable to values reported in other parts of the world.

Calcium content of leaves was high, averaging 1.4%. This was comparable to values found for native shrublands in northern Saudi Arabia (Mirreh 1994). Sodium content of the halophyte leaves averaged 5.7%, ranging from 4.4% in *A. nummularia* to 7.3% in *A. halimus*. Phosphorus content in the leaves averaged 0.31%, which is considered adequate for leaf stripping sheep. But when the whole plant is considered, the average phosphorus content was 0.25%, which is similar to the 0.26% phosphorus for native shrubs in the spring (Mirreh 1994). Calcium-to-phosphorus ratio in leaves was 4.5 : 1. Crude protein (CP) for young leaves of one-year-old shrubs averaged 18%, while CP levels were more than 15% in leaves of chenopods. CP levels of 16–22% for *Atriplex* spp. were reported (Table 3).

Table 3. Proximate components of halophytic shrubs (% DM).

Species	CP	Ash	OM	P	Ca	Ka	Na	EE	CF	NFE
<i>Atriplex lentiformis</i>										
Leaves	23.4	28.3	71.7	0.34	0.87	5.36	5.59	3.07	7.03	40.50
Stems	8.9	13.0	87.0	0.16	0.74	3.83	1.28	0.72	38.50	41.40
<i>A. canescens</i>										
Leaves	11.1	30.0	70.0	0.18	1.67	4.88	6.32	3.06	12.50	49.80
Stems	4.6	8.8	91.2	0.13	0.75	2.31	0.81	1.85	40.00	47.30
<i>A. halimus</i>										
Leaves	20.5	36.0	64.0	0.39	2.22	5.05	7.27	2.30	6.80	41.80
Stems	10.7	19.0	81.0	0.19	1.83	3.33	2.50	0.65	32.80	36.50
<i>A. leucoclada</i>										
Leaves	16.7	27.4	72.6	0.40	1.27	4.73	5.40	1.45	9.00	48.40
Stems	7.7	13.3	86.7	0.33	1.27	2.23	1.22	0.77	34.40	45.90
<i>Salsola chaudharyi</i>										
Leaves	18.9	22.1	77.9	0.30	0.80	3.79	5.04	3.53	12.50	45.40
Stems	10.4	12.8	87.2	0.15	0.81	2.45	2.62	0.98	31.60	46.80
<i>A. nummularia</i>										
Leaves	18.2	26.1	73.9	0.25	1.57	5.36	4.35	2.61	5.19	50.10
Stems	7.7	10.1	89.9	0.14	1.07	2.27	1.19	1.14	41.90	41.60
Mean Leaves	18.1	28.3	71.7	0.31	1.4	4.86	5.66	2.67	8.84	46.00
Mean Stems	8.3	12.8	87.2	0.18	1.08	2.74	1.60	1.02	36.50	43.30

In the Mediterranean region, crude fiber (CF) of one-year-old shrubs averaged 22.7% when the whole plant is considered. CF in the leaves averaged 8.8%. CF increased as plants matured, and CF content of old leaves in protected enclosures reached 15.4% (Franclet and Le Houérou 1971; Dehaye et al. 1974; Benjamin et al. 1986; Correal et al. 1990; Hassan et al. 1979). Similar patterns were reported for *A. lentiformis* by Watson et al. (1987).

The nitrogen free extract (NFE) averaged 44% for the six halophytic shrubs in this study. This is similar to the 42% reported for native shrubs in northern Saudi Arabia (Mirreh 1994). The ether extract (EE) was 1.6%, comparable to the 1.9% reported for native shrubs (Mirreh 1994).

Nutritive values of the shrubs, as calculated from prediction equations, are given in Tables 4, 5, and 6. Average TDN on a dry matter basis varied from 46.6% in a non-grazed enclosure to 51.2% in leaves of young plants for the six halophytic shrubs. Gihad (1992) found TDN values of 60% in *A. halimus*, 56% in *A. leucoclada*, and 51% in *A. nummularia*. Respective values in this study were 50%, 50%, and 53% for *A. halimus*, *A. leucoclada*, and *A. nummularia*, respectively. Wilson (1992) found digestibility in leaves of *A. nummularia* to be 68–74%, and 80% for *A. lentiformis*. These values are substantially higher than the values in this study for TDN.

Table 4. Forage value in the leaves of six one-year-old halophyte shrubs (% DM).

Species	CP	DP	TDN	DE	ME
<i>Atriplex lentiformis</i>	23.4	17.1	53.4	2.35	1.92
<i>A. canescens</i>	11.1	6.3	47.1	2.07	1.70
<i>A. halimus</i>	20.5	14.5	49.7	2.19	1.79
<i>A. leucoclada</i>	16.7	11.1	49.9	2.20	1.80
<i>A. nummularia</i>	18.2	12.5	52.9	2.33	1.91
<i>Salsola chaudharyi</i>	18.9	13.1	54.4	2.39	1.96
Mean	18.1	12.4	51.2	2.26	1.85
SD	4.13	3.63	2.78	0.12	0.10

Table 5. Forage value of three-year-old plants of six grazed halophyte shrubs (%DM).

Species	CP	DP	TDN	DE	ME
<i>Atriplex lentiformis</i>	14.5	9.6	46.0	2.03	1.66
<i>A. canescens</i>	17.8	12.5	55.0	2.43	1.99
<i>A. halimus</i>	16.5	11.4	43.4	1.91	1.57
<i>A. leucoclada</i>	15.4	10.4	53.7	2.35	1.92
<i>A. nummularia</i>	14.4	9.5	45.6	2.01	1.65
<i>Salsola chaudharyi</i>	12.6	7.9	46.7	2.06	1.69
Mean	15.2	10.2	48.4	2.13	1.75
SD	1.8	1.61	4.76	0.21	0.17

CP and digestible protein (DP) of shrub leaves varied with stage of growth. Average CP and DP levels in young plants were 18.1% and 12.4%, respectively, and 14.2% and 9.5% in older plants. High CP and DP in halophytes were reported to satisfy the protein requirement of ruminants (Wilson 1992; Mirreh 1994).

Table 6. Forage value of non-grazed leaves of three-year-old plants of six halophytic shrubs (% DM).

Species	CP	DP	TDN	DE	ME
<i>Atriplex lentiformis</i>	14.9	9.9	38.3	1.68	1.38
<i>A. canescens</i>	12.1	8.6	51.6	2.27	1.86
<i>A. halimus</i>	14.2	9.3	46.5	2.05	1.68
<i>A. leucoclada</i>	12.3	7.6	44.9	1.98	1.62
<i>A. nummularia</i>	16.4	11.2	50.1	2.20	1.81
<i>Salsola chaudharyi</i>	15.5	10.5	47.9	2.11	1.73
Mean	14.2	9.5	46.6	2.05	1.68
SD	1.73	1.30	4.71	0.21	0.17

Digestibility of nitrogen (N) in *Atriplex* spp. was found to be approximately 65%, with only 55% of digestible N retained (Yaron et al. 1985; Benjamin et al. 1986). Le Houérou (1991) found that approximately 45% of the unretained digestible N was non-protein nitrogen. Some 50% of this was glycinebetaine, which can be degraded by rumen micro-flora when enough energy is available for micro-organisms to develop and animals are adjusted to salt diets. Studies of small ruminants fed with *Atriplex* spp. as a sole diet have shown a negative N balance (Hassan et al. 1977; El Shaer 1981; Kandil and El Shaer 1988). The main reason given for the negative N balance was the deficiency of available carbohydrates and rapid hydrolysis of CP in the rumen, resulting in accumulation of non-utilizable ammonia (Hassan et al. 1979; El Shaer 1981; Wilson 1977; Wilson et al. 1969; Weston et al. 1970). However, N retention of halophyte shrubs can be considerably increased when energy is present in the diet (El Shaer 1981; and Le Houérou 1991).

Digestible and metabolizable energy values (DE and ME) averaged 2.3 and 1.9 Mcal/kg DM, respectively, for young leaves, and 2.1 Mcal/kg and 1.7 Mcal/kg ME for older leaves. These values are considered marginal and are comparable to the 2.1 DE and 1.7 ME found for shrubs, forbs, and annuals in northern Saudi Arabia (Bhattacharya 1991). Energy content of saltbush forages ranged from 0.5 to 0.7 MJ ME/kg DM, but was enough to maintain body weight if animals consumed 1.2–1.6 kg DM/day (Le Houérou 1991). The year-round energy deficiencies of several halophytic species in Egypt were determined (El Shaer 1981). Weight losses of small ruminants grazing *Atriplex* spp., despite high CP and DP, are well documented (El Shaer and Kandil 1990; Mirreh 1991; Wilson 1977; Crampton 1957; Wilson and Graetz 1980).

Forage Preferences and Use

Sheep stocked in the area concentrated on grazing annual species growing with the shrubs, grubbing them to ground level and often digging the roots with their hooves. After the annuals were exhausted, sheep grazed the shrubs in the following order of preference: *A. leucoclada*, *S. chaudharyi*, *A. lentiformis*, *A. canescens*, *A. halimus*, and *A. nummularia*.

Table 7 shows the percentage of leaves and stems removed from individual species. Sheep virtually strip leaves from shrubs, but the percentage of leaves removed depends upon the stock density of grazing animals, plant morphological form, stage of growth, and leaf accessibility.

Table 7. Percentage of leaves and stems grazed (young and old plants of six shrubby species).

Species	One year old (%)		Four years old (%)	
	Leaves	Stems	Leaves	Stems
<i>Atriplex lentiformis</i>	80.8	32.5	89.2	29.2
<i>A. canescens</i>	53.2	21.2	94.4	4.1
<i>A. halimus</i>	88.8	28.0	70.4	-30.6 [†]
<i>A. leucoclada</i>	96.3	59.0	96.8	74.1
<i>A. nummularia</i>	90.4	22.1	10.6 [†]	-6.1 [†]
<i>Salsola chaudharyi</i>	-20.6 [†]	-19.2 [†]	87.6	-125.0

[†] Biomass after grazing was higher than before grazing.

One year after establishment, the percentage of leaves removed ranged from 53% in *A. canescens* to 96% in *A. leucoclada*. The low percentage of *A. canescens* removal was attributed to the relatively low production of leaves in the first year. More hardwood was formed as thick stems and branches, with leaves protected, except at the top of the plant.

When plants are young, sheep remove a substantial portion of the small branches of stems (twigs). The amount of stemmy material removed depends upon the texture of the plants and the preference of the sheep. The percentage of stemmy branches removed ranged from 21% in *A. canescens* to 59% in *A. leucoclada* for one-year-old plants, even though the stock density of the grazing sheep was only 25 on the 2.25 ha area. The proportion of leaves and stems grazed was difficult to determine for *S. chaudharyi*. The species was well grazed early in the growing period (late May), but the standing biomass measured when grazing ended was higher than that measured at the start of grazing. This was attributed to the compounding effect of growth, early seed setting, and the leaf morphological plasticity of the species. In the ungrazed enclosure, the above-ground biomass in October was twice that in June.

Removal of stem branches declined as plants got older. The proportion of stem branches was substantially higher at the end of grazing than at the start. This was

apparently due to woody growth and poor use. Removal of stems (branches) ranged from 4% in *Atriplex canescens* to 74% in *Atriplex leucoclada*. As plants got older in 1994, leaf removal substantially increased for all species except *A. halimus* and *A. nummularia*. In *A. halimus*, the decline in the percentage of leaf reduction was attributed to the production of more woody branches, which made leaves inaccessible to grazing sheep. In *A. nummularia*, it was attributed to reduced palatability of the species for grazing sheep. It is not clear what caused this reduced palatability in the fourth year, but the sheep tended to avoid fruit-bearing plants, since most of the plants fruited in the spring/summer of 1994.

Le Houérou (1992) found a decline in the forage value of old plants of *A. halimus* and *A. canescens* when plants were not cut. Although sheep defoliate shrubs, grazing sheep to not achieve a cut-back to remove the woody material. Apparently, camels can cut back woody materials. This was observed when camels grazed after sheep (Table 8).

Table 8. Dry matter production and consumption for one-year-old and four-year-old plants for six shrubs.

Species	One year old				Four years old			
	1	2	3	4	1	2	3	4
<i>Atriplex lentiformis</i>	826	426	399	48	1,311	691	620	47
<i>A. canescens</i>	360	227	133	36	714	423	291	40
<i>A. halimus</i>	1,919	828	1,089	56	2,857	2,845	617	21
<i>A. leucoclada</i>	1,165	221	943	81	435	72	363	83
<i>A. nummularia</i>	2,156	974	1,181	54	6,877	7,397	0	0
<i>Salsola chaudharyi</i>	462	555	277	33	1,508	2,113	527	20
Shrub mix.	511	358	152	29	1,098	1,302	306	27
Total 2.25 ha	7,403	3,567	4,178		14,804	14,845	2,727	
DM/ha	3,290	1,585	1,857		6,579	6,598	1,212	

1 = production; 2 = remaining; 3 = consumption; and 4 = use (%).

Dry matter production and consumption of shrubs are shown in Table 8. In 1992, when shrubs were young and had a higher forage value, the estimated intake was 4,177 kg DM on the 2.25 ha grazed by 25 Naimi sheep for 129 days. This includes estimated average daily disappearances, such as trampling damage and desiccation, but does not include disappearance of annuals during the early part of grazing, and regrowth of grazed shrubs. Dry matter intake of 1.2 kg/day for sheep grazing a shrubby range in good condition was reported in Tamriat, northern Saudi Arabia. The estimated requirement of dry sheep, with a 25% adjustment for walking, and using $63 \text{ g/day per kg}^{-0.75}$ (Kearl 1982), gave 1.46 kg DM/day for the flock in 1992.

Dry matter intake of 0.8–1.6 kg/head per day was found for *Atriplex* in Spain and Israel (Correal et al. 1990; Belmonte et al. 1990; Otal et al. 1992; Benjamin et al. 1986). Le Houérou (1992a, b) found initial intake of *Atriplex* spp. over a period of

3–5 months of 0.8–1.2 kg DM/head per year, with final intake of 1.5–2.5 kg DM/head per day. The high intake in this experiment was attributed to a longer period of use, which allowed the ruminal microflora to adjust to the halophytic diet. In this study, the estimated intake from before and after clipping is within the lower limit of estimated intake for sheep grazing for a long period on an *Atriplex* diet.

In 1994, when plants matured, the DM intake from before and after clipping was underestimated: only 0.457 kg DM/head per day. The requirement for DM intake was calculated at 1.388 kg/head per day for maintenance. Considering that animals supplemented with 400 g barley/head per day were maintaining themselves, intake from shrubs was apparently 0.988 kg DM/head per day. This is comparable to results obtained for *Atriplex* in other countries (Correal et al. 1990; Otal et al. 1992; Benjamin et al. 1986).

Wilson (1993) estimated intakes of 615 g DM/head per day for *A. undulata*, 700 g DM/head per day for *A. lentiformis*, and 843 g DM/head per day for *A. nummularia*. These intakes are comparable to those found in the present study. The low estimated intake in this study was attributed to several factors. Inherent bias in estimating regrowth, which disappears for grazing, fallen leaves from mature plants apparently consumed by sheep, which could not be accounted for, increases of the wood component for most species, which reduce grazing value, and reduced palatability of the most productive species, *A. nummularia*, might all have contributed to the estimated apparent low intake. The actual intake was higher for supplemented animals.

The high variation in estimated intakes of *Atriplex* spp. in different countries is apparently due to variations resulting from the stage of growth of the species, its inherent palatability, the length of grazing (which affects dietary adjustment), the measurement technique, and the condition of measuring instruments. The difficulty of measuring shrub production and intake was acknowledged by several investigators (Le Houérou 1991). Apparently, dry matter intake for sheep of salt shrubs ranges from 0.5 to 1.5 kg, depending on the phenological stage of growth, when availability is not limiting.

Sheep Performance with Halophyte Shrubs

Mature dry Naimi sheep on approximately 2.25 ha supporting six halophyte species were monitored for weight changes at two-week intervals for three consecutive years. They showed weight losses when halophytes were the sole diet. In 1992, when the shrubs were one year old, with a stock density of 25 sheep on 2.25 ha, the average pre-grazing weight of 50.2 kg dropped to 47.2 kg (Table 9) after 129 days of grazing.

Table 9. Weight changes of 25 Naimi ewes grazing young halophytes in 1992.

Dates	14/7	12/8	26/8	9/9	26/9	7/10	21/10	4/11	18/11
Mean weight (kg)	50.2	48.2	48.1	48.9	46.7	47.3	47.2	46.9	47.2
Coefficient of variation (%)	15.0	14.8	15.3	14.8	15.3	15.5	15.3	14.8	15.3

Most of the weight loss occurred during the first three weeks, when grazing sheep were eating the nutritively rich annual species mixed with the shrubs. Weight loss when sheep were grazing solely on young halophyte shrubs was only 1 kg from 12 August to 18 November. The average daily loss for the whole grazing period of 129 days was 23 g/head per day.

Fifty mature dry Naimi ewes kept in the same area for a period of 160 days in 1993 showed different responses over different periods (Table 10). During the early grazing period, from May to mid-June, sheep gained 114 g/head per day. This gain was attributed to the availability of 250 kg DM/ha from nutrient-rich annuals and mild spring temperature, which allowed a longer period of grazing. Sheep were conditioned to grazing halophytes, as they had previously grazed the native range of Wadi Tamriat in northern Saudi Arabia. The flock started losing weight at the end of June, when grazing shrubs only. The weight loss was steady, with 5.1 kg (61.4 g/head per day) lost over a period of 83 days.

Table 10. Weight changes of 50 Naimi ewes grazing halophyte shrubs in 1993.

Dates	Mean weight (kg)	Coefficient of variation (%)
09.05.93	51.0	6.56
24.05.93	52.7	6.38
15.06.93	54.0	5.91
30.06.93	50.4	5.92
13.07.93	48.7	6.52
27.07.93	47.1	6.08
10.08.93	46.2	6.23
24.08.93	46.0	6.49
07.09.93	46.4	6.07
21.09.93	45.3	6.15
05.10.93	47.1	6.15
26.10.93	48.5	5.60

Barley Supplement of Shrubs

A Naimi flock of 48 head, comprising 24 yearlings and 24 dry mature ewes, was divided into two groups. Half the flock was supplemented with 0.4 kg barley/head per day and grazed in an area with three-year-old halophytes. Response of sheep to supplemented and non-supplemented shrubs is given in Table 11. The supplemented group, after an initial weight loss during the adjustment period, gained 2.8 kg/head (22 g/day per head) over 127 days. The weight gain of the

supplemented animals depended on live biomass: adult ewes with average live biomass above 50 kg gained only 0.8 kg/head (6.3 g/day per head) for the whole grazing period, while yearlings gained 4.9 kg/head (38.6 g/head per day) over the same period. Non-supplemented animals grazing halophytes during the same period lost weight at a steady rate. The non-supplemented group lost 5.4 kg (42.5 g/head per day) over 127 days. Adult ewes showed the highest weight loss: 6.8 kg. Forage for grazing was not considered limiting. A slight weight gain was observed in early to mid-October. This was due to the growth of early germinating annuals in the grazed area, which were completely consumed before the end of the month.

Table 11. Effect of supplementation on Naimi sheep grazing halophytic shrubs (1994).

Grazing period (after adjustment)	Supplemented weight (kg)			Non-supplemented weight (kg)		
	Flock	Adults	Yearlings	Flock	Adults	Yearlings
26.06.94	42.8	51.7	33.9	43.7	53.2	33.3
11.07.94	43.4	51.6	35.2	42.9	52.4	32.4
25.07.94	43.9	52.3	35.5	42.8	52.5	32.2
08.08.94	44.2	52.5	35.9	41.7	51.1	31.4
22.08.94	44.4	52.5	36.3	40.5	49.4	31.1
05.09.94	44.6	52.0	37.2	40.3	49.0	30.8
19.09.93	44.8	52.3	37.4	39.6	47.9	30.5
03.10.94	45.0	52.3	37.7	38.7	46.9	29.7
21.10.94	45.8	52.7	38.8	39.1	47.1	30.3
31.10.94	45.6	52.5	38.8	38.3	46.4	29.4

The data for non-supplemented adults in 1993 and 1994 show similar average daily losses of 61.4 g/head per day in 1993 and 53.5 g/head per day in 1994. This indicates that shrubs alone are not enough to maintain body weight of grazing sheep. However, minor supplementation with an energy diet allows for body weight maintenance, or even gain, as when sheep grazed barley stubble and an *A. leucoclada* mixture in October 1993, and when 400 g barley was used as a supplement in 1994. The results obtained in this study are similar to those found in several experiments in Mediterranean arid zones (Franclet and Le Houérou 1971; Dehaye et al. 1974; Dumancic and Le Houérou 1981; Otal et al. 1992). Le Houérou (1991) reported a weight gain when grazing was combined with pen supplementation with an energy source (straw, stubble, etc.), and a difference between supplemented and non-supplemented animals of 41 g/head per day. In this study, the difference between supplemented and non-supplemented sheep was 64.5 g/head per day. Wilson (1992) found that most value is obtained from halophytes when they are eaten with other plants to provide a more balanced protein-energy diet. The general impression in this study and others cited is that halophyte shrubs may be integrated into a farming or feeding system that takes advantage of their long period of high protein if an energy supplement is used.

Water Consumption

Water consumption of sheep grazing only halophytic shrubs for one week in July 1992 was 10.8 L/head per day. This high water consumption is similar to those reported in other countries. Le Houérou (1991) found a water consumption of 11 L/head per day for sheep grazing *Atriplex* spp. during the summer. Sheep grazing *A. vesicaria* rangelands consumed 7–12 L/day, while grassland sheep consumed 3–5 L/day (Wilson 1974). Drinking water intake increased by 61.36% for sheep on *A. halimus*, compared to clover hay (Gihad 1990). Le Houérou (1992a, b) found that sheep grazing *Atriplex* spp. in hot summer weather may consume up to 12 kg/head per day for a 40 kg sheep. The high water demand of sheep grazing halophytes is due to the high mineral salt content of halophytes. This high water consumption is needed for urinary excretion of the high salt intake. Wilson (1992) found that at salt levels higher than 10–15%, animals increase their water consumption and urine output and may still grow. Free water intake per gram of sodium was 74 mL for sheep grazing *A. vesicaria* (Wilson et al. 1969). Similar levels of 70.8 mL/g of Na were recorded by Hassan et al. (1979). Average Na content of leaves and stems were 5.56 and 1.60%, respectively, with sodium chloride (NaCl) of 14.15% in leaves and 4% in stemmy branches.

Sheep consumed approximately 80% of leaves and 20% of stemmy branches. Estimated dry matter intake when plants were young was 1.295 kg/head per day. Salt consumption was approximately 157 g NaCl/head per day, with a water intake of 10.8 L/head per day, measured in the summer of 1992. Free water consumption was 68.8 mL/g of NaCl. This is similar to the 70.8 mL/g (Hassan et al. 1979) and 74 mL (Wilson 1969) of free water intake per gram of sodium ingested reported in other studies.

References

- Bhattacharya, A.N. 1991. Nutrient contents and feed values of commonly browsed desert range shrubs, forbs and tree leaves in northern Saudi Arabia. *World Rev. of Animal Production* 26: 29–82.
- Belmonte, C., T. Otal y E. Correal. 1990. Determinacion de la capacidal de ingestion de *Atriplex nummularia* por ovejas segarenas estabuladas en boxes. Pages 363–370 in XXX Reunion Cientif. de la SEEP, San Sebastian, España. Pastos no. extraordinario.
- Benjamin, R.W., D. Barbal, Y. Larie and M.A. Forti. 1986. Evaluation of the use on introduced species in Agro-pastoral systems. In Fodder Production and Utilization by Small Ruminants in Arid Regions CALA Project (FOPAR), APRI, Dokki, Cairo, Egypt.
- Correal, E., J. Otal and J.A. Sotomayor. 1990. Utilization of sheep on oldman saltbush (*Atriplex nummularia*): Palatability, browse efficiency, voluntary intake and chemical composition. In 6th Meeting of FAO European Sub-network on Mediterranean Pastures and Fodder Crops. Bari, Italy.

- Crampton, E.W. 1957. Interrelation between digestible nutrients and energy content, voluntary dry matter intake the overall feeding value of forages. *Journal Animal Science* 16: 546.
- Draz, O. 1989. Fodder shrubs for range improvement: The Syrian experience. Pages 245–440 in *The Biology and Utilization of Shrubs* (C.M. Mckell, ed.). Academic Press, New York.
- Dehay, R., A.N. Le Hou rou et M. Sarson. 1974. Am lioration de Paturages et de l'Elevage au Hodna (Algeria) AGS-DD-ALG. 66-509, FAO, Rome.
- Dumancic, D., and H.N. Le Hou rou. 1981. *Acacia cyanophylla* as supplementary feed for small stock in Libya. *Journal of Arid Environments* 4: 161–167.
- El Shaer, H.M. 1981. A comparative nutrition study on sheep and goats grazing southern Sinai desert range with supplements. PhD Thesis, Fac. Agric. Ain Shams Univ., Egypt.
- El Shaer, H.M. and H.M. Kandil. 1990. Comparative study on the nutrition value of wild cultivated *A. halimus* by sheep and goats. *Com. Sci. and Dev. Res.* 29: 81.
- Forti, M. 1971. Introduction of fodder shrubs and their evaluation for use in the semi-arid areas of the northwest Negev Institute for Arid Zones Research, Bear-Sheva, Israel. Minco.
- Franclet, A. et H.N. Le Hou rou (1971). Les *Atriplex* en Tunisie et en Afrique du Nord. FO: SF/TUN II Rapport technique No. 7. FAO, Rome. English translation by US Forest Service FAO Doc. Center Microfiche No. 17909 El. FAO, Rome.
- Gihad, E.A. (1990). Utilization of high salinity tolerant plants and saline water by desert animals. Int. Conf. on High Salinity-tolerant Plants in Arid Regions. El Ain, UAE, 8–15 Dec.
- IFI. 1982. Nutrient Requirement of Ruminants in Developed Countries. International Feedstuffs Institute, Utah Agric. Expt. Sta., Utah State University, Logan, Utah, USA.
- Hassan, N.I., H.M. Abdelaziz and A.E. El Tabbah. 1979. Evaluation of some forages introduced to newly reclaimed areas in Egypt. *World Rev. of Anim. Prod.* XV 2: 31–35.
- ILCA. 1980. Browse in Africa, the Current State of Knowledge. (H.N. Le Hou rou, ed.).
- Kandil, H.M. and H.M. El Shaer. 1988. The utilization of *A. nummularia* by goats and sheep in Sinai. Proc. of the International Symposium on the Constraints and Possibilities of Ruminant Production in the Dry Sub-tropics, 5–7 Nov. Cairo, Egypt.
- Kearl, C.L. 1982. Nutrient Requirements of Ruminants in Developing Countries. IFI Utah Agric. Exp. Stat. Utah State Univ. Logan, USA.
- Le Hou rou, H.N. 1992a. The role of salt bushes (*Atriplex* spp.) in aridland rehabilitation in the Mediterranean basin: A review of agroforestry systems. 18: 107–148. Kluwer, The Netherlands.
- Le Hou rou, H.N. 1992b. Forestry halophytes and salt-tolerant fodder crops in the Mediterranean basin. Halophytes as a resource for livestock husbandry: Problems and prospects. Workshop held at UNEP, Nairobi. (draft)
- Malcolm, C.V. and J.E. Pol. 1986. Grazing management of saltland shrubs. *Journal Agric. W. Australia* 27(2): 59–63.
- Malcolm, C.V. 1989. Forage shrub production from salt-affected soils. Pages 553–575 in *The Biology and Utilization of Shrubs* (C.M. Mckell, ed.). Academic Press, New York.

- Mirreh, M.M. 1991. The effect of early or late grazing on vegetation and sheep growth in the wadi Tamriat, northern Saudi Arabia. UTFN/SAU/008/SAU, Range and Animal development Research Center, Al Jouf, FAO/MAW.
- Mirreh, M.M., A.A. Osman, M.S. Al Daraan and M.M. Al Rowaili. 1991. Effect of different trimming levels on growth recovery for six shrubby species. UTFN/SAU/008, Range and Animal Development Research Center, Al Jouf, FAO/MAW.
- Mirreh, M.M. 1994. Nutrient contents of some perennial shrubs and grasses in northern Saudi Arabia. UTFN/SAU/008, Range and Animal development Research Center, Al Jouf, FAO/MAW.
- Otal, J.C., C. Belmonte, E. Correal and J.A. Safomayor. 1992. Evaluation of sheep production under continuous rotational grazing of a saltbush plantation (*Atriplex* spp.) in southeast Spain. Proceedings of the IVth International Rangeland Congress, 22–26 April, Montpellier, France.
- Sankary, M.N. 1986. Species distribution and growth in salt affected land in Syria. *Reclamation and Revegetation Research* 5: 125–143.
- Warden, M.F. 1981. Model for estimating energy and protein utilization for feeds. In Nutrient Requirements of Ruminants in Developing Countries. IFI Utah State University, Logan, Utah, USA.
- Weston, R.H., J.P. Hogan and J.A. Hemsley. 1970. Some aspects of the digestion of *A. nummularia* (saltbush) by sheep. Proceeding of the Aust. Society of Animal Production 8: 517.
- Watson, M.C., J.W. O'Leary and R.P. Glenn. 1987. Evaluation of *Atriplex lentiformis* and *Atriplex nummularia* as irrigated forage crops. *Journal of Arid Environments* 13: 293–303.
- Wilson, A.D., J.H. Leigh and W.E. Mullaham. 1969. A study of merino sheep grazing a bladder saltbush (*Atriplex vesicaria*) cotton bush (*c+Kochia aphylla*) community on the Riverine plain. *Australian Journal of Agricultural Research* 20: 1123.
- Wilson, A.D. 1974. Water consumption and water turnover of sheep grazing semi-arid pasture communities in New South Wales. *Australian Journal of Agricultural Research* 25: 339.
- Wilson, A.D. 1977. The digestibility and voluntary intake of the leaves of trees and shrubs by sheep and goats. *Australian Journal of Agricultural Research* 28: 501.
- Wilson, A.D. and R.D. Graetz. 1980. Cattle and sheep production on *Atriplex vesicaria* (saltbush) community. *Australian Journal of Agricultural Research* 31: 369.
- Wilson, A.D. 1992. Halophytes and halophytic plants in Australia: Ecology and potential as a rangeland resource. International Workshop on Halophytes Reclamation of Saline Wastelands and as a Resource for Livestock: Problems and Prospects. Nairobi, Kenya. 22–27 Nov. (draft)
- Wilson, A.D. 1993. Nutritive value and utilization of halophytes as livestock feed. International Workshop on Halophytes Reclamation of Saline Wastelands and as a Resource for Livestock: Problems and Prospects. Nairobi, Kenya. 22–27 Nov. (draft)
- Yaron, A., L. Levi and R.W. Benjamin. 1985. Analysis of shrub leaves for crude protein content. Pages 82–92 in *Fodder Production and its Utilization by Small Ruminants in Arid Regions*. Inst. of Applied Research, Ben Gurion Univ. of the Negev, Beer Sheva.

Agroforestry Plantations of Fodder Shrubs and Herbaceous Crops in Relation to their Chemical Nutritive Constituents

M.S. El-Hakeem

Desert Research Center, Cairo, Egypt

Abstract

This study investigated the effect of population density on the nutritive constituents of several components in an agroforestry plantation. Sixteen treatments were tested by interplanting *Medicago arborea* shrubs at four population densities (100, 200, 300, and 400 shrubs/fed) with *Acacia* shrubs (200 shrubs/fed). An herbaceous fodder crop (barley or *Vicia*) was planted in the inter-spaces and a fertilizer (300 kg calcium super-phosphate, 16.5% P_2O_5 , 500 kg/fed mineral sulfur) applied. Experiments were carried out at El-Qasr in Matrouh in 1991/92 and 1992/93. The nutritive constituents (phosphorus, carbohydrates, crude protein, crude fiber, ether extract contents, total digestible nutrients) in the shrubs were significantly affected by most of the factors under study, and their interactions.

Introduction

Fodder quality, specifically its nutritive chemical constituents, is of great importance to appropriate animal feeding and its impact on animal performance and production. This is especially true under arid desert conditions, where feeding materials are not abundant enough to satisfy demand. Planting herbaceous fodder crops within the inter-spaces of fodder shrubs on intensive agroforestry plantations could solve the animal feeding problem in arid desert areas, especially if it is characterized by high-quality components.

Church (1980) recorded chemical constituents and total digestible nutrients of some fodder crops as follows: for oat, DM, CP, CF, and TND were 16.1, 15.6, 25.0, and 64.%, respectively; for *Acacia* twigs, they were 88, 11.2, 36.0, and 37.0%, respectively; and for vetch, they were 22.0, 20.9, 28.0, and 59.0%, respectively.

Trevino et al. (1981) recorded the components of *Vicia monantha* during different stages of maturity. Mean values on a dry matter basis were as follows: crude protein, 26.2–19.7%; neutral detergent fiber, 19.9–42.5%; acid detergent fiber, 17.7–29.8%; cellulose, 12.8–20.4%; hēmi-cellulose, 2.2–12.7%; lignin, 4.4–9.1%; and ash 10.3–9.1%.

Lunnan (1987) found that barley in a mixture contained more protein than in other treatments. A mixture of fodder pea (cv Tino) and *Vicia* (vetch) produced the highest dry matter content (40%) and the highest crude protein content (13%). Tiedman and Johnson (1992) found that leaves and twigs of *A. saligna*, with their high protein content, were good forage for sheep and goats during the summer.

Materials and Methods

Experiments were conducted in calcareous soils at El-Qasr in Matrouh on the northwest coast of Egypt during 1991/92 and 1992/93 (Table 1).

Table 1. Soil characteristics at El-Qasr experimental site.

pH	EC (mmhos/cm)	Particle size analysis (mm)				Texture class	CaCO ₃ (%)	OM (%)
		Coarse sand	Fine sand	Silt	Clay			
8.0–8.5	0.3–3.3	8.96	53.87	20.97	16.20	SL	17–23	0.34

Vegetative Fodder Plants Selected for Study

Two perennial shrubs were studied, *A. saligna* and *M. arborea*, and two annual herbaceous fodder crops, barley (*Hordeum vulgare*) and vetch (*V. monantha*).

Acacia saligna shrubs were selected because of their well-known adaptability to the environmental conditions at Matrouh. Selection of *M. arborea* shrubs for this study was based on the similarity between *M. arborea* and *M. sativa* (alfalfa), in terms of their favorable fodder quality. *Medicago arborea* is a leguminous shrub that can tolerate adverse environmental desert conditions and doesn't need nitrogen fertilization (it is nitrogen fixing). The available information suggests that such shrubs can grow well despite the limitations of a desert environment. The introduction of such shrubs in Matrouh is an excellent contribution toward the goal of increasing and upgrading fodder potential and creating favorable environmental conditions. Selection of the two winter herbaceous fodder crops was based on their potential for growth and production under the prevailing desert conditions and appropriate management.

Factors under study:

- Four population densities of *M. arborea* (100, 200, 300, and 400/fed).
- Two annual fodder crops (barley and *Vicia*).
- Two phosphorus and sulfur mixtures (300 kg super-phosphate + 500 kg mineral sulfur/fed, and a check).

The experiment had a split plot design, with the four population densities of *M. arborea* randomly assigned to the main plots, the two different winter fodder crops assigned to the first order sub-plots, and the fertilization treatment and control assigned to the second order sub-plots.

In October 1990, two-year-old *A. saligna* shrubs were established in a permanent field, with a spacing of 6×7 m (200 shrubs/fed). The area was divided into smaller experimental units of 9.5×8.5 m, and surrounded by borders (2 m wide), considered 1/50 of a feddan. Four *Acacia* shrubs were placed in the corners of each unit at a 1 m spacing.

Table 2. Sixteen treatments of the study.

	Fodder shrubs/feddan		Herbaceous crops		Fertilizer (P + S)	
	<i>Acacia</i>	<i>M. arborea</i>	Barley	<i>Vicia</i>	Without	With
1	200	100	x		x	
2	200	100	x			x
3	200	100		x	x	
4	200	100		x		x
5	200	200	x		x	
6	200	200	x			x
7	200	200		x	x	
8	200	200		x		x
9	200	300	x		x	
10	200	300	x			x
11	200	300		x	x	
12	200	300		x		x
13	200	400	x		x	
14	200	400	x			x
15	200	400		x	x	
16	200	400		x		x

Seedlings of *M. arborea* and *A. saligna* shrubs were produced in the nursery of the Desert Research Center. Seeding was done on 15 February 1991, in a media of 1:1, V:V, peat and washed sand. The seedlings were transported to the site under appropriate management on 1 October 1991.

The two herbaceous winter fodder crops were planted between the perennial shrubs to emulate an intensive desert fodder agroforestry plantation. Barley was seeded in November 1991 and 1992 at a seeding rate of 35 kg/fed. *Vicia* was seeded on the same date, at a rate of 20 kg/feddan.

The fertilization treatment, a mixture of 300 kg calcium super-phosphate ($15.5 \text{ P}_2\text{O}_5$) + 500 kg mineral sulfur per feddan, was added during soil preparation and before seeding the winter annuals.

One cut, to simulate grazing, was performed on the inter-planted crops in April 1992 and 1993.

Chemical analysis included:

- Phosphorus content (P), according to Frie et al. (1964).
- Total carbohydrate content, according to Dubois et al. (1950).
- Crude protein content (CP), calculated by multiplying the nitrogen content by 6.25, using modified Micro-Kjedahl according to Peach and Tracey (1956).
- Crude fiber (CF), according to the AOAC (1970).
- Ether extract (EE), according to the AOAC (1970).

Chemical analysis was conducted on a dry matter basis. Random vegetative samples were dried in an air-forced oven to a constant weight. The oven-dried samples were ground and stored in air-tight containers in a cool place to be chemically analyzed.

Total Digestible Nutrients

This parameter, estimated by Radwan and El-Fakhry (1976) and Farid et al. (1979), gives a better understanding of potential animal feeding value. The average TDN value for the whole plantation was calculated to identify the quality of each of the proposed agroforestry plantations as an appropriate model in terms of animal nutritional.

Statistical analysis and mean separation for the two growing seasons individually and together, were carried out according to Steel and Torrie (1980) using the Co-State Computer Program.

A homogeneity test for the data was carried out according to Le Clerg et al. (1966). This test indicates the validity of the combined analysis.

Results and Discussion

For the sake of brevity, the effect of the treatments on the chemical constituents of fodder materials is considered for both years together.

Phosphorus Content

Table 3 presents the effects of the treatments on the phosphorus content of the plantations.

Phosphorus content of *Acacia* and *M. arborea* was substantially decreased as the population density of the inter-planted *M. arborea* increased. It was 0.16, 0.13, and 0.12% for *M. arborea*, with significant differences between the lowest density (100 shrubs/fed) and either of the two highest densities (300 and 400 shrubs/fed). This decrease could be due to inadequate available phosphorus, especially given the calcareous soil. Phosphorus content of both fodder shrubs was significantly higher when the inter-planted herbaceous crop was barley rather than *Vicia*: 0.15% and 0.11%, respectively, for *Acacia*, and 0.14% and 0.13%, respectively, for *Medicago arborea*.

Both inter-planted herbaceous crops exhibited a substantial decrease in phosphorus as population density increased. Phosphorus content was 0.16, 0.15, 0.13, and 0.11% for barley and 0.13, 0.11, 0.10, and 0.09% for *Vicia* at densities of 100, 200, 300, and 400 shrubs/fed. This decrease was due to inadequate available phosphorus in the soil. Barley contained more phosphorus than *Vicia*. However, it is well known that leguminous crops usually contain more phosphorus than cereal crops. This may be because *Vicia* is on the field a shorter time than barley. This relatively short period may be insufficient to accumulate enough phosphorus in *Vicia* plant tissues. Vigorous barley growth may be another reason.

Acacia and *M. arborea* contained more phosphorus when inter-planted with barley, with significant differences as shown in Table 3. Phosphorus content for *Acacia* fodder material inter-planted with barley was 0.15%, and when inter-planted with *Vicia*, 0.11%. For *M. arborea* fodder material, content was 0.14% and 0.13%, respectively. In general, barley had a higher phosphorus content than *Vicia*. Phosphorus content was 0.14% and 0.11%, respectively. Both *Acacia* and *M. arborea* responded to the applied phosphorus + sulfur treatment. Phosphorus content was significantly higher than in the control. Fertilized *Acacia* contained 0.15% phosphorus, compared to 0.11% for the control. The corresponding phosphorus contents of *M. arborea* were 0.15% and 0.12%.

Similar responses to the phosphorus plus sulfur treatment were observed in the inter-planted herbaceous crops. The phosphorus content in the fertilized barley was 0.16%, while in the unfertilized barley it was 0.12%—a 33% difference. Phosphorus content was 0.12% in the fertilized *Vicia* and 0.10% in unfertilized *Vicia*—0.20% difference.

In conclusion, the phosphorus content, measured on a dry matter basis, of *Acacia* and *M. arborea*, decreased as the population density of the latter increased. Phosphorus content was higher when the inter-planted herbaceous crop was barley, rather than *Vicia*. All plants (*Acacia*, *M. arborea*, barley, and *Vicia*) had a higher phosphorus content when fertilized with phosphorus plus sulfur, compared to the untreated control. It is clear that the fertilizer treatment had a favorable impact on the plantation in terms of growth and production.

Table 3. Phosphorus content of fodder shrubs and herbaceous crops.

Fertilizer treatment (P + S)	Phosphorus content (%)														
	D = 200 A + 100 M			D = 200 A + 200 M			D = 200 A + 300 M			D = 200 A + 400 M			Total		
	B	V	Mean	B	V	Mean	B	V	Mean	B	V	Mean	B	V	Mean
<i>Acacia saligna</i>															
Without	0.16	0.12	0.14	0.13	0.09	0.11	0.11	0.08	0.10	0.11	0.07	0.09	0.13	0.09	0.11
With	0.19	0.15	0.17	0.18	0.11	0.15	0.15	0.12	0.14	0.15	0.11	0.13	0.17	0.12	0.15
Mean	0.18	0.14	0.16	0.16	0.10	0.13	0.13	0.10	0.12	0.13	0.09	0.11	0.15	0.11	0.13
LSD 5% for:	Density = 1.01			Species = 0.02			Fertilizer = 0.01								
	Years = 0.8														
<i>Medicago arborea</i>															
Without	0.13	0.14	0.14	0.12	0.11	0.12	0.10	0.11	0.11	0.11	0.08	0.10	0.12	0.11	0.12
With	0.18	0.16	0.17	0.15	0.15	0.15	0.15	0.12	0.14	0.13	0.12	0.13	0.16	0.14	0.15
Mean	0.16	0.15	0.16	0.14	0.13	0.14	0.13	0.12	0.13	0.12	0.10	0.12	0.14	0.13	0.14
LSD 5% for:	D = 0.0			S = 0.01			F = 0.01								
	Years = 0.01														
Herbaceous crop (barley or <i>Vicia</i>)															
Without	0.14	0.11	0.13	0.13	0.09	0.11	0.11	0.10	0.10	0.10	0.08	0.09	0.12	0.10	0.11
With	0.18	0.14	0.16	0.17	0.13	0.15	0.14	0.11	0.12	0.13	0.09	0.11	0.16	0.12	0.14
Mean	0.16	0.13	0.14	0.15	0.11	0.13	0.13	0.10	0.11	0.12	0.04	0.10	0.14	0.11	0.12
LSD 5% for:	D = 0.02			S = 0.01			F = 0.01								
	Years = 0.01														

A = *Acacia*; M = *M. arborea*; B = Barley; V = *Vicia*; D = density; F = fertilizer; S = species.

It appears that the sulfur component of the fertilizer treatment was very effective in strengthening phosphorus availability by decreasing soil pH. This decrease in the pH of calcareous soil made both the applied and the fixed phosphorus available. In addition, other important micro-nutrients were transformed from fixed to available status.

Carbohydrate Content

Data on the effect of the treatments on carbohydrate content of the planted species are shown in Table 4. Carbohydrate levels, calculated on a dry matter basis, in the fodder material of *Acacia*, *M. arborea*, barley, and *Vicia* increased significantly as the intensity of the inter-planted *M. arborea* shrubs increased. The highest carbohydrate content of any of the fodder plants was obtained at the highest population density (400 shrubs/fed), as shown in Table 5.

Table 4. Effect of population density on carbohydrate content of shrubs and annuals.

<i>M. arborea</i> population (shrubs/fed)	Perennial shrubs		Winter herbaceous crops	
	<i>Acacia</i>	<i>M. arborea</i> (CH ₂ O %)	Barley	<i>Vicia</i>
100	13.6	31.0	34.9	20.3
200	15.6	32.0	36.0	22.5
300	18.9	34.0	37.5	28.2
400	21.5	37.0	38.7	33.8
LSD at 5%	1.4	1.4	1.3	1.3

The increase in carbohydrates may be due to the improved micro-environment created within the plant canopies when unfavorable thermal infra-red radiation (IR) is cut off, thus increasing photosynthetic active radiation (PAR). This stimulated photosynthesis is reflected in the accumulated carbohydrate content.

The shade created by the plant canopy may help lower the surrounding air temperature, which would reduce evapotranspiration and thus moisture loss in both plant and soil. This is an important factor under rainfed desert agriculture. This savings of moisture could also increase photosynthetic activity and carbohydrate accumulation.

When inter-planted with barley, as opposed to *Vicia*, fodder shrubs showed a slight but significant increase in carbohydrate content (Table 3). Carbohydrate content for *Acacia* was 19.1% with barley, and 15.6% with *Vicia*. Values for *M. arborea* were 35 and 32%, respectively.

Inter-planted barley had a 40% higher carbohydrate content (36.9%) than *Vicia* (26.3%). This result was expected, as cereal fodder crops are known as a high energy source, while leguminous fodder crops have a high protein content. Under phosphorus plus sulfur fertilization, carbohydrate content increased slightly but

significantly over the control for both *Acacia* (18.8% vs 15.9%) and for *M. arborea* (36.0% vs 30.3%). The carbohydrate content of the herbaceous crops was slightly but significantly lower for the control than for the fertilized plants. The addition of phosphorus plus sulfur could increase available phosphorus and release the required essential micronutrients. This may have a synergistic effect on activating photosynthesis and carbohydrate accumulation in plant tissue (Devlin 1984).

Crude Protein Content

Crude protein content of each component is shown in Table 6. Crude protein content of *Acacia* fodder was slightly but significantly decreased as the population density of *M. arborea* was increased from 100 to 400 shrubs/fed. At the lowest and highest population densities of *M. arborea*, the crude protein content of *Acacia* fodder was 18.4 and 17.1%, respectively. Population density did not show a clear trend on the CP of *M. arborea* fodder.

As the population density of *M. arborea* increased from 100 to 300 shrubs/feddan, CP of herbaceous crops tended to decrease, although these decreases were without statistical significance.

Table 6 shows that the CP of *Acacia* was significantly lower when inter-planted with barley (16.6%) than with *Vicia* (18.8%). The inter-planted *Vicia* had a significantly higher CP (19.2%) than the barley (14.7%). This indicates that barley is a heavier feeder on soil N than *Vicia*.

Fertilization of *Acacia* and *M. arborea* increased the CP of fodder material. On fertilized and unfertilized plots, *Acacia* fodder CP was 19.3 and 16.1%, respectively, and for *M. arborea*, 18.6 and 16.0%, respectively.

Results for crude protein content are opposite to the results for carbohydrate content. This is expected, since carbohydrates and crude protein are very much related, and together form most of the dry matter content. In other words, any increase in one of the two components is at the expense of the other. Fertilization caused a significant increase in crude protein content over the control: by 19% for barley, and by 21% for *Vicia*.

The highest crude protein content for *Acacia* was obtained when inter-planted with *Vicia* and fertilized. There was a significant interaction effect of population density (100 shrubs/fed) when inter-planted with barley, and fertilized with phosphorus plus sulfur.

Table 5. Carbohydrate content of each component of the fodder plantations.

Fertilizer	Carbohydrate content (%)															
treatment	D = 200 A + 100 M			D = 200 A + 200 M			D = 200 A + 300 M			D = 200 A + 400 M			Total			
(P + S)	B	V	Mean	B	V	Mean	B	V	Mean	B	V	Mean	B	V	Mean	
Acacia saligna																
Without	12.8	11.4	12.1	15.0	11.9	13.5	17.1	15.7	17.4	22.2	19.0	20.6	17.3	14.5	15.9	
With	17.4	12.7	15.1	21.9	13.2	17.6	20.8	19.0	19.9	23.0	21.8	22.4	20.8	16.7	18.8	
Mean	15.1	12.1	13.6	18.5	12.6	15.6	20.0	17.4	18.9	22.6	20.4	21.5	19.1	15.6	17.4	
LSD at 5% for:	D = 1.4			S = 1.4			F = 1.0									
	Years = 1.0															
Medicago arborea																
Without	29	25	27	30	27	29	31	30	31	34	33	34	31	29	30	
With	37	31	34	37	33	35	38	35	37	41	36	39	38	34	36	
Mean	33	28	31	34	30	34	35	33	34	33	35	37	35	32	33.5	
LSD at 5% for:	D = 1.4			S = 0.9			F = 1.4									
	Years = 0.9															
Herbaceous crops (barley or Vicia)																
Without	35.3	21.0	28.2	37.5	24.0	30.8	39.0	30.0	34.5	40.5	34.5	37.5	36.2	27.4	32.8	
With	34.5	19.5	27.0	34.5	21.0	27.8	36.0	27.0	31.5	36.8	33.0	34.9	35.5	25.1	30.3	
Mean	34.7	20.3	27.6	36.0	22.5	29.3	37.5	28.5	33.0	38.7	33.8	36.2	36.9	26.3	31.6	
LSD at 5% for:	D = 1.3			S = 1.3			F = 0.7									
	S × F = 1.0			Years = 0.01												

A = *Acacia*; M = *M. arborea*; B = Barley; V = *Vicia*; D = density; F = fertilizer; S = species.

Table 6. Crude protein content of each component of the fodder plantations.

Fertilizer treatment (P + S)	Crude protein content (%)														
	D = 200 A + 100 M			D = 200 A + 200 M			D = 200 A + 300 M			D = 200 A + 400 M			Total		
	B	V	Mean	B	V	Mean	B	V	Mean	B	V	Mean	B	V	Mean
<i>Acacia saligna</i>															
Without	15.3	18.7	17.0	15.6	16.8	16.2	13.4	18.1	15.8	13.3	17.6	15.5	14.4	17.8	16.1
With	18.9	20.5	19.7	21.5	19.0	20.3	17.5	19.7	18.6	17.2	20.1	18.7	18.7	19.8	19.3
Mean	17.1	19.6	18.4	18.6	17.9	18.3	15.5	18.9	17.2	15.3	18.9	17.1	16.6	18.8	17.7
LSD at 5% for:	Density = 0.4 S x F = 0.5			Species = 0.4 Years = 0.3			Fertilizer = 0.3								
<i>Medicago arborea</i>															
Without	15.6	16.3	16.0	17.5	16.7	17.1	15.8	15.1	15.5	15.6	14.9	15.3	16.1	15.8	16.0
With	21.1	19.0	20.1	18.7	18.1	18.4	15.7	18.8	18.8	17.9	16.5	17.2	19.1	18.1	18.6
Mean	18.4	17.7	18.1	18.1	17.4	17.9	17.3	17.0	17.2	16.8	15.7	16.3	17.6	17.0	17.3
LSD at 5% for:	Density = NS D x S = 47			Species = NS S x F = 1.1			Fertilizer = 0.6 Years = 0.4			D x S x F = 1.6					
Herbaceous crops (barley or <i>Vicia</i>)															
Without	16.3	17.9	17.1	12.4	16.7	14.6	12.2	15.0	13.6	12.8	19.7	16.3	13.4	17.3	15.4
With	19.3	24.7	22.0	14.8	16.9	17.2	14.5	18.5	16.5	15.1	21.2	18.2	15.9	21.0	18.5
Mean	17.8	21.3	19.6	13.6	18.2	15.9	13.4	16.8	15.1	14.0	20.5	17.3	14.7	19.2	17.0
LSD at 5% for:	Density = NS			Species = 0.6			Fertilizer = .01			D x S x F = 40					

A = *Acacia*; M = *M. arborea*; B = Barley; V = *Vicia*; D = density; F = fertilizer; S = species.

Crude Fiber Content

Table 7 summarizes the effect of the treatments on crude fiber content for each component of the fodder plantation. Crude fiber content of *Acacia* was not affected by the population density of the inter-planted *M. arborea*. However, crude fiber content of *M. arborea* shrubs did increase significantly as population density increased: it was 13%, 18%, and 19% for population densities of 100, 300, and 400 shrubs/fed, respectively. This effect is probably the result of competition within the dense *M. arborea* plantation for essential growth requirements, especially light. This leads to the elongation of plant organs and causes an increase in crude fiber content as a mechanical component for supporting such growth.

Crude fiber content of barley and *Vicia* increased significantly as the population density of *M. arborea* increased. Crude fiber content for barley was 22.4, 24.2, 25.0, and 25.9%, while for *Vicia* it was 17.2, 17.8, 18.8, and 19.9% at *M. arborea* population densities of 100, 200, 300, and 400 shrubs/fed, respectively. This increase may be due to the competition for light and essential growth requirements at intense densities. Both *Acacia* and *M. arborea* showed significantly higher crude fiber content when inter-planted with barley, rather than *Vicia*. Crude fiber content of *Acacia* fodder, when inter-planted with barley and *Vicia*, was 24 and 22%, respectively. The corresponding crude fiber contents for *M. arborea* fodder were 18 and 15%, respectively.

Barley contained 24.4% crude fiber, while *Vicia* contained 18.4%, a significant difference of 33%. This result was expected, as cereal crops contain more crude fiber content than leguminous crops. The fertilization treatment significantly reduced the crude fiber content of both *Acacia* and *M. arborea* fodder, compared with the unfertilized control. Crude fiber content of *Acacia* was 21 and 24% for the fertilized and unfertilized treatments, respectively. Crude fiber content of *M. arborea* was 15 and 18%, respectively.

Crude fiber content for fertilized barley was 26.5%, compared to 22.2% for the control. For *Vicia*, crude fiber content was 19.8 and 17.0%, respectively. Fertilization helped create soil conditions that stimulate better growth through the accumulation of better nutritive materials, such as carbohydrates, as compared to crude fiber content. This again proves the role of phosphorus and sulfur in upgrading the physical and chemical properties of calcareous soils.

Medicago arborea shrubs contained the highest crude fiber content (19.0%) at population densities of 300 and 400 shrubs/fed when inter-planted with barley, as opposed to *Vicia*. Generally, increasing the population density of *M. arborea* did not significantly affect the crude fiber content of *Acacia*, but did increase both its own fodder crude fiber content, and the crude fiber content of the inter-planted herbaceous fodder crop.

Table 7. Crude fiber content of each component of the fodder plantations.

Fertilization treatment (P + S)	Crude fiber content (%)														
	D = 200 A + 100 M			D = 200 A + 200 M			D = 200 A + 300 M			D = 200 A + 400 M			Total		
	B	V	Mean	B	V	Mean	B	V	Mean	B	V	Mean	B	V	Mean
<i>Acacia saligna</i>															
Without	23	22	23	22	23	23	25	23	24	29	24	27	25	23	24
With	21	17	19	20	20	20	22	21	22	23	20	22	22	20	21
Mean	22	20	21	21	22	22	24	22	23	26	22	25	24	22	23
LSD at 5% for:	D = NS			S = 1.7			F = 0.8			D x S x F = 40					
	D x F = 1.6			Years = 1.2											
<i>Medicago arborea</i>															
Without	17	11	14	19	16	18	20	17	19	21	19	20	19	16	18
With	11	9	12	16	14	15	18	15	16	17	16	17	16	14	15
Mean	16	10	13	18	15	17	19	16	18	19	18	19	18	15	17
LSD at 5% for:	D = 1.3			S = 1.1											
	D x S = 1.9			Years = 0.9											
Herbaceous crops (barley or <i>Vicia</i>)															
Without	25.2	18.3	21.8	25.1	18.7	21.9	27.9	20.0	24.0	27.8	22.2	25.0	26.5	19.8	23.2
With	19.5	16.0	17.8	23.2	16.8	20.0	22.0	17.5	19.8	23.9	17.0	20.8	22.2	17.0	16.9
Mean	22.4	17.2		24.2	17.8	20.9	25.0	18.8	21.9	25.9	19.9	22.9	24.4	18.4	21.4
LSD at 5% for:	D = 1.0			S = 1.0			F = 0.5								
	S x F = 20			Years = 0.7											

A = *Acacia*; M = *M. arborea*; B = Barley; V = *Vicia*; D = density; F = fertilizer; S = species.

Acacia and *M. arborea* fodders, when inter-planted with barley, had higher crude fiber content than *Vicia*. Of course, barley contains significantly higher crude fiber content than *Vicia*, due to its unique growth habits and specifications. The phosphorus plus sulfur treatment significantly reduced the crude fiber content for all components of the plantations. This decrease was at the expense of the increase in crude protein, carbohydrates, and phosphorus contents previously reported.

Ether extract

Ether extract was not significantly affected by the treatments under study (Table 8). This result proves the value of the fertilization treatment in improving the quality of the fodder crops in terms of nutritive value.

Table 8. Effect of treatments on ether extract (% on a dry matter basis).

Limits	Leguminous shrubs		Herbaceous crops	
	<i>Acacia</i>	<i>M. arborea</i>	Barley	<i>Vicia</i>
Maximum	4.1	3.5	7.4	8.2
Minimum	2.4	1.8	5.0	5.3

Total Digestible Nutrients

Results in Table 7 show that the various densities of *M. arborea* did not affect total digestible nutrients (TDN) of *Acacia* fodder. However, the TDN of *M. arborea* varied slightly according to population density: 45% at 100 shrubs/fed and 49% at 400 shrubs/fed, a significant increase of 9%. This increase may be due to the increase in carbohydrate and fiber contents, as discussed above. The TDN of barley (58%) was slightly but significantly higher than that of *Vicia* (52%). This result may be due to the higher carbohydrate and fiber contents of barley, when compared with *Vicia*.

Each component of the plantation exhibited an increase in TDN, compared with the control, as a result of the fertilization treatment. TDN content was: 44% for fertilized *Acacia*, and 41% for the unfertilized control; 50% for fertilized *M. arborea* and 45% for the unfertilized control; 58% for fertilized barley and 57% for the unfertilized control; and 53% for fertilized *Vicia* and 52% for the unfertilized control. This increase corresponds with the increases in carbohydrate and fiber contents. The addition of the fertilization treatment to calcareous soils with high pH and limited nutrients helped correct the soil imbalance. This reflects upon the productivity and quality of the proposed agroforestry fodder plantation system.

The chemical constituents of each of the fodder components are similar to those reported by Church (1980) and Trevino et al. (1981).

Table 9. Ether extract for each component of the fodder plantations.

Fertilization treatment (P + S)	Ether extract content (%)														
	D = 200 A + 100 M			D = 200 A + 200 M			D = 200 A + 300 M			D = 200 A + 400 M			Total		
	B	V	Mean	B	V	Mean	B	V	Mean	B	V	Mean	B	V	Mean
<i>Acacia saligna</i>															
Without	3.7	3.6	3.7	3.1	2.5	2.8	2.9	2.6	2.8	2.6	2.4	2.5	3.1	2.8	3.0
With	4.1	4.0	4.1	3.4	3.3	3.4	3.3	3.0	3.2	2.8	2.7	2.8	3.4	3.3	3.4
Mean	3.9	3.8	3.9	3.3	2.9	3.1	3.1	2.8	3.0	2.7	2.6	2.7	3.3	3.1	3.2
<i>Medicago arborea</i>															
Without	3.3	3.4	3.4	3.0	3.3	3.2	2.6	3.0	2.8	2.2	1.8	2.0	2.8	2.9	2.9
With	3.5	3.5	3.5	3.3	3.4	3.4	2.9	3.2	3.1	2.4	2.2	2.3	3.0	3.1	3.1
Mean	3.4	3.5	3.5	3.2	3.4	3.3	2.8	3.1	3.0	2.3	2.0	2.2	2.9	3.0	3.0
Herbaceous crops (barley or <i>Vicia</i>)															
Without	5.0	5.6	5.3	6.0	5.3	5.7	5.8	5.5	5.7	6.6	6.6	6.6	5.9	5.8	5.9
With	5.8	6.8	6.3	6.4	6.8	6.6	6.6	7.2	6.9	7.4	8.2	7.8	6.6	7.3	7.0
Mean	5.4	6.2	5.8	6.2	6.1	6.2	6.2	6.4	6.3	7.0	7.4	7.2	6.3	6.6	6.5

A = *Acacia*; M = *M. arborea*; B = Barley; V = *Vicia*; D = density; F = fertilizer; S = species.

Table 10. Average TDN for each component of the fodder plantations.

Fertilization treatment (P+S)	Average TDN content (%)														
	D = 200 A + 100 M			D = 200 A + 200 M			D = 200 A + 300 M			D = 200 A + 400 M			Total		
	B	V	Mean	B	V	Mean	B	V	Mean	B	V	Mean	B	V	Mean
<i>Acacia saligna</i>															
Without	44	41	42.5	46	42	44	46	45	45.5	48	49	48.5	46	44	45
With	48	45	46.5	50	46	48	49	48	48.5	51	51	51	50	48	49
Mean	46	43	44.5	48	44	46	47.5	46.5	47	49.5	50	49.8	48	46	47
<i>Medicago arborea</i>															
Without	49	47	48	49	44	46.5	49	46	47.5	51	49	50	50	47	48.5
With	52	47	49.5	53	46	49.5	51	49	50	52	50	51	52	48	50
Mean	50.5	47	48.8	51	45	48	50	47.5	48.8	51.5	49.5	50.5	51	47.5	49.3
Herbaceous crops (barley or <i>Vicia</i>)															
Without	47	45	46	48	43	45.5	48	46	47	49	49	49	48	46	47
With	50	46	48	52	46	49	50	49	49.5	52	50	51	51	48	49.5
Mean	48.5	45.5	47	50	44.5	47.3	49	47.5	48.3	50.5	49.5	50.0	49.5	47	48.3

A = *Acacia*; M = *M. arborea*; B = Barley; V = *Vicia*; D = density; F = fertilizer; S = species.

References

- AOAC (Association of Official Agriculture Chemists). 1970. Official methods of analysis. AOAC Washington (11th ed.). Washington, DC.
- Church, D.C. 1980. Digestive physiology and nutrition of ruminants. Vol. 3, Procial Nutrition (2nd ed.).
- Devlin, R.M. 1984. Plant physiology. Handbook. Van Nostrand and Reinhold Comp., New York.
- Dubois, M.K., J.K. Gilles, P.A. Hamilton and F. Smith. 1950. A calorimetric method for the determination of sugar. *Nature* 168–169.
- El-Hakeem, M.S. 1990. Effect of forage mixtures at different mixing ratios on yield and quality. *Egyptian Journal of Applied Science* 5(7): 804–817.
- Farid, M.F.A., M.F. Wardeh, L. Cerol, L. Haris and H. Loid. 1979. Arab and Middle East Tables of Feed Composition. Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) and Utah Agric. Exp. Stat.
- Frie, E., K. Pyer and E. Schutz. 1964. Determination of phosphorus by ascorbic acid. *Schw. Landwert Sch. Forschung. Heft* 3: 318–328.
- Le Clerg, E.L., W.H. Leonard and A.G. Clark. 1966. Field Plot Technique. Burgtoss Publishing Co. Minneapolis Minnesota, USA.
- Lunnan, T. 1987. Mixtures of barley and legumes for green feed. Nordisk-Jordbrugsfors Kning C.F. *Bibliographic Citation* 69(2): 293.
- Peach, K. and M.V. Tracey. 1956. Modern Methods of Plant Analysis. Springer-Verlag, Berlin.
- Radwan, M.S. and A.K. El-Fakhry. 1976. Forage Crops and Pastures. Agronomy Dept., Fac. of Agric. and Forestry, El-Mosel Univ.
- Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics (2nd ed.). McGraw-Hill Co. NY, USA.
- Tiedman, J.A. and D.E. Johnson. 1992. *Acacia cyanophylla* for forage and fuel-wood in North Africa. *Agroforestry Systems* 17: 169–180.
- Trevino, T., R. Caballero and J. Gil. 1981. The utilization of tare (*Vicia monantha* Pehiz) as a forage plant, chemical composition, digestibility and energy value at different stages of maturity. *Pastos* 11(2): 461–370.

Effectiveness of Hybridization for Improving Some Characters of *Atriplex canescens*: Germination and Survival Performance

O.H. Soliman¹ and J.R. Barrow²

¹Field Crop Research Institute, ARC, Giza, Egypt

²New Mexico State University, Las Cruces NM, USA

Abstract

Mass selection was compared with intraspecific hybridization of selected parental materials and their hybrids for its effectiveness in improving germination and survival performance of fourwing saltbush (*Atriplex canescens*). Selected fourwing saltbush (4n) tetraploid populations from six different sites in New Mexico, USA, were established in a breeding nursery at the Plant Science Research Center, NMSU, in July 1990. In 1992, a top-cross breeding scheme was used to perform intercrossing between the common pollinator and the five female populations. Entries, including six parents and five hybrids, were investigated in two experiments. In the first experiment, rate and percentage of seed germination were determined in a greenhouse. In the second experiment (September 1993), percentage of seed germination and survival of seedlings were analyzed in the field. Percentage of seed germination of the parental populations was significantly higher than their F₁ hybrids. The reduced germination of hybrids appeared to be influenced by the genotype of the common pollinator and proved that the crossing scheme was effective. No difference in survival was observed for seedlings of the parents or their F₁ hybrids at the Jornada Experimental Range. However, there were significant differences in percentage of germination. A high correlation coefficient between seed germination in the greenhouse and field germination indicated that a greenhouse might be suitable for such germination tests. These results indicate that mass selection within the parental population may be more effective than hybridization for improving germination and survival performance of native fourwing saltbush populations, especially with unselected and highly genetically variable populations. Mass selection within adapted populations should be carried out for the various ecological sites with similar environmental conditions

Key words: mass selection, intraspecific hybridization, F₁ hybrids, parental populations, top-cross, germination, and survival performance.

Introduction

Shrubby chenopods, or saltbushes, cover millions of hectares of the world's arid, alkaline ranges. They are of particular importance in the deserts of North America,

Australia, Africa, and Eurasia (Branson 1966). Fourwing saltbush (*Atriplex canescens* [Pursh] Nutt.) is distributed over western North America, from the Great Plains to the Pacific coast, and from southern Canada to central Mexico. Its abundance, evergreen habitat, drought resistance, high palatability, and high nutritional quality make it one of the most important shrubs in this region. Given its wide geographical distribution, it is well-adapted to a variety of climatic and edaphic conditions.

Fourwing saltbush grows well on moderately saline sites, but is not restricted to these areas. It is used to reseed rangelands and reclaim surface-mined lands (Springfield 1970). Fourwing saltbush is a valuable forage that provides essential nutrients, such as protein, phosphorus, calcium, and carotene year round for livestock and wildlife (Cordova and Wallace 1975; Cook et al. 1977). Fourwing saltbush exhibits considerable morphological variation, particularly with respect to leaf and fruit bract shape and size.

This diversity can be partially attributed to environmental factors, but is primarily under genetic control (Stutz and Sanderson 1979). The high genetic variability for these traits suggests the possibility that mass selection would be an effective breeding method. Its dioecious nature allows for the possibility of natural intercrossing.

However, germplasm development through selection or genetic manipulation, or both, has been limited (McArthur 1988). This study compared mass selection with intermating of selected parental material for their effectiveness in improving fourwing saltbush germination and survival performance.

Material and Methods

Breeding Materials

Seed from multiple native tetraploid ($2n = 4 \times = 36$) fourwing saltbush plants (50 plants from each site) was hand-harvested in December 1989 from six sites in New Mexico (Table 1).

These six populations represented different ecotypes and had good range values such as hardiness, palatability, sustained forage production, and evergreen tendency. Seed was first dewinged in a Champion Hammer Mill, 2 HP motor, 700 RPM (0.63 cm hole screen), and then stored in paper bags at room temperature until planted.

Table 1. Locations, elevation, and average annual precipitation where fourwing saltbush seed was collected in New Mexico (December 1989).

Population number	Ecotype	County	Location	Elevation (m)	Precip. (mm) [†]
89-1	Carrizozo	Lincoln	Highway 54 miles post 101 south of Carrizozo	1,475	250
89-2	Fort Stanton	Lincoln	Fort Stanton just east of regional airport	2,145	380
89-4	Ancho	Lincoln	1/2 mile east of Ancho	1,981	350
89-8	Ghost Range	Rio Arriba	Highway 84 miles post 231 near Ghost Ranch	1,981	300
89-12	Jornada	Dona Ana	Jornada Experimental Range Headquarters 23 miles north of Las Cruces	1,371	229
89-13	Deming	Luna	Highway 180 miles post 154 north of Deming	1,371	240

[†] Average annual precipitation.

Breeding Nursery

The breeding nursery was set up at the NMSU Plant Science Research Center (PSRC) on 25 July 1990. In April 1990, seed of the six parent populations was sown in plastic tube packs (5 cm × 25 cm × 20 cm) in a greenhouse with about 25% of natural sunlight. Seedlings were watered every three days until transplanted to the breeding nursery. Forty seedlings (25 cm tall) from each population were transplanted into rows 1.8 m apart in an intermingling planting scheme with 12 rows. Two rows were allocated for each population. The nursery was irrigated immediately after transplanting, and again 2 months later. Good establishment was obtained, and no further irrigation was applied. By the spring of 1992, all plants had reached reproductive maturity. In the incomplete top-cross scheme, population No. 89-13 was used as the common pollinator, and all pollen-producing plant parts were removed from populations 89-1, 89-2, 89-4, 89-8, and 89-12. Southwesterly winds dispersed pollen over the five female populations. In December 1993, hybrid seed was hand-harvested from four randomly selected plants within each of the female populations. Parent seed was hand-harvested from several randomly selected plants and bulked from each native site in December 1992. Seed was dewinged and cleaned as described above. The plant material used in experiments I and II consisted of 26 entries of six parents and four female plants of each of the five hybrids. Percentage heterosis for mid-parent and high-parent was calculated according to the equation of Laosuwan and Atkins (1977).

Experiment I: greenhouse germination

A randomized design was used to evaluate germination in the greenhouse. Thirteen plastic flats (50.8 cm × 25.4 cm × 5.1 cm) were filled with a sandy rangeland soil. Each flat contained eight 25 cm rows spaced 5 cm apart. Each entry was randomly

replicated in four rows. On 7 March 1993, two hundred seeds for each replicate were sown in each row. Flats were watered every 2 days. The number of cotyledons emerging from the soil surface was recorded each week for 20 weeks. Percentage of germination for the parents and their hybrids was submitted to 20 separate analyses of variance (Steel and Torrie 1980). The percentage of germination was calculated in terms of $100 \times (\text{number of seeds germinated}/200)$.

Experiment II: Jornada germination and survival

This experiment was conducted at the Jornada Experimental Range, NMSU, where there are several soil types, ranging from fine sandy loam to clay loam. The climate there is typical of a semi-arid grassland.

Average annual precipitation over 30 years is 228 mm, with 56% occurring between 1 July and 30 September. The average annual temperature is 16°C; June is the hottest month, with an average maximum temperature of 36°C; and January is the coldest, with an average maximum temperature of 13°C. The frost-free period averages 200 days/year (Dept. of Comm. 1990). Each entry was arranged in a randomized complete block design with four replications (blocks). Each block (8 m $\times$ 25 m) was established in a shallow gully. Blocks were spaced 50 m apart and each block contained 104 plots. Each block was fenced with portable metal panels to eliminate damage by grazing animals.

On 19 May 1993, 200 seeds/entries were randomly sown in each experimental unit and protected from damage by rodents by galvanized wire mesh cages (60 cm $\times$ 30 cm $\times$ 0.5 cm). Using a portable sprinkler system, the blocks were irrigated twice to aid in establishment: once immediately after planting and again one week later. No further irrigation was applied. Eight weeks after seeding, merging seedlings were counted and calculated, as above. Sixteen weeks after seeding, the percentage of survival was calculated as the number of surviving seedlings $\div$ number of seeds germinated $\times$ 100.

Results and Discussion

Greenhouse Germination

Analysis of variance for greenhouse germination indicated that a significant ($P < 0.01$) phenotypic variance was present both between and within parents and their F_1 hybrids. These results were expected, as genetic diversity, in terms of maternal seed germination, between the parents and their F_1 hybrids (9.50 and 2.04%) started to appear after week 2, and remained stable from weeks 3 to 6 (Table 2). This agrees with the observation of Springfield (1970), that emergence is complete within 12 to 20 days.

Parental germination in week 3 (9.5%) was similar to that reported by Stutz et al. (1975). Germination of F_1 hybrids was lower than their parents (Table 2). Parent populations 89-1, 89-2, 89-4, 89-8, and 89-12 germinated at 11.00, 13.00, 11.63, 13.25, and 6.75%, respectively; however, the male population No. 89-13 only germinated at 1.38%. The hybrid populations (13×1 , 13×2 , 13×4 , 13×8 and 13×12) germinated at 1.38, 3.00, 2.22, 1.91, and 1.72%, respectively (Fig. 1).

Table 2. Average percentage of germination for five hybrid and six parent populations of fourwing saltbush from weeks 1 to 6 in the greenhouse.

Type of plant	Germination percentage (week)					
	1	2	3	4	5	6
Hybrid population						
89-13 $\times$ 89-1	0.03a	0.69a	1.38a	1.34a	1.31a	1.34a
89-13 $\times$ 89-1	0.22a	1.16a	3.00b	3.09b	3.06bc	3.09bc
89-13 $\times$ 89-1	0.25a	1.22a	2.22ab	2.13ab	2.16ab	2.16ab
89-13 $\times$ 89-1	0.16a	1.13a	1.91ab	1.69ab	1.59a	1.59a
89-13 $\times$ 89-1	0.22a	0.78a	1.72ab	1.63a	1.41a	1.41a
Mean	0.18	0.99	2.04	1.98	1.91	1.92
Range	0.03–0.25	0.69–1.22	1.38–3.00	1.34–3.09	1.31–3.06	1.34–3.09
SE	0.13	0.33	0.51	0.48	0.44	0.44
Parent population						
89-1	0.00a	5.13b	11.00d	11.25d	10.50d	10.38d
89-2	0.50ab	9.38cd	13.00d	12.38d	12.38d	12.38d
89-4	0.50ab	8.25c	11.63d	10.88d	11.25d	11.25d
89-8	1.00b	10.75d	13.25d	13.00d	13.00d	12.75d
89-12	0.50ab	5.50b	6.75c	6.00c	4.75c	4.63c
89-13	0.00a	0.88a	1.38ab	1.38ab	1.25a	1.25a
Mean	0.42	6.65	9.50	9.15	8.85	8.77
Range	0.00–1.00	0.88–10.75	1.38–13.25	1.38–13.00	1.25–13.00	1.25–12.75
SE	0.27	0.65	1.02	0.95	0.88	0.88

Means within columns with different letters differed significantly ($P < 0.05$) for all types of plants. SE = standard error.

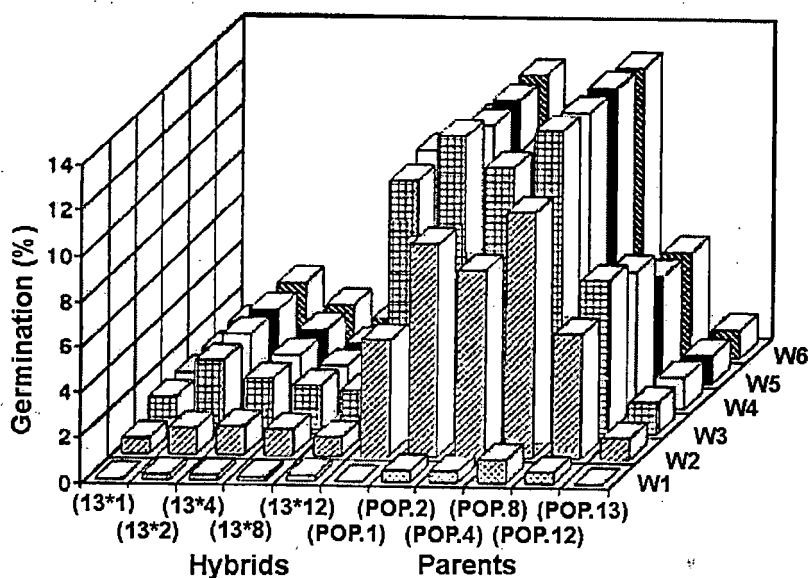


Figure 1. Percentage of germination over 6 weeks for parents and their F_1 hybrids of fourwing saltbush populations. Parents had significantly ($P < 0.01$) higher germination than hybrids. The male population (No. 13) had a negative impact on the hybrids.

Jornada Germination and Survival

Germination of fourwing saltbush in the field (Jornada) was significantly different ($P < 0.01$) between the parents and their F_1 hybrids. However, survival percentages exhibited no difference ($P < 0.05$) either between or within the parents and their F_1 hybrids (Table 3).

The mean germination of the parents was quite high (15.41%) compared to their F_1 hybrids (3.63%) (Fig. 2). The survival percentage of the parents was also higher (32.48%) than the F_1 hybrid mean of 23.17% (Fig. 3). Significant negative heterotic responses (Table 4) were found for both germination and survival, indicating that intermating fourwing saltbush populations results in inferior F_1 hybrids.

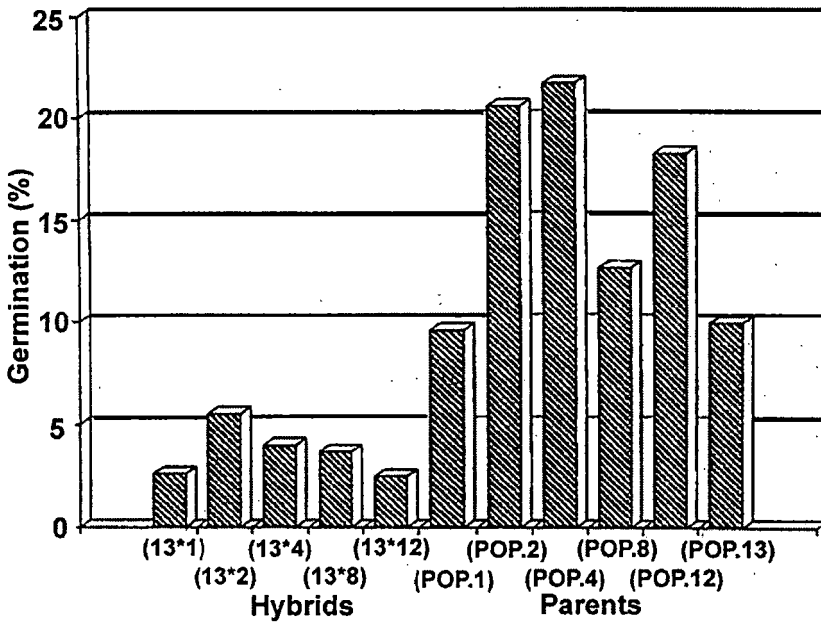


Figure 2. Mean percentage germination of parents and their F₁ hybrids of fourwing saltbush populations. The difference between the two groups was significant ($P < 0.01$).

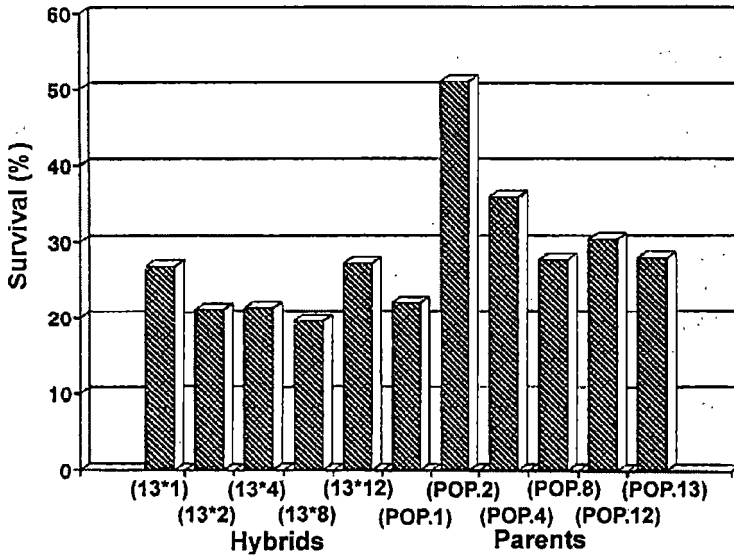


Figure 3. Mean survival percentage of parents and their F₁ hybrids of fourwing saltbush populations. No significant difference ($P < 0.05$) were present, either between or within the two groups.

Table 3. Mean germination and survival percentages for five hybrids and six parent populations of fourwing saltbush at the Jornada Experimental Range.

Type of plant	Germination percentage (8 weeks)	Survival percentage (16 weeks)
Hybrid population		
89-13 × 89-1	2.59a	26.84a
89-13 × 89-1	5.46ab	20.97a
89-13 × 89-1	3.99ab	21.24a
89-13 × 89-1	3.67a	19.53a
89-13 × 89-1	2.46a	27.26a
Mean	3.63	23.17
Range	2.46–5.46	19.53–27.26
SE	1.24	4.15
Parent population		
89-1	9.53bc	21.97a
89-2	20.56de	51.03b
89-4	21.63de	35.88ab
89-8	12.63cd	27.68ab
89-12	18.22cde	30.33ab
89-13	9.91bc	27.99ab
Mean	15.41	32.48
Range	9.53–21.63	21.97–51.03
SE	2.48	8.30

Means within column with different letters differed significantly ($P < 0.05$) for all types of plants. SE = standard error.

Table 4. Germination and survival percentages of parents and the means of their F_1 crosses, and heterosis of the F_1 s expressed as a percent of mid-parent and high-parent for five population crosses of fourwing saltbush at the Jornada Experimental Range.

Type of cross	Generation			Heterosis		
$P_1 \times P_2$	P_1	P_2	Parent mean	F_1	MP%	HP%
Percent germination at 8 weeks						
89-13 × 89-1	9.91	9.53	9.72	2.59	-73.35	-73.86
89-13 × 89-2	9.91	20.56	15.24	5.46	-64.17	-73.44
89-13 × 89-4	9.91	21.63	15.77	3.99	-74.70	-81.55
89-13 × 89-8	9.91	12.63	11.27	3.67	-67.44	-70.94
89-13 × 89-12	9.91	18.22	14.07	2.46	-82.52	-86.50
Percent survival of seedlings after 16 weeks						
89-13 × 89-1	27.99	21.97	24.98	26.84	7.45	-4.11
89-13 × 89-2	27.99	51.03	39.51	20.97	-46.92	-58.91
89-13 × 89-4	27.99	35.88	31.94	21.24	-33.50	-40.80
89-13 × 89-8	27.99	27.68	27.84	19.53	-29.85	-30.23
89-13 × 89-12	27.99	30.33	29.16	27.26	-6.52	-10.12

Conclusions

Fourwing saltbush exhibits a wide variation in seed germination from population to population.

This study shows that hybridization has a significant negative impact on percentage of germination. It appears that the male parent influences low germination in the hybrids.

Greenhouse germination was significantly correlated with field germination, indicating that a greenhouse could be used for germination.

These results show that mass selection in unselected and genetically variable populations would be more effective than hybridization for improving germination and survival performance of native fourwing saltbush population.

References

- Branson, F.A. 1966. Geographic distribution and factors affecting the distribution of salt desert shrubs in the United States. Pages 13–43 in *Introduction to Plant Breeding* (F.N. Briggs and P.F. Knowles, eds.). USDA Bureau of Land Management Salt Desert Shrub Symposium, Cedar City, Utah. Reinhold Publishing.
- Cook, C.W., R.D. Child and L.L. Larson. 1977. Digestible protein in range forages as an index to nutrient content and animal response. *Range Sci. Dept. Sci. Ser. No. 29*. Colorado State Univ., Fort Collins.
- Cordova, F.J. and J. Wallace. 1975. Nutritive value of some browse and forb species. *Proceedings of the West. Sec. American Society of Animal Science* 26: 160–162.
- Department of Commerce. 1990. Climatological data, New Mexico. National Oceanic and Atmospheric Administration.
- Laosuwan, P. and R.E. Atkins. 1977. Estimates of combining ability and heterosis in converted exotic sorghums. *Crop Science* 17: 47–50.
- McArthur, E.D. 1988. New Plant Development in range management. Pages 81–112 in *Vegetation Science Applications for Rangeland Analysis and Management* (P.T. Tueller, ed.). Kluwer, The Netherlands.
- Springfield, H.W. 1970. Germination and establishment of fourwing saltbush in the southwest. USDA For. Serv. Res. Pap. RM-55. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colorado.
- Steel, R.G.D. and J.H. Torrie. 1980. *Principles and Procedures of Statistics* (2nd ed.). McGraw Hill, New York, NY.
- Stutz, H.C., J.M. Melby and G.K. Livingston. 1975. Evolutionary studies of *Atriplex*: A relic gigas diploid population of *Atriplex canescens*. *American Journal of Botany* 62: 236–245.
- Stutz, H.C. and S.C. Sanderson. 1979. The role of polyploidy in the evolution of *Atriplex canescens*. Pages 615–621 in *Arid Land Plant Resources* (J.R. Goodin and D.K. Northington, eds.). Texas Tech. Univ. Press, Lubbock.

Contribution à la Définition d'une Méthode d'Estimation de la Biomasse d'*Atriplex* *nummularia* au Maroc Oriental

M. Acherkouk
INRA, Oujda, Maroc

Résumé

L'étude a été menée en 1993 dans une plantation expérimentale de 0.8 ha installée en décembre 1989 à Sidi Amer (altitude : 1035 m ; Pluviométrie : 162 mm sur 22 ans et 112 mm pour 1992/93). Son objectif était d'estimer la biomasse consommable de cinq écotypes d'*Atriplex nummularia* à partir des paramètres de croissance. La méthode d'estimation consistait à mesurer la hauteur et la circonférence de la plante puis la défolier à la main entièrement en vue de déterminer la matière sèche. Des corrélations entre celle-ci et les paramètres de croissance sont établies à l'aide des équations de régression. Les résultats obtenus révèlent que la matière sèche est maximum chez l'écotype "Ouarzazate" (414 kg/ha) et minimum chez l'écotype "Oued El Rarak" (105 kg/ha) avec une moyenne générale pour tous les écotypes de l'ordre de 250 kg/ha. Quant à l'estimation de cette biomasse à l'aide des paramètres de croissance, la formule de régression incluant à la fois la hauteur et la circonférence reste la plus précise et la plus significative ($R^2 = 0,76$) par rapport à ce qu'elle serait si l'on considérait les deux paramètres séparément. Cette formule, une fois validée, permettrait d'apprécier la biomasse de l'*Atriplex nummularia* sans détruire la plante.

Mots-clés : *Atriplex nummularia*, écotype, biomasse, paramètres de croissance, équation de régression.

Abstract

This study was carried out in 1993 on an experimental plantation of *Atriplex nummularia* established in December 1989 (altitude 1,035 m; 162 mm average rainfall over 22 years, and 112 mm in 1992/93). The purpose was to estimate the biomass of five ecotypes of *A. nummularia* based on growth parameters (GP). The height (H) and circumference (C) of the plant were measured, and plants were then hand defoliated to evaluate the dry matter (DM). Correlation between DM and GP was established using regression equations. The DM was highest with the "Ouarzazate" ecotype (414 kg/ha) and lowest with the "Oued El Rarak" ecotype (105 kg/ha). The average for all ecotypes was about 250 kg/ha. The regression formula that gave the best correlation ($R^2 = 0.76$) included both H and C in the

equation. Consequently, this method gives a good estimate of the biomass of *Atriplex nummularia* without destroying the plant.

Introduction

Dans les zones arides et semi-arides, l'introduction d'arbustes fourragers pourrait constituer une technique adéquate de réhabilitation des pâturages dégradés. Dans ces régions, plusieurs programmes de plantation d'arbustes fourragers, notamment à base d'*Atriplex nummularia* sont réalisés et/ou en cours de réalisation. Toutefois, les données relatives à leurs comportement, productivité et mode d'exploitation, demeurent encore très limitées sinon indisponibles dans le contexte "complexe" des parcours steppiques du Maroc Oriental. La connaissance de leur productivité dans ces zones est fondamentale de développer une méthode non destructive permettant pour une exploitation raisonnable. L'objectif de cette étude est d'estimer la biomasse d'*Atriplex nummularia* à l'aide des paramètres facilement mesurables de croissance.

Matériels et Méthodes

Description du Site

L'étude a été conduite dans une plantation expérimentale de 0.8 ha installée en décembre 1989 à Sidi Amer, zone pastorale extensive dans laquelle le Service d'Élevage d'Oujda a effectué, en tant que mesure d'amélioration pastorale, une plantation d'*Atriplex nummularia* sur environ 1800 ha. Le site expérimental est situé sur les hauts plateaux à une altitude d'environ 1035 m et à environ 140 km au sud-ouest de Oujda.

Le climat est aride à hiver frais à froid ($Q = 14.3$). La pluviométrie moyenne, très variable dans le temps et dans l'espace, de la station la plus proche (Aïn Béni Mathar) calculée sur 22 ans, est d'environ 162 mm. Durant 1992/93, la pluviosité a été de 111,6 mm. Les températures moyennes (sur 10 ans) maximale et minimale sont respectivement de 23,5 et 5,7°C. Les mois les plus chauds sont juillet et août (36,2 et 35,2°C respectivement); ceux les plus froids sont décembre (-1,7°C) et janvier (-3,1°C). Le sol, à texture limono-sableuse, est très peu profond et développé sur une croûte calcaire affleurante par endroits. La végétation spontanée est très dégradée: l'armoise blanche, *Artemisia herba-alba*, étant l'espèce principale du peuplement naturel d'origine, a quasiment disparu, et a été remplacée par *Anabasis aphyllum*, espèce sans intérêt pastoral.

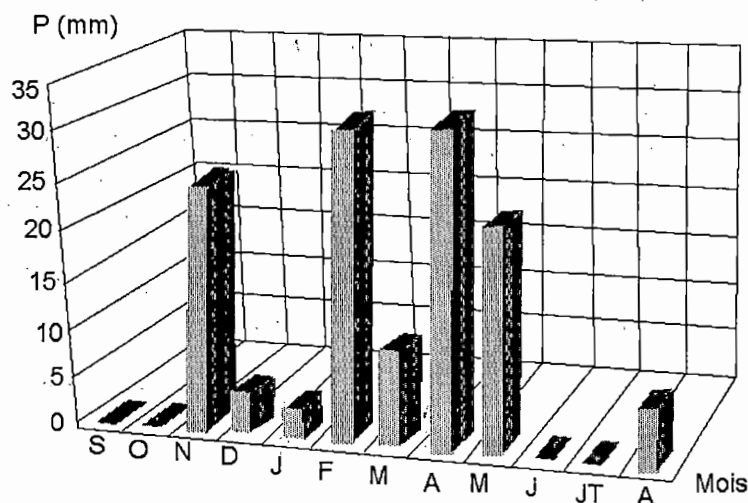


Figure 1. Répartition pluviométrique à Ain Beni Mathar (1992/93).

Paramètres Étudiés et Méthodes de Mesure

Les mesures ont été réalisées au mois de décembre 1992 sur des plants à l'âge de 36 mois. Les paramètres étudiés sur chaque arbuste sont la hauteur maximale (H), la circonférence de la couronne (C), et la biomasse consommable (MS).

Mesure de paramètres de croissance (méthode non destructive)

Les mesures des H et C ont porté sur deux arbustes par écotype et par répétition pour un total de 5 écotypes et 4 répétitions. Les 4 arbustes/10 sont choisis au hasard sur la ligne de contour.

Défoliation (méthode destructive)

L'opération de défoliation a concerné les mêmes arbustes ayant servi pour la mesure de H et C. La défoliation, faite à la main, est totale et a porté sur les feuilles et rameaux tendres. Les échantillons sont pesés pour la matière verte puis passés à l'étuve (64°C pendant 48 heures) pour la matière sèche.

Analyses Statistiques

Les traitements statistiques des données sont effectuées à l'aide du logiciel SYSTAT et ont concerné l'analyse de la variance à un seul facteur de variation.

Résultats et Discussion

Croissance et Production

L'analyse de la variance à un seul facteur de variation (écotype) a concerné trois variables : H, C, et MS. Globalement, une différence significative ($P = 0.05$) entre les écotypes n'est observée que pour C et MS. Les valeurs moyennes des H, C, et MS sont respectivement de l'ordre de 71 cm, 59 cm, et 251 g/arbuste (Tableau 1). Leurs minimum et maximum sont : 37,5–109 cm pour H, 31–93 cm pour C, et 42–920,5 g/arbuste pour MS. Cette dernière dépend, entre autres, de l'écotype. Elle est minimale chez l'écotype "Oued El Raak" (105 g/arbuste) et maximale chez l'écotype "Ouarzazate" (414 g/arbuste). Ce dernier apparaît déjà dans le site expérimental comme étant l'écotype le plus vigoureux et le plus feuillé.

Tableau 1. Croissance et biomasse de cinq écotypes d'*Atriplex nummularia* (valeurs moyennes).

Écotype	H (cm)	C (cm)	MS (g/arbuste)
Australie	71.63	58.31	230.88
Deroua	73.75	72.75	377.98
Ouarzazate	83.13	66.12	414.03
O.El Rarak	60.75	45.94	104.88
B. Slimane	65.88	46.06	128.83
Moyenne	71.03	59.20	251.32

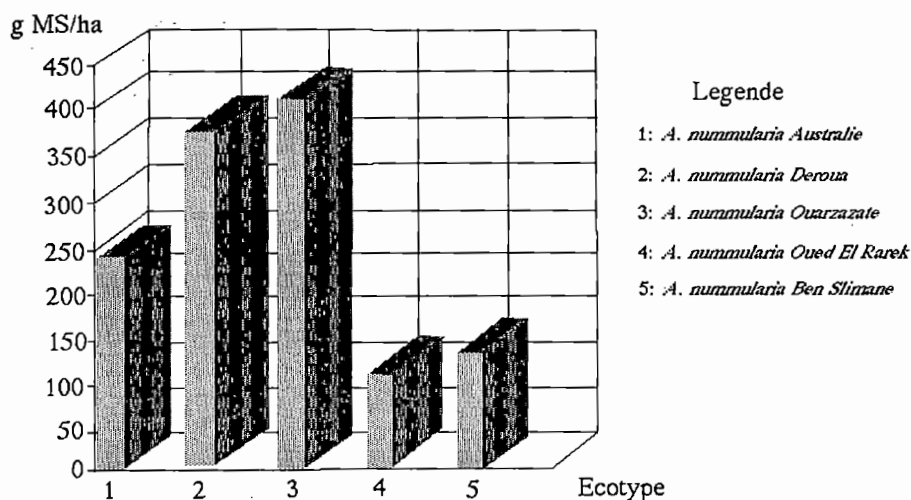
Élaboration des Équations de Régression

Plusieurs chercheurs ont essayé d'établir des formules de régression pour approcher la biomasse à l'aide des paramètres de croissance (Wilson et Harrington 1980 ; Tazi et al. 1991). Le tableau 2 présente les équations de régression où la biomasse de l'*Atriplex nummularia* âgé d'environ 36 mois est fonction de la H et/ou de la C. Que ce soit pour la H, la C ou la combinaison des deux, la biomasse consommable semble être bien estimée par ces paramètres. Cependant, la MS reste plus corrélée aux H et C considérées ensemble ($R^2 = 0.76$) que si elles sont prises séparément ($C:R^2 = 0.67$; $H:R^2 = 0.65$). Pour Tazi et al. (1991), la MS de la biomasse consommable des plants d'*Atriplex nummularia* âgés de 30 mois au sud du Maroc est plutôt mieux corrélée à la C. Ces auteurs rapportent une valeur moyenne de cette biomasse de 420 g/arbuste. Dans des conditions pluviométriques plus favorables en Espagne (350 mm/an), la biomasse de l'*Atriplex nummularia* âgé de 24 mois peut atteindre jusqu'à 2600 g/arbuste (Otal et Correal 1989).

Tableau 2. Equations de régression de la biomasse d'*Atriplex nummularia*.

Droites de régression	r	R ²	R' ²
MS = 6,86 H + 6,66 C - 630,59	0,87	0,76	0,73
MS = 11,17 C - 409,70	0,82	0,67	0,65
MS = 12,39 H - 628,32	0,81	0,65	0,63

Légende : r = coefficient corrélation ; R² = c. détermination ; R'² = R² ajusté.

Figure 2. Production d'*Atriplex nummularia* en fonction d'écotype.

Conclusion

L'*Atriplex nummularia*, 36 mois après sa transplantation dans le périmètre pastoral de Sidi Amer (altitude : 1,035 m ; pluviométrie : 162 mm/22 ans et 112 mm/1992–93) paraît être une espèce performante et résistante aux conditions arides de ce site ; plus particulièrement l'écotype "Ouarzazate." La MS de la biomasse consommable de ce dernier est d'environ 414 g/arbuste.

L'estimation de la production de cette espèce à partir des paramètres de croissance pourrait être effectuée grâce à des formules de régression. La formule améliorant la précision de cette estimation nécessite d'inclure dans son équation la Hauteur et la Circonférence ensemble. Les résultats obtenus peuvent, donc, constituer une référence importante pour raisonner la gestion d'un pâturage à base de cet arbuste.

Références

- Otal, J. y E. Correal. 1989. Productividad primaria y aprovechamiento ovino de *Atriplex nummularia*, arbusto forrajero introducido en el España. Reunion iberica de pastos y forrages. Badajoz-Elvas, España.
- Tazi, M., A. Birouk, B. Hafidi et A. Haimoura. 1991. Comportement d'*Atriplex nummularia* en zone aride du sud marocain. IVème Congrès International des Terres de Parcours, Montpellier, France.
- Wilson, A.D. et G.N. Harrington. 1980. Valeur nutritive des plantes ligneuses fourragères d'Australie. Colloque sur les fourrages ligneux en Afrique. Addis Abeba, Éthiopie.

Improving Feed Resources and Quality in the Dryland Areas of Morocco by Introducing the Strip-alley Cropping System

E. El Mzouri, A. Chriyaa, M. El Mourid and A. Laamari

Centre Aridoculture, INRA, Settat, Morocco

Abstract

Livestock production remains the main component of the farming systems of the semi-arid areas of Morocco. Sheep raising, once conducted under semi-extensive management with lamb production as the primarily objective, is now generally managed under semi-intensive or highly intensive management to increase profits and insure sustainability in these high-risk environments. Forage crops are scarce and rarely cultivated. The rangelands are heavily degraded and subject to soil and phytogenetic erosion. Feed scarcity and low quality generally occur during autumn, coinciding with the most critical physiological stages of the sheep (pregnancy, lambing, and milking). There is thus a need to provide high-quality feed alternatives that can be used during this period. The objectives of this work were: (i) to introduce a strip-alley cropping system that includes forage shrubs inter-cropped with different annual forages (medics, an oat/vetch mixture, and barley/fodder pea); (ii) to reduce the cost of feed; (iii) to provide farmers with good-quality feed and an environmentally sustainable forage production system; and (iv) to train technicians and farmers on establishing, managing, and using these forage alternatives, while protecting natural resources. This work was conducted over two years on three private farms in a semi-arid region of Morocco (Doukkala). The average rainfall of this area is 320 mm/year; soils are degraded and on slopes varying between 10 and 30%. Strip-alley cropping produced energy equivalent to barley production on the same area. In terms of crude proteins, however, strip-alley cropping exceeded barley 2.5–3.3 times. The system improved productivity and quality over the whole growing season and improved the land-equivalent ratio when quality was considered as well as total biological yield. At the same time, natural resources (soil and plant biodiversity) were protected by the use of low-cost and sustainable management. Training farmers and extension agents on establishment, choice of species, and use of these crops increased interest in using the strip-alley system on a larger scale. In conclusion, intensifying biomass production by introducing strip-alley cropping may have a place in unfavorable areas where rainfall is limiting, soils are highly degraded, and dry matter production is urgently needed.

Introduction

Livestock production remains the main component of the farming systems of the semi-arid areas of west-central Morocco (Chaouia, Doukkala, Abda, Rhamna, Shiadma, Zaer, and the phosphate plateaux). Sheep are the main component of the animal production system. However, livestock production has changed over the last few years as a result of successive droughts, the non-availability or the high price of good-quality feed, and the low productivity of the communal rangelands. Most sheep production, once conducted under a semi-extensive management with lamb production as its primarily objective, is now managed under semi-intensive, sometimes highly intensive, management to increase profits and insure the sustainability of livestock holders in these relatively high-risk environments. Like similar regions in North Africa and Western Asia, the livestock production system is heavily integrated with a crop production system with barley or wheat as its main crop. Forage crops are scarce and rarely cultivated. The rangelands are generally heavily degraded and subject to soil and phytogenetic erosion. The major feed resources are: barley grain, barley and wheat straw, green forage barley, forage pea, weedy fallow, crop residue (stubble), and communal rangelands. Some concentrates and alfalfa hay can be bought from local markets. Feed scarcity and low quality occur when the animal's physiological needs are greatest (pregnancy, lambing, and milking), from late September to early February. Under these circumstances, actions to improve forage and feed resources, as well as quality, are needed. Costs and dependency on the market to buy feed must be reduced, along with the risks resulting from drought and price fluctuations.

The objectives of this work were to:

- Introduce a strip-alley cropping system with forage shrubs inter-cropped with annual forages (medics, an oat/vetch mixture, and barley/fodder pea).
- Provide farmers with good-quality feed and an environmentally sustainable forage production system throughout the year.
- Reduce the cost of feed.
- Train technicians and farmers to conduct, manage, and use these forage alternatives while protecting natural resources (soil, biodiversity of range plants, and efficient use of rainwater).

Materials and Methods

Four trials for strip-alley cropping were established on three farms in Oulad Amrane (Doukkala region), where the average annual rainfall is 320 mm, and soils are bare, shallow, and have low fertility. Soil erosion is intense because of the slopes, the bareness of the soil, overgrazing, and the torrential rains that occur early and late in the growing season. Trials were carried out in which four parallel

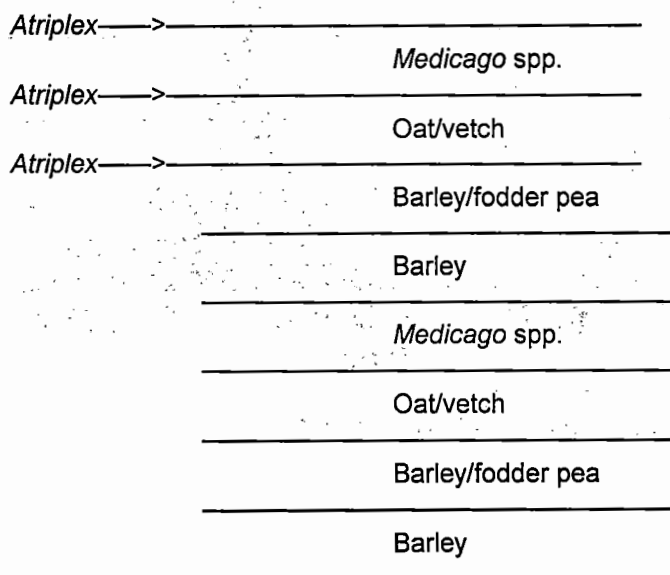
strips of different forage crops were cultivated, each separated by a row of fodder shrubs (*Atriplex nummularia*). Each strip was repeated two times:

- A strip of annual medics for grazing in early summer, to complement low-quality feed (cereal stable) and improve ground cover, organic matter, and soil nitrogen.
- A strip of an oat/vetch mixture to produce high-quality hay that can be fed during critical periods (late summer to early winter).
- A strip of barley/fodder pea to produce high-quality feed.
- A strip of forage barley that can be cut for silage or hay or harvested for grain.

Each strip was 5–10 meters wide, depending on the slope, to allow mechanization where possible.

Fodder shrubs were planted to retain soil (reduce soil erosion), provide feed from late summer to early winter, and use rainwater efficiently. Shrubs were transplanted in April 1995. The distance between plants in the row was 2.5 m. The planting density varied between 550 and 800 plants/ha. Nitrogen + P_2O_5 was applied at a rate of 30 + 40–45 kg/ha for barley, 30–45 kg/ha for the mixtures, and 45 kg P_2O_5 /ha for medics. Except for the Ait Ammar farmer, who harvested the whole trial for seed, all trials were harvested for hay, including the medic pastures.

Observations included biological yield, percent legumes and grasses in the mixture, first year biological yield per shrubs, and shrub yield per hectare.



Results and Discussion

Rainfall patterns varied between years. During the 1995/96 growing season, rainfall was lower than the annual average. Since it was dry during shrub establishment, irrigation was required. However, the following season was very wet, with rainfall exceeding the annual average. This extra rain improved establishment and led to the early exploitation of the shrubs (Fig. 1). The average biological yield of the annual forage species ranged from satisfactory to high, exceeding 4 tonnes DM/ha. Mild temperatures increased the contribution of legumes in the mixtures (Table 1). Biomass production of shrub leaves and stems varied among farms. Areas where soils were relatively deep and fertile, and where slopes faced northwest, produced more total biomass per plant and higher leaf/stem ratio than poorer soils or where slopes faced southeast (Fig. 2; Table 2). However, total biomass production per hectare was higher on poor and sloping areas because of the higher planting densities at these sites (Fig. 3). Barley had the highest forage yield, followed by barley/fodder pea, the oat/vetch mixture, medics, and lastly, forage shrubs (Fig. 4).

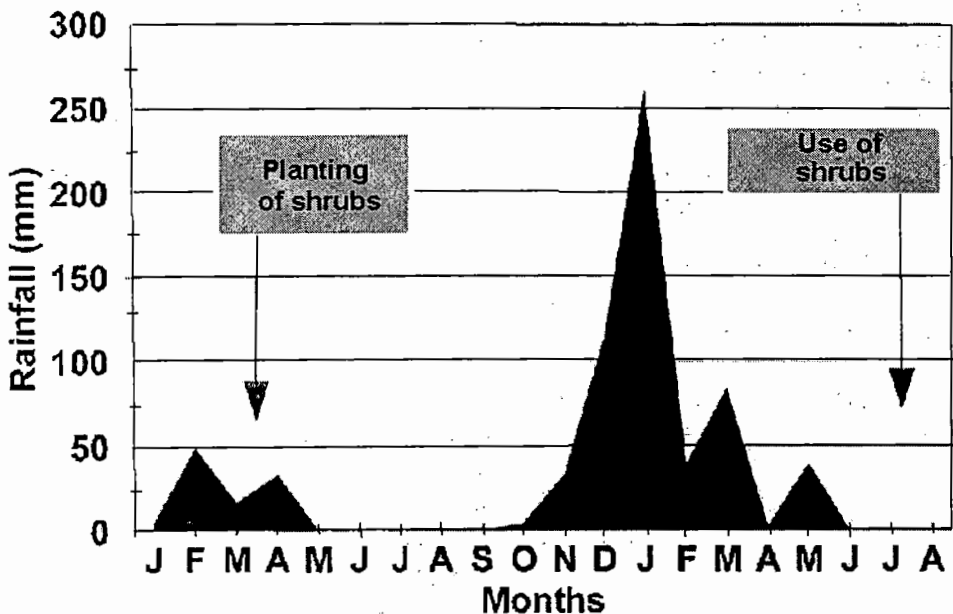


Figure 1. Monthly rainfall during 1994/95 and 1995/96.

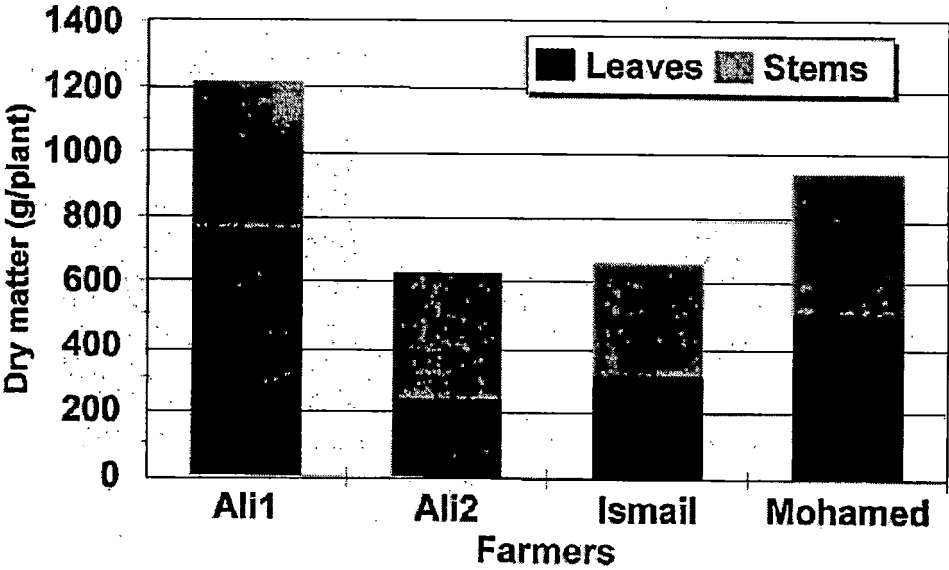


Figure 2. Leaf and stem biomass production (g/plant) per plant and per farm.

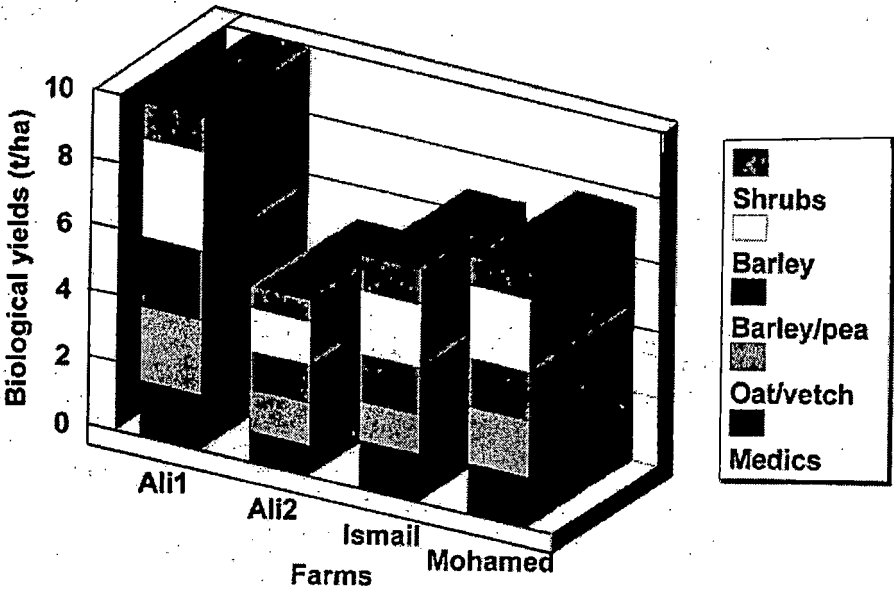


Figure 3. Biological yield of different components of the strip-alley cropping system.

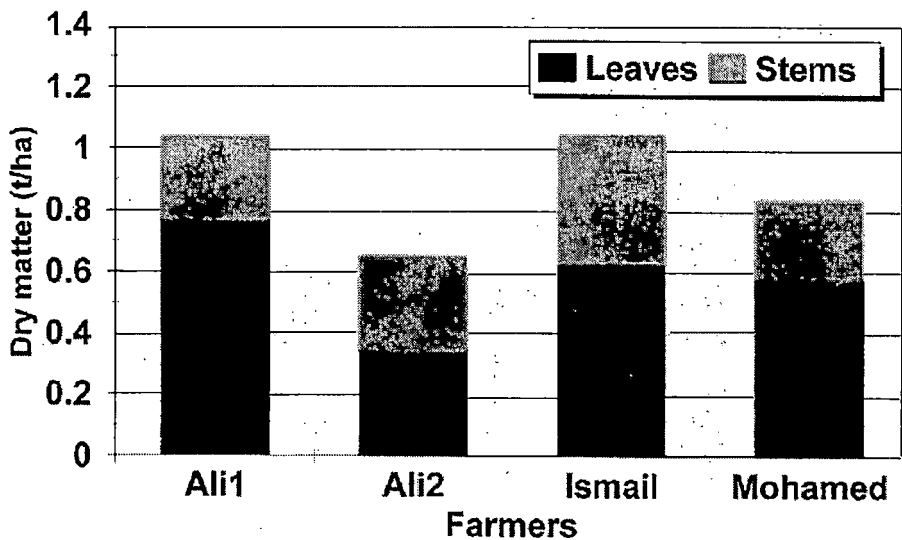


Figure 4. Leaf and stem biomass production (t/ha) per hectare and per farm.

In terms of energy, strip-alley cropping yielded 3,000–6,300 UF/ha, an increase of 90–400% over barley produced under the same conditions. Barley and the forage mixtures had the highest energy yields, followed by medics and forage shrubs (Fig. 5). Crude protein yields varied from 800 to 1,600 kg CP/ha. Medics and the forage mixtures had the highest yields, followed by fodder shrubs or barley (Fig. 6).

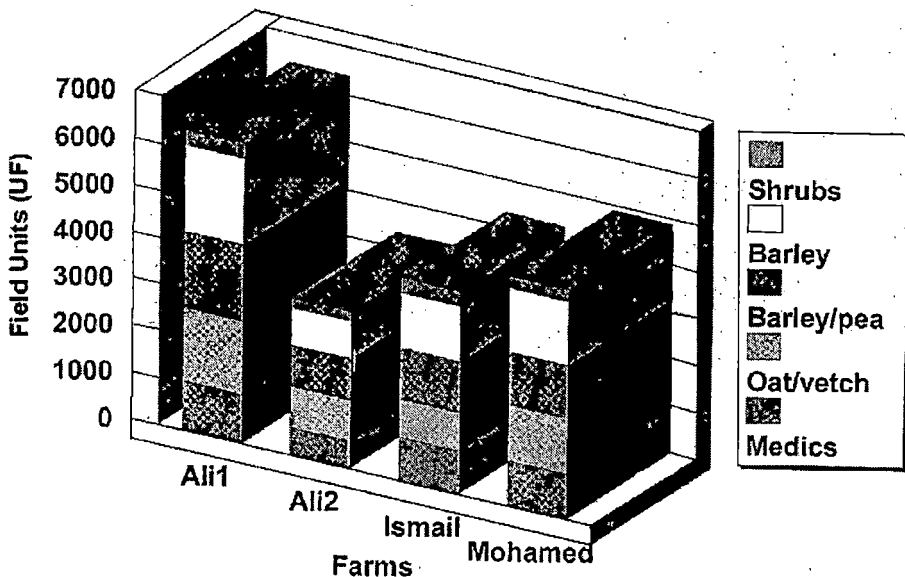


Figure 5. Feed units for the different components of the strip-alley cropping system.

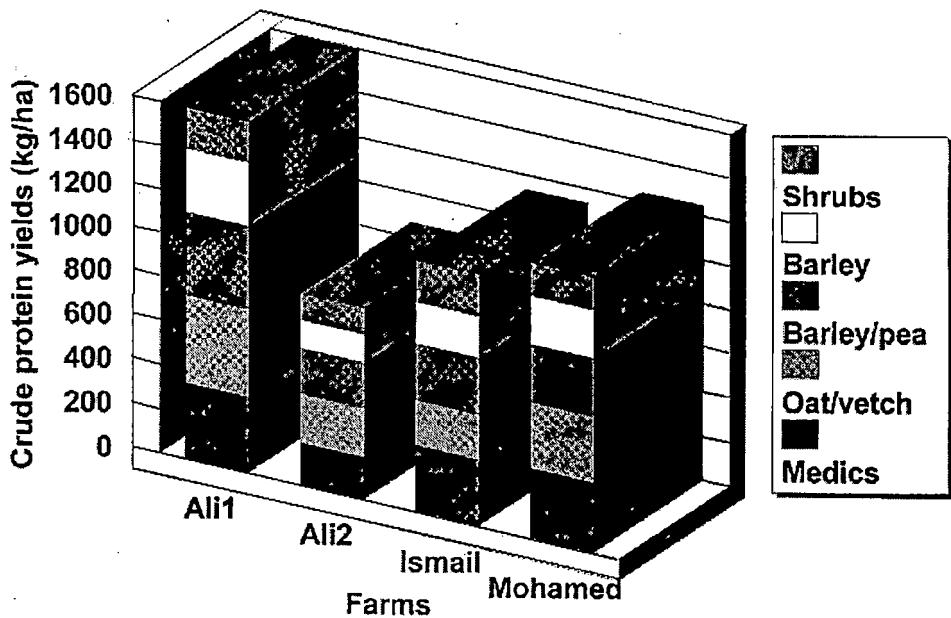


Figure 6. Crude protein yields for the different components of the strip-alley cropping system.

The economic study showed the advantage of the strip-alley cropping system over the sole barley crop in terms of both quantity and quality of feed. This system, which introduces other forage resources beside fodder shrubs, represents a way to diversify feed resources in unfavorable environments to reduce risk. It also leads to a more uniform distribution of good-quality feed resources throughout the year and during difficult periods while preserving soil, water, and phylogenetic resources.

Table 1. Proportion (t/ha DM) of legumes, grasses, and weeds harvested per strip at the five different sites of the project area.

Treatments		Sub-zones			
		Lhaj Ali 1	Lhaj Ali 2	Lhaj Smaïl	Mohamed Ben Boudali
Medics	Medics	5.83	2.60	4.39	3.58
Pasture	Others	0.66	1.03	1.30	2.41
Oat/vetch	Vetch	6.34	3.09	2.23	5.32
Mixture	Oat	2.47	1.83	2.33	1.54
Barley/pea	Pea	3.73	1.98	2.10	2.37
Mixture	Barley	4.69	2.56	3.51	3.39
Forage	Barley	10.50	4.30	5.99	8.76
Barley	Weeds	1.32	0.83	1.60	0.00

Table 2. Leaf and stem biological yield and leaf/stem ratio of *Atriplex nummularia* in a strip-alley system on four farms in west-central Morocco.

Farmer	Biological yield per plant (g/Plant)					Total biological yield (t/ha)		
	Fresh weight	Dry matter	Total dry matter	%	Leaves/ stem	Leaves	Stems	Total
Lhaj Ali 1	2,042.0	780.3	1,040.6	27.3	2.8	0.780	0.277	1.040
Lhaj Ali 2	858.2	239.9	466.5	27.8	1.6	0.336	0.317	0.653
Lhaj Ismaïl	883.0	315.8	525.4	36.4	1.5	0.632	0.419	1.051
Mohamed Himri	1,858.6	517.4	764.2	28.4	2.1	0.569	0.272	0.841

Conclusion

Given the variability of rainfall and soil in the arid areas, and the importance of livestock (sheep), urgent actions are needed to improve feed production and quality while preserving natural resources (soil, water, and phytogenetic resources) that are already degraded. The strip-alley cropping system presents an alternative for private farms in the barley-based farming system of the semi-arid and arid areas of Morocco. The short-term (biological), medium-term (economic), and long-term (environmental) data support strongly the need to extend this kind of technology to farmers in the target regions to insure sufficient sheep production for increasing populations.

Saisonnalité des Réponses des Ligneux Sahéliens à l'Aridité : Cas de *Acacia tortilis* (Forssk.) Hayne subsp. *raddiana* (Savi) Brenan dans la Zone Soudano-Sahélienne du Sénégal (Dahra-Djolloff)

D. Macoumba¹ and G. Michel²

¹Département de Biologie Végétale, Faculté des Sciences et Techniques Université Cheikh Anta Diop de Dakar, Sénégal

²Laboratoire d'Ecologie Végétale Orstom, Dakar, Sénégal

Résumé

Le Sénégal est un pays sahélien caractérisé par un climat tropical sec, avec une courte saison de pluies (3 à 4 mois), et une longue saison sèche (8 à 9 mois). Les précipitations y sont faibles et aléatoires.

Les thérophytes et les phanérophytes, bien adaptés aux conditions écologiques de la zone, sont les principaux types biologiques. Parmi les phanérophytes, les mimosées sont les plantes arido-actives qui dominent largement. Cependant, leurs stratégies d'adaptation à l'aridité dans ce milieu restent encore peu connues. C'est pourquoi, nous avons essayé de caractériser les réponses adaptatives de *Acacia tortilis* (Forssk.) Hayne subsp. *raddiana* (Savi) Brenan, arbuste très utilisé comme fourrage (fruits, feuilles, jeunes rameaux) surtout pendant les périodes sèches. Pour cela, nous avons suivi la phénologie de la plante, son état hydrique (tension de sève de base et maximale), en relation avec les facteurs édapho-climatiques (répartition des pluies, réserve hydrique du sol). Globalement, les changements phénologiques observés épousent étroitement les modifications du statut hydrique de la plante et du sol. On a pu montrer ainsi que l'échappement est la réponse d'adaptation de cette espèce au déficit hydrique.

Mots-clés : saisonnalité, réponses, aridité, phénologie, relations hydriques, *Acacia tortilis* (Forssk.) Hayne subsp. *raddiana* (Savi) Brenan, Sahel, Sénégal.

Abstract

Senegal is a Sahelian country characterized by a dry tropical climate with a short rainy season (3–4 months) and a long dry season (8–9 months). The rainfall is low and unreliable. Therophytes and phanerophytes are the main life-forms, and are well-adapted to the ecological conditions of the zone. Among the latter, the Mimosaceae are the dominant arido-active plants. However, their different adaptative strategies with respect to drought remain poorly studied in this area.

Thus we investigated the adaptative responses of *Acacia tortilis* (Forssk.) Hayne subsp. *raddiana* (Savi) Brenan, which is very useful as fodder (pods, leaves, young twigs), particularly during dry periods. The phenology and water status (pre-dawn and minimum water potential) of the plant, related to pedoclimatic factors (distribution of rainfall and soil water content), were monitored. A significant linkage was found between seasonal changes in phenology and those in plant and soil water status. Avoidance responses were considered as a drought-adaptation mechanism for this species.

Key words: seasonality, responses, drought, phenology, water relations, *Acacia tortilis* (Forssk.) Hayne subsp. *raddiana* (Savi) Brenan, Sahel, Senegal.

Introduction

Au Sahel, la végétation spontanée constitue la base de l'alimentation des troupeaux. Sur le plan de la production, les espèces ligneuses vivaces présentent un étalement plus grand de leur phase végétative par rapport aux communautés annuelles. D'ailleurs, le rôle important que jouent les espèces ligneuses dans l'alimentation animale en milieu sahélien, aussi bien en quantité (Le Houérou 1979) qu'en qualité (Bille 1978 ; Le Houérou 1980) a été déjà prouvé.

Au Sénégal, Grouzis et al. (1996) ont montré que dans les zones sèches du nord, ce sont les phanérophyles microphylls qui sont les plus fréquents et notamment ceux appartenant au genre *Acacia*. Cependant, on peut constater qu'en zone tropicale sèche en général, les travaux sur la phénologie de ces ligneux sont encore rares (Poupon 1979, 1980 ; Akpo 1993 ; Diouf 1996 pour le Sénégal, Traoré 1978 ; Grouzis et Sicot 1980 ; Grouzis et al. 1991 pour le Burkina Faso).

Pour cette raison, cette étude menée au Sénégal a porté sur la phénologie de *Acacia tortilis* (Forssk.) Hayne subsp. *raddiana* (Savi) Brenan dans la zone pastorale nord entre les isohyètes 100 et 400 mm. Cette espèce fournit des ressources appréciables à l'économie rurale (fourrage d'appoint, combustible, pharmacopée) et joue un rôle écologique déterminant. Elle couvre près des 2/3 du territoire national avec des densités plus fortes dans la zone sahélienne au sens strict (Diouf et Grouzis 1996).

Ce travail réalisé dans le cadre du programme STDIII Contrat TS3 * CT92-0047, a pour objectif de caractériser la variabilité des phénophases de cette plante en relation avec les facteurs liés au climat, au sol et son état hydrique interne.

Matériel et Méthodes

Cadre de l'Étude

La station d'étude (15° 21' 71" N lat. et 15° 26' 50" O long.) est située dans le Centre de Recherches Zootechniques (CRZ) de Dahra-Djolooff qui appartient à la zone soudano-sahélienne du Sénégal (400 à 600 mm) (PNUD 1994).

La zone d'étude est caractérisée par un climat tropical sec (Le Houérou 1989) avec deux saisons bien distinctes : une saison humide avec des pluies appelée *hivernage* (saison pluvieuse de juin à octobre) de cinq à trois mois et une saison sèche de neuf à huit mois. Les précipitations annuelles très aléatoires (CV = 34%) se concentrent entre juillet et septembre (85% des pluies annuelles). Les années d'observation se situent dans un contexte de déficit pluviométrique avec 303 mm en 1993 et 250 mm en 1994 pour une moyenne de 445 mm.

Selon l'étude pédologique réalisée par Maignien (1965), la station d'étude appartient au groupe des sols steppiques brun-rouges subarides.

La physionomie générale de la végétation de la zone d'étude est celle de la steppe arbustive (Le Houérou 1989).

Suivi de la Phénologie de la Population en Milieu Réel

Le principe consiste à déterminer *de visu* les stades phénologiques de la plante pour les différentes dates d'observation, à partir de critères liés au développement de ses organes (feuilles, fleurs, et fruits). Ces observations ont été réalisées de juin 1993 à octobre 1994.

Echantillonnage

Nous avons procédé à l'inventaire des espèces ligneuses et à l'établissement de la structure de la population en fonction des classes de diamètre. Cette structure a permis notamment de définir l'échantillonnage pour l'étude de la phénologie. Cet échantillonnage a été effectué selon la méthode de Grouzis et al. (1991) en tenant compte des exigences de Frankie et al. (1974).

Nous avons ainsi choisi un échantillon de 32 individus sur la base de la structure de la population établie au départ (Fig. 1) sur un effectif de 100 pieds. La figure 1 donne l'histogramme de la répartition des individus de la population par classes de diamètre. Il apparaît que la distribution des fréquences dans cette population est globalement de type bimodal.

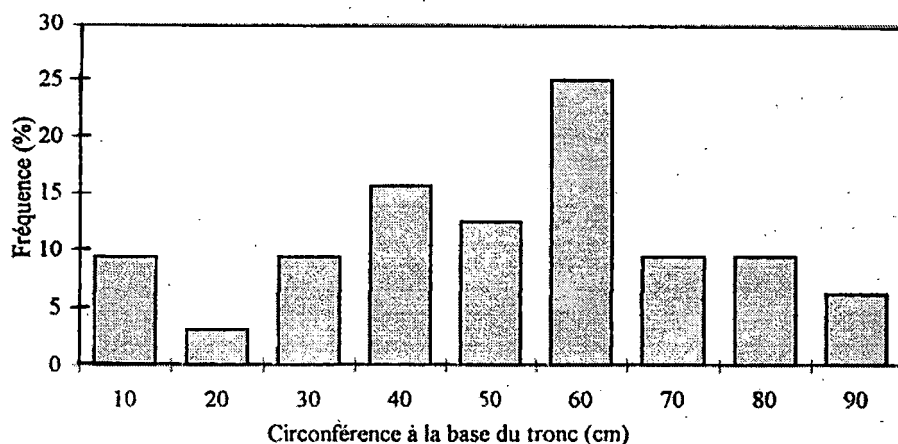


Figure 1. Structure de la population de *Acacia raddiana* à Dahra (CRZ).

Caractéristiques des Observations Phénologiques

La fréquence des observations sur la plante, le climat et le sol a été en moyenne de 15 jours en saison des pluies et d'un mois en saison sèche. Pour la caractérisation phénologique, les stades repères retenus sont ceux proposés par Grouzis et al. (1991).

Pour la feuillaison: V1

Gonflement des bourgeons, pas de feuilles développées ; V2 : bourgeons foliaires + feuilles épanouies (plus de 10% et moins de 50% des rameaux de l'individu) ; V3 : feuilles en majorité épanouies ; V4 : feuilles vertes + feuilles sèches ou ayant changé de couleur (plus de 10% et moins de 50%) ; V5 : plus de 50% des rameaux de l'individu ont des feuilles sèches ; chute des feuilles. Ce stade V5 est difficile à situer parce que selon l'espèce, elle peut couvrir plusieurs mois.

Pour la floraison: F1

Bourgeons floraux uniquement ; F2 : bourgeons floraux et fleurs épanouies (plus de 10% et moins de 50%) ; F3 : plus de 50% des rameaux portent des fleurs épanouies ; F4 : fleurs épanouies + fleurs sèches (plus de 10% et moins de 50%) ; F5 : fleurs sèches en majorité ; chute des pièces florales.

Pour la fructification. (F1) : nouaison ; F2 : phase d'évolution du fruit jusqu'à sa taille normale ; F3 : maturité du fruit ; F4 : fruit mûr + début de dissémination (ouverture des gousses, ou chute des fruits) ; F5 : fruit entièrement sec et chute.

Pour les 2 années d'observations, le spectre phénologique de *Acacia raddiana* a été construit après le calcul, des fréquences au sein de la population, des individus en phase de feuillaison (V%), de floraison (F%) et de fructification (F%) (Grouzis et Sicot 1980 ; Grouzis et al. 1991). Pour ce faire, nous utilisons la formule suivante :

$P\% = (n/N) * 100$; avec, P% : désigne selon la phase, V%, f% ou F% ; n : nombre d'individus en phase ; N : effectif de la population.

On considère Grouzis et al. (1991) qu'un individu est en phase, lorsqu'il présente l'un des 3 stades suivants : 2, 3, et 4 ; les stades 1 et 5 marquant respectivement l'installation et la fin des phases.

Suivi des Autres Paramètres

- Une station micro-météorologique munie d'une centrale d'acquisition Micrologger type Campbell modèle 21X qui permet un enregistrement en continu des paramètres climatiques, a été installée.
- La sonde à neutrons Solo 25 nous a permis, après son étalonnage sur le site, de mesurer *in situ* et de manière continue l'humidité volumique du sol.
- La tension de sève (Ts) a servi d'indicateur de l'état hydrique de la plante. La chambre à pression Scholander type PMS Instruments, Corvallis, USA modèle a été utilisée pour mesurer cette Ts.

Les mesures ont porté sur un individu représentatif de l'individu moyen de la population. Ces mesures commencent avec la tension de sève de base (Tsb) mesurée en fin de nuit à 5h du matin et se poursuivent jusqu'à 19h. Les valeurs présentées représentent au minimum les moyennes de 5 valeurs horaires.

Résultats

La Figure 2 donne une représentation du spectre phénologique et des données décennales de facteurs climatiques (Fig. 2a) caractéristiques de la période du suivi ; notamment : la pluviométrie (P mm), l'humidité relative moyenne de l'air (Hrm) et la température moyenne de l'air (Tm). Elle donne également l'évolution du stock hydrique (Fig. 2c) pour l'épaisseur de sol 0-450 cm (S_{0-450}) pour la même période.

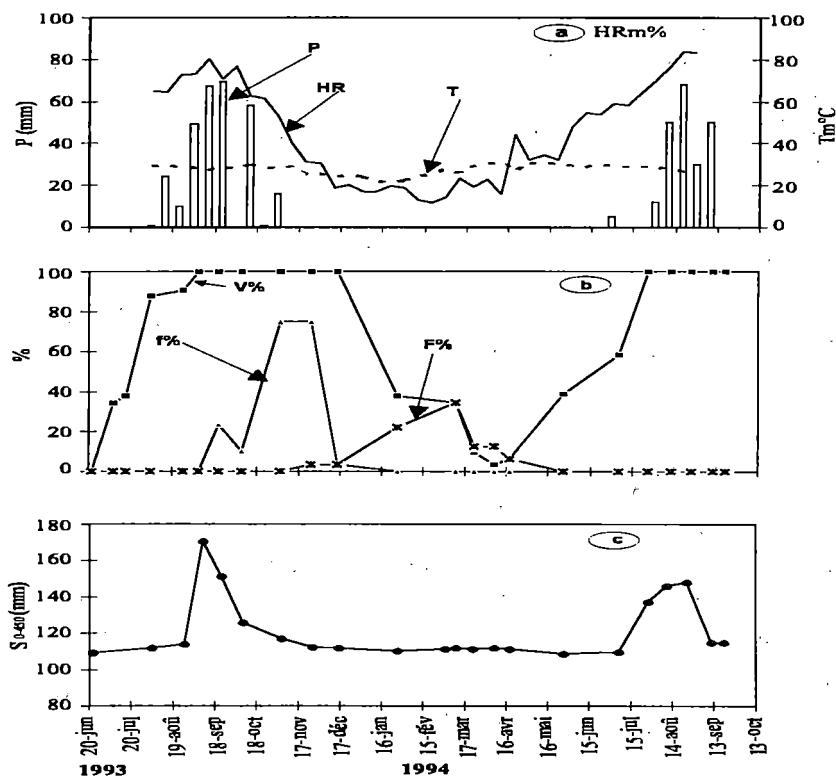


Figure 2. Spectre phénologique de *Acacia raddiana*, variations saisonnières de facteurs climatiques et de la réserve hydrique totale du sol ; avec : V% = Pourcentage de feuillaison ; f% : Pourcentage de floraison ; F% : Pourcentage de fructification.

L'observation du spectre phénologique de la plante sur la figure 2b permet de situer l'installation de la phase de feuillaison entre la 3ème décade de juin et la 1ère décade de juillet. Cette feuillaison atteint son maximum respectivement pendant la 1ère décade de septembre 1993 et la 3ème décade de juillet 1994.

On note une période de chute partielle des feuilles à partir de la 1ère décade de janvier. Cette défeuillaison durera jusqu'à la 2ème décade d'avril, date à laquelle, moins de 5% des individus de la population conservent encore leurs feuilles. En 1994, la mise en place des nouvelles feuilles s'est faite en saison sèche. Dès la mi-mai, on compte un taux de feuillaison de 40%.

Soulignons que l'apparition de ces nouvelles a été plus hâtive en 1994 qu'en 1993 où il a fallu attendre la 1ère décade de juillet pour voir les premières feuilles. Aussi pour cette 2ème année, le maximum de feuillaison a été noté dès la 3ème décade de juillet.

La floraison démarre avec un retard par rapport à la feuillaison à partir de la 2ème décennie de septembre 1993 et n'avait toujours pas débuté au moment où nous avons arrêté nos observations (2ème décennie de septembre 1994). Le maximum obtenu (75%) à partir de la 1ère décennie de novembre se maintient jusqu'à la 2ème décennie de décembre 1993 ; date à partir de laquelle, elle retombe immédiatement à zéro. On peut signaler la coulure survenue suite à la phase sèche enregistrée pendant la 2ème décennie de septembre, et qui se manifeste par une chute du pourcentage de floraison.

Les premiers fruits (moins de 5%) coïncident avec le maximum de floraison. Cette fructification est déphasée par rapport à la floraison et présente un pic majeur (~30%) pendant la 3ème décennie de mars 1994. Elle ne durera pas longtemps puisque dès la 2ème décennie de mai 1994, plus aucun arbre ne porte de fruits.

Dans le cadre des études sur le fonctionnement hydrique des essences tropicales, il n'est pas courant de voir les auteurs établir le lien entre les phénophases et leur déterminisme écologique ; notamment entre les variations saisonnières du stock d'eau du sol et les fluctuations de l'état hydrique interne de ces plantes (la tension de sève). La figure 3 montre qu'au cours des saisons humides 1993 (entre le 06/08/1993 et le 24/09/1993) et 1994 (entre le 26/07/1994 et le 25/08/94), on a une baisse significative de la tension de sève de base qui s'amorce dès les premières pluies.

Ces périodes correspondent aux maxima de la réserve hydrique, 170,5 mm en 1993 et 148,5 mm en 1994 : pour une épaisseur de sol 0–450 cm. Nous avons pu apprécier l'instantanéité de la réponse de la Tsb en mesurant celle-ci le 05/08/1993 puis le 06/08/1993 après une averse de 8 mm. On a noté que la Tsb est passée de -1.84 MPa à -1,23 MPa.

Suite à l'arrêt des précipitations, et au retour progressif de la réserve du sol à son niveau minimum de saison sèche, on observe une nette augmentation de cette tension de sève de base. Ce niveau de saison sèche est atteint le 25/01/1994 date à laquelle la Tsb atteint sa plus forte valeur.

Pendant la saison sèche 1993/1994, alors qu'on assiste à une défeuillaison qui atteint son optimum à la fin du mois de mars (23/03/1994), on note un abaissement de la tension de sève de base avant le débourrement et l'installation du nouveau feuillage.

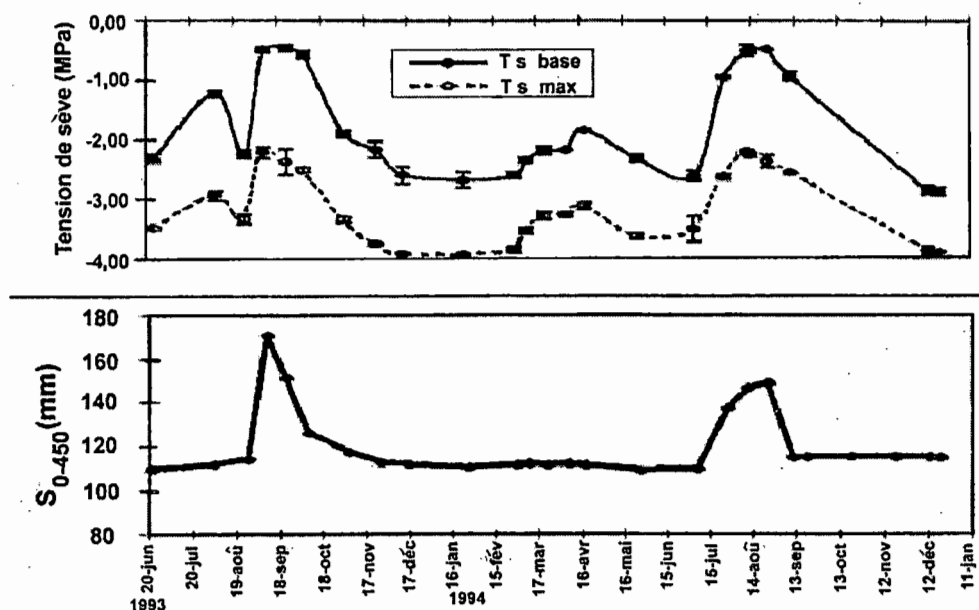


Figure 3. Evolution saisonnière de la relation entre la tension de sève et la réserve hydrique du sol.

Discussion

Nous avons noté une certaine homogénéité de l'état phénologique entre les individus de l'échantillon suivi au cours de l'étude. Par contre, une variabilité inter-site relativement importante a été mise en évidence entre Souilène (Anonyme 1994) et Dahra (présent travail).

Pour ce qui est de la phase végétative, la mise en place des feuilles et la défeuillaison sont plus précoces à Dahra qu'à Souilène où d'ailleurs, plus de 50% des individus de la population ne perdent pas leur feuilles. La date du début de la floraison est similaire à Dahra et à Souilène. Il en est de même de l'ampleur de la floraison quoiqu'elle dure plus longtemps à Souilène. A Dahra, le début de la fructification serait plus précoce et la durée plus longue. Par contre son taux est largement à l'avantage de la station de Souilène (85% contre seulement 34% des individus en fruits). Halevy et Orshan (1973) montrent que la phénologie de cette plante présente une très grande variabilité aussi bien entre individus du même site, qu'entre branches d'un même individu.

Cette variabilité de comportement entre les sites est à mettre globalement en relation, tout au moins pour l'année 1993, avec les niveaux de réserve hydrique très différents malgré des précipitations du même ordre de grandeur (297 mm à

Souilène et 303 mm à Dahra) et des sols de même nature. L'influence de la microtopographie à Souilène et les différences dans les méthodes d'étalonnage de la sonde dans les 2 sites seraient à l'origine de ces écarts.

Cependant, les résultats ne semblent pas montrer l'influence de la réserve hydrique sur la mise en place du feuillage. Cette feuillaison se manifeste bien avant la recharge de la réserve hydrique du sol et même avant l'arrivée des premières pluies.

Le débourrement qui s'effectue bien avant le début de la saison des pluies est très lié à l'humidité relative d'une part, ce qui rejoint les résultats de Grouzis et Sicot (1980) puis Borchert (1994) ; et à la température de l'air d'autre part. En effet, on remarque que l'apparition des premières feuilles coïncide chaque fois avec une atmosphère humide ($HR > 60\%$ en 1993 et $\sim 50\%$ en 1994) et chaude.

De même, la chute des feuilles intervient pour une HR faible comme le montrent Grouzis et Sicot (1980), une réserve hydrique du sol revenue à son niveau sec, et une température élevée.

A propos de l'effet de la température, nos résultats confirment ceux de Halevy et Orshan (1973) qui ont montré que *Acacia raddiana* manifestait systématiquement une défoliation de 40 à 50% au mois de juillet de tous les ans. Ce moment correspondant à la période des chaleurs (été) dans le Negev et le Sinaï. Ils ont essayé de relier ce comportement à un rythme de développement endogène qui serait plus en adéquation avec les conditions climatiques de son origine (défoliation en période chaude) : l'Afrique sahélienne. Ullmann (1985) aussi soutient que les fortes températures favorisent la chute des feuilles de cette plante.

Par contre, ces résultats s'opposent à ceux de Grouzis et Sicot (1980) qui soulignent qu'il ne semble pas y avoir de rapport entre les variations de ce paramètre et celles des cycles phénologiques. De même, Friedel et al. (1994) montre que la température influençait secondairement la floraison des *Acacia* du centre australien.

Nous devons toutefois préciser qu'une influence de la réserve hydrique du sol sur l'installation de la feuillaison ne semble pas nette. On peut remarquer que le débourrement se passe bien avant la saison des pluies, donc avant la reconstitution de la réserve hydrique. Ce résultat nous laisse concevoir comme Grossnickle (1989) et Fournier (1995), une liaison entre la mise en place du feuillage et un phénomène d'ajustement osmotique (libération de solutés osmotiquement actifs dans les vaisseaux xylémiens) dans notre cas en fin de saison sèche.

Le débourrement tardif en 1993 par rapport à 1994 pourrait s'expliquer par la pluviométrie très faible de 175 mm en 1992 contre 303 mm en 1993 puisqu'on peut constater que la hauteur d'eau tombée influe sur la durée des phases.

D'ailleurs, Walker et al. (1995) montrent que la variabilité climatique affecte beaucoup la phénologie de la plante.

La phase de chute des fleurs s'accorde bien avec l'arrêt ou le déficit des pluies (entre la 3ème décade de septembre et la 1ère décade d'octobre).

S'agissant de la réserve en eau du sol, Grouzis et Sicot (1980) puis Borchert (1994) trouvent pour un même site, selon la disponibilité en eau du sol, des différences phénologiques entre les espèces qu'ils ont étudiées, mais aussi pour les mêmes espèces entre des sites différents. Ils montrent que les changements phénologiques, notamment le jaunissement suivi de la chute des feuilles, interviennent après l'arrêt des pluies. Nos résultats s'accordent avec ceux de Grouzis et Sicot (1980) qui révèlent une action prépondérante de la réserve hydrique du sol sur le déterminisme des phases phénologiques des ligneux sahéliens.

Plus tard, Borchert (1994) note une bonne corrélation entre les phénophases (défoliation, floraison, développement des bourgeons) et la tension de sève des plantes. En fait, comme souligné par Reich et Borchert (1984), c'est moins la pluviométrie en valeur absolue qui contrôle la phénologie que son influence sur la teneur en eau du sol, donc sur l'état hydrique de la plante.

D'autre part, Borchert (1994) précise que la réduction des pertes d'eau par transpiration pendant la phase de chute des feuilles favorise l'utilisation de l'eau résiduelle de la plante, donc permet d'assurer une réhydratation des tissus et par conséquent, le débourrement observé en période sèche.

Il conclue qu'entre autres facteurs, l'état hydrique de la plante apparaît comme le principal déterminant de la phénologie. On peut d'ailleurs constater une bonne adéquation entre l'évolution de la tension de sève (Fig. 3) et celle de la feuillaison (Fig. 2b).

Conclusion

Nos résultats mettent en évidence une importante variabilité des phénophases. Cette variabilité observée dans cette population peut aussi s'exprimer entre des populations de différents sites. Elle est surtout liée aux fluctuations des facteurs écologiques quoiqu'on puisse soupçonner l'action de la photopériode.

Il faut cependant dire que les conditions d'alimentation hydrique sont déterminantes puisque l'eau constitue le facteur limitant principal. On a pu d'ailleurs constater que c'est le stock hydrique du sol qui assure le rôle fondamental sur le déterminisme de ces phénophases. Ce rôle est matérialisé au

niveau de l'état hydrique de la plante dont ce stock contrôle de façon prioritaire les variations.

Il apparaît également que la température de l'air et l'humidité relative peuvent influencer significativement la phénologie de cette plante et notamment, sa feuillaison. On peut aussi noter que la microphyllie et le feuillage caduque permettent de réduire les surfaces transpirantes et d'éviter le déficit hydrique.

Références

- Akpo, L.E. 1993. Influence du couvert ligneux sur la structure et le fonctionnement de la strate herbacée en milieu sahélien. Les déterminants écologiques. *TDM* No. 93, ORSTOM, Paris.
- Anonyme, 1994. Réhabilitation des terres dégradées au nord et au sud Sahara. Utilisation de légumineuses pérennes et des micro-organismes associés pour le rétablissement des formations pluristrates. Rapport de deuxième année, novembre.
- Bille, J.C. 1978. Le rôle des arbres et des arbustes en tant que sources de protéines dans la gestion des pâturages de l'Afrique tropicale. 8ème Congrès Forest, Mondial. Jakarta.
- Borchert, R. 1994. Soil and stem water storage determine phenology and distribution of tropical dry forest trees. *Ecology* 75(5): 1437–1449.
- Diouf, M. 1996. Etude du fonctionnement hydrique et des réponses à l'aridité des ligneux sahéliens. Cas de *Acacia tortilis* (Forssk.) Hayne subsp. *raddiana* (Savi) Brenan en zone soudano-sahélienne du Sénégal. Thèse de Doctorat, 3ème cycle. Université Cheikh Anta Diop de Dakar, Sénégal.
- Diouf, M. and M. Grouzis. 1996. Natural distribution of *Acacia tortilis* (Forssk.) Hayne subsp. *raddiana* (Savi) Brenan in Senegal: ecological determinism. *International Tree Crops Journal* 9: 69–75.
- Fournier, C. 1995. Fonctionnement hydrique de six espèces ligneuses coexistant dans une savane sahélienne (Région du Ferlo, nord-Sénégal), TDM, ORSTOM.
- Frankie, G.W., H.G. Baker and P.A. Opler. 1974. Tropical plant phenology: application in studies in community ecology. Pages 287–298 in *Phenology and Seasonality Modelling* (H. Lieth, éd.). Springer-Verlag, Berlin.
- Friedel, M.H., D.J. Nelson, A.D. Sparrow, J.E. Kinloch and J.R. Maconochie. 1994. Flowering and fruiting of arid zone species of *Acacia* in central Australia. *Journal of Arid Environments* 27: 221–239.
- Grossnickle, S.C. 1989. Shoot phenology and water relations of *Picea glauca*. *Can. J. For. Res.* 19: 1287–1290.
- Grouzis, M. et M. Sicot. 1980. Une méthode d'étude phénologique de populations d'espèces ligneuses sahéliennes: Influence de quelques facteurs écologiques. Pages 231–237 in *Les fourrages ligneux en Afrique: état actuel des connaissances* (H.N. Le Houérou, éd.). CIPEA, Addis Abeba.
- Grouzis, M., I. Diédhiou et A. Rocheteau. 1996. Legumes diversity and root symbioses on an aridity gradient in Senegal. *African Journal of Ecology* (soumis).
- Grouzis, M., J. Nizinsky et C. Fournier. 1991. Interactions entre arbre et herbe au Sahel : Effets sur la composition floristique et sur l'efficacité de l'utilisation de l'eau. *Physiologie des Arbres et Arbustes en zones arides et semi-arides*, Groupe d'Etude

de l'Arbre, Paris.

- Halevy, G. and G. Orshan. 1973. Ecological studies on *Acacia* species in the Negev and Sinaï. II. Phenology of *Acacia raddiana*, *Acacia tortilis* and *Acacia gerrardii* subsp. *negevensis*. *Israel Journal of Botany* 22: 120–138.
- Le Houérou, H.N. 1979. Le rôle des arbres et des arbustes dans les pâturages sahéliens. C.D.I.
- Le Houérou, H.N. 1980. Chemical composition and nutritive value of browse in tropical West Africa. Pages 261–289 in *Browse in Africa. The Current State of Knowledge* (H.N. Le Houérou, éd.). ILCA, Addis Abéba.
- Le Houérou, H.N. 1989. The grazing land ecosystems of the African Sahel. *Ecological Studies* 75, Springer-Verlag, Berlin.
- Maignien, R. 1965. Carte pédologique du Sénégal au 1/1000000ème + notice explicative, ORSTOM, Dakar.
- PNUD. 1994. Bilan diagnostic des ressources en eau du Sénégal. Projet MH/PNUD/DADSG SEN/87/006, Dakar, 4 parties.
- Poupon, H. 1979. Etude de la phénologie de la strate ligneuse à Fété-Olé (Sénégal septentrional) de 1971 à 1977. *Bulletin IFAN*, 41, sér. A, 1: 44–85.
- Poupon, H. 1980. Structure et dynamique de la strate ligneuse d'une steppe sahélienne du Nord-Sénégal. Trav. Doc. 115, ORSTOM, Paris.
- Reich, P.B. and R. Borchert. 1984. Water stress and tree phenology in a tropical dry forest in the lowlands of Costa Rica. *Journal of Ecology* 72: 61–74.
- Traoré, B. 1978. Observations sur la phénologie de quelques espèces herbacées et ligneuses sahéliennes. ACC-LAT (Haute-Volta), DGRST/ORSTOM/ISP, Ouagadougou.
- Ullmann, I. 1985. Diurnal courses of transpiration and stomatal conductance of Sahelian and Saharian *Acacia* in the dry season. *Flora* 176: 383–409.
- Walker, M.D., R.C. Ingersoll and P.J. Webber. 1995. Effects of interannual climate variation on phenology and growth of two alpine forbs. *Ecology* 76(4): 1067–1083.

The Production of Indigenous and Exotic Shrubs in the Marginal Areas of the Western Cape

J.M. Van Heerden, A.J. Heydenrych and J.C. Botha
Department of Agriculture, Western Cape, Elsenburg, South Africa

Abstract

Low rainfall areas (<200 mm/year) of the Northwest, Little Karoo, and Ceres Karoo rangelands are characterized by a low cover of largely unpalatable shrub species, which supply very little or no green feed during the dry summer. In this particular area there are approximately 300,000 ha of old lands. The grazing capacity of this area could be improved, or even doubled, by the establishment of palatable evergreen shrubs. Our objective was to evaluate more productive species for establishment in these areas. Trials were conducted on 18 farms in eight districts. Of the 38 shrub species evaluated, 14 were exotic and 24 indigenous. A wide range of treatments was applied, involving various species at different heights and frequencies in undisturbed rangeland and established stands. Of the shrubs evaluated, *Atriplex nummularia* was the species most widely adapted and also the most productive. When compared to *A. nummularia*, *A. halimus* was higher producing on soils with higher potential, but lower producing on sandy and shallow soils. Other promising species were *Atriplex undulata*, *Atriplex breweri*, *Chrysanthemoides incana*, *Otholobium oppositifolia*, *Atriplex rhagodioides*, *Atriplex cinerea*, *Otholobium candicans*, *Didelta spinosa*, *Atriplex lentiformis*, *Kochia pubescens*, and *Medicago arborea*. Species traditionally used to revegetate rangeland "*Osteospermum sinuatum*, *Chaetobromus dregeanus*, *Ehrharta calycina*, *Hirpicium integrifolium*, and *Exomis microphylla*" were much lower producing.

Key words: shrubs, rangeland, dry matter production, old cultivated lands.

Résumé

Les zones de précipitations minimales (<200mm/an) du Northwest, Little Karoo, et Ceres Karoo sont caractérisées par une flore constituée habituellement d'une dissémination d'arbustes peu appétissants, ne produisant que très peu, ou pas du tout, de verdure de subsistance durant la saison sèche d'été. Cette zone comprend également à peu près 300,000 hectares de terres usées. Il est donc possible d'améliorer, ou de doubler, la capacité pâtureable de cette région, en y introduisant des arbustes à feuilles persistantes. Notre but fut donc d'évaluer des espèces plus productives, afin de les introduire dans ces régions. Des essais expérimentaux

furent fait à 18 fermes réparties dans 8 districts. Des 38 espèces d'arbustes qui furent évalués, 14 étaient d'espèce exotique, et 24 indigènes. Les tests consistèrent de toute une gamme de traitements, dans lesquels une série d'arbustes de différentes espèces, plantés dans des pâturages vierges et dans d'autres déjà établis, furent coupés à différents intervalles, à des hauteurs variées. De tous les arbustes évalués, l'espèce la plus adaptable et la plus productive fut l'*Atriplex nummularia*. La production de l'*Atriplex halimus*, supérieure dans des sols au potentiel plus élevé, est cependant moindre en sols sablonneux et peu profonds, comparé à l'*Atriplex nummularia*. D'autres espèces prometteuses étaient l'*Atriplex undulata*, l'*Atriplex breweri*, le *Chrysanthemoides incana*, l'*Ortholobium oppositifolia*, l'*Atriplex rhagodioides*, l'*Atriplex cinerea*, l'*Ortholobium candicans*, le *Didelta spinosa*, l'*Atriplex lentiformis*, le *Kochia pubescens*, et le *Medicago arborea*. Les espèces habituellement utilisées pour la régénération des pâturages, par exemple : l'*Osteospermum sinuatum*, le *Chaetobromus dregeanus*, l'*Ehrharta calycina*, l'*Hirpicium integrifolium* et l'*Exomis microphylla*, produisirent bien moins que les espèces du groupe mentionné ci-dessus. Il est donc évident que des études plus approfondies devraient être faites dans les espèces *Atriplex*.

Mots-clés: arbuste, pâturages, production de matière sèche, terres usées.

Introduction

In the Western Cape, exploitable rangeland (9.5 million ha) is limited to extensive grazing areas with low (<200 mm/year) and variable rainfall (de Kock 1980; Van Breda and Barnard 1991). Rangelands in these areas have a low plant cover, of which a large percentage (>21%) of the species is unpalatable (Joubert 1968; Joubert and Stindt 1979). Perennial shrubs in this rangeland are mostly summer deciduous. This results in a critical shortage of green feed during that period (Barnard 1985). In the low rainfall regions of the Northwest and Little Karoo, there are approximately 300,000 ha of old cultivated land, formally planted to wheat, a practice that has become uneconomical. Mainly annual species of low productivity and quality grow on these lands during winter. During summer there is only stubble, with no green pasturage.

Over the last four decades, much research has been directed toward finding ways to increase the capacity of Mediterranean grazing lands (Le Houérou 1993). Research has shown that the grazing capacity of natural rangeland and old lands in these areas can be increased through the establishment of more palatable and productive evergreen perennial shrubs (Joubert 1980; Barnard 1985; Malcolm and Pol 1986; Barnard 1987; Le Houérou 1989; Watson 1990; Barnard et al. 1992; Barrett-Lennard et al. 1992). A program to evaluate and select more productive evergreen shrub species was therefore launched.

Methods

Cutting trials were conducted with shrubs over five seasons (1989–1995) in the Northwest and Little Karoo at 18 farms in eight districts (Worcester, Ladismith, Ceres, Touwsrivier, Montagu, Oudtshoorn, Uniondale, and Lamberts Bay). The districts, farms, and species evaluated at each locality are shown in Tables 1 and 2. Of the 38 shrub species evaluated, 14 were exotic and 24 indigenous. The shrubs were cut at a range of frequencies from planted stands, as well as natural rangeland. Plant spacing, cutting frequency, and height varied between localities. Total dry mass (DM) production was determined after drying the cut material at 60°C.

Table 1. Localities where shrubs were evaluated.

Locality	Farm
Worcester	Veld Reserve
Ladismith	Brandrivier, Ganskop, Muisakraal, Nature Reserve, Oudenwagensdrif, Rietvlei, Van Zylsdamme, Zeekoeigatdrif, Zorgvliet
Ceres	Sadawe
Lamberts Bay	Nortier
Touwsrivier	Jan de Boers
Montagu	Grootvlakte
Oudtshoorn	Roodeheuvel
Uniondale	Hartbeesrivier, Toorwaterberg

Table 2. Species evaluated.

Locality	Species
Worcester	<i>Atriplex breweri</i> , <i>A. canescens</i> , <i>A. cinerea</i> , <i>A. halimus</i> , <i>A. lentiformis</i> , <i>A. nummularia</i> , <i>A. paludosa</i> , <i>A. repanda</i> , <i>A. rhagodioides</i> , <i>A. semibaccata</i> , <i>A. undulata</i> , <i>Chrysanthemoides incana</i> , <i>Exomis microphylla</i> , <i>Justicia cuneata</i> , <i>Kochia pubescens</i> , <i>Medicago arborea</i> , <i>Osteospermum sinuatum</i> , <i>Otholobium candicans</i> , <i>Pteronia membranacea</i>
Ladismith	<i>A. nummularia</i> , <i>Berkheya cuneata</i> , <i>B. spinosa</i> , <i>Eriocephalus africanus</i> , <i>Exomis microphylla</i> , <i>Hirpicium integrefolium</i> , <i>Monechma spartioides</i> , <i>Osteospermum sinuatum</i> , <i>Pentzia incana</i> , <i>Salsola glabrescens</i> , <i>Tetragonia fruticosa</i> , <i>Zygophyllum flexuosum</i> , <i>Z. morganii</i>
Ceres	<i>Osteospermum sinuatum</i>
Lamberts Bay	<i>A. canescens</i> , <i>A. halimus</i> , <i>A. nummularia</i> , <i>Chamaecytisus palmensis</i> , <i>Chrysanthemoides incana</i> , <i>Ch. Monilifera</i> , <i>Didelta spinosa</i> , <i>Euphorbia burmannii</i>
Touwsrivier	<i>Atriplex halimus</i> , <i>A. nummularia</i>
Montagu	<i>A. canescens</i> , <i>A. halimus</i> , <i>A. nummularia</i> , <i>A. semibaccata</i>
Oudtshoorn	<i>A. canescens</i> , <i>A. halimus</i> , <i>A. nummularia</i>
Uniondale	<i>A. nummularia</i>

The average monthly rainfall over the trial period at the eight districts is given in Figures 1 and 2. Ladismith, Montagu, Oudtshoorn, and Uniondale (Fig. 1) had better rainfall distribution than Worcester, Nortier, Touwsrivier, and Ceres Karoo (Fig. 2).

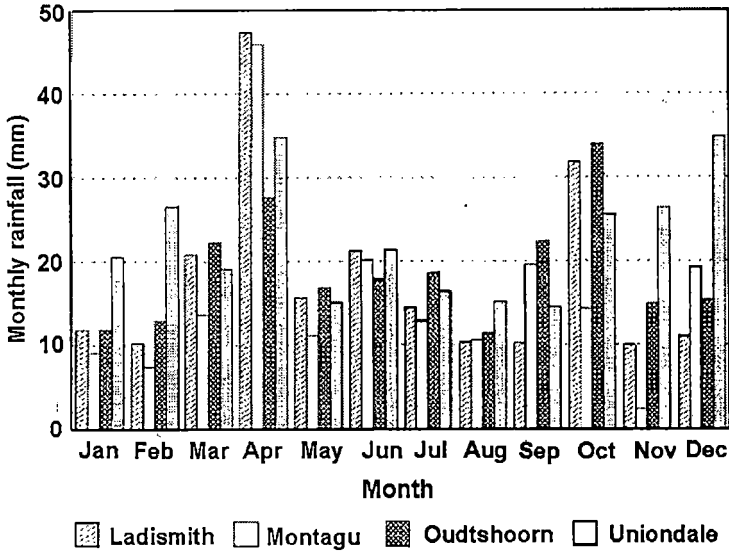


Figure 1. Monthly rainfall at first four sites.

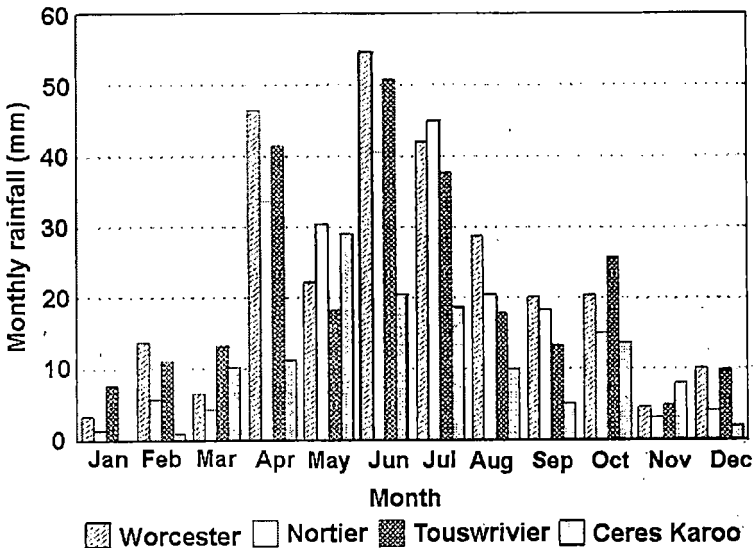


Figure 2. Monthly rainfall at second four sites.

Results

The mean yields for the different shrubs in the eight districts are given in Figures 3–6. Unfortunately, the same species were not used at all localities, which makes comparison difficult.

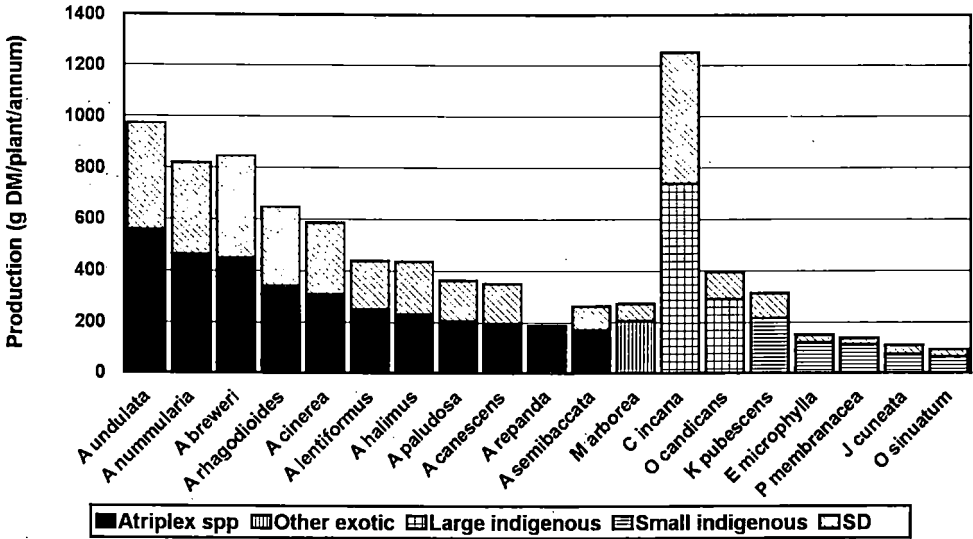


Figure 3. The production (g DM/plant per year) of various shrubs at Worcester.

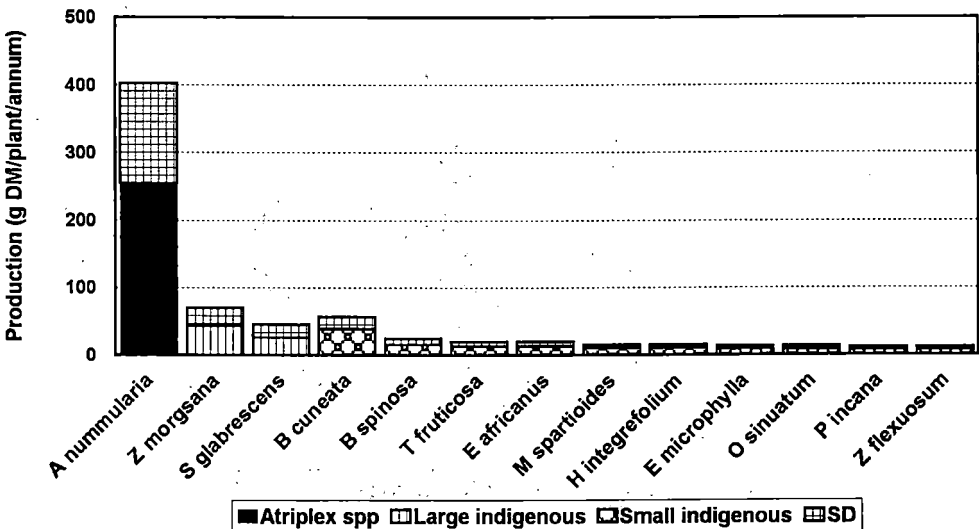


Figure 4. The production (g DM/plant per year) of various shrubs at Ladismith.

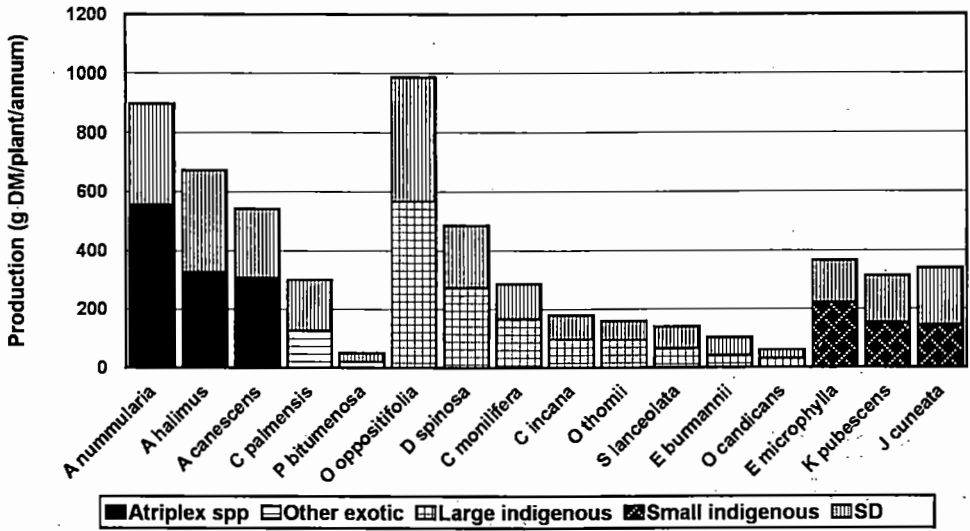


Figure 5. The production (g DM/plant per year) of various shrubs at Nortier.

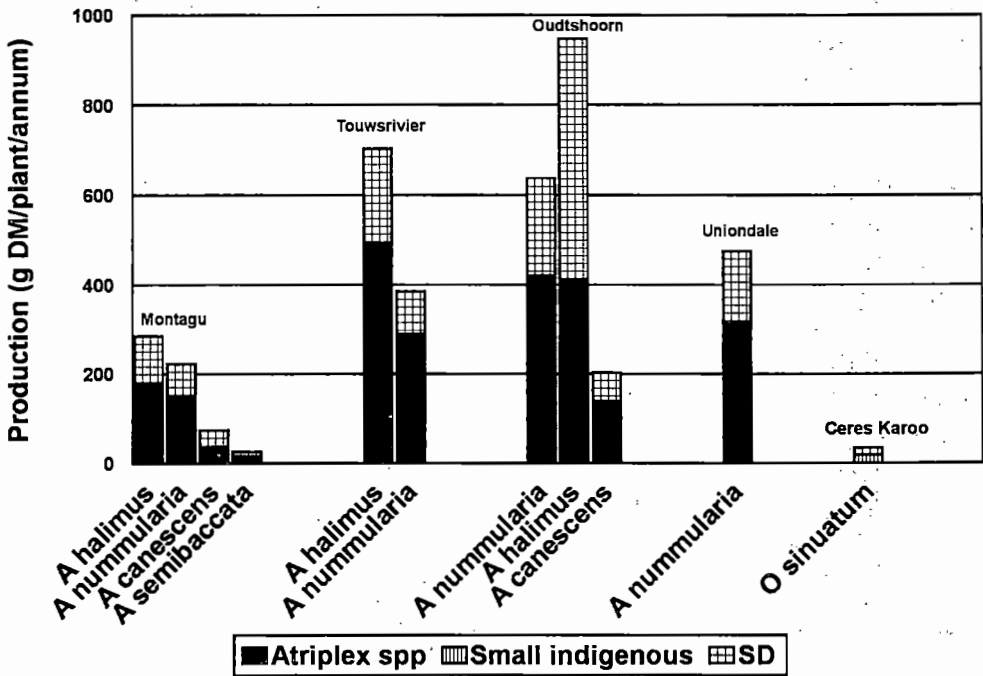


Figure 6. The production (g DM/plant per year) of various shrubs at five sites.

A large standard deviation in yield was observed at all sites. *Atriplex nummularia* and *A. halimus* were evaluated at most of the sites and were the highest yielding of all species. The highest yield for *A. nummularia* was found at Nortier, and the lowest at Roodeheuwel. For *A. halimus*, the highest yield was derived at Jan de Boers and the lowest at Worcester Veld Reserve. Other promising *Atriplex* species at the Worcester Veld Reserve were *A. undulata* and *A. breweri*.

Locality had a large influence on the relative yield of the shrubs. At the Worcester Veld Reserve, the Karoo selection of *Chrysanthemoides incana* was the highest yielding. The West Coast variant did not fair quite as well there, but was on average one of the ten highest-producing shrubs at all the localities. However, at Nortier, neither of these shrubs fared well. Other shrubs that did well were *Osteospermum oppositifolia*, *A. rhagodioides*, *A. cinerea*, *Otholobium candicans*, *Didelta spinosa*, *Atriplex lentiformis*, *Kochia pubescens*, and *Medicago arborea*.

The results of the cutting trials at Ladismith show that *A. nummularia* was much more productive than the highest-yielding indigenous species, namely *Berkheya cuneata*. Indigenous species such as *Osteospermum sinuatum*, *Chaetobromus dregeanus*, *Ehrharta calycina*, *Hirpicium integrifolium*, and *Exomis microphylla* also had lower and rather disappointing yields. The exotic shrub, *A. semibaccata*, also had a low yield. The six last-mentioned species are commonly used in the reseeding of rangeland. The future use of these species for this purpose can therefore be questioned.

Conclusions

It was difficult to compare the various species, as they were not all evaluated at the same localities. However, it is possible to establish certain guidelines. *A. nummularia* seems to be the most widely adapted and highest yielding. *A. halimus* was also high yielding, while the relative yield of *A. nummularia* and *A. halimus* seems to be determined by environment, especially soil. *A. halimus* seems to perform well on soils with high potential (Roodeheuwel and Jan de Boers), but less so on shallow (Worcester Veld Reserve) and sandy (Nortier) soils. There are, however, other species that have shown potential in specific trials, i.e. *A. undulata*, *A. breweri*, *C. incana*, *O. oppositifolia*, *A. rhagodioides*, *A. cinerea*, *O. candicans*, *D. spinosa*, *A. lentiformis*, *K. pubescens*, and *M. arborea*. These species were not, however, evaluated over the wide range of conditions that the first two were.

The indigenous species traditionally used for the reseeding of rangeland, i.e. *O. sinuatum*, *C. dregeanus*, *E. calycina*, *H. integrifolium* and *E. microphylla*, however, were low yielding. This clearly indicates that more productive species should be used in the future. Palatability, level of use, and certain ethical aspects, as well as managerial problems are, however, all factors that will have to be taken

into consideration when exotic shrubs, such as *A. nummularia*, are sown in rangeland or used to replace it.

References

- Barnard, S.A. 1985. Oumansoutbos in die Winterreënstreek. *Elsenburg Journal* Aug 1985: 18–22.
- Barnard, S.A. 1987. Influence of sowing depth on the germination of Karoo shrubs and grasses. *Journal of the Grassland Society of Southern Africa* 4(4): 123–126.
- Barnard, S.A., J.M. Van Heerden and H. Gerber. 1992. Evaluation of shrub species for sheep grazing in the Strandveld of the Cape west coast of South Africa. *Journal of the Grassland Society of Southern Africa* 9: 111–113.
- Barrett-Lennard, E., F. Frost, S. Vlahos and N. Richards. 1992. Revegetating salt-affected land with shrubs. *Journal of Agriculture: Western Australia* 32: 124–129.
- de Kock, G.C. 1980. Drought resistant fodder shrub crops in South Africa. Pages 399–410 in Browse in Africa: The Current State of Knowledge. (H.N. Le Houérou, ed.). International Livestock Centre for Africa, Addis Ababa, Ethiopia.
- Joubert, J.G.V. 1968. Die ekologie van die weiveld van die Robertson-Karoo. PhD Thesis, University of Stellenbosch, Stellenbosch.
- Joubert, J.G.V. 1980. Veld and Pastures in animal production systems in the Western Cape and South West Africa/Namibia. *South African Journal of Animal Science* 10: 299–303.
- Joubert, J.G.V. and H.W. Stindt. 1979. The nutritive value and general evaluation of natural pastures in the districts of Montagu, Robertson and Worcester in the winter rainfall area of the Republic of South Africa. *Technical Communications* No. 155.
- Le Houérou, H.N. 1989. An Assessment of the Economic Feasibility of Fodder Shrubs Plantation (with Particular Reference to Africa). In *The Biology and Utilization of Shrubs*. Academic Press.
- Le Houérou, H.N. 1993. Grazing Lands of the Mediterranean basin. In *Natural grassland, Eastern Hemisphere and Résumé. Ecosystems of the World, Vol 8 B*. (R.T. Coupland, ed.). Elsevier Science Publisher, Amsterdam.
- Malcolm, C.V. and J.E. Pol. 1986. Grazing and management of saltland shrubs. *Journal of Agriculture: Western Australia* 27: 59–63.
- Van Breda, P.A.B. and S.A. Barnard. 1991. Veld plants of the winter rainfall region. A guide to the use of veld plants for grazing. *Bulletin No. 422*. Government Printer, Pretoria.
- Watson, M.C. 1990. *Atriplex* species as irrigated forage crops. *Agriculture, Ecosystems and Environment* 32: 107–118.

The Influence of Spacing on the Production of Saltbush Species in the Little Karoo Region of the Western Cape

J.M. Van Heerden, A.J. Heydenrych and J.C. Botha
Department of Agriculture, Western Cape, Elsenburg, South Africa

Abstract

Saltbush species (*Atriplex* spp.) are important pasture crops in the winter rainfall area of South Africa. This can be attributed to their extreme drought tolerance and ability to produce green feed in winter, as well as during the dry summer. As these shrubs are traditionally planted as single plants, and plant density may influence production, this aspect was investigated with 10 saltbush species over four seasons (1989/90–1992/93) at the Worcester Veld Reserve. Seedlings of *Atriplex halimus*, *A. nummularia*, *A. undulata*, *A. paludosa*, *A. repanda*, *A. canescens*, *A. cinerea*, *A. lentiformis*, *A. semibaccata*, and *A. lentiformis* subsp. *breweri* were established during 1989 on a Valsrivier soil. Four rows of each species were planted in a fan-shaped formation in triangular plots, with the plants at the narrowest end closest together and at the widest end furthest apart. Five different spacings were used: 2 m × 2 m (2,500 plants/ha), 2 m × 1.5 m (3,333 plants/ha), 1.5 m × 1.5 m (4,444 plants/ha), 1.5 m × 1 m (6,666 plants/ha), and 1 m × 1 m (10,000 plants/ha). Yield (g DM/plant) was determined by cutting the two middle rows of each plot to a height of 400 mm at three-month intervals and weighing the cut herbage after drying at 60°C. The two side rows were used as borders only. The annual rainfall at the trial site was below 250 mm/year and lowest in the third (1991/92) season, but during the other three seasons the rainfall was very similar: 275–300 mm per annum. *Atriplex undulata* was the highest producer. *Atriplex breweri* yielded the second-highest dry matter, but not significantly so. *Atriplex paludosa*, *A. canescens*, and *A. cinerea* were lower producing, but their yields tended to be higher than those of *A. nummularia* and *A. halimus*, the two shrubs used most often in practice. The yield of all the species was significantly higher during the first two seasons. The yield of *A. repanda* and *A. semibaccata* declined most, and the two species were clearly not persistent. The yield of all species decreased significantly with increased plant population, but the response of the different species varied. The yield of *A. undulata* and *A. nummularia* declined most with increased plant density. The mean yield decline was greatest between the two lowest densities. Plant density had a much smaller influence on yield per hectare, but yield increased significantly with increased plant density. Decrease in yield per plant, caused by higher plant densities, was largely neutralized by the higher plant population over the range of densities.

Key words: *Atriplex*, dry matter production, plant density.

Introduction

In the Little Karoo region of South Africa, various saltbush species (*Atriplex* spp.) are important fodder crops (de Kock 1980; Barnard 1985; Barnard 1987; Van Breda and Barnard 1991; Barnard et al. 1992; Hoon and King 1992; Le Roux et al. 1994; Shearing 1994). The important role of these crops can be attributed to their ability to produce green feed throughout the year in extremely low rainfall (<200 mm/year) areas. These shrubs are evergreen and therefore produce green feed during the dry summer, when most of the indigenous rangeland species are dry and leafless. These crops are also used as fodder banks and left ungrazed for long periods, for use when grazing is scarce.

In practice, three species are used, namely *A. nummularia* (oldman saltbush), *A. halimus* (Jewish saltbush) and *A. semibaccata* (creeping saltbush). Oldman saltbush is used in both the Northwest and Little Karoo, while the use of Jewish saltbush is restricted to the Little Karoo region. Creeping saltbush is also used, but only sporadically, mainly because it is not as persistent as the other saltbush species.

There are, however, numerous other *Atriplex* species available, occurring naturally in almost all known climatic regions (Osmond et al. 1980; Watson 1990; Le Hou  rou 1993a, 1993b). This massive genetic resource should therefore be used. Jewish and oldman saltbushes, although very well-adapted to the Western Cape and highly productive, have one major limitation, their low palatability. This results in low intake and reduced animal production. A program was therefore launched in Little Karoo to evaluate a greater variety of species. As shrubs are usually planted and used as single plants, plant spacing and density should influence production (Benjamin et al. 1995). The influence of spacing on the production of a number of *Atriplex* species was therefore also investigated.

Methods

Plants of ten different *Atriplex* spp., *A. halimus* (HAL), *A. nummularia* (NUM), *A. undulata* (UND), *A. paludosa* (PAL), *A. repanda* (REP), *A. canescens* (CNS), *A. cinerea* (CIN), *A. lentiformis* (LEN), *A. semibaccata* (SEM), and *A. lentiformis* subsp. *breweri* (BRE), were cultivated in a nursery and established at the Worcester Veld Reserve during May/June 1989. The seedlings were propagated in an open fiberglass greenhouse. Seed was sown in seeding trays and the seedlings subsequently transplanted in plastic bags, before being established in a Valsrivier soil.

Four rows of each species were planted in a fan formation, with the plants at the narrow end of each triangular plot closest together and those at the wider end, widest apart. Five spacings were used: 2 m $\times$ 2 m (2,500 plants/ha), 2 m $\times$ 1.5 m

(3,333 plants/ha), 1.5 m $\times$ 1.5 m (4,444 plants/ha), 1.5 m $\times$ 1 m (6,666 plants/ha), and 1 m $\times$ 1 m (10,000 plants/ha). The trial was laid out as a 10 $\times$ 5 factorial with three replications.

The trial was executed over five seasons (1989–1993), but only the data from the last four years were used. Individual shrubs in all four rows within a plot were harvested at three-month intervals, but only the data of the two middle rows were used. At each harvest, the shrubs were cut to a height of 400 mm. The dry matter yield per harvest was determined by weighing the total wet material, after which a representative sample was taken, dried at 60°C, and weighed. The annual yield was calculated by accumulating the four harvests.

In Figure 1, the total annual rainfall over the four seasons (1990–1993) at Worcester is shown. Rainfall during the third season was much lower than during the other three seasons.

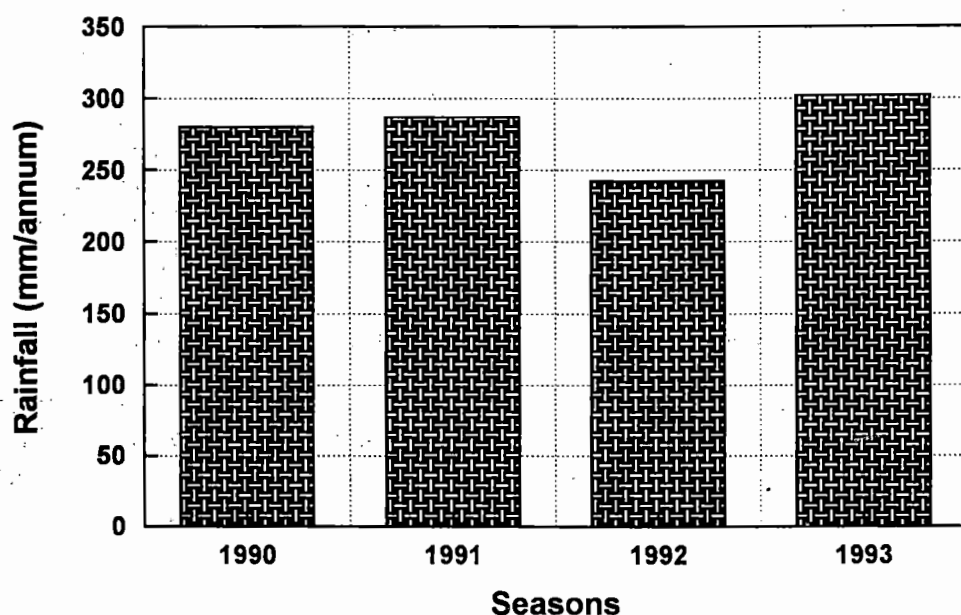


Figure 1. Annual rainfall at Worcester during the evaluation period (1990–1993).

Results

Figure 2 shows the mean yield (g DM/plant per year) of the different species over four seasons (1990–1993). *Atriplex undulata* had, on average, the highest

production per plant. *Atriplex breweri* had the second highest yield; however, it was not significantly higher than *A. nummularia*, *A. halimus*, *A. cinerea*, *A. canescens*, and *A. paludosa*.

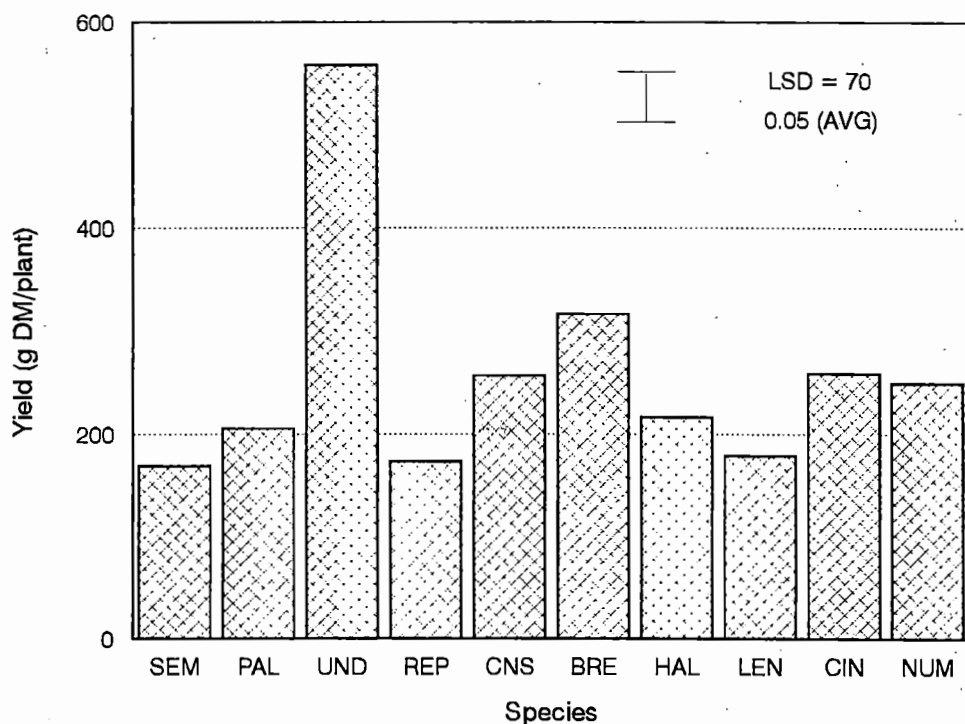


Figure 2. Average yield for ten saltbush species at Worcester over four seasons.

Yield (g DM/plant) of all the species (Figs. 3 and 4) decreased with increased planting density. Yield of *A. undulata* and *A. nummularia* decreased the most. This decrease, however, was smaller during the last two seasons and at the highest plant densities.

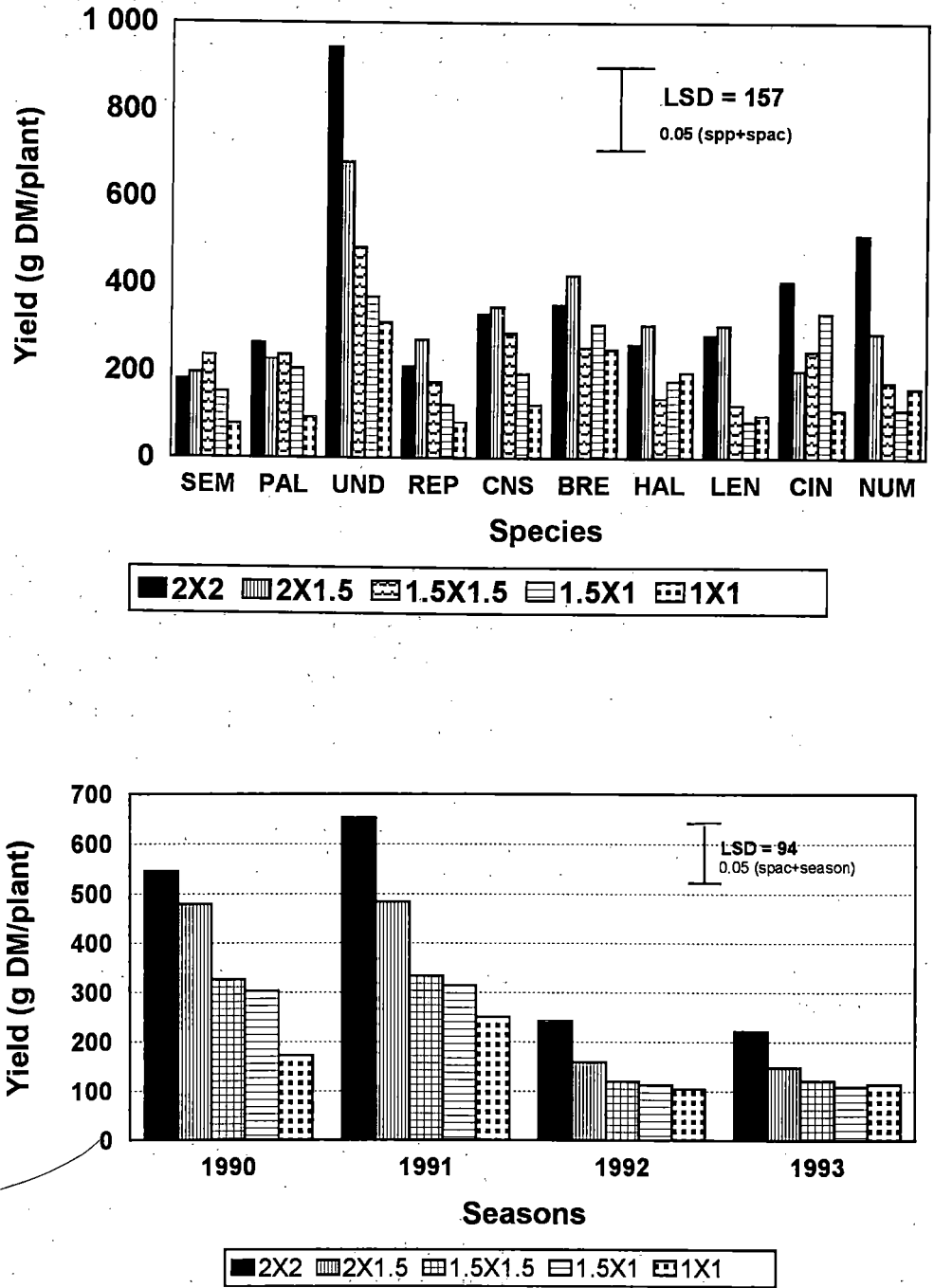


Figure 4. Seasonal influence of spacing on the average yield/plant of ten saltbush species.

The yield per hectare of all the species tended to increase with increased plant density (Fig. 5). Plant density, however, had a smaller influence on yield per hectare (kg/ha) than on yield per plant. Apparently, the greater number of shrubs per unit area at high populations was largely neutralized by the decrease in individual shrub yield.

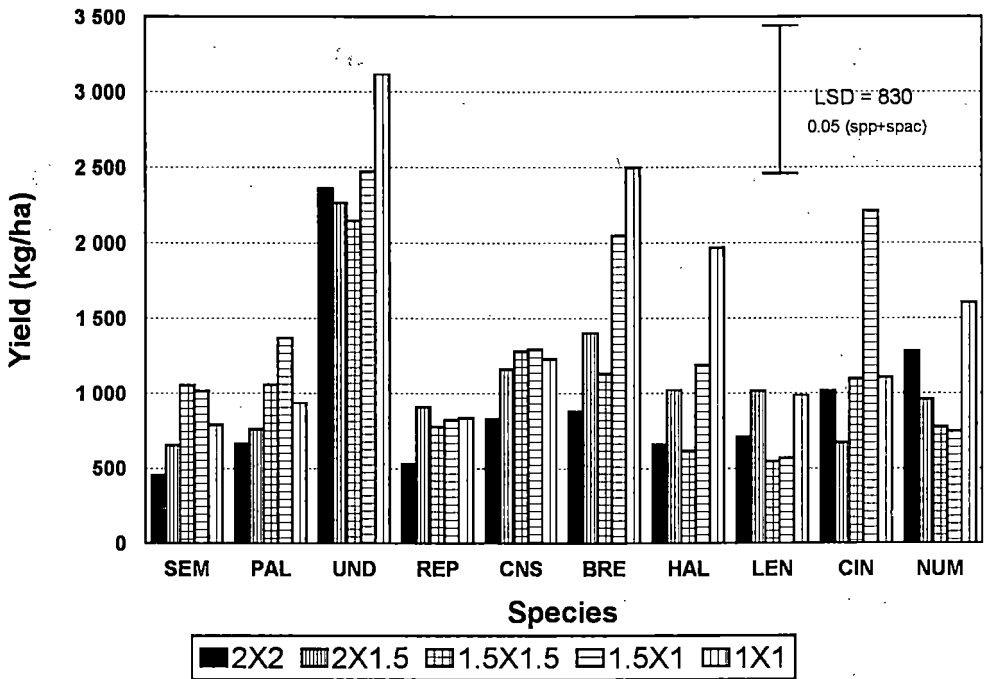


Figure 5. Influence of spacing on the average yield/ha of ten saltbush species over four seasons.

Conclusions

Atriplex undulata was the most productive species. Although *A. paludosa*, *A. canescens*, *A. breweri*, and *A. cinerea* were less productive than *A. undulata*, their production matched that of *A. nummularia*, and *A. halimus*, which are the two most commonly used species. Increased plant population resulted in a decrease in the production of individual shrubs, but this influence became less with increased plant density. Increased plant density also had a much smaller influence on yield per hectare than in the yield per shrub. The influence of plant density on

production per hectare, within the range of densities used in this study, does not therefore seem to be as important as was expected.

References

- Barnard, S.A. 1985. Oumansoutbos in die Winterreënstreek. *Elsenburg Journal* Aug 1985: 18–22.
- Barnard, S.A. 1987. Influence of sowing depth on the germination of Karoo shrubs and grasses. *Journal of the Grassland Society of Southern Africa* 4: 123–126.
- Barnard, S.A., J.M. Van Heerden and H. Gerber. 1992. Evaluation of shrub species for sheep grazing in the Strandveld of the Cape west coast of South Africa. *Journal of the Grassland Society of Southern Africa* 9: 111–113.
- de Kock, G.C. 1980. Drought resistant fodder shrub crops in South Africa. Pages 399–410 in *Browse in Africa: The Current State of Knowledge* (H.N. Le Houérou, ed.). International Livestock Centre for Africa, Addis Ababa, Ethiopia.
- Hoon, J.H. and B.R. King. 1992. Die bepaling van vrywillige inname van oumansoutbos (*Atriplex nummularia*) in drie verskillende vorms. *Karoo Agriculture* 4(4): 4–6.
- Le Roux, P.M., C.D. Kotzé, G.P. Nel and H.F. Glen. 1994. Bossieveld. Grazing plants of the Karoo and Karoo-like areas. Bulletin No. 428. CTP Book Printers, Cape Town.
- Shearing, D. 1994. Karoo. Veldblomgids van Suid-Afrika 6. Nasionale Boek Drukkers, Kaapstad.
- Le Houérou, H.N. 1993a. Salt-tolerant plants for the arid regions of the Mediterranean isoclimatic zone. Pages 403–422 in *Towards the Rational Use of High Salinity Tolerant Plants*, Vol 1 (H. Lieth and A. Masoon, ed.). Kluwer, Netherlands.
- Le Houérou, H.N. 1993b. Environmental aspects of fodder trees and shrubs plantation in the Mediterranean basin. In *Fodder Trees and Shrubs in the Mediterranean Production Systems: Objectives and Expected Results of the EEC Research Contract*. (V. Papanastasis, ed.). Commission of the European Communities, Brussels.
- Osmond, C.B., O. Björkman and D.J. Anderson. 1980. Physiological processes in plant ecology toward a synthesis with *Atriplex*. Springer, Berlin.
- Van Breda, P.A.B. and S.A. Barnard. 1991. Veld plants of the winter rainfall region. A guide to the use of veld plants for grazing. Bull. No. 422. Gov't. Printer, Pretoria.
- Watson, M.C. 1990. *Atriplex* species as irrigated forage crops. *Agriculture, Ecosystems and Environment* 32: 107–118.

The Production of Karoo Bitou (*Osteospermum sinuatum* DC) in the Ceres and Robertson Karoo

J.M. Van Heerden, A.J. Heydenrych and J.C. Botha

Department of Agriculture, Western Cape, Elsenburg, South Africa

Abstract

Karoo bitou (*Osteospermum sinuatum* DC) is one of the most important palatable grazing shrubs on the rangelands of the arid Mediterranean environment of the Karoo. The response of Karoo bitou to defoliation was evaluated over five seasons (1989/90–1993/94) at the Worcester Veld Reserve in the Robertson Karoo and at a commercial farm, Sadawe, in the Ceres Karoo. At Worcester, individual shrubs of Karoo bitou were cut at five frequencies (monthly, bimonthly, three-monthly, six-monthly, and annually) and four heights (100, 150, 200, and 250 mm). At Sadawe, shrubs were cut at two sites. At site A (shallow, shale soil), the shrubs were cut at two frequencies (three-monthly and six-monthly) and four heights (100, 150, 200, and 250 mm). At site B (deep, sandy soil), they were cut at two frequencies (three-monthly and six-monthly) and two heights (150 and 250 mm). Total dry matter yield per shrub was determined at each harvest after drying at 60°C. The total annual rainfall at Worcester was approximately 270 mm over the trial period. At Sadawe, rainfall varied between 60 and 170 mm. Yields were much lower there than at Worcester and higher at the sandy site than at the shale site. At all three sites the total annual DM yield (g DM/plant per year) declined, while the response to cutting frequency increased, over the trial period. At Worcester and the sandy site at Sadawe, there was a significant interaction between cutting frequency and cutting height. At these two sites, shrub yield was more sensitive to cutting height with frequent than with less-frequent cutting. It was clear that, although Karoo bitou seems to be resistant to defoliation, a combination of both frequent and drastic defoliation eventually results in decreased production.

Key words: Karoo, *Osteospermum sinuatum*, dry matter production, defoliation, cutting height.

Introduction

Karoo bitou (*Osteospermum sinuatum* DC) is one of the most important grazing shrubs in Ceres Karoo and Robertson Karoo (Booyens 1972; Joubert and Stindt 1979; Van der Westhuizen 1982; Le Roux et al. 1994). This shrub forms a major component of the palatable rangeland species in this arid Mediterranean environment (Van Breda and Barnard 1991; Shearing 1994). The species also

establishes very successfully when sown on rangelands (Joubert and Van Breda 1976). It is also a prolific seeder, and it is relatively easy to produce its seed, which can be sown without any prior treatment (Joubert and Van Breda 1971; Joubert 1980). The species therefore merits research.

Previous research on the species was largely done in controlled environments (Booyens 1972; Van der Westhuizen and Joubert 1982). No results were available on the production potential of the shrub and its response to defoliation under field conditions. The response of Karoo bitou to frequency and intensity of defoliation was therefore evaluated under these conditions.

Methods

Cutting trials were conducted over five seasons at the Worcester Veld Reserve in the Robertson Karoo and at two sites on a commercial farm, Sadawe, in the Ceres Karoo. At Worcester, individual shrubs of Karoo bitou were cut over five seasons (1989/90–1993/94) at five frequencies (monthly, bimonthly, three-monthly, six-monthly, and annually) and four heights (100, 150, 200, and 250 mm). Total dry matter (DM) yield per shrub was determined at each harvest by weighing the cut samples (leaves plus stems) after drying at 60°C. Ten plants were used per treatment, and the 20 treatments were allocated randomly to plants within a 25-year-old stand of bitou, which was normally used to produce seed for revegetation studies and for sale to farmers.

At Sadawe, shrubs of Karoo bitou were cut at two sites. At site A (shallow, shale soil) the shrubs were cut at two frequencies (three-monthly and six-monthly) and four heights (100, 150, 200, and 250 mm). At site B (deep, sandy soil) the shrubs were cut at two frequencies (three-monthly and six-monthly) and two heights (150 and 250 mm). At both sites, the treatments were applied over four seasons (1990/91–1993/94) to ten randomly selected shrubs. Total DM yield (leaves plus stems; g/plant per year) was determined.

Total annual rainfall at Worcester over the trial period, and the long-term mean value, are shown in Figure 1. Annual rainfall did not vary much over the trial period and was very similar to the long-term average (270 mm/year). The annual precipitation was, however, slightly lower than average during the 1991/92 season. As with total annual rainfall, the distribution thereof, shown in Figure 2, compared very well with the long-term pattern.

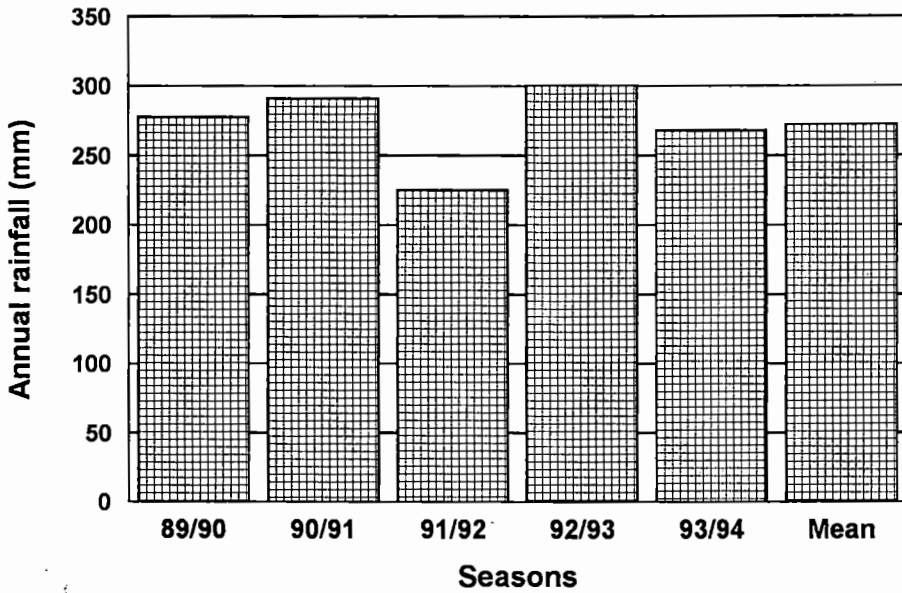


Figure 1. Annual rainfall received at Worcester during the evaluation period.

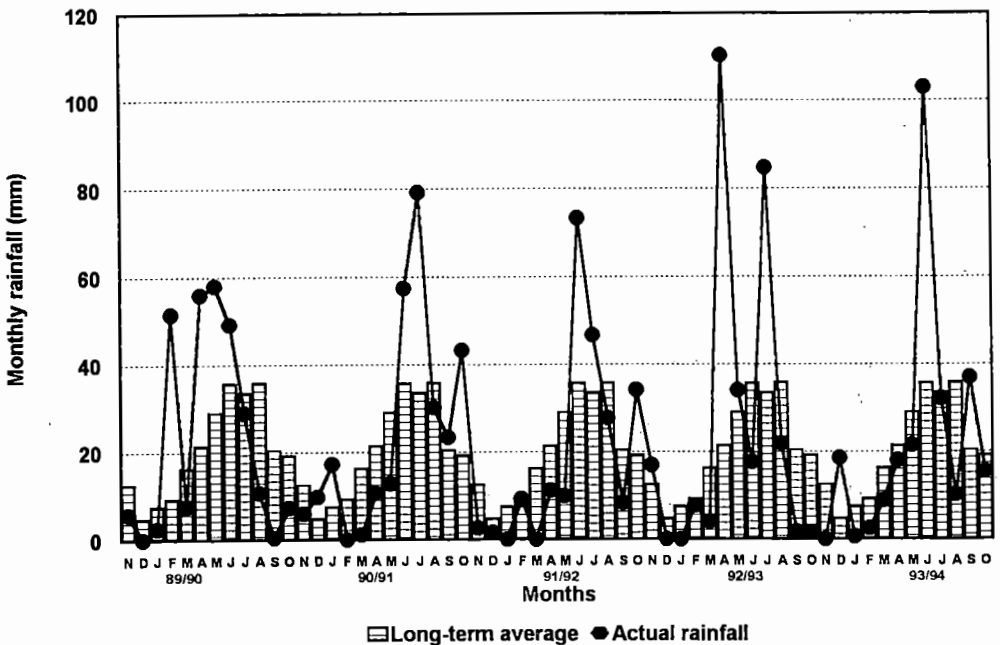


Figure 2. Monthly rainfall received at Worcester during the evaluation period.

Total annual rainfall and its seasonal distribution for Sadawe in the Ceres Karoo are shown in Figures 3 and 4, respectively. Total annual rainfall at this site did not vary much over the first three seasons (170 mm/year), but it was much lower (60 mm/year) during the last season (1993/94). The rainfall distribution compared very well with the long-term pattern.

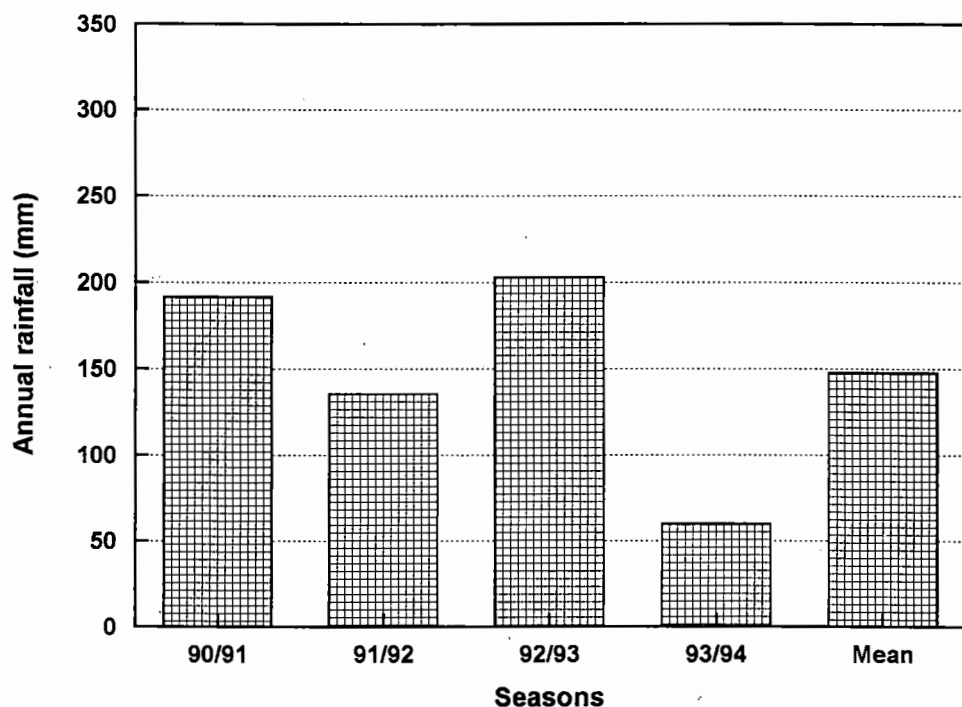


Figure 3. Annual rainfall received at Sadawe during the evaluation period.

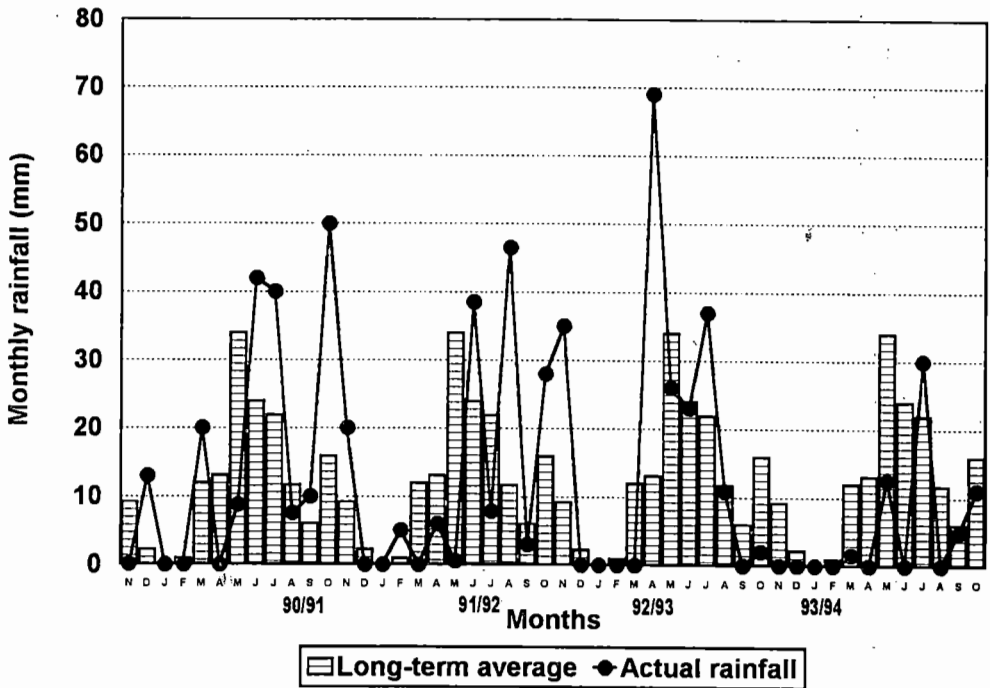


Figure 4. Monthly rainfall received at Sadawe during the evaluation period.

Results

The effect of cutting frequency on total annual dry matter yield (g DM/plant per year) over seasons at Worcester is shown in Figure 5. Yield per shrub declined over the trial period, while the response to cutting frequency increased over consecutive seasons. During the first season (1989/90), the highest yield occurred with the monthly cutting treatment, but during all subsequent seasons, the highest yield was derived at the annual cutting. A decrease in cutting frequency, from monthly to annually, resulted in the most significant increase in individual shrub yield during the last two seasons.

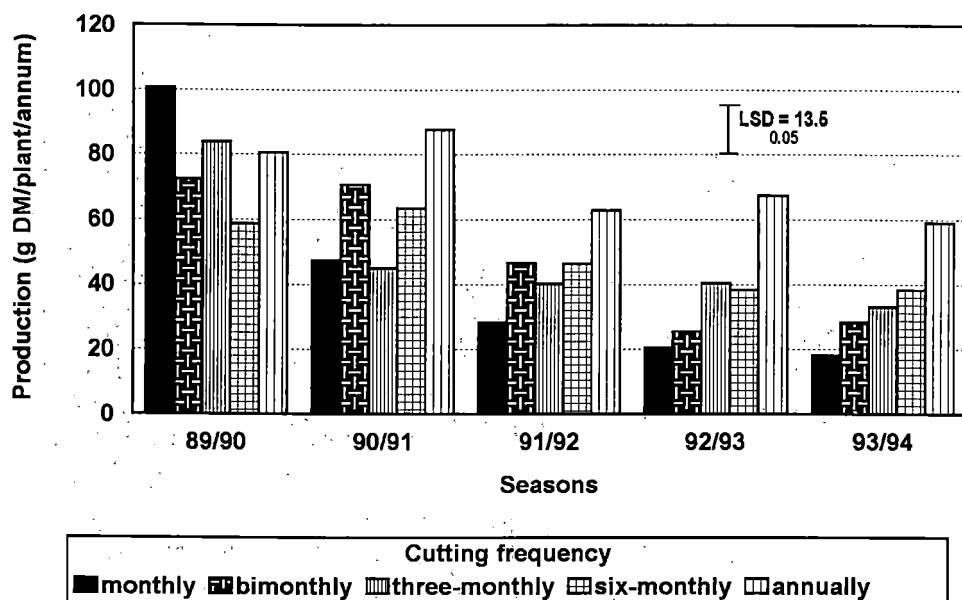


Figure 5. Influence of cutting frequency on production at Worcester.

There was a significant interaction between cutting frequency and at Worcester (Fig. 6). There was no clear response to cutting frequency at 250 mm or to height at the annual frequency. Individual shrub yield was, however, significantly lower at 100 than at 250 mm with the monthly, bimonthly, and three-monthly cuttings, but not with the six-monthly or annual cuttings at this site.

The results of the cutting trials at Sadawe are shown in Figures 7–10. Yields at this site were much lower than at Worcester, which can mainly be attributed to low rainfall. As at Worcester, the individual shrub yields tended to decrease over seasons and were lowest during the last season at both sites A and B (Fig. 7). Yields were, however, higher at site B (sandy soil) than at site A (shallow, stony soil with a high clay content). At site A, there was a significant interaction between cutting height and frequency, with shrub yield clearly more sensitive to cutting height at the three-monthly than the six-monthly regime (Fig. 8). At site B, there was no significant interaction between cutting frequency and height, but yields were significantly higher at 250 mm than 150 mm (Fig. 9), and increased as the cutting frequency decreased from three- to six-monthly (Fig. 10).

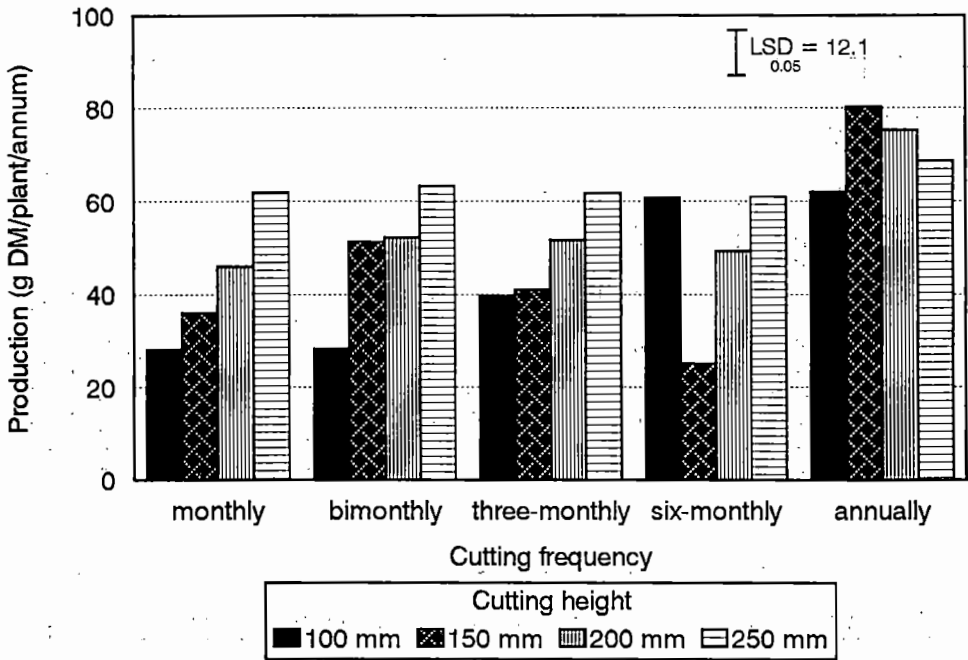


Figure 6. Influence of cutting frequency and height on production at Worcester.

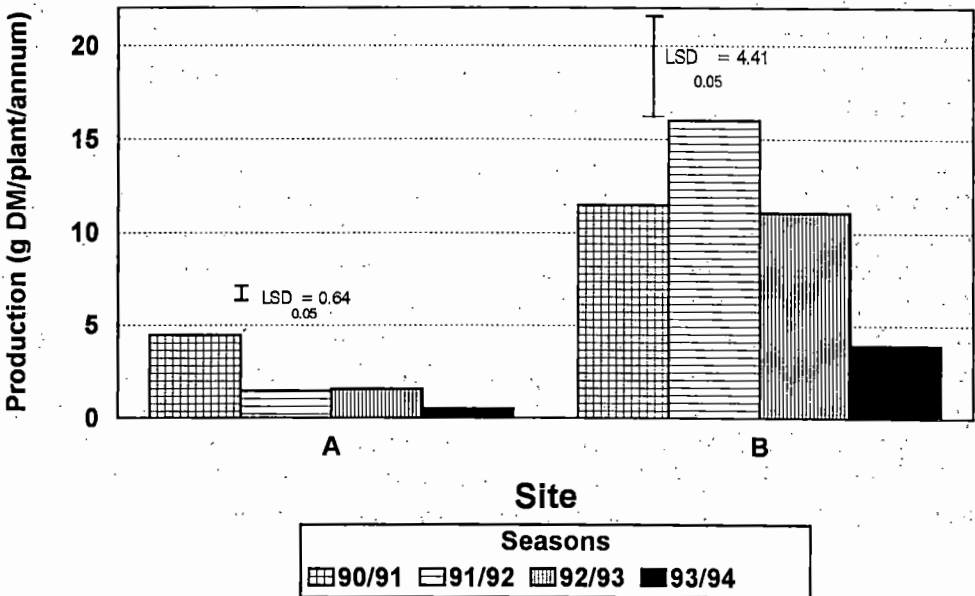


Figure 7. Mean production of bitou at two sites at Sadawe.

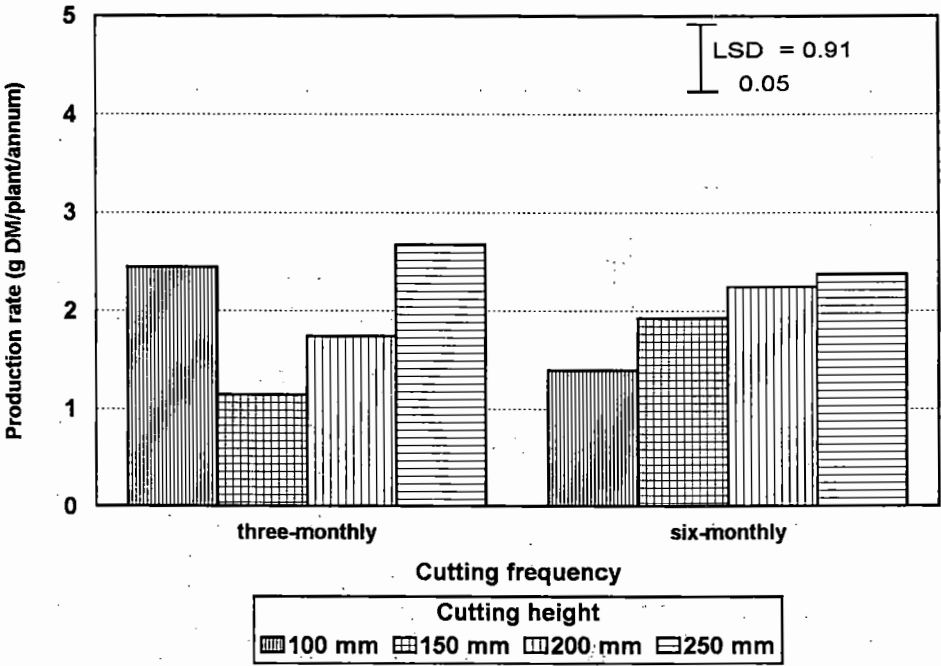


Figure 8. Influence of cutting frequency and cutting height on production at site A at Sadawe.

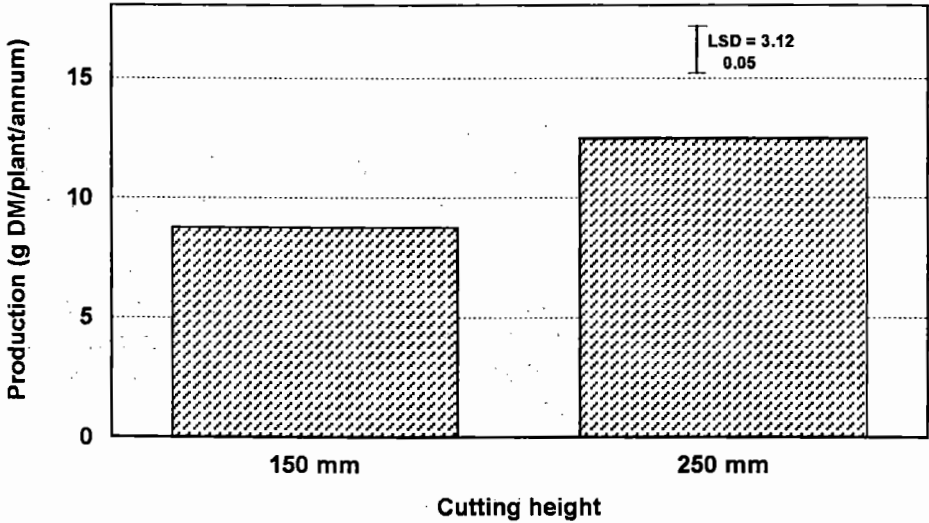


Figure 9. Influence of cutting height on production at site B at Sadawe.

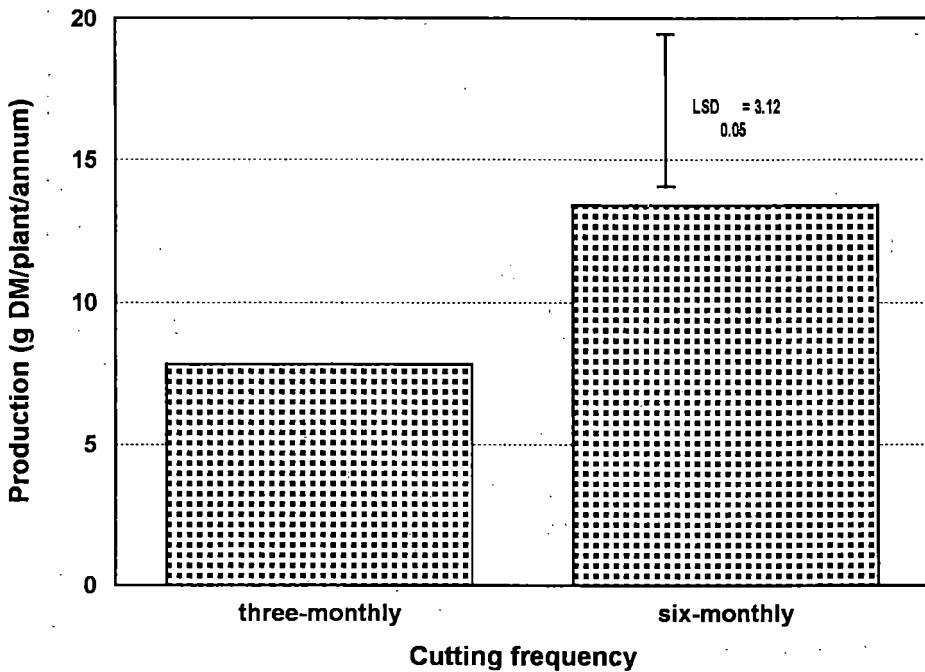


Figure 10. Influence of cutting frequency on production at site B at Sadawe.

Conclusions

The yield of Karoo bitou varied substantially between sites. It is clear that infrequent defoliation may result in shrubs less sensitive to severity of defoliation, while light defoliation may result in a lower sensitivity to frequent defoliation. This underscores a very important principle, i.e. although Karoo bitou is resistant to both frequent, lenient defoliation and infrequent, drastic defoliation, a combination of both frequent and drastic defoliation results in a decrease in production. Furthermore, the negative influence of a combination of frequent and severe defoliation seems to be cumulative over seasons, and becomes more severe when repeated over a number of seasons.

References

- Booyens, C.A. 1972. Die invloed van temperatuur en grondtipe op die groei en ontwikkeling van *Osteospermum sinuatum*. MSc (Agric.) Thesis, University of Stellenbosch, Stellenbosch.

- Joubert, J.G.V. and P.A.B. Van Breda. 1971. Bitou (*Osteospermum sinuatum*) has the properties for the radical improvement of the veld of the Little Karoo. Department of Agricultural technical services, Leaflet No. 56 Veld Improvement Series No. 1.
- Joubert, J.G.V. 1976. Methods of establishing *Osteospermum sinuatum* in the Little Karoo Veld. *Proceedings of the Grassland Society of Southern Africa* 11: 123-124.
- Joubert, J.G.V. 1980. Veld and Pastures in Animal production systems in the Western Cape and South West Africa/Namibia. *South African Journal of Animal Science* 10: 299-303.
- Joubert, J.G.V. and H.W. Stindt. 1979. The nutritive value and general evaluation of natural pastures in the districts of Montagu, Robertson and Worcester in the winter rainfall area of the Republic of South Africa. Technical Communications No. 155.
- Le Roux, P.M., C.D. Kotzé, G.P. Nel, and H.F. Glen. 1994. Bossieveld. Grazing plants of the Karoo and Karoo-like areas. Bulletin No. 428. CTP Book Printers, Cape Town.
- Shearing, D. 1994. Karoo. Veldblomgids van Suid-Afrika 6. Nasionale Boek Drukkers, Kaapstad.
- Van Breda, P.A.B. and S.A. Barnard. 1991. Veld plants of the winter rainfall region. A guide to the use of veld plants for grazing. Bull. No. 422. Gov't. Printer, Pretoria.
- Van der Westhuizen, F.G.J. 1982. Invloed van sneei op fotosintese, reserwestatus en droëmateriaalproduksie van *Ehrharta calycina* J E Sm. en *Osteospermum sinuatum* DC. PhD (Agric.) Thesis, University of Stellenbosch, Stellenbosch.
- Van der Westhuizen, F.G.J. and J.G.V. Joubert. 1982. Die invloed van sneei tydens antese op koolsuurgasabsorpsie en koolhidraadinhoud van *Ehrharta calycina* en *Osteospermum sinuatum*. *Proceedings of the Grassland Society of Southern Africa* 17: 99-105.

Le Frêne (*Fraxinus* spp.) et le Pistachier de l'Atlas (*Pistacia atlantica*) : Écologie et Utilisation en Algérie

A. Abdelguerfi et M. Laouar

Laboratoire d'Amélioration des Plantes, Enasa El Harrach, Algérie

Résumé

Le frêne avec ses deux espèces (*Fraxinus angustifolia* et *F. xanthoxyloïdes*) et le pistachier de l'Atlas sont très utilisés en Algérie. *Fraxinus angustifolia* est un arbre d'émondage très exploité et intervient de façon remarquable dans l'alimentation du cheptel dans les régions montagneuses du nord (Kabylie). *Fraxinus xanthoxyloïdes*, fréquent dans les Aurès, est très recherché par le cheptel. Seuls les spécimens qui poussent dans les buissons arrivent à survivre à cause du surpâturage. Le pistachier (bétoum) subit la même pression. Dans la steppe il se maintient très difficilement dans les dayas (bas fonds) et les seuls individus qui arrivent à se maintenir sont ceux qui poussent dans le *Ziziphus lotus* qui les protège de la dent du bétail. Dans le Hoggar, le *Pistacia atlantica* est aussi soumis à la pression du pâturage et seuls les sujets qui poussent dans le Myrte, le long des oueds, arrivent à se maintenir.

Mots-clés : *Fraxinus* spp., *Pistacia atlantica*, écologie, utilisation, Algérie.

Abstract

Two species of ash (*Fraxinus angustifolia* and *F. xanthoxyloïdes*) and the Atlas pistachio tree are much used in Algeria. *Fraxinus angustifolia* plays an important role in feeding livestock of the northern mountainous regions. *Fraxinus xanthoxyloïdes* is often found on the Aurès, where it is considered the best feed for livestock. Because of overgrazing, only specimens that grow in bushes can survive. This is also true of pistachio. In the steppes, where there are *dayas* (depressions), it is difficult to keep these species alive. They grow only with the *Ziziphus lotus*, which protects them from overgrazing. In the Hoggar, *Pistacia atlantica* is subjected to overgrazing and survives only when grown with the myrtle (*Myrtus nivellei*).

Key words: *Fraxinus* spp., *Pistacia atlantica*, ecology, utilization, Algeria.

Introduction

La plus grande partie du territoire algérien est localisée sous les bioclimats semi-arides et arides. Les régions humides et sub-humides sont très limitées et sont souvent très accidentées.

La surface agricole par habitant ne fait que diminuer compte tenu de la croissance démographique, de l'urbanisation et de l'érosion des sols.

A côté de la céréaliculture, les fourrages occupent une surface relativement réduite. Cette surface ne pourrait augmenter, compte tenu des besoins en production végétale pour l'alimentation humaine. Bien au contraire, les surfaces réservées aux parcours sont en train de se rétrécir suite à la mise en culture et au surpâturage (Abdelguerfi et Laouar 1996 ; Laouar et Abdelguerfi 1996).

Par ailleurs, le cheptel est soumis à des déficits alimentaires saisonniers et inter-annuels. Les ressources fourragères et pastorales sont insuffisantes et aléatoires à causes des conditions climatiques et de la dégradation des parcours et des sols.

Compte tenu de la surface agricole limitée, du relief souvent accidenté, du déficit fourrager intra- et inter-annuel, les arbres et les arbustes fourragers sont importants pour l'augmentation et la régularisation de la production fourragère et pastorale particulièrement dans les régions arides et semi-arides.

Dans ce sens, des arbres fourragers comme le frêne (*Fraxinus* spp.) et le bétoum (*Pistacia atlantica*) jouent un rôle important dans l'alimentation du cheptel.

Nous tenterons de préciser l'écologie et l'utilisation de ces arbres selon les conditions du milieu.

Écologie et Utilisation des Frênes

Le genre *Fraxinus* est représenté en Algérie par deux espèces : *Fraxinus angustifolia* Vahl. et *F. xanthoxyloides* Wamm.

La première espèce, bien qu'elle se rencontre dans toute l'Algérie (Quezel et Santa 1963), est très fréquente autour des habitations et le long des routes. Le frêne est planté dans les terroirs irrigués ou à proximité de ceux-ci (Bourbouze et Donadiou 1987). C'est un arbre à feuilles caduques très apprécié pour son ombre en été et pour la qualité de son bois.

En Kabylie, *F. angustifolia* Vahl. (syn. *F. oxycarpa* Willd., *F. oxyphylla* M. Biel.) est très recherché aussi pour la qualité de son fourrage. C'est un arbre très respecté et même vénéré pour la valeur de son fourrage et pour la qualité de son ombre. C'est un excellent arbre d'émondage. Il semble que la production laitière est

souvent améliorée par la consommation du frêne. Les agro-éleveurs n'ayant pas assez d'arbres de ce type louent les arbres des agriculteurs de la région pour réaliser un émondage et utiliser la production fourragère.

Traditionnellement, *F. angustifolia* est très exploité en Kabylie et les arbres sont souvent fortement émondés les années de sécheresse.

Selon Bourbouze et Donadieu (1987), les feuilles des arbres à feuilles caduques récoltées entre le 1er juillet et le 1er octobre constituent un fourrage d'aussi bonne qualité que la luzerne ou le sainfoin, avec un taux de digestibilité du même ordre. La digestibilité des feuilles de *Fraxinus ornus* varie entre 53 et 64% (Papachristou et Nastis 1990). La valeur fourragère du feuillage du frêne à 12–15% d'humidité est de 0,60 à 0,75 UF/kg (Bourbouze et Donadieu 1987), elle est supérieure à celle du mûrier, du robinier, du févier et du chêne vert.

Dans les autres régions d'Algérie, *F. angustifolia* est apprécié surtout pour la qualité de son ombre et la qualité de son bois. Les plantations restent, cependant, très limitées.

Le frêne épineux, *F. xanthoxyloides* Wamm. (syn. *F. dimorpha* Coss. et Dur.) est fréquent dans la région des Aurès, Bellezma, Monts du Hodna et rarissime ailleurs (Quezel et Santa 1963); il est très apprécié par le cheptel caprin en particulier. Sous la pression du pâturage, les jeunes sujets n'arrivent à pousser que si la germination a lieu au niveau des buissons. Malgré cela, seules les parties hautes des arbustes échappent à la dent du bétail.

Enfin, il est important de signaler que *Fraxinus ornus* L. et *F. excelsior* L. sont parfois cultivés dans le Tell (Quezel et Santa 1963).

Écologie et Utilisation du Bétoum

En Algérie, le genre *Pistacia* est représenté par *P. lentiscus* L. (Lentisque) dans toute l'Algérie, *P. terebinthus* L. (Térébinthe) dans le Tell surtout et *P. atlantica* Desf. (bétoum) dans toute l'Algérie sauf dans les régions très arrosées (Quezel et Santa 1963).

Le bétoum va du Maroc au Moyen Orient et pénètre jusqu'en Iran (Le Flo'h et al. 1989). En Algérie, il est disséminé à travers les hauts plateaux et l'Atlas saharien. En Tunisie, il est plus fréquent dans les régions prédésertiques alors qu'au Maroc il peut monter jusqu'à 2.000 m dans l'Anti-Atlas et le Haut Atlas (Le Flo'h et al. 1989).

Selon Monjauze (1967), c'est l'arbre par excellence des hautes plaines centrales du Maghreb et des dayas (bas fonds) du piémont méridional de l'Atlas Saharien.

Le bétoum, *P. atlantica*, est un arbre qui peut atteindre 15 à 20 mètres de hauteur, les plus beaux spécimens se rencontrent dans les dayas du sud de l'Atlas Saharien entre Laghouat et Ghardaïa. Il s'installe sous l'abri des buissons du jujubier (*Ziziphus lotus*). Dans les immensités pré-désertiques la daya (bas-fond) avec le bétoum reste le seul refuge où la halte est rendue possible aux nombreux voyageurs et aux bergers (Abdelkrim 1988). Les dayates à Pistachier de l'Atlas constituent, dans les steppes, une physionomie de type « steppes arborées » et l'association à *P. atlantica* et *Ziziphus lotus* apparaît comme le refuge d'un paysage « forestier » du bioclimat saharien (Abdelkrim 1985).

Dans le Hoggar, le bétoum a été rencontré dans l'oued Idikel à l'intérieur des buissons de myrte (*Myrtus nivellei*) (Abdelkrim 1989). Le myrte joue le même rôle que le jujubier dans les groupements à pistachiers des dayas.

Bencharif et al. (1991) ont complété le travail par un inventaire dans le massif de la Taessa (Atakor, Ahaggar) et ont montré que cette espèce relique méditerranéenne est relativement plus abondante que ne laissaient prévoir les études antérieures.

Dans cette région, le bétoum assure aussi un appui fourrager non négligeable. Son écorce, mise dans les denrées stockées, permet semble-t-il de réduire les attaques d'insectes selon les Touareg.

Pistachia atlantica est une plante aux nombreuses propriétés (Le Floch 1983).

Enfin, il est important de mentionner que selon les régions le *P. atlantica* peut se régénérer sous d'autres espèces que *Ziziphus lotus* et *Myrtus*. Selon Monjauze (1968), le bétoum se régénère tout aussi bien dans les touffes d'*Asparagus stipularis*, *Asparagus albus*, *Lycium intricatum* et *Calycotome intermedia* sur le piémont septentrional de la maeseta oranaise, dans la moyenne vallée de la Tafna, sur les basses collines et dans la plaine du Chelif.

Conclusion

Le frêne, dans le nord du pays, et le bétoum, dans la steppe et dans le sud, jouent un rôle important dans la protection des sols et la production fourragère. Le frêne épineux, dans les Aurès, et le bétoum, dans la steppe et dans le Sahara, se maintiennent grâce à l'ingéniosité de la nature. La première espèce est protégée de la dent du bétail par les buissons alors que le bétoum n'arrive, semble-t-il, à se régénérer que grâce au *Ziziphus lotus* dans la steppe et au *Myrtus nivellei*. Il serait judicieux d'imiter la nature pour permettre l'extension et le maintien des arbres et des arbustes fourrager dans les régions arides et semi-arides. Une telle approche permettra un développement durable dans les régions marginales où la pression sur le milieu est très forte.

Références

- Abdelguerfi, A. et M. Laouar. 1996. La privatisation du foncier: impact sur l'environnement et sur les ressources génétiques en Algérie. *En Impact du Régime Foncier sur la Gestion de l'Espace Pastoral et de la Conduite des Troupeaux en Régions Arides et Semi-Arides*. 4ème Séminaire International du Réseau Parcours, 17-19 Octobre 1996, Gabès (Tunisie). *Parcours*. (sous presse)
- Abdelkrim, H. 1985. Les dayates du Sud de l'Atlas Saharien (Algérie). Pages 361-371 *en* *Végétation et Géomorphologie Proceedings du Colloque Phytosociologie No. XIII*. Bailleul, 1985.
- Abdelkrim, H. 1988. Les dayas. Pages 158-159 *in* Guide de l'Excursion Internationale de Phytosociologie: Algérie du Nord (T. Worterski, ed.). Association Internationale pour l'étude de la Végétation, Institut National Agronomique El Harrach Algérie. Föttingen, RFA.
- Abdelkrim, H. 1989. Un joyau floristique: l'oued Idikel, oued à *Pistacia atlantica* et *Myrtus nivellei* dans le Hoggar. *Ann. Inst. Nat. Agron. El Harrach* 13(1): 32-43.
- Bencharif, M., N. Boucheneb et S. Bensaid. 1991. Le pistachier de l'Atlas dans le massif de l'Ahaggar. 3ème Séminaire National sur les Ressources Phytogénétiques Locales et leurs Valorisations, 15-19 juin 1991, INA El Harrach. (sous presse)
- Bourbouze, A. et R. Donadieu. 1987. L'élevage sur Parcours en Régions Méditerranéennes. CIHEAM/IAM-Montpellier.
- Laouar, M. et A. Abdelguerfi. 1996. Privatisation et partage du foncier : une des causes de la dégradation des milieux naturels en Algérie. *In Impact du Régime Foncier sur la Gestion de l'Espace Pastoral et de la Conduite des Troupeaux en Régions Arides et Semi-Arides*. 4ème Séminaire International du Réseau Parcours, 17-19 Oct 1996, Gabès (Tunisie). *Parcours*. (sous presse)
- Le Floc'h, E. 1983. Contribution à une étude ethnobotanique de la flore tunisienne. Pages 146-147 *in* Publications Scientifiques Tunisiennes. Programme: Flore et Végétation. Deuxième partie.
- Le Floc'h, E., A. Schoenenberger, M.A. Nabli et G. Valderon. 1989. Deuxième partie: Biologie et écologie des principaux taxons. Pages 19-193 *en* Essai de Synthèse sur la Végétation et la Phyto-écologie Tunisiennes. I. Éléments de botanique et de phyto-écologie. MAB/Fac des Sciences Tunis.
- Monjauze, A. 1967. Note sur la régénération du bétoum, par semis naturels dans la place d'essais de Kef Lefaa. *Bull. Soc. Hist. Nat. Afrique du Nord* 68: 59-64.
- Monjauze, A. 1968. Répartition et écologie de *Pistacia atlantica* Desf. en Algérie. *Bull. Soc. Hist. Nat. Afrique du Nord* 56: 5-128
- Papachristou, T.G. and A.S. Nastis. 1990. Nutritive value of two broadleaved fodder trees (*Carpinus duinensis* and *Fraxinus ornus*) in early summer and autumn. Pages 147-151 *en* Development and preservation of low input mediterranean pastures and fodder systems. Proceedings of 6th Meeting FAO on Mediterranean pastures and fodder crops. 17-19 Oct, Bari, Italy.
- Quezel P. et S. Santa. 1963. Nouvelle flore d'Algérie et des régions désertiques méridionales. CNRS Paris. 2: 611-612 et 739.

Biological Nitrogen Fixation and ^{15}N -Labeled Mineral Nitrogen Uptake by *Acacia cyanophylla*, *Acacia cyclops* and *Atriplex* spp.

M. Ismaili¹, B. Saloua¹ and M.P. Salema²

¹University Moulay Ismail, Faculte des Sciences, Benimhamed, Meknes Morocco

²Soil fertility and Irrigation Section (AEA), Vienna, Austria

Abstract

In many regions of Morocco, soil fertility has deteriorated in recent years. Establishment of *Acacia* and *Atriplex* species is the best way to restore fertility and productivity. An experiment was conducted in an arid site on a sandy clay loam soil under 178 mm annual rainfall. Five trees of *Atriplex nummularia*, *Acacia cyanophylla*, *Acacia cyclops*, and *Eucalyptus torquata* received 4 g of ammonium sulfate enriched with 10% atom excess ^{15}N diluted in water. The trees were five years old. Twelve months later, each tree was destroyed and divided into five parts, from top to roots. Each part was divided into leaves and stems. Dry matter, total N, and ^{15}N were determined. The establishment and growth of *Atriplex* were rapid, showing that this plant is very well adapted to arid environments. Trees accumulated significant ^{15}N excess in all parts. *Atriplex* had less ^{15}N than *Eucalyptus* and *Acacia*, showing that it has a high ability to absorb and assimilate soil nitrogen and also fix atmospheric N_2 . *Acacia cyclops* fixed only 11% of its nitrogen. *Acacia cyanophylla* fixed 41% of its nitrogen, but *Acacia cyclops* took up more N from the soil. *Atriplex* also fixed N_2 ; its ^{15}N concentration was very low. Less than half the total dry matter for *Atriplex* was in its woody tissue. *Atriplex* had higher N than *Acacia cyanophylla*. Paranodulation of *Atriplex nummularia* was studied to explain the high N accumulation by nitrogen fixation. *Rhizobium*, *Azorhizobium*, and *Azospirillum* were added to the soil after seeding. The isotope-dilution method showed high dilution of ^{15}N in the *Atriplex* plants.

Key words: ^{15}N isotope dilution, *Atriplex* spp., *Acacia* spp., N uptake, biological nitrogen fixation.

Introduction

Seed productivity may be best achieved by planting *Acacia* and *Atriplex* species. These species fix nitrogen, produce nutritious foliage, green manure, shade, and firewood, and reduce soil erosion. Phosphorus deficiency limits the establishment of most N_2 -fixing trees in many soils. An increase in total nitrogen due to P application was reported for several legumes and is attributed to higher N_2 -fixing activity.

Atriplex nummularia is a halophyte and accumulates N. Investigations on partitioning of N and N uptake by *Acacia* species, *Atriplex nummularia*, and *Eucalyptus* spp. are important to understand how these trees behave in arid environments.

The objectives of the present study were to:

- Study the partitioning of N by *Acacia*, *Eucalyptus*, and *Atriplex* species under different P treatments.
- Determine N uptake by *Acacia*, *Eucalyptus*, and *Atriplex* species under different P treatments.
- Investigate biological nitrogen fixation by *Acacia* and *Atriplex* species.
- Investigate paranodulation in *Atriplex* plants.

Materials and Methods

Experiments were conducted in the Sidi Chiker range perimeter (175 mm rainfall). The soil was fine loamy. Soil chemical characteristics were: H₂O pH = 7.80; KCl pH = 7.40; total C = 1.40%; organic matter = 1.86%; total N = 0.08%; available P = 15 ppm; available K = 126 ppm; Ca = 41 meq/100g; Mg = 4.50 meq/100g.

The study comprised three phosphorus treatments: P0 (0 ppm added), the unfertilized control; P1 (50 kg/ha P₂O₅); and P2 (100 kg/ha P₂O₅). *Atriplex nummularia*, *Acacia cyanophylla*, *Acacia cyclops*, and *Eucalyptus torquata* were transplanted from a nursery in 40 × 40 × 40 cm holes. At planting, the plots (1 m²/tree) were fertilized with 2g of ammonium sulfate enriched with 10% atom excess ¹⁵N. Ammonium sulfate was diluted in water and the solution was injected at a 10 cm depth around each tree in two applications. The soil was irrigated after fertilization. The experimental design was randomized with five replications. The plants were harvested 11 months after planting. The above-ground part was cut at the soil level. The roots were removed, and nodules were collected and counted. Dry matter, total N, and ¹⁵N were determined.

An experiment was carried out on a five-year-old plantation of *Atriplex nummularia*, *Acacia cyanophylla*, *Acacia cyclops*, and *Eucalyptus torquata*. Five trees of each species received 4 g of ammonium sulfate enriched with 10% atom excess ¹⁵N injected into the soil around the trees at a depth of 20 cm. The trees were cut 12 months later for testing. Each tree was destroyed and divided into five parts. Part 1 was the upper part of the tree, part 2 the middle part, part 3 the basal part, part 4 was the trunk, and part 5 the roots. Each part was divided into leaves and stems. N₂ fixation was measured by the isotope dilution method. *Eucalyptus* spp. served as the control.

A pot experiment was conducted to study paranodulation on *Atriplex nummularia*. After germination, different strains of *Rhizobium*, *Azorhizobium*, and *Azospirillum* were added to the soil, which had been previously enriched with ^{15}N . The hormone 2-4-D, at a 1 ppm concentration, was added in solution to stimulate the production of paranodules. After four days, the pots were watered intensively.

Results and Discussion

Nodule number and dry weight of *Acacia cyanophylla* were not affected by P (Table 1).

Table 1. Effect of phosphorus treatment on nodules/plant and nodule dry weight of *Acacia cyanophylla*.

Phosphorus (P_2O_5 kg/ha)	Nodule		
	Number	Dry weight (mg/plant)	LSD 0.05
0	22	100	8
100	16	70	32

Atriplex nummularia had a much higher shoot dry weight and total N than *Acacia* or *Eucalyptus*. Establishment and growth of *Atriplex nummularia* were rapid. Phosphorus treatments increased growth and total N of *Atriplex* (43% by addition of 100 kg/ha P_2O_5), but reduced that of *Acacia* and *Eucalyptus* (Table 2).

The ^{15}N in *Atriplex nummularia* was much lower than in *Acacia* and *Eucalyptus*. The dilution of ^{15}N in this plant may be due to the high N accumulation in its tissues and to biological N_2 fixation (Table 2).

Table 2. Dry weight (g), total N (mg), and ^{15}N of *Acacia cyanophylla* grown with *Eucalyptus gonphocephala* and *Atriplex nummularia* under three phosphorus treatments (0, 50, and 100 kg/ha P_2O_5).

	Shoot			Root		
	DW (g)	TN (mg)	^{15}N (%)	DW (g)	TN (mg)	^{15}N (%)
<i>Atriplex nummularia</i>						
P0	178	2,854	0.067	34	285	0.161
P2	175	2,773	0.075	35	264	0.125
P3	256	3,990	0.085	42	332	0.203
<i>Acacia cyanophylla</i>						
P0	28	340	0.324	12	96	0.351
P2	26	361	0.290	11	84	0.383
P3	18	253	0.306	16	101	0.499
<i>Eucalyptus gonphocephala</i>						
P0	65	0.71	0.407	17	0.07	0.424
P2	65	0.73	0.573	18	0.07	0.488
P3	49	0.56	0.523	15	0.06	0.512
LSD 0.05	76	1.25	0.090	7.6	0.08	0.060

Acacia cyanophylla fixed more N at P1 than at P0 and P2 (Table 3). The addition of 20 kg P/ha was sufficient for good growth of *Atriplex nummularia*.

Table 3. Shoot percentage N dfa of *Acacia cyanophylla* and *Atriplex nummularia*

Phosphorus (P ₂ O ₅ kg/ha)	<i>Acacia cyanophylla</i>	<i>Atriplex nummularia</i>
0	20	85
50	49	87
100	41	84

Leaf N was higher than stem N. Trunks of *Acacia cyanophylla* had higher total N (41% of N in the plant) than other species: *Atriplex nummularia* (16%), *Acacia cyclops* (20%), and *Eucalyptus torquata* (20%). However, root N was higher in *Acacia cyanophylla* (14%) than in the other species: *Atriplex nummularia* (5%), *Acacia cyclops* (8%), and *Eucalyptus torquata* (9%) (Table 4).

Table 4. Dry weight and total N of different plant parts of *Acacia cyanophylla*, *Acacia cyclops*, *Eucalyptus torquata*, and *Atriplex nummularia*.

	<i>E. torquata</i>		<i>Acacia cyclops</i>		<i>Acacia cyanophylla</i>		<i>Atriplex nummularia</i>	
	DW (g)	TN	DW	TN	DW	TN	DW	TN
Part 1 L	412	4.24	719	10.71	95	2.37	474	12.23
Part 1 S	165	0.64	212	1.91	182	2.44	188	2.74
Part 2 L	2,097	21.18	2,262	30.31	541	13.47	2,472	73.30
Part 2 S	839	2.27	680	4.22	1,038	14.43	940	10.10
Part 3 L	1,144	10.98	1,811	22.46	541	12.50	1332	37.96
Part 3 S	457	1.33	520	2.86	1,041	14.68	548	7.73
Trunk	5,644	12.98	4,430	20.69	6,718	53.74	4043	29.92
Roots	2,384	5.24	1,163	8.61	1,792	19.17	1103	9.38
Whole plant	13,142	59	11,770	102	11,948	133	11,200	184
LSD 0.05	177	1.05	76	3.24	130	8.18	71	5.25

L = leaves, S = stems. The trees were five years old.

After six years of growth, there was no difference in dry weight among tree species. But *Atriplex nummularia* accumulated more soil N. N of *Atriplex nummularia* (1.64%) was higher than *Acacia cyanophylla* (1.11%), *Acacia cyclops* (0.9%), and *Eucalyptus* (0.5%).

Atriplex nummularia had less ¹⁵N than *Eucalyptus torquata* or the two *Acacia* species, showing a high ability to absorb soil N and a good potential for N₂ fixation.

Although *Acacia cyanophylla* and *Acacia cyclops* showed similar yields (11.9 and 11.8 kg/plant, respectively), the former fixed more N₂ and the second took up more soil N. Paranodules were observed, but were too small in pot experiments and

disappeared rapidly during sampling. Biological nitrogen fixation alone cannot explain the high levels of N accumulation by *Atriplex* spp.

Table 5. Excess ^{15}N and N dfa of whole *Acacia cyanophylla*, *Acacia cyclops*, *Eucalyptus torquata*, and *Atriplex nummularia*.

	<i>Eucalyptus torquata</i>	<i>Acacia cyclops</i>	<i>Acacia cyanophylla</i>	<i>Atriplex nummularia</i>
Excess ^{15}N (%)	0.041	0.037	0.024	0.020
LSD 0.05	0.005			
N dfa (%)		11	41	50

Conclusion

Atriplex nummularia accumulated more N and had a lower ^{15}N concentration than *Acacia*. It also showed good potential for N_2 fixation. Nitrogen fixation of *A. cyanophylla* was higher than *A. cyclops*, but both species grew well in arid soils with low fertility. Growth of *Eucalyptus* and *Acacia* was favored only by low levels of P. However, *Atriplex nummularia* responded to all P treatments.

Acknowledgments

Financial support from the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and the International Center For Agricultural Research in the Dry Areas (ICARDA) is gratefully acknowledged.

Effects of Spacing and Grazing on Relative Growth Rate of Woody Fodder Plants in a Semi-arid Area of Northern Greece

A.B. Ainalis¹ and C.N. Tsiouvaras²

¹Forest Service, Lagadas, Greece

²Laboratory of Range Science, Aristotle University, Thessaloniki, Greece

Abstract

The relative growth rate of some woody species, in relation to spacing and grazing of sheep, was studied in a semi-arid area with poor sandy soil in northern Greece. Four species were planted (*Robinia pseudoacacia*, *Gleditschia triacanthos*, *Amorpha fruticosa*, and *Morus alba*) at three spacings (1.5×1.5 m, 2.5×2.5 m, and 3.5×3.5 m). One-year-old plants, grown from seed, were kept in a shrubby form by cutting during the winter. Grazing was carried out two times during the summer (early July and late August) in 1992, 1993, and 1994. Results showed that RGR was not affected by spacing. *Robinia* presented the highest shoot relative growth rate (0.34 cm/day) and leaf relative growth rate (0.14 cm/day). Grazing increased leaf relative growth rate, but decreased shoot relative growth rate. *Morus* was well-adapted to specific environment and to grazing.

Introduction

Fodder trees and shrubs can fill the gaps in feed for livestock during summer in the arid and semi-arid areas of the Mediterranean region (Baumer 1983; Tsiouvaras 1993). In the lower and semi-mountainous zones of Greece, the grasslands occupy an area of about 0.6 million ha. The production and quality of herbage from these grasslands is below potential due to heavy and uncontrolled grazing over many years. In addition, the herbaceous vegetation dries out early in the summer and is of low nutritional value. The introduction of woody and, especially, leguminous species to this land will provide multiple benefits, such as the production of green and nutritious fodder during summer, the decrease of soil erosion, the enrichment of soil with nitrogen, and the improvement of the wildlife habitat, landscape, and food resources (Le Houérou 1993; Papanastasis 1993). In order to determine which species are better adapted in these areas, the growth dynamic, in relation to planting distance (spacing) and proper grazing, should be studied.

This study assessed the effects of plant spacing and grazing on the growth dynamic of the species black locust (*Robinia pseudoacacia*), honey locust (*Gleditschia triacanthos*), bastard-indigo (*Amorpha fruticosa*), and white mulberry (*Morus alba*), introduced onto an overgrazed grassland.

Materials and Methods

The study was conducted at Scholari village, 45 km east of Thessaloniki, Macedonia, Greece, at 40° 41' north latitude, 23° 14' east longitude, at an elevation of 100 m. The long-term average annual rainfall is 438 mm and the mean air temperature is 14°C. The climate of the area, according to the bioclimatogram of Emberger, is characterized as semi-arid with a cold winter (Emberger 1942). The soils are derived from conglomerates of the tertiary period and colluvials from river or torrent bank deposits. They are sandy to sandy silt in texture.

The trial was conducted on an area of 1.7 ha covered by herbaceous vegetation. The experimental area was fenced in order to control grazing. The four species (*Robinia pseudoacacia*, *Gleditschia triacanthos*, *Amorpha fruticosa*, and *Morus alba*) were planted at three spacings (1.5 × 1.5 m, 2.5 × 2.5 m, and 3.5 × 3.5 m) corresponding to three different densities: 4,440, 1,600, and 810 shrubs/ha. Plants, grown from seed, were one year old at the time of planting in 1991. The experimental layout was a split plot design with three replications (Steel and Torrie 1980). Every December, all plants were cut back to a height of 50 cm. Half of the area was grazed by sheep (0.8 sheep/ha per year) and the rest remained ungrazed (control). Grazing was carried out twice in the summer (early July and late August) during 1992, 1993, and 1994. The growth dynamic of each species was determined by measuring the growth rate of the shoot and the leaf length in the grazed and ungrazed plants. Shoot and leaf length was measured every six days from the beginning of the growing season (April) to the end (late September). Measurements were obtained from four plants in every species and spacing treatment. In order to determine the shoot and leaf relative growth rates (SGR and LGR), the difference between two successive measurements was divided by the number of days between the two measurements according to the formula $SGR = dl \text{ shoot}/dt$ and $LGR = dl \text{ leaf}/dt$ and expressed in cm/day.

Results and Discussion

Relative Growth Rate of Shoot

The seasonal change of SGR in the ungrazed shrubs is not much affected by spacing (Fig. 1). Only in mid-May did the SGR of *Robinia* and *Amorpha* show a difference attributable to spacing, with the 2.5 × 2.5 m spacing slightly favored (Fig. 1). The SGR of *Gleditschia* and *Morus* was similar for all spacings.

In general, the trend of SGR was downwards until the end of August. *Robinia* presented the highest SGR and *Gleditschia* the lowest. Grazing did not change the downward trend, but it did seem to cause the appearance of two maximum values (for all species except *Gleditschia* and treatments) just after the first and the

second grazings (Fig. 2). The SGR for *Morus* was lower than that of *Robinia* and *Amorpha* at the beginning of the growing season, but after grazing it was similar to *Amorpha*. The second grazing (late August) caused an important decrease of SGR, especially in *Gleditschia* (Fig. 2). The SGRs of *Robinia*, *Amorpha*, and *Morus* were similar in all spacings following the second grazing (Fig. 2).

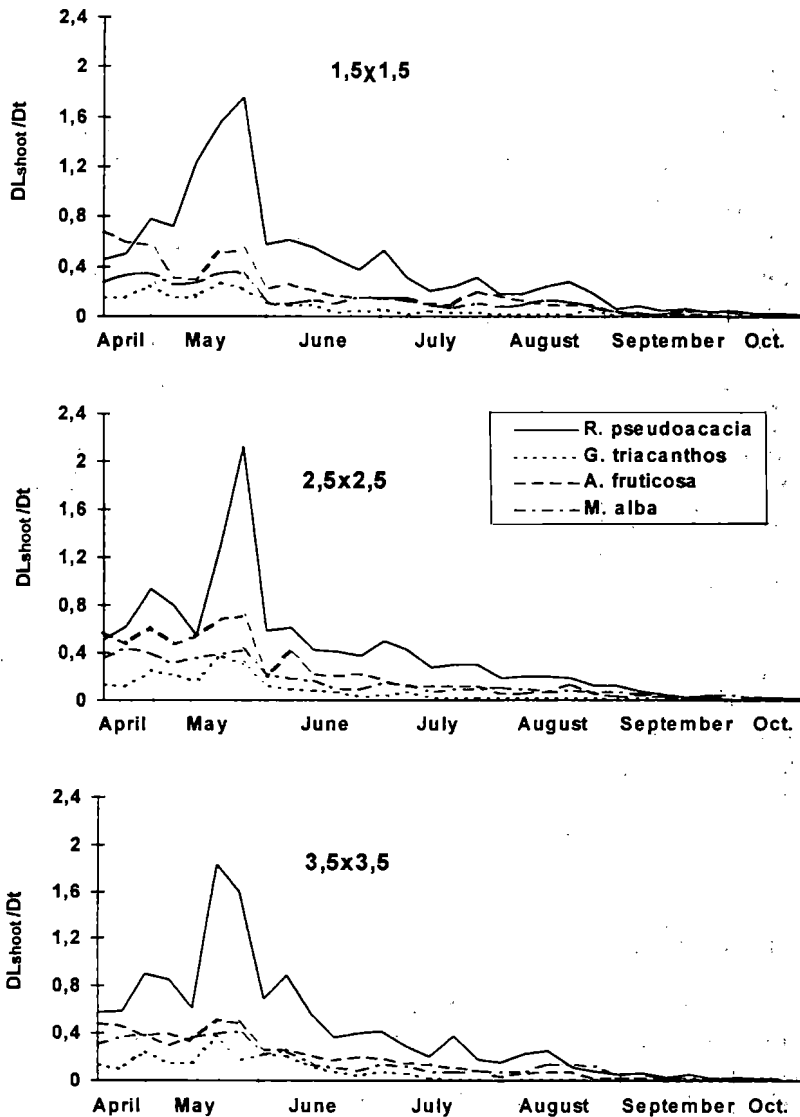


Figure 1. Relative shoot growth rate (average of 1992, 1993, and 1994) in ungrazed plants of *Robinia pseudoacacia*, *Gleditschia triacanthos*, *Amorpha fruticosa*, and *Morus alba*.

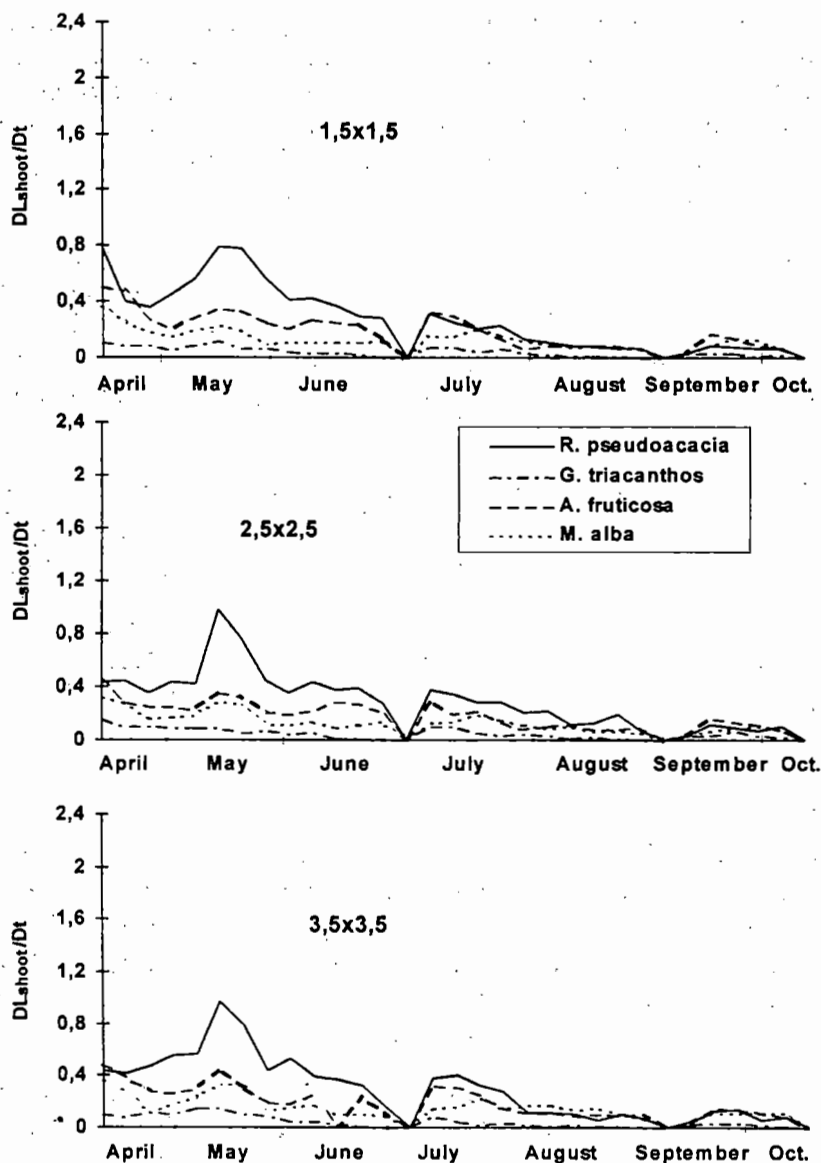


Figure 2. Relative shoot growth rate (average of 1992, 1993, and 1994) in grazed plants of *Robinia pseudoacacia*, *Gleditschia triacanthos*, *Amorpha fruticosa*, and *Morus alba*.

The most important grazing effect was the stimulation of new growth in all species during the dry period of the year. Comparison of the SGR averages (Table 1) shows that grazing had a negative affect on the SGR of the woody species. This can probably be explained by the partitioning of the same portion of assimilates to

the high number of new lateral shoots produced after grazing. This is known as the apical dominance theory (Wareing and Phillips 1978). Alternatively, it may be due to the production of a larger photosynthetic surface (leaf area), as stated in Ainalis (1996). From a management point of view, this is the desired result, as shoot growth occurs in the late summer and early autumn, facilitating livestock grazing. In the control plants, growth almost stopped in late August.

Comparison of SGR among species shows that *Robinia* has by far the highest SGR (0.34 cm/day). There was no significant difference in SGR between the three spacing treatments (Table 1). The difference of SGR, according to Kramer and Kozlowski (1960) and Gardner et al. (1985), is due to the morphogenetic characteristics of the species. The same investigators report race form and habitat growth as the factors that affect the evolution of species growth.

Table 1: Effect of grazing, plant species, and spacing on shoot growth rate (cm/day).

Species	Grazed (0.16 b ¹)		Ungrazed (0.20 a)	
	<i>R. pseudoacacia</i>	<i>G. triacanthos</i>	<i>A. fruticosa</i>	<i>M. alba</i>
	0.34 a	0.06 c	0.19 b	0.14 b
Spacing (m)	1.5 × 1.5	2.5 × 2.5	3.5 × 3.5	
	0.18 a	0.18 a	0.18 a	

¹ Means in the same row followed by the same letter are not significantly different at the 0.05 level.

Leaf Relative Growth Rate

The seasonal change of LGR for ungrazed plants showed one maximum in early May and another, secondary maximum in mid-to-late May and early June. *Robinia* showed the highest LGR in the growing season (Fig. 3). The LGR for *Robinia* and *Amorpha* was slightly favored by the 1.5 × 1.5 and 2.5 × 2.5 m spacings (Fig. 3), while LGR for *Gleditschia* and *Morus* was similar at all spacings. LGR continued until late June in all species of ungrazed plants.

The downward seasonal pattern of LGR was similar to the SGR pattern in the grazed plants (Fig. 4). At the beginning of the growing season, *Morus* had a lower LGR than the other species, but after the first and second grazing its LGR was similar to *Gleditschia*'s. After the second grazing (late August), *Robinia* and *Amorpha* showed a similar LGR, higher than that of *Morus* or *Gleditschia*. In general, the LGR of *Robinia* showed the highest resistance to grazing (Korsztesi 1988; Barret 1991).

Grazing had a positive effect on leaf growth (Table 2). Thus, grazing stimulated the plants to regrow and produce a larger photosynthetic surface. *Robinia* has a significantly higher LGR (0.14 cm/day) than the other species. There was no significant difference in LGR among the three spacing treatments (Table 2).

Table 2. Effect of grazing, plant species, and spacing on leaf growth rate (cm/day).

Species	Grazed (0.11 a ¹)		Ungrazed (0.05 b)	
	<i>R. pseudoacacia</i> 0.14 a	<i>G. triacanthos</i> 0.05 c	<i>A. fruticosa</i> 0.09 b	<i>M. alba</i> 0.04 c
Spacing (m):	1.5 × 1.5 0.08 a	2.5 × 2.5 0.08 a	3.5 × 3.5 0.08 a	

¹ Means in the same row followed by the same letter are not significantly different at the 0.05 level.

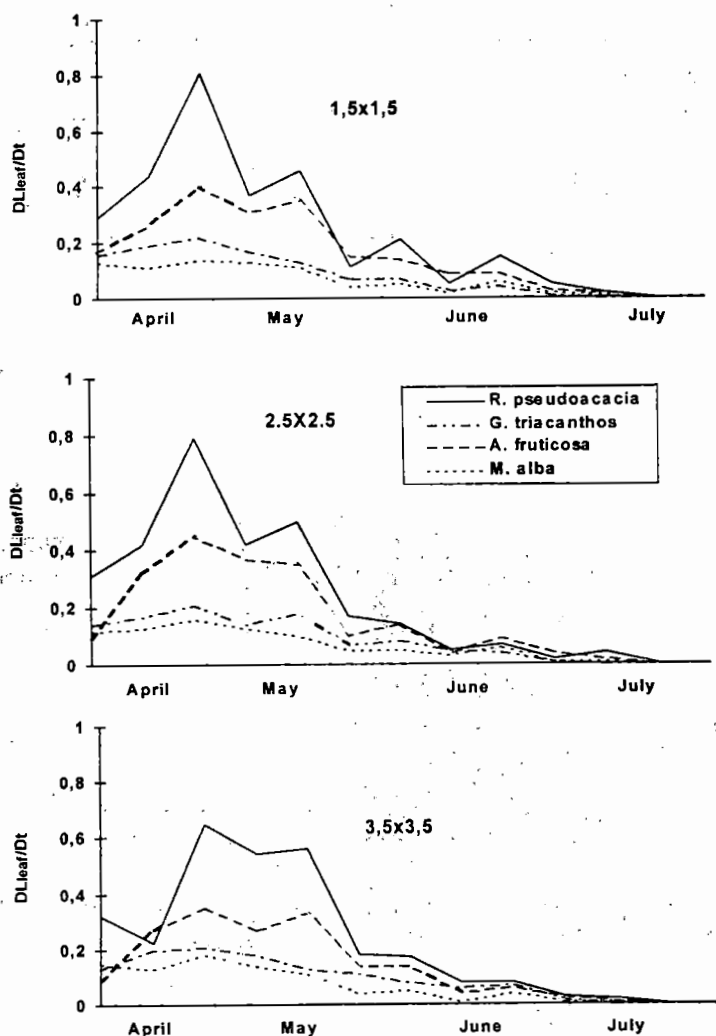


Figure 3. Relative leaf growth rate (average of 1992, 1993, and 1994) in the ungrazed plants of *Robinia pseudoacacia*, *Gleditsia triacanthos*, *Amorpha fruticosa*, and *Morus alba*.

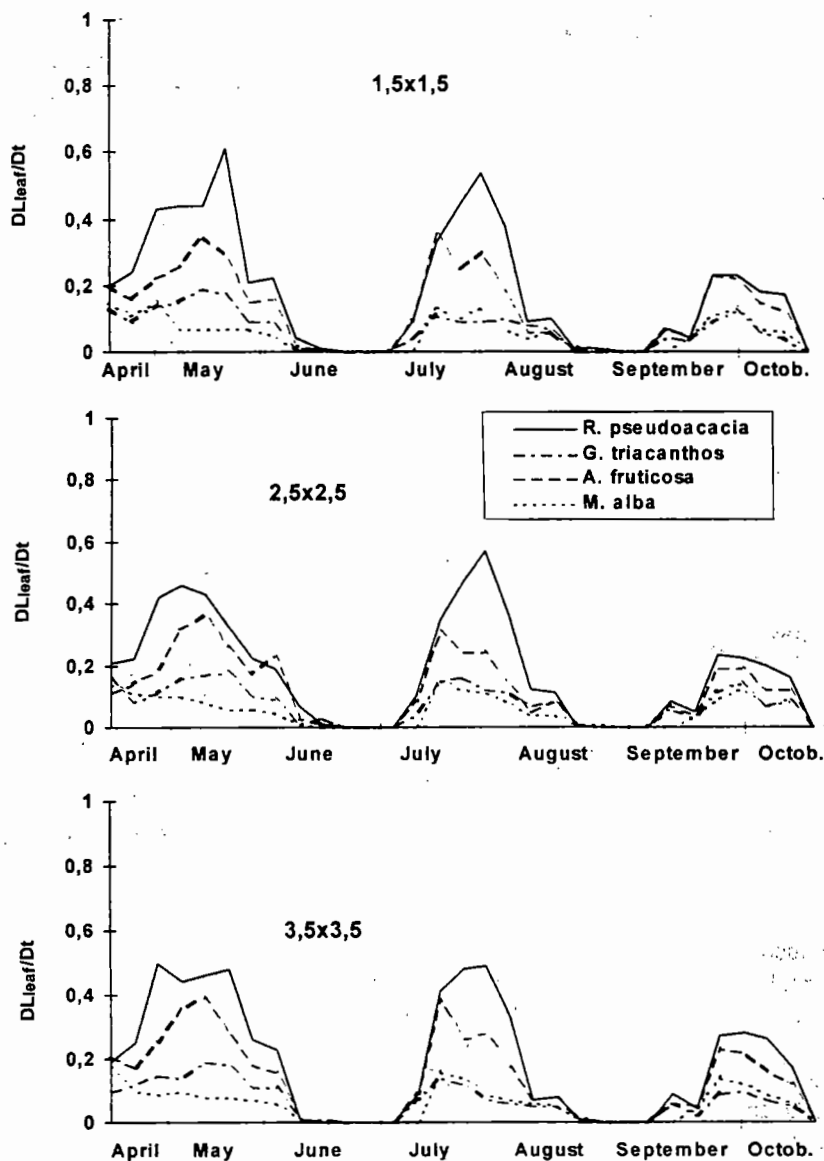


Figure 4. Relative leaf growth rate (average of 1992, 1993, and 1994) in the grazed plants of *Robinia pseudoacacia*, *Gleditschia triacanthos*, *Amorpha fruticosa*, and *Morus alba*.

Conclusions

Among the species tested, *Robinia pseudoacacia* seems to be the best-adapted species to the poor sandy soil of the semi-arid grassland, followed by *Amorpha*

fruticosa and *Morus alba*. *Gleditschia triacanthos* showed very poor establishment. Shoot growth rate in all species appears to be reduced significantly by grazing. However, leaf growth rate appears to be increased significantly by grazing. Spacing did not significantly affect SGR and LGR.

References

- Ainalis, A. 1996. Growth dynamic, production and nutritive value of some shrubby form species in relation to spacing and grazing. PhD dissertation. Aristotle Univ., Thessaloniki, Greece.
- Barrett, R.P. 1991. Forage plantation management for Black Locust. Pages 259–272 in *Proceedings of the International Conference on Black Locust: Biology, Culture and Utilization*. (J.W. Hanover, K. Miller and S. Plesko, eds.). Michigan State University.
- Baumer, M. 1983. Notes on trees and shrubs in arid and semi-arid regions. EMASAR, Phase II, FAO, Rome.
- Emberger, L. 1942. Un project d' une classification des climats du point de vue phytogéographique. *Bul. Soc. D' Histoire Naturelle de Toulouse* 77: 97–124.
- Gardner, F.P., R.B. Pearce and R.L. Mitchell. 1985. *Physiology of Crop Plants*. Iowa State University Press.
- Korsztesi, B. 1988. The Black Locust. Page 197 in *Forestry Monograph Series of the Agricultural Science Department of the Hungarian Academy of Science* (B. Kersztesi, ed.). Budapest.
- Kramer, P.J. and T.T. Kozlowski. 1960. *Physiology of Trees*. McGraw Hill, N.Y.
- Le Houérou, H.N. 1978. The role of browse in the management of natural grazing lands. Position paper, Item No. 10., 8th World Forest Congress, Jakarta, Indonesia, 16–28 October.
- Le Houérou, H.N. 1993. Environmental aspects of fodder trees and shrubs plantation in the Mediterranean basin. Pages 11–34 in *Fodder Trees and Shrubs in the Mediterranean Production Systems: Objectives and expected results* (V. Papanastasis, ed.). Agriculture Agrimed Res. Progr. EUR 14459 EN.
- Papanastasis, V. 1993. Fodder trees and shrubs in the Mediterranean production systems. Pages 3–8 in *Objectives and Expected Results of the EC Research Contract. Agriculture, Agrimed Res. Progr., EUR 14459 EN*.
- Steel, R.G.D. and J.H. Torrie. 1980. *Principles and Procedures of Statistics* (2nd ed.). McGraw Hill, N.Y.
- Tsiouvaras, C.N. 1991. Potential of fodder trees and shrubs for marginal lands in Greece. Pages 35–43 in *Proceedings of the EEC Workshop in Thessaloniki, Greece: Fodder Trees and Shrubs in the Mediterranean Production Systems. Objectives and expected results* (V. Papanastasis, ed.). Agrimed Res. Progr., EUR 14459 EN.
- Wareing, P.F., and I.D.J. Phillips. 1978. *The Control of Growth and Differentiation in Plants*. Pergamon, Oxford.

Echanges Gazeux Instantanés, Efficacité de la Transpiration et Fluorescence de la Chlorophylle "A" Chez Différentes Espèces du Genre *Atriplex*

R.Y.H. Silva and S. Lailhacar

Laboratorio Relación Suelo-Agua-Planta, Departamento de Producción Agrícola y
Departamento de Producción Animal, Facultad de Ciencias Agrarias y Forestales,
Universidad de Chile, Casilla, Santiago, Chile

Résumé

Les variations de l'utilisation de l'eau, en termes d'efficacité transpirationnelle (TE, définie comme la relation entre la quantité de CO₂ par unité d'eau transpirée) et la fluorescence de la chlorophylle "A" ont été étudiées, au cours du printemps 1995 et l'été 1997 sur huit espèces et provenances du genre *Atriplex* de la zone aride méditerranéenne du Chili. La photosynthèse et la transpiration ont été mesurées au niveau des feuilles dans un système d'échanges gazeux en circuit ouvert (CIRAS, PP System). La fluorescence "A" et l'efficacité photochimique du photosystème II ont été évalués dans un fluorimètre (PEA, Hansatech). Les résultats ont mis en évidence des variations inter-spécifiques et intra-spécifiques. Ainsi, durant l'été 1997, trois provenances d'*Atriplex halimus* ont donné respectivement des TE de [5,5–3,7–4,5] µMol de CO₂ par mmol d'eau respectivement ($P < 0,05$). Chez des provenances d'*A. nummularia* (607 et 693) la photosynthèse nette est différente mais les différences ont été établies sur la conductance stomatique et de la transpiration. Par contre la TE n'est pas différente. Les autres espèces présentent des valeurs intermédiaires. Les paramètres de la fluorescence (Fo, Fv et Fm) ne sont pas affectés par l'espèce et l'efficacité photochimique du PII n'est pas modifiée par la sécheresse. En conclusion, ces résultats montrent qu'il existe des différences dans la valeurs de la TE au sein du genre *Atriplex* et que les paramètres d'échange gazeux peuvent servir comme critère de sélection d'espèces en condition de sécheresse.

Mots-clés : *Atriplex*, contrainte hydrique, photosynthèse, transpiration, efficacité de transpiration (TE), fluorescence.

Introduction

La contrainte hydrique est un facteur qui modifie la photosynthèse et la transpiration, laquelle est déterminé par l'alimentation hydrique, par le déficit de saturation atmosphérique ou par l'influence de ces deux facteurs. Son effet s'exprime sur la fermeture stomatique et l'inhibition des réactions enzymatiques

associées à la photosynthèse. De manière générale, les auteurs distinguent deux types d'actions du stress hydrique sur la photosynthèse : une augmentation de la résistance stomatique qui limite la diffusion du CO_2 vers l'intérieur de la feuille et diminue donc le taux de photosynthèse et une action métabolique au niveau de la cellule ou des organites qui agira aussi bien sur la photosynthèse que sur la respiration.

Lorsque la conductance stomatique augmente, la photosynthèse augmente, la photosynthèse augmente vers une valeur maximale, pendant que la transpiration augmente de façon linéaire (Cowan, 1982 ; Toft et al., 1989). En conséquence, la TE diminue au fur et à mesure que la conductance augmente. De cette façon pour une capacité photosynthétique donnée, les changements de l'ouverture stomatique contrôlent l'efficacité de transpiration.

Les plantes se différencient largement par leur sensibilité stomatique à la sécheresse. Cette variabilité est partiellement associée à des stratégies d'adaptation, au manque d'eau en fonction des mécanismes d'évasion. C'est une réponse qui se retrouve généralement chez des espèces très sensibles au stress hydrique, par exemple les caducifoliés ; la tolérance à la sécheresse qui est présente chez des espèces ayant très peu de sensibilité stomatique, et qui développent des qualités structurelles et fonctionnelles comme par exemple des trichomes : Ceci contribue de façon significative au bilan d'énergie au niveau foliaire et à la régulation hydrique.

La disponibilité en eau affecte la TE. Lorsque l'eau est abondante, beaucoup de plantes montrent une conductance stomatique importante pour augmenter la fixation du CO_2 , mais la conductance peut diminuer au fur et à mesure que la disponibilité d'eau diminue, ce qui conduit à une augmentation de la TE (Gollan et al. 1985). Mais, on postule que la TE est un paramètre constant qui ne change pas en fonction de la disponibilité en eau, du fait que la fixation du CO_2 et que la conductance stomatique évoluent de façon parallèle en n'affectant pas la concentration interne du CO_2 (Wong et al. 1989). Cependant des valeurs de TE sont associées à chacune des voies métaboliques. L'efficacité de la fixation du CO_2 en relation de l'eau transpirée est fonction du système photosynthétique. De cette façon les plantes en C_4 sont généralement plus efficaces que les espèces en C_3 sous conditions normales de température ($20\text{--}25^\circ\text{C}$) et de pression atmosphérique (0,1 MPa).

Les mesures de la TE fournissent des informations sur la variation entre plantes, en conditions de pluviométrie limitée, pour la production de matière sèche et le rendement.

D'autres travaux ont montrés que des stress hydriques drastiques pouvaient réduire la photosynthèse par des mécanismes non stomatiques. Certains processus

biochimiques de la photosynthèse peuvent être affectés par le déficit hydrique tel que le fonctionnement des photosystèmes, avec réduction de la ferrédoxine et production de NADPH, la photophosphorylation et la production d'ATP, la carboxylation et la régénération de l'accepteur primaire du CO₂ (Yoshie, 1986). La lumière absorbée par l'organe photosynthétique peut être utilisée pour la photosynthèse, dissipée comme chaleur ou comme fluorescence re-irradiée. Ce dernier processus bien qu'il contribue très peu à la propagation de l'énergie absorbée, peut être mesuré et analysé en fournissant de l'information sur les deux premières activités, sur quelques paramètres possibles pour déduire la mesure de la fluorescence : l'efficacité photochimique du photosystème II ; le degré auquel l'accepteur primaire, dans le photosystème II est réduit dans le centre de réaction ; et le degré auquel l'énergie excessive est dissipée comme chaleur (Bjorkman 1987 ; Schreiber et al. 1986 ; Demmig-Adams et al. 1989).

Sous conditions de stress hydrique, l'absorption d'énergie lumineuse peut être supérieure à celle nécessaire par la production d'ATP et NADPH pour la fixation du carbone et le photosystème peut diminuer. Le fonctionnement du photosystème est mesurée par la fluorescence de la chlorophylle, actuellement utilisée comme un critère de résistance au stress hydrique. Certains auteurs ont observé que le stress hydrique augmente la susceptibilité à la photo-inhibition (Bjorkman et Powles 1984). Néanmoins, des travaux plus récents indiquent que le stress hydrique a peu d'effet sur le photosystème II (Havaux 1992 ; Jefferies 1994 ; Valladares et Pearcy 1997). De même façon, les résultats de Martinez (1996), dans six variétés de haricots ont établi que les plantes sous stress hydrique ne modifient pas le fonctionnement du photosystème II. Cependant, on connaît très peu l'effet du stress hydrique dans les paramètres de fluorescence chez des plantes en C4.

Étant donné que le potentiel photosynthétique et l'efficacité photochimique du photosystème II de espèce d'*Atriplex* sont peu connus, le but de cette étude est de caractériser l'échange gazeux et la fluorescence au niveau de tissu photosynthétique. Ces réponses pourraient montrer des différences dans la capacité photosynthétique ou de transpiration et, en conséquence de la TE : ceci pourrait conduire à l'identification des paramètres physiologiques pour la sélection des espèces pour les zones arides.

Matériels et Méthodes

Site Expérimental

Le travail expérimental est réalisé pendant la période 1995–1997 à la Station Expérimentale Las Cardas, qui appartient à la Faculté de Sciences Agraires et Forestière de l'Université du Chili, située entre les 30° 13' à 30° 19' latitude sud et les 71° 13' à 71° 19' latitude ouest (IV Région de Coquimbo, Chili).

Le bioclimat est méditerranéen aride : Il se caractérise par une précipitation moyenne annuelle de 138 mm, (moyenne des 100 dernières années), dont plus de 70% en hiver. La moyenne de la température la plus basse absolue est de 2°C (juin). La température moyenne mensuelle la plus basse est de 6,5°C (juillet) et les températures les plus hautes atteignent 30°C (mars) et 19,5°C (janvier). Ce climat se caractérise par une haute humidité relative moyenne de 80% et une radiation maximale pendant l'été qui varie entre 1800 et 2100 $\mu\text{E m}^{-2} \text{s}^{-1}$. Le sol se caractérise par sa topographie plane, avec un bon drainage, sans présence de sels. Il présente une structure des blocs angulaires moyens et fins, avec une texture sableuse et une activité biologique dans les premiers 50 cm en profondeur (Silva 1991).

Matériel Végétal

Les plantes choisies pour cette étude correspondent à huit espèces et provenances du genre *Atriplex*, établies à la Station Agronomique Expérimentale Las Cardas (Tableau 1), dans un dispositif aléatoire à quatre répétitions.

Tableau 1. Espèces et provenances d'*Atriplex* établies à la Station Agronomique Expérimentale de Las Cardas (Chili).

Espèces	Code	Origine de l'espèce
<i>Atriplex nummularia</i>	CU607	Australie
<i>A. nummularia</i>	CU693	Australie
<i>A. undulata</i>	CU634	Argentine
<i>A. atacamensis</i>	CU637	Chili
<i>A. canescens</i>	CU610	États Unis d'Amérique et Mexique
<i>A. halimus</i>	CU688	Bassin méditerranéen
<i>A. halimus</i>	CU689	Bassin méditerranéen
<i>A. halimus</i>	CU690	Bassin méditerranéen

Mesures

On a commencé les essais au printemps de 1995 et on a réalisé les mesures suivantes dans l'unité expérimentale.

Échange Gazeux

Les mesures de la photosynthèse, transpiration, conductance stomatique et concentration interne du CO_2 ont été réalisés dans un système d'échange gazeux en circuit ouvert (IRGA CIRAS PPM SYSTEM UK) entre 11 et 14 heures sous une radiation photosynthétiquement active de 1800–2100 $\mu\text{E m}^{-2} \text{s}^{-1}$. Dans chaque groupe de mesures, le niveau de lumière n'a pas varié de plus de 10%. Dans la chambre d'échange gazeux de 10 cm^2 , type Parkinson ADC connecté au IRGA, on

a introduit la feuille pendant 30 à 60 secondes, jusqu'à l'équilibre du échange gazeux. La température de l'air dans la cuvette a varié entre 25 et 29°C.

Les données des échanges gazeux ont été analysées selon des procédés et des méthodes signalées par PPM System. La concentration interne du CO₂, a été calculé selon l'équation proposée par Von Caemmerer et Farquhar (1981).

La TE a une échelle instantanée, s'est obtenue à partir de la relation F/T, exprimée en mol CO₂ par mmol d'eau.

Fluorescence

Les paramètres de fluorescence de la chlorophylle "A" et l'efficacité photochimique du photosystème II ont été déterminés par un fluorimètre portatif PEA Hansatech U.K. (Plant Efficiency Analyser), lequel a des pinces, une partie sensible (émetteur des radiations) et un dispositif de contrôle. Les pinces s'adaptent à la superficie de la feuille. La partie sensible est constituée par un ensemble de six diodes qui émettent une lumière rouge de 650 nm et une unité de détection de l'émission de fluorescence avec une longueur d'onde supérieur a 740 nm. Pour effectuer les mesures, la partie sensible se situe sur la pince qui a maintenu une partie de la feuille dans l'obscurité pendant 25 minutes.

Le dispositif de contrôle possède un analyseur des données qui permet le contrôle de toutes les fonctions de l'instrument. L'analyse des données calcule automatiquement les principaux paramètres de la fluorescence : Fo, Fm, Fv et la relation entre Fv/Fm. La fluorescence initiale (Fo) est définie comme le niveau de fluorescence de la chlorophylle quand les centres de réaction du photosystème II est réduit et l'accepteur primaire des électrons de ce photosystème (QA) est complètement oxydé (Krause 1973). La fluorescence maximale (Fm), est le niveau le plus grand d'émission de fluorescence quand les plastoquinones du centre de réaction du photosystème II se trouve réduit (Krause 1973). La fluorescence variable (Fv), correspond à la différence entre Fm et Fo. Généralement, la valeur de Fv diminue quand la plante est soumise à un certain type de stress hydrique et thermique qui déterminent des changements au niveau des membranes du tylacoids (Krause 1984).

L'efficacité photochimique du photosystème II (Fv/Fm), est définie comme le rapport entre Fv et Fm (Genty et al. 1989). Généralement la valeur diminue quand la plante est soumise a certain type de stress. En plus, on a pu constater que ce paramètre est en relation directe avec le rendement quantique (Genty et al. 1989 ; Cornic et Briantais 1991).

L'analyse des données a été réalisée avec l'aide du programme statistique MSTAC (1988) et les différences ont été considérées comme significatives à une probabilité de $P < 0,05$.

Résultats

Entre les provenances d'*A. halimus*, la capacité photosynthétique maximale est observée sur la Ah688 pendant le printemps 1995 avec $16 \text{ mol m}^{-2} \text{ s}^{-1}$. Celle qui présente la plus faible a été Ah689. La fluctuation entre les saisons de ces valeurs démontre la dépendance de la photosynthèse en fonction de la disponibilité en eau, étant donné que les précipitations dans la zone se concentrent vers le fin de l'hiver.

Cependant, l'espèce qui a montrée l'activité photosynthétique la plus élevée au printemps 1995 est U634 avec une taux moyenne de $27 \text{ mol m}^{-2} \text{ s}^{-1}$, en diminuant significativement vers l'été 1997 à $4 \text{ mol m}^{-2} \text{ s}^{-1}$.

La variation par saison de la transpiration démontre une tendance similaire à ce qui a été observé en photosynthèse. Des taux élevés sont observés au printemps en diminuant progressivement en l'hiver. Quand on compare les provenances d'*A. halimus* et *A. nummularia*, cette dernière a enregistré les taux le plus élevé en arrivant à $7 \text{ mmol m}^{-2} \text{ s}^{-1}$ pour An693. D'autre part, Ah 688 présente le taux le plus élevé au printemps et en hiver avec une valeur proche à $4 \text{ mmol m}^{-2} \text{ s}^{-1}$. Pendant l'été 1997, ceci a fluctué entre 1 et $4,8 \text{ mmol m}^{-2} \text{ s}^{-1}$.

En relation aux autres espèces la perte d'eau par transpiration a varié entre 1 et $5 \text{ mmol m}^{-2} \text{ s}^{-1}$ pour Aa637 et Ac610 respectivement. Au cours de l'été 1997, les valeurs moyen ont été de $2 \text{ mmol m}^{-2} \text{ s}^{-1}$.

L'efficacité de transpiration à l'échelle instantanée, déduite à partir des taux de photosynthèse et de transpiration montrent les différences inter-spécifiques et intra-spécifiques dans les deux paramètres dans le cas de *A. halimus*. De cette façon, lorsqu'on compare par saison les provenances de Ah et An, la TE a fluctué entre 4 et $10 \text{ mol CO}_2/\text{mmol H}_2\text{O}$. Les valeurs plus hautes sont enregistrées pendant l'hiver. Ceci s'explique par une moindre perte d'eau par transpiration dû au fait que l'exigence évaporative atmosphérique est aussi plus petite, à l'entretien de l'activité photosynthétique avec des valeurs moyens de $10 \text{ mmol m}^{-2} \text{ s}^{-1}$ et au développement d'une épaisse couche vésiculaire ou tricomes au niveau de la feuille. Ceci qui caractérise les espèces d'*Atriplex* (travail en cours).

Mais dans les espèces Aa, Au et Ac, leurs valeurs maximales de TE ont été observé au printemps de 1995, la manque des valeurs pendant l'été, automne et l'hiver (1996) est dû au faible développement de surface photosynthétique. Ce dernière aspect signale la plus haute sensibilité de ces espèces à la sécheresse par rapport à An et Ah, étant donné que les précipitations durant 1995 a été seulement

de 7 mm. La TE, enregistré durant l'été de 1997 est significativement plus élevée, puisque la précipitation total en 1996 a été de 90 mm, en arrivant à valeurs de 2 dans le cas de Au634 et de 4 mol CO₂/mmol H₂O en Aa637 et Ac610 respectivement. Par contre la TE chez An et Ah arrivent autour de 5 mol CO₂/mmol H₂O.

Les valeurs de conductance stomatique évaluée pendant l'été 1997 dans les espèces et provenances d'*Atriplex*, fluctuent entre 40 et 110 mmol m⁻² s⁻¹ normalement associés à des plantes avec un métabolisme C₄. L'analyse de discrimination isotopique C₁₃/C₁₂ montre que la totalité des espèces en étude sont C₄ (Lailhacar, communication personnelle).

De même façon la concentration interne de CO₂ entre les espèces d'*Atriplex* a fluctué entre 70 et 200 ppm pendant la période expérimentale, ce qui indique la haute efficacité de carboxylation de ces espèces.

Fluorescence de la Chlorophylle "A"

Le Tableau 2 montre la variation des paramètres de la fluorescence basal et la relation fluorescence variable/fluorescence maximale ou efficacité photochimique du photosystème II évalués pendant l'été (1997). Les valeurs inter-spécifiques et intra-spécifiques enregistrées en termes d'unités relatives (u.r) de la Fo, Fv, et de la Fm ont été très proches. La valeur moyenne de la FO a été de 293,4 u.r. Ainsi, l'efficacité photochimique du photosystème II (Tableau 3), évaluée dans des termes de Fv/Fm, a été similaire aussi entre les espèces et provenances. Les valeurs moyennes ont été de 0,720 u.r.

Tableau 2. Valeurs moyenne de la Fluorescence initiale (Fo) et de l'efficacité photochimique du photosystème II (rapport Fv/Fm) en unités relatives (u.r) (n = 48).

Espèce	Fo(u.r)	Fv/Fm(u.r)
<i>Atriplex nummularia</i>	(607) 275,3 15	0,732 0,02
<i>A. nummularia</i>	(693) 329,5 30	0,721 0,01
<i>A. undulata</i>	(634) 309,8 25	0,725 0,06
<i>A. atacamensis</i>	(637) 290,5 11	0,725 0,09
<i>A. canescens</i>	(610) 306,7 6	0,714 0,10
<i>A. halimus</i>	(688) 282,3 13	0,706 0,10
<i>A. halimus</i>	(689) 299,8 9	0,720 0,09
<i>A. halimus</i>	(690) 288,8 15	0,719 0,02

Ces valeurs montrent la stabilité du photosystème II, il n'y a pas des différences entre provenances en *A. nummularia* et *A. halimus*, on pourrait affirmer aussi qu'il n'y a pas non plus des différences intra-spécifiques entre les espèces étudiées. Ces valeurs généralement sont associés à la voie métabolique C₄ étant donné que dans les espèces C₃, ces valeurs sont plus élevées (Martínez 1996). Ces valeurs ne sont pas liées à la capacité photosynthétique.

Discussion

L'effet du déficit hydrique sur les plantes est complexe et celles-ci répondent selon plusieurs mécanismes adaptatifs en fonction de leur habitat et de leur voie métabolique. En conséquence, il n'y a pas de mécanisme universel de résistance à la sécheresse, sinon qu'il se produit sous certains types d'adaptations dans chaque groupe éco-physiologique.

L'adaptation au manque d'eau produit des changements morphologiques et physiologiques que réduisent les effets du déficit d'eau. Les espèces du genre *Atriplex*, peuvent être qualifiées d'aride-actives (Silva 1991) parce qu'elles ont un feuillage persistant, avec un système racinaire puissant qui peut atteindre plus de 20 m en profondeur. Néanmoins la comparaison inter-spécifique montre que les différences phénotypiques sont remarquables au niveau de la forme, des dimensions de la feuille et de leur architecture. Il y a des autres différences au niveau de la couleur de la feuille, par exemple, caractère associé à une efficacité de transpiration plus élevée. Ainsi, les espèces étudiées, montrent une couleur vert-cendré caractéristique déterminée par une plus haute densité des trichomes sur la feuille, excepté le cas d'*A. canescens* qui montre une couleur verte plus intense. La couleur est déterminé par la relation des chlorophylles "a" et "b". Les trichomes contribuent en forme significative à l'épaisseur de la couche limite et pourtant au bilan énergétique des feuilles et peut être associés à une majeur TE. De même des essais en cours démontrent une relation entre la quantité des chlorophylles "a/b" et la TE.

Les donnés d'échange gazeux montrent de façon indirecte que le développement d'une couche de trichomes sur les deux surfaces des feuilles, a une influence sur la transpiration et n'a pas seulement un effet sur l'augmentation de la résistance totale à la vapeur d'eau. Il se manifeste par une réduction de la température liée à une augmentation de la réflexion de la radiation incidente. Plusieurs travaux ont montré que le développement des trichomes réduit la température. Pourtant la transpiration reste sans effet sur la photosynthèse. Dans ces conditions une majeur TE se produit (Edward et al. 1985 ; Osmond et al. 1982 ; Percy et Ehleringer 1984).

Les plantes d'*Atriplex nummularia* ont montré une photosynthèse plus élevée pendant la période expérimentale, apparemment associée à une activité physiologique et à des températures plus élevées, un niveau de saturation lumineuse supérieure et ainsi une TE plus élevée en comparaison à *A. halimus*.

Cette augmentation de la capacité photosynthétique peut établir sans différences dans le taux de transpiration ou bien, une réduction de la transpiration peut être observé pour une taux photosynthétique stable ou la combinaison des deux.

En plus des valeurs élevée de la TE sont normalement associée à une grande tolérance des tissus à des potentiel hydriques plus bas, comme ceci est démontré dans d'autres résultats en travaillant chez les mêmes espèces (essais en cours).

Les résultats démontrent la stabilité du photosystème II par rapport à la sécheresse chez les espèces d'étudiés en plus il n'y a pas effet saisonnier sur les différents paramètres de la fluorescence.

La fermeture stomatique associé au stress hydrique restreint l'assimilation du carbone. En conséquence dans les plantes soumises au déficit hydrique, l'absorption d'énergie lumineuse peut excéder celle nécessaire pour les processus photochimiques et peut endommager le photosystème. Certains auteurs ont montré que le déficit hydrique augmente la susceptibilité à la photo-inhibition (Bjorkman et Powles, 1984). Ces résultats sont en accord avec ceux rapporté par Genty et al. (1989) et Havaux (1992) dans le sens que le stress hydrique a peu d'effet sur le fonctionnement du photosystème II.

Sous conditions de déficit hydrique pour minimiser le dommage au photosystème, l'excès d'énergie peut être dissipé soit dans le photosystème par une réduction non photochimique, dans le cas de plantes en C₄ comme les plantes d'*Atriplex* étudiées, bien que les mécanismes moléculaires sont incertains ou par réduction photochimique, par exemple à travers la photo-respiration plus importante chez les plantes en C₃.

Conclusions

A l'échelle instantanée la photosynthèse, la transpiration et la conductance stomatique dépendent de la disponibilité en eau chez toutes les espèces et provenances d'*Atriplex*. Des plantes d'*A. nummularia* montrent une plus haute résistance à la sécheresse par rapport au d'autres espèces étudiées. Ces résultats montrent qu'il existe des différences dans la valeur de la TE (Efficacité Transpirationnelle) au niveau inter-spécifique du genre *Atriplex*. Au niveau intra-spécifique chez *A. halimus* (688, 689 et 690) et *A. nummularia* (607 et 693) il n'y a pas des différences sur l'efficacité de transpiration, mais des valeurs sont associés au métabolisme C₄. L'efficacité photochimique du photosystème II ne change pas par effet de la sécheresse. Nous pouvons établir que les paramètres d'échange gazeux sont plus sensibles que les paramètres de fluorescence aux effets de la sécheresse. L'échange gazeux est plus performant que la fluorescence, sous les conditions de cette étude comme critère de sélection d'espèces en condition de sécheresse.

Références

- Bjorkman, O. and S.B. Powles. 1984. Inhibition of photosynthetic reactions under water stress: interaction with light level. *Planta* 161: 490–504.
- Bjorkman, O. and T.D. Sharkey. 1987. Comparisons of photosynthetic responses of *Xanthium strumarium* and *Helianthus annuus* to chronic and acute water stress in sun and shade. *Plant Physiology* 84: 476–482.
- Cowan, I.R. 1982. Regulation of water use in relation to carbon gain in higher plants. Pages 589–613 in *Physiological Plant Ecology II* (Encyclopedia of Plant Physiology, NS, Vol. 12B (O.L. Lange, P.S. Nobel, C.B. Osmond and H. Ziegler, eds.) Springer-Verlag, Berlin and New York.
- Cornic, G. and J.M. Briantais. 1991. Partitioning of photosynthetic electron flow between CO₂ and O₂ reduction in a C₃ leaf (*Phaseolus vulgaris* L.) at different CO₂ concentration and during drought stress. *Planta* 183: 178–184.
- Demmig, B. Adams, K. Winter, A. Kruger and F.C. Czygan. 1989. Light stress and photoprotection related to the carotenoid zeaxanthin in higher plants. *Plant Biology* 8: 375–391.
- Edward, G.E., K.U. Ms and R.K. Monson. 1985. C₄ Photosynthesis and its regulation. Pages 287–327 in *Topics in Photosynthesis*, Vol. 6 (J. Arer and N.R. Aker, eds.). Elsevier, Amsterdam
- Farquhar, G.D. and T.D. Sharkey. 1982. Stomatal conductance and photosynthesis. *Annual Review Plant Physiology* 33: 317–345.
- Genty, B., J.M. Briantais and N.R. Baker. 1989. The relationship between the quantum yield of photosynthetic electron transport and quenching of chlorophyll fluorescence. *Biochim Biophys Acta* 990: 87–92.
- Gollan, T., N.C. Turner and E.D. Schulze. 1985. The responses of stomata and leaf gas exchange to vapour pressure deficits and soil water content. III. The sclerophyllous woody species *Nerium oleander*. *Oecologia* 65: 356–362.
- Havaux, M. 1992. Stress tolerance of photosystem II. Antagonistic effects of water heat to inhibition stresses. *Plant Physiology* 100: 424–432.
- Krause, G.H. 1973. The high energy state of the thylakoid system as indicated by chlorophyll fluorescence and chloroplast shrinkage. *Biochim. Biophys. Acta* 292: 715–728.
- Krause, G.H. 1984. Photoinhibition of photosynthesis. An evaluation of damaging and protective mechanisms 1988. *Physiologia Plantarum* 74: 566–574.
- Jefferies, R.A. 1994. Drought and chlorophyll fluorescence in field-grown potato (*Solanum tuberosum*). *Physiologia Plantarum* 90: 93–97.
- Martinez, J.P. 1996. Caracterización ecofisiológica de seis cultivares de frejol (*Phaseolus vulgaris* L.) bajo condición de estrés hídrico. Memoria de Título Ingeniero Agrónomo. Fac. Cs. Agr. y Forestales Universidad de Chile.
- Michigan State University. 1988. User's guide to MSTAT-C. A software program for the design, management and analysis of agronomic research experiments. Department of Crop and Soil Sciences and Department of Agricultural Economics.
- Osmond, C.B., K. Winter and H. Ziegler. 1982. Functional significance of different pathways of CO₂ fixation in photosynthesis. Pages 479–547 in *Encyclopedia of Plant Physiology*, New Series, Vol. 12B (O.L. Lange, P.S. Nobel, C.B. Osmond and H. Ziegler, eds.). *Physiological Plant Ecology II*, Springer-Verlag, Berlin.
- Pearcy, R.W. and J. Ehleringer. 1984. Comparative ecophysiology of C₃ and C₄ plants.

Plant, Cell and Environment 7: 1–13.

- Schreiber, U., U. Schliwa and W. Bilger. 1986. Continuous recording of photochemical and non-photochemical chlorophyll fluorescence quenching with a new type of modulated fluorometer. *Photosynthetic Research* 10: 51–62.
- Silva, H. 1991. Etude de l'efficacité de l'utilisation de l'eau chez des espèces autochtones et introduites dans la zone aride méditerranéenne du Chili. Thèse de Doctorat. Université de Montpellier II, France.
- Toft, N.L., J.E. Anderson and R. Nowak. 1989. Water use efficiency and carbon $\delta^{13}C$ isotope composition of plants in a cold desert environment. *Oecologia* 80: 11–18.
- Valladares, F. and R.W. Pearcy. 1997. Interactions between water stress, sun shade acclimation, heat tolerance and photoinhibition in the sclerophyll heteromeles arbutifolia. *Plant, Cell and Environment* 20(1): 25–36.
- Von Caemmerer, S. and G.D. Farquhar. 1981. Some relationships between the biochemistry of photosynthesis and the gas exchange of leaves. *Planta* 153:376–387.
- Wong, S.C., I.R. Cowan and G.D. Farquhar (1979) Stomatal conductance correlates with photosynthetic capacity. *Nature* 282: 424–426.
- Yoshie, F. 1986. Intercellular CO_2 concentration and water use efficiency of temperate plants with different life-forms and from different microhabitats. *Oecologia* 68: 370–374.

Relations Hydriques Chez Huit Espèces ou Provenances d'*Atriplex* Installées dans la Zone Aride Méditerranéenne du Chili

R.Y.H. Silva and S. Lailhacar

Universidad de Chile, Casilla, Santiago, Chile

Résumé

L'un des mécanismes physiologiques de tolérance aux conditions de déficit hydrique réside dans la capacité de la plante à maintenir un potentiel de turgescence en conditions de potentiel hydrique total faible. Actuellement, les programmes portant sur les espèces cultivées ont pour objectif la définition et l'utilisation des caractéristiques physiologiques comme critère de sélection des espèces. Une des caractéristiques physiologiques associée à la contrainte hydrique est la capacité d'ajustement osmotique qui peut être associée à la modification des propriétés d'élasticité des cellules et des tissus. Ces types de réponses maintiennent divers processus dépendant de la turgescence cellulaire lesquels ont un effet sur la croissance et la productivité. Afin d'étudier les relations hydriques internes, les variations saisonnières et inter-annuelles du potentiel hydrique maximum et minimum, de la pression osmotique et de l'élasticité des tissus, huit provenances d'*Atriplex* installées dans la zone aride méditerranéenne du Chili, ont été sélectionnées pour l'analyse des relations hydriques au moyen de la technique pression—déficit relatif en eau. Des valeurs moyennes à échelle annuelle montrent une variation entre -1,4 et -2,8 MPa de la valeur du potentiel hydrique maximum, par rapport aux -2,9 et -4,1 des valeurs du potentiel hydrique minimum avec des différences inter-spécifiques et aussi intra-spécifiques. Sous conditions de stress hydrique la plupart des plantes étudiées arrivent à ajuster le potentiel osmotique de leurs tissus malgré la diminution du potentiel hydrique total. Dans le cas d'*A. canescens* et *A. atacamensis*, le potentiel osmotique à turgescence maximale a été de -4 Mpa, par contre chez *A. nummularia*, la valeur du module d'élasticité a été la plus basse avec -5,7 Mpa en moyenne annuelle et donc avec la plus haute élasticité des parois cellulaires. Chez les plantes d'*A. halimus* nous avons observé des changements de la concentration des solutés et aussi de l'élasticité des parois cellulaires à échelle saisonnière.

Introduction

L'effet de la contrainte hydrique sur les plantes est complexe et celles-ci répondent selon divers processus adaptatifs. En accord avec Henckell (1964), il n'y a pas de mécanisme universel de résistance à la sécheresse, mais il se produit certains types d'adaptation dans chaque groupe éco-physiologique. L'adaptation à la sécheresse

produit des changements, morphologiques et physiologiques, qui atténuent les effets de la contrainte hydrique.

Dans les dernières années les programmes portant sur les espèces cultivées ont eu pour objectif la définition et l'utilisation des caractéristiques physiologiques comme critères de sélection des espèces. Une des caractéristiques physiologiques associées à la contrainte hydrique est la capacité d'ajustement osmotique, celle-ci est considérée comme un mécanisme de tolérance puisqu'elle conduit au maintien de la turgescence cellulaire à faible potentiel hydrique.

La modification des propriétés d'élasticité des parois cellulaires et des tissus par la sécheresse est à l'heure actuelle sujette à discussion dans la mesure où les résultats sont mis en cause, mais normalement, sous conditions de stress hydrique il y a des changements morphologiques au niveau cellulaire.

Dans le but d'établir la variabilité de ces paramètres en réponse à la contrainte hydrique, nous avons effectué une analyse des relations hydriques chez différentes espèces et provenances d'*Atriplex*. On se propose de déterminer les effets de la sécheresse sur le π^{100} (potentiel osmotique à la pleine turgescence), sur la teneur relative en eau (TRE) et sur le module d'élasticité (ϵ).

Matériel et Méthodes

Le travail a eu lieu sur le terrain de la Station Agronomique Expérimentale Las Cadras, Région IV du Chili. Elle est située à 71° longitude ouest et à 30° latitude sud. Le climat correspond à un climat aride méditerranéen sous étage inférieur, défini par un régime de pluies d'hiver et de sécheresse estivale. En fonction d'un profil agro-climatique, on peut déduire qu'il s'agit d'un climat chaud, sec et sans gelée (Silva 1990).

Le sol a un bon drainage. La texture est sableuse. Le sol, de couleur brun rouge foncé, sans sels ni alcalis, présente une texture de blocs angulaires moyenne et fine avec activité biologique. Au dessous d'un mètre de profondeur, le sol a une structure sableuse grossière, renferme peu de racines et n'a pas d'activité biologique (Silva et Acevedo 1994).

Matériel Biologique

Les plantes utilisées dans cette étude ont été coupées à 25 cm du sol à la fin de l'hiver en 1994 (Lailhacar et al. 1995). Malgré la sécheresse de cette région pendant les deux dernières années, avec 41 et 10 mm de précipitation respectivement pour la première et deuxième année, les plantes ont montré une reprise après la coupe. En fonction de ce groupe de plantes, nous avons choisi trois

provenances d'*A. halimus*, deux provenances d'*A. nummularia*, une d'*A. atacamensis*, *A. canescens*, et *A. undulata* (Tableau 1).

Tableau 1. Espèces et provenances d'*Atriplex* installées à la Station Agronomique Expérimentale Las Cadras, Chili, 1996.

Espèces	Code	Origine de l'espèce
<i>Atriplex halimus</i>	CU 688	Bassin méditerranéen
<i>A. halimus</i>	CU 689	Bassin méditerranéen
<i>A. halimus</i>	CU 690	Bassin méditerranéen
<i>A. atacamensis</i>	CU 637	Chili
<i>A. canescens</i>	CU 610	États Unis d'Amérique et Mexique
<i>A. nummularia</i>	CU 607	Australie
<i>A. nummularia</i>	CU 693	Australie
<i>A. undulata</i>	CU 634	Argentine

Relations Hydriques

Pour l'analyse des relations hydriques nous avons utilisé la chambre à pression. Les mesures ont été faites à l'aube à midi pour potentiel hydrique maximum et pour le potentiel hydrique minimum.

Sur la base de la procédure classique développée par Tyree et Hammel (1972) et modifiée par Silva et Acevedo (1994), nous avons utilisé deux chambres à pression à double trou pour obtenir 4 répétitions simultanées. Dans ces conditions, on peut avoir les courbes pression—déficit relative en eau. Généralement on représente la valeur réciproque de la pression appliquée en fonction de la teneur relative en eau (TRE) ou 1-TRE. La courbe 1/P en fonction de 1-TRE comporte une première partie rectiligne puis une deuxième curviligne. La zone non linéaire de la courbe est la résultante des variations de pression osmotique et de pression de turgescence, alors que la partie rectiligne peut être attribuée seulement à la composante osmotique. L'extrapolation de la partie rectiligne sur l'axe des ordonnées permet d'estimer le potentiel osmotique à la pleine turgescence. Le module d'élasticité est calculé en fonction de la variation du potentiel de pression (turgescence) et de la variation de la teneur en eau ($\Delta P / \Delta TRE$).

A partir de l'automne 1995 et jusqu'à l'été 1996, des mesures ont été faites sur chaque espèce ou provenance avec 4 répétitions. Les données sont analysées par le programme statistique MSTAC et l'application du test de Duncan.

Résultats et Discussion

Potentiel Hydrique Maximum et Minimum

En conditions de terrain, les valeurs du potentiel hydrique maximum enregistrées sur les différentes espèces d'*Atriplex* à l'échelle annuelle ont varié entre -1,4 Mpa chez *A. nummularia* et de -2,8 Mpa chez l'*A. halimus*. Les valeurs du potentiel hydrique minimum ont varié entre -3,1 et -4,1 Mpa toujours sur les mêmes espèces, avec des différences significatives. Chez les différentes provenances d'*A. halimus*, la provenance 688 a les potentiels maximum plus négatifs par rapport aux provenances 689 et 690, ces dernières avec valeurs semblables. Chez *A. nummularia* il n'y a pas de différences significatives avec une valeur moyenne annuelle de -1,4 Mpa pour les deux écotypes (607 et 693).

On observe aussi une tendance aux valeurs les plus basses du potentiel hydrique minimum chez les différentes espèces ou provenances. Ainsi *A. nummularia*, *A. canescens* et *A. halimus* 689 montrent des valeurs semblables un peu plus proche de 0 Mpa. Cependant pour la plupart des espèces étudiées les différences interspécifiques s'avèrent très hautement significatives (Tableau 2).

A échelle saisonnière, on observe une diminution aussi bien pour le potentiel hydrique maximum que pour le potentiel hydrique minimum vers les saisons plus sèches et chaudes du printemps et de l'été. A un niveau donné de disponibilité d'eau et de conductivité hydraulique, le potentiel hydrique des tissus est déterminé par le taux transpiratoire. Au fur et à mesure que le sol se dessèche pendant la saison, le potentiel hydrique à l'aube et à midi peuvent changer en parallèle en fonction du potentiel hydrique du sol. Pendant l'augmentation du stress hydrique on peut enregistrer un écart plus ou moins constant de la variation du potentiel des tissus à mesure que le sol se dessèche. Selon Kappen et al. (1975), Schulze (1991), ce type de réponse est typique et généralement observé chez les plantes des différentes formes de vie et d'habitat.

Tableau 2. Résultat de l'analyse de variance effectué sur l'effet de l'espèce ou provenance (facteur A) et de la saison (facteur B) dans la valeur du potentiel hydrique maximum et minimum. Las Cadras, Chili, 1995-1996.

Source de variation	Degré de liberté	ψ maximum		F calculé	Probabilité
		Somme des carrés	Carré moyenne		
Facteur A	7	14,608	2,087	26,96	0,000
Facteur B	3	16,828	5,609	72,47	0,000
AB	21	21,317	1,015	13,11	0,000
Erreur	64	4,953	0,077		
Total	95	57,707			

Coefficient de variation inter-spécifique : 15,64%.

Ψ minimum					
Source de variation	Degré de liberté	Somme des carrés	Carré moyenne	F calculé	Probabilité
Facteur A	7	24,180	3,454	32,0363	0,000
Facteur B	3	12,241	4,080	37,8416	0,000
AB	21	30,284	1,442	13,3749	64
Erreur	64	6,901	0,108		
Total	95	73,605			

Coefficient de variation inter-spécifique : 8,07%.

Paramètres hydriques

Le tableau 3 montre des différences entre les paramètres déduits des courbes de pression en rapport avec le déficit relatif en eau à l'échelle annuelle. On peut observer que le rapport PS/PT ne change pas au niveau inter-spécifique. Par contre la teneur relative en eau a été plus basse chez *A. halimus* et *A. nummularia* par rapport aux autres espèces. On peut envisager une stratégie différente pour la conservation de l'eau au niveau des tissus photosynthétiques. D'une part, la TRE a été semblable chez les deux espèces (moyenne de 78%) et donc sans différences significatives. *A. nummularia* a des feuilles d'une grande surface et un mésophyle plus épais en comparaison à *A. halimus* qui effectivement ne retient pas l'eau. Ces types de réponses peuvent être expliqués par le rapport PS/PT plus grand chez *A. nummularia*. Les autres espèces montrent une TRE similaire.

Tableau 3. Comparaison annuelle inter-spécifique des paramètres hydriques chez des plantes d'*Atriplex* installées à Las Cadras, Chili.

Espèce	PS/PT	TRE (%)	π_o (Mpa)	π^{100} (Mpa)	ϵ (Mpa)
<i>A. halimus</i>	23,2	77,8	-3,8	-2,6	11,0
<i>A. atacamensis</i>	22,5	88,2	-4,0	-3,0	15,3
<i>A. canescens</i>	24,0	83,3	-4,0	-2,8	13,4
<i>A. nummularia</i>	24,1	79,7	-3,4	-2,6	7,6
<i>A. undulata</i>	21,6	81,0	-3,2	-2,2	14,5

PS/PT : Rapport poids sec/poids turgescent des rameaux.

TRE : Humidité relative des rameaux.

π_o : Potentiel osmotique à turgescence nulle.

π^{100} : Potentiel osmotique à pleine turgescence.

ϵ : Module d'élasticité.

Le potentiel osmotique à turgescence nulle est de -4,0 Mpa chez les espèces *A. atacamensis* et *A. canescens*. Ces valeurs sont en étroite relation avec des valeurs du potentiel minimum. La valeur la plus élevée a été enregistrée sur *A. undulata* (-3,2 Mpa). De façon semblable, des valeurs du potentiel hydrique à pleine turgescence plus négatives ont été enregistrées chez *A. atacamensis* et *A. canescens*. Ces valeurs peuvent refléter un ajustement osmotique, mais à l'échelle annuelle c'est plus difficile à établir (Tableau 4).

Le module d'élasticité le plus bas enregistré sur *A. nummularia* pourrait déterminer une plus haute élasticité des parois cellulaires.

Tableau 4. Résultats de l'analyse de variance effectué en fonction de l'effet de l'espèce ou provenance (Facteur A) et de la saison (Facteur B) sur les paramètres hydriques : PS/PT (poids sec/poids turgescent) ; TRE (teneur relative en eau) ; π_0 (potentiel osmotique à turgescence nulle) ; π^{100} (potentiel osmotique à pleine turgescence) et ε (module d'élasticité).

S/PT					
Source	Degrés de liberté	Somme des carrés	Carré moyen	Valeur F	Probabilité
Facteur A	7	1187,103	169,586	9,4451	0,0000
Facteur B	2	105,918	52,959	2,9496	0,0628
AB	14	1549,945	110,710	6,1660	0,000
Erreur	44	790,013	17,955		
Total	67	3632,979			

TRE (%)					
Source	Degrés de liberté	Somme des carrés	Carré moyen	Valeur F	Probabilité
Facteur A	7	1,611,462	230,209	92,5269	0,0272
Facteur B	2	3,303,984	1,651,992	18,1331	0,0000
AB	14	3,114,736	222,481	2,4421	0,0113
Erreur	47	4,281,883	91,104		
Total	70	12,312,066			

π_0					
Source	Degrés de liberté	Somme des carrés	Carré moyen	Valeur F	Probabilité
Facteur A	7	12,135	1,734	3,5765	0,0000
Facteur B	2	19,987	9,994	20,6169	0,0000
AB	14	18,576	1,327	2,7373	0,0050
Erreur	47	22,782	0,485		
Total	70	73,480			

π^{100}					
Source	Degrés de liberté	Somme des carrés	Carré moyen	Valeur F	Probabilité
Facteur A	7	8,437	1,205	4,6468	0,0005
Facteur B	2	10,870	5,435	20,9539	0,0000
AB	14	14,213	1,015	3,9138	0,0002
Erreur	47	12,191	0,259		
Total	70	45,712			

6

Source	Degrés de liberté	Somme des carrés	Carré moyen	Valeur F	Probabilité
Facteur A	7	767,356	109,622	12,0190	0,0000
Facteur B	2	1768,528	884,264	96,9511	0,0000
AB	14	751,147	53,653	5,8826	0,0000
Erreur	46	419,553	9,121		
Total	70	3706,585			

Conclusions

Notre étude a mis en évidence une grande variabilité inter-spécifique et intra-spécifique dans le cas d'*A. halimus*. Mais chez les écotypes d'*A. nummularia*, nous n'avons presque pas enregistré de différence dans les paramètres hydriques.

L'analyse des courbes pression—déficit relatifs en eau permettent d'établir l'existence des réponses différentes sur chaque paramètre hydrique. On observe qu'il n'y a pas une seule réponse valable pour toutes les espèces, mais que chaque espèce a ses propres mécanismes qu'elle utilise en réponse à la contrainte hydrique.

A l'échelle annuelle, la comparaison inter-spécifique montre qu'il n'y a pas de différence sur le rapport PS/PT, sur la TRE et aussi sur le module d'élasticité sauf dans le cas d'*A. nummularia*, qui a montré la valeur la plus basse du module d'élasticité et donc une plus haute élasticité des parois cellulaires. A cette échelle, *A. atacamensis* et *A. canescens* montrent une plus haute capacité d'ajustement osmotique en comparaison aux autres espèces.

A l'échelle saisonnière, *A. nummularia*, étant donné que la TRE ne change pas, montre un ajustement osmotique avec des valeurs plus basses du potentiel osmotique à pleine turgescence -4,2 Mpa. On a observé aussi des changements dans la valeur du module de l'élasticité chez les autres espèces.

Les différences qui se manifestent entre les espèces ou provenances dans chaque paramètre, peuvent être en partie attribuées aux effets de la sécheresse, aussi bien qu'à des caractéristiques constitutives de chaque espèce, ce qui montre la grande variabilité des réponses physiologiques.

Références

- Henckell, P. 1964. Physiology of plants under drought. *Annual Review of Plant Physiology* 15: 363–386.
- Kappen, L., J. Oretli, O. Lange, E. Schulze and V. Buschbom. 1975. Seasonal and diurnal courses of water relations of the arido-active plant *Hammada scoparia* in the Negev

desert. *Oecologia* 21: 175–192.

- Lailhacar, S., H. Rivera, H. Silva y Y.J. Caldentey. 1995. Rendimiento de leña y recuperación al corte en diferentes especies y procedencias arbustivas del género *Atriplex*. *Avances en Silvicultura* (en revisión).
- Schulze, E.D. 1991. Water and nutrient interactions with plant water stress. Pages 89–101 in *Responses of Plants to Multiple Stresses* (H. Money, W. Winner and E. Pell, eds.). Academic Press.
- Silva, H. 1990. Efficacité de l'utilisation de l'eau chez des espèces natives et introduites de la région aride méditerranéenne du Chili. Thèse Doctorat Université de Montpellier Sciences et Techniques du Languedoc.
- Silva, H. y Y.E. Acevedo. 1994. Relaciones hidricas en *Atriplex repanda* Phil., a dos niveles de disponibilidad de agua. *Revista Chilena de Historia Natural* 56: 351–367.
- Tyree, M. et H. Hammel. 1972. The measurement of the turgor pressure and the water relations of plants by the pressure bomb technique. *Journal of Experimental Botany* 23: 267–283.

Efficacité Transpirationnelle au Niveau des Échanges Gazeux chez des Espèces du Genre *Atriplex* Installées dans la Zone Aride Méditerranéenne du Chili

R.Y.H. Silva et S. Lailhacar

Universidad de Chile, Casilla, Santiago, Chile

Résumé

L'efficacité transpirationnelle (ET), définie comme le rapport entre la quantité de CO₂ fixée par unité d'eau transpirée, a été déterminée à partir des échanges gazeux instantanés sur huit provenances appartenant à cinq espèces d'*Atriplex* : *A. halimus*, *A. nummularia*, *A. atacamensis*, *A. canescens*, et *A. undulata*, installées dans la zone aride méditerranéenne du Chili. La photosynthèse et la transpiration ont été mesurées simultanément sur des feuilles intactes, sur le terrain, dans un système de mesure d'échanges gazeux en circuit ouvert. Les résultats montrent des différences intra-spécifique et inter-spécifique au niveau de la photosynthèse nette et aussi de la transpiration. Pendant le printemps, *A. atacamensis* montre les valeurs de ET les plus élevées, atteignant à peu près 7,7 μMol de CO₂/mMol d'eau. Chez *A. canescens*, elle atteint seulement 2,2 μMol CO₂/mMol d'eau. Pendant l'été, les valeurs de ET furent plus basses : 3,1 μMol CO₂/mMol d'eau pour *A. halimus* et 3,7 μMol CO₂/mMol d'eau pour *A. nummularia*.

Introduction

La contrainte hydrique est un facteur limitant de la photosynthèse et de la transpiration (Condon et Richards 1993). Elle est déterminée soit par un apport d'eau limité au sol, soit par le déficit de saturation atmosphérique ou par les deux, et son effet s'exprime notamment par la fermeture de stomates et par l'inhibition des réactions enzymatiques associées à la photosynthèse (Read et al. 1991).

En général, pour photosynthétiser, les stomates doivent être ouverts et dans ces conditions, beaucoup d'eau est perdue. L'efficacité de la fixation du CO₂ par rapport à l'eau perdue est fonction du système photosynthétique. Ainsi les espèces CAM sont plus efficaces que les espèces en C₄ et en C₃ sous des conditions normales de température (20 à 25°C) et de pression (0,1 MPa).

Pour assimiler un volume donné de CO₂ les plantes en C₃ doivent perdre un équivalent de 600 à 1000 fois ce volume d'eau. En raison de leur grande capacité de carboxylation, les plantes en C₄ ont un taux relatif de perte d'eau plus réduit, à peu près de 300 (Black 1973). Les plantes CAM fixent le CO₂ pendant la nuit, les

stomates étant alors ouverts dans des conditions de moindre demande d'évaporation, le CO_2 est assimilé avec une quantité minimale d'eau perdue: Le taux d'eau perdue par CO_2 assimilé est en moyenne de 10 à 150 (Osmond et al. 1980).

Dans ce travail, les caractéristiques des échanges gazeux sont analysées comme paramètres de l'efficience transpirationnelle. Nous essaierons d'étudier l'effet de la sécheresse sur cette efficience et cela nous permettra aussi de voir si la valeur reste constante quelles que soient les conditions de développement des plantes.

Étant donné que le potentiel photosynthétique de ces espèces n'est pas connu, cette étude est conçue pour caractériser les échanges gazeux au niveau des feuilles. Ces réponses pourraient refléter des différences de capacité photosynthétique ou de transpiration et, en conséquence, pourraient conduire à l'identification de paramètres physiologiques pouvant servir à la sélection des espèces.

Matériels et Méthodes

Nous avons entrepris l'étude saisonnière et inter-annuelle de l'efficacité transpirationnelle en fonction des échanges gazeux au niveau des feuilles sur des plantes d'*Atriplex*, à partir de printemps 1995. Ces plantes ont été installées entre 1979 et 1980 à la Station Agronomique Expérimentale, Las Cadras ; elle est située à 71°13' longitude ouest et à 30°13' latitude sud.

Matériel Biologique

Les plantes utilisées dans cette étude ont été obtenues après la coupe à 25 cm du sol (Lailhacar et al. 1995). Malgré la sécheresse dans la région pendant les deux dernières années (41 mm en 1994 et 10 mm en 1995), des plantes ont été récupérées après la coupe. En fonction de ce groupe de plantes nous avons choisi trois provenances d'*Atriplex halimus*, deux provenances d'*Atriplex nummularia*, une provenance d'*A. canescens*, *A. atacamensis*, et *A. undulata* (Tableau 1).

Tableau 1. Espèces et provenances d'*Atriplex* installées à la Station Agronomique Expérimentale (Las Cadras, Chili, 1996).

Espèces	Code	Origine de l'espèce
<i>Atriplex halimus</i>	CU 688	Bassin méditerranéen
<i>A. halimus</i>	CU 689	Bassin méditerranéen
<i>A. halimus</i>	CU 690	Bassin méditerranéen
<i>A. atacamensis</i>	CU 637	Chili
<i>A. canescens</i>	CU 610	États Unis d'Amérique et Mexique
<i>A. nummularia</i>	CU 607	Australie
<i>A. nummularia</i>	CU 693	Australie
<i>A. undulata</i>	CU 634	Argentine

Échanges Gazeux Instantanés

Pour étudier l'influence des facteurs de l'environnement et particulièrement de la sécheresse, on a utilisé des échantillons de feuilles sur la plante, prélevés autour de midi, avec un niveau de radiation élevée, et à conditions semblables du potentiel hydrique du sol.

Des paramètres d'échange gazeux ont été évalués en début de printemps (1995) et été (1996) dans un système en circuit ouvert (CIRAS 1-PP S.). Une feuille de surface connue est placée dans une chambre d'assimilation dans laquelle circule l'air à un débit donné. Le principe consiste à déterminer l'abaissement de la teneur en CO_2 de l'air, dû à l'activité photosynthétique de la feuille ou assimilation (A) et l'augmentation de la vapeur d'eau due à la transpiration (T). L'assimilation exprimée en $\mu\text{Mol de CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ et la transpiration en $\mu\text{Mol de H}_2\text{O m}^{-2} \text{ s}^{-1}$. L'efficacité transpirationnelle correspond au rapport A/T.

Dans ces conditions, on a évalué la conductance stomatique, la photosynthèse nette, la transpiration et la concentration interne du CO_2 .

Dispositif Experimental et Analyse des Données

Nous avons utilisé un dispositif expérimental complètement aléatoire avec 4 à 8 répétitions. Les analyses ont été effectuées à l'aide d'un programme statistique MSTAC (Michigan State University 1988) et les différences sont considérées significatives à une probabilité de $P < 0,05$.

Résultats et Discussions

La photosynthèse nette a été plus haute pendant le printemps par rapport à l'été. Ainsi la variation durant le printemps a un écart entre 12 et 22 $\mu\text{Mol m}^{-2} \text{ s}^{-1}$. Chez les deux provenances d'*A. nummularia* on a enregistré les plus hautes valeurs en moyenne de 18 $\mu\text{Mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$. Par contre chez *A. halimus* 689 on a enregistré la valeur la plus basse avec 9,6 $\mu\text{Mol de CO}_2 \text{ m}^{-2} \text{ s}^{-1}$.

Pendant l'été on observe des résultats semblables. *A. nummularia* maintient ses capacités photosynthétiques par comparaison aux autres espèces. Mais chez *A. halimus*, les valeurs de photosynthèse sont semblables à celles observées pendant le printemps. Dû à la diminution de la surface foliaire, il n'a pas été possible de mesurer l'échange gazeux sur les autres espèces et *A. halimus* 689.

De manière similaire au printemps *A. nummularia* a le taux de transpiration le plus élevé avec 7,8 $\mu\text{Mol H}_2\text{O m}^{-2} \text{ s}^{-1}$ et la valeur minimum a été observée sur des plantes d'*Atriplex acatamensis* avec 1,6 $\mu\text{Mol H}_2\text{O m}^{-2} \text{ s}^{-1}$.

Finalement, pendant l'été *A. nummularia* 693 et 607 maintient un taux de transpiration élevé à peu près $4,2 \mu\text{Mol H}_2\text{O m}^{-2} \text{ s}^{-1}$ et les provenances d'*A. halimus* avec $4 \mu\text{Mol m}^{-2} \text{ s}^{-1}$.

L'efficacité transpirationnelle la plus élevée a été observée chez les plantes d'*Atriplex atacamensis* pendant le printemps et chez *A. nummularia* pendant l'été.

Conclusions

L'espèce *A. nummularia* a montré la plus grande capacité photosynthétique par rapport aux provenances d'*A. halimus* (689), laquelle atteint seulement les 50% au printemps. On a enregistré des résultats similaires sur le taux de transpiration chez les mêmes espèces. Donc les valeurs de l'efficacité transpirationnelle se situent à peu près entre 3 et $5 \mu\text{Mol de CO}_2$ par $\text{mMol de H}_2\text{O}$. Ces valeurs sont normalement associées aux plantes en C4.

On a aussi observé une étroite relation entre la conductance stomatique, la photosynthèse et la transpiration et, apparemment, il n'y a pas de fermeture stomatique chez toutes les provenances d'*Atriplex* étudiées.

Références

- Black, R.F. 1973. Photosynthetic carbon fixation in relation to net CO_2 uptake. *Australian Journal of Plant Physiology* 24: 253–286.
- Condon, A. and R. Richards. 1993. Exploiting Genetic Variation in Transpiration efficiency in wheat. An Agronomic View. Pages 435–450 in Stable Isotopes and Carbon-Water Relations (J.R. Ehleringer, A. Hall and G.D. Farquhar, eds). Academic Press, San Diego.
- Lailhacar, S., H. Rivera, H. Silva et. J. Caldentey. 1995. Rendimiento de leña y recuperación al corte en diferentes especies y procedencias arbustivas del género *Atriplex*. *Avances en Silvicultura* (soumis pour publication).
- Michigan State University. 1988. Analysis Statistic. Programme MSTC.
- Osmond, C.B., O. Bjorkman and D.J. Anderson. 1980. Physiological Processes in Plant Ecology. Toward a Synthesis with *Atriplex*. Ecological Studies. Springer Verlag.
- Read, J., Johnson D., K.H. Assay and L. Tieszen. 1991. Carbon isotope discrimination, gas exchange and water use efficiency in Crested Wheatgrass clones. *Crop Science* 1203–1208.

Distribution of Fodder Shrubs in the Arid and Saharan Zones of Morocco

M. Tazi¹, A. Birouk², B. Hafidi² and M. Aghlabi³

¹Centre de Production des Semences Pastorales, El Jadida, Maroc

²Institut Agronomique et Veterinaire Hassan II, Daap, Rabat, Maroc

³Office Regional de Mise en Valeur Agricole de Souss-Massa, Agadir, Maroc

Abstract

Most of the range improvement projects in Morocco are based on the plantation of *Atriplex nummularia*. This native fodder shrub species occurs in the arid and Saharan zones of the country, and represents valuable genetic diversity for the selection of adapted material to be used in range improvement and desertification projects. Selection of local ecotypes requires knowledge of the ecology and the distribution of species in terms of edaphic, climatic, and biotic factors. Between 1989 and 1995, several missions to collect forage germplasm were undertaken in the arid and Saharan regions of the country. A total of 461 collections, representing 10 legume genera, 18 grass genera, and 22 shrub genera, were made at 128 sites. The shrub collection represents 25% of the total accessions. The seven most frequent genera (*Atriplex*, *Acacia*, *Crotalaria*, *Nucularia*, *Rhus*, *Salsola*, and *Zilla*), were present at 4–20% of observed sites. The ecology of these species and their distribution were studied according to environmental factors in terms of altitude and rainfall reported.

Key words: distribution, ecology, fodder shrubs, Morocco.

Résumé

La plupart des projets d'amélioration pastorale au Maroc sont basés sur les plantations de l'espèce *Atriplex nummularia*. Les arbustes locaux des zones arides et sahariennes du Maroc présentent une diversité génétique importante pouvant servir dans les programmes de sélection de matériel végétal qui peut être utilisé dans les programmes d'amélioration pastorale et de la lutte contre la désertification. La sélection de ces écotypes locaux exige la connaissance de l'écologie et de la distribution des espèces en fonction des facteurs édaphiques, climatiques et biotiques. Plusieurs prospections de collecte des ressources phytogénétiques fourragères ont été menées durant la période 1989 à 1995 à travers les régions arides et sahariennes du pays. Durant ces missions, 461 écotypes représentant 10 genres de légumineuses, 18 principaux genres de graminées et 22 genres d'arbustes. Ces arbustes représentent 25% du total des échantillons collectés. Sept genres (*Atriplex*, *Acacia*, *Crotalaria*, *Nucularia*, *Rhus*, *Salsola*, and *Zilla*), les plus fréquents, sont rencontrés dans 4 à 20% des relevés.

L'écologie de ces espèces en relation avec les facteurs du milieu a été étudiée et leurs distributions en fonction de l'altitude et la pluviométrie ont été reportées.

Mots-clés: distribution, écologie, arbustes fourragers, Maroc.

Introduction

There are more than 50 million hectares of rangeland in Morocco. These lands have experienced severe degradation due to drought and overgrazing. Several techniques are used to improve these rangelands, and one of the most successful is fodder shrub plantation. Most range improvement projects in Morocco are based on the plantation of *Atriplex nummularia*. To offer an alternative to this species, and diversify the material used in range rehabilitation, a series of missions was made to collect native shrubs in the arid and Saharan zones of Morocco (Prendergast et al. 1992; Tazi and Birouk 1994). However, the biology, productivity, and uses of the species collected are still unknown. The selection of these ecotypes requires an understanding of their ecology and their distribution in terms of edaphic, climatic, and biotic factors.

The objective of this study was to relate the distribution of Moroccan shrub species to environmental, climatic, and other factors. This information was given to development programs to select cultivars adapted to local conditions.

Methods

Several collecting missions were undertaken between 1989 and 1995 in the arid and Saharan regions of Morocco. This area runs from 33° 18' N latitude in the north to 23° 50' N latitude in the south, and from the littoral zone in the west to the High Atlas mountain in the east. This includes the regions of Doukkala, Chaouia, Abda, Chiadma, Haouz, and Souss as well as the pre-Saharan, and Saharan zones. The collecting missions covered areas ranging from sea level to 1,600 m asl, and from desert to forest. The average rainfall data over 25 years were obtained from published records. The altitude was either measured using an altimeter or obtained from local maps. Most of the missions were carried out in collaboration with the Royal Botanic Gardens, Kew, UK.

Most of the species collected were identified. Several of them were endemic. Their local name and forage value were recorded, following inquiry with local herders. The collected material is under multiplication and characterization at the Centre de Production des Semences Pastorales in El Jadida. A catalogue illustrating the principal species of the Saharan regions of Morocco has been published (Birouk et al. 1991).

Results

Frequency and Abundance of Species

A total of 461 samples representing 10 legumes, 18 grasses, and 21 shrubs were collected from 128 sites during 1989–1995 (Table 1). The shrub collection represents 25% of the total accessions. *Atriplex* species were found on 22% of the sites, *Salsola* and *Acacia* species on 7%, and *Crotalaria saharae* and *Zilla spinosa* on 5%. Less frequent but still common were *Rhus* spp., *Nucularia perrinii*, and *Retama* spp.

Table 1. List of main genera collected by the CPSP (1989–1995).

Arbustes		Grasses		Legumes	
Genus	Samples	Genus	Samples	Genus	Samples
<i>Acacia</i>	9	<i>Aegilops</i>	1	<i>Astragalus</i>	29
<i>Anabasis</i>	4	<i>Agropyron</i>	1	<i>Bisserula</i>	5
<i>Anvillea</i>	3	<i>Alopecurus</i>	2	<i>Hippocrepis</i>	16
<i>Atriplex</i>	28	<i>Aristida</i>	17	<i>Lotus</i>	20
<i>Bubonium</i>	10	<i>Bromus</i>	3	<i>Lupinus</i>	5
<i>Citrus</i>	1	<i>Cenchrus</i>	13	<i>Medicago</i>	98
<i>Crotalaria</i>	7	<i>Cymbopogon</i>	2	<i>Onobrychis</i>	2
<i>Genista</i>	1	<i>Dactylis</i>	11	<i>Scorpiurus</i>	28
<i>Haloxylon</i>	2	<i>Eragrostis</i>	2	<i>Trifolium</i>	5
<i>Hedysarum</i>	1	<i>Festuca</i>	1	<i>Trigonella</i>	3
<i>Nitraria</i>	3	<i>Hyparrhenia</i>	5	<i>Vicia</i>	1
<i>Nucularia</i>	6	<i>Lolium</i>	1	Other legumes	18
<i>Ononis</i>	2	<i>Lygeum</i>	3		
<i>Retama</i>	3	<i>Oryzopsis</i>	11		
<i>Rhus</i>	5	<i>Panicum</i>	8		
<i>Salsola</i>	9	<i>Pennisetum</i>	1		
<i>Traganum</i>	1	<i>Phalaris</i>	2		
<i>Withania</i>	1	<i>Stipa</i>	9		
<i>Zilla</i>	7	Other grasses	17		
<i>Zygophyllum</i>	1				
Other shrubs	17				
Total	121		110		230

Distribution and Ecology

Only the seven most frequent species (*Acacia*, *Atriplex*, *Crotalaria*, *Nucularia*, *Rhus*, *Salsola*, and *Zilla*) are considered in this paper.

Influence of Rainfall

The areas prospected were divided into three zones on the basis of average annual rainfall (P):

- Sub-Saharan and Saharan zone: $P \leq 100$ mm
- Arid zone: $100 < P \leq 250$ mm
- Semi-arid zone: $P > 250$ mm

All seven genera were found in the Saharan zone, at a frequency of occurrence above 60%. *Atriplex*, *Acacia*, and *Salsola* spp. were widespread in the arid zone. *Rhus* was the only species found in areas receiving more than 250 mm rain. *Crotalaria* and *Nucularia* are confined to the Sahara, where they are endemic.

Influence of Altitude

The relative frequency of species collected at three classes of altitude (H) are:

- The littoral and adjacent zones: $H \leq 150$ m.
- The plain zones: 150–400 m.
- The plateau and mountainous zones: $H > 400$ m

The seven genera were all encountered in the low altitude zone (< 150 m), with more than 65% of the ecotypes represented. Fifteen percent of *Zilla spinosa* ecotypes were also found in the plains zones (150–400 m). Two of the genera, *Atriplex* and *Acacia*, were widespread in all three zones. Collections of *Crotalaria*, *Rhus*, and *Salsola* were also made in areas above 400 m altitude.

Discussion

The natural distribution of shrub species in Morocco is influenced by climatic, environmental, and edaphic factors. It is important to determine the occurrence of these species in the driest sites of the Sahara desert. Several species are endemic in the Sahara region. This was shown by Lewalle et al. (1994) in a phytochorology study of the 573 species recorded in the Sahara.

Conclusion

Genetic erosion has been observed in the arid and desert regions of Morocco due to overgrazing and desertification. However, it is difficult to assess the impact of this loss of genetic diversity. Thus, it is important that other collection missions be made at the right time to collect these valuable plants. The selection of adapted ecotypes from these shrub species will provide valuable plant material with large variability that can be used in the range improvement projects in Morocco in association with *Atriplex nummularia*.

References

- Birouk, A., J. Lewalle et M. Tazi. 1991. Le Patrimoine Végétal des Provinces Sahariennes du Maroc. Rabat, Actes Editions.
- Lewalle, J., A. Birouk et M. Tazi. 1994. Chorologie du peuplement végétal des provinces sahariennes du Sud du Maroc. Séminaire National sur les Ressources Phytogénétiques et Développement Durable, 24–26 Oct 1994. Institut Agronomique et Vétérinaire Hassan II, Rabat, Maroc.
- Prendergast, H.D.V., A. Birouk and M. Tazi. 1992. International team collects a rich trove of wild species in Morocco. *Diversity* 8(3): 16–19.
- Tazi, M. et A. Birouk. 1994. Distribution des espèces autochtones d'intérêt fourrager et pastoral dans les zones arides et semi-arides du Maroc. Pages 27–38 in *Amélioration Pastorale et Production Fourragère dans le Maghreb* (M. Tazi and A. El Gharbaoui, eds.): Actes du Séminaire Régional du Réseau Maghrébin des Parcours et Fourrages, 19–20 Février 1993, Meknès, Maroc. Imprimerie Balabil Fes, Maroc.

The Ecology and Biology of Fodder Shrub and Undershrub Chenopodiaceae in Khorasan Province, Northeastern Iran

M.H. Rashed

Ferdowsi University of Mashhad, Mashhad, Iran

Abstract

Khorasan occupies almost one fifth of the area of Iran. It has diverse climatic conditions and vegetation cover, ranging from mountains in the north to warm desert in the south. Average annual rainfall ranges from 400 mm to less than 100 mm in the two main deserts that extend into this province. The main fodder shrub and undershrub species are scattered across the arid desert lands. They are mainly Chenopodiaceae, including: *Anabasis*, *Atriplex*, *Chenopodium*, *Halocnemum*, *Haloxylon*, *Kochia*, *Salicornia*, and *Salsola* species. Dominant shrubs from other families include: *Cundelia*, *Pteroporum*, *Atraphaxis*, *Crataegus*, *Rosa*, *Berberis*, *Amygdalus*, and *Zygophyllum*. These plants are usually grazed by domestic animals, especially camel and goat. This paper analyzes the ecological distribution of the main native fodder shrubs, especially Chenopodiaceae, of the Khorasan province. These shrubs comprise a large proportion of the grazing feed in the arid lands of the middle and southern portions of the province. Shrub and undershrub species from Chenopodiaceae and other families were collected and identified. Distribution, life form, and other botanical characteristics were described. These characteristics were determined on the basis of experimental field work conducted by our regional herbarium, which specializes in the flora of Khorasan.

Key words: ecology, biology, fodder shrub, fodder undershrub, Chenopodiaceae, Khorasan.

Introduction

Khorasan, which is a vast region in northeastern Iran, is the country's largest province, with a total area of 313,000 km². It lies between 53° 28' and 61° 14' E longitude and 30° 21' and 38° 17' N latitude. The topographic conditions governing Khorasan province vary considerably, and thus the plant distribution is remarkable (Fazly Bazzaz et al. in press).

In northern Khorasan, mesophytic plants dominate, while in western and southern Khorasan we observe mainly xerophytic plants. The familiar shrub and undershrub species in the mountainous north are: *Berberis*, *Rosa*, *Amygdalus*, *Crataegus*, *Cotoneaster*, and cushion-type plants such as *Acantholimon*, *Onobrychis*, and *Astragalus*. The leaves, flowers, and even fruits of these plants are used by

domestic animals, especially sheep and goat. The most common shrub and undershrub species in western and southern Khorasan are: *Astraphaxis*, *Pteropyrum*, *Atriplex*, *Tamarix*, *Salsola*, *Haloxylon*, *Alhagi*, and *Zygophyllum*. Among the shrub and undershrub species, Chenopodiaceae are considered good forage desert plants in dry and salty region such as Khorasan (Rashed 1992).

The main objective of this project was to collect and identify the shrub and undershrub Chenopodiaceae species used for forage in Khorasan. The focus was on the biology and habitat of these plants.

Materials and Methods

Plants were collected by the author and his co-workers over 15 years (1981–1996) during numerous herbarium missions to various parts of Khorasan province. Each specimen at each site was collected, numbered, and annotated with the date of collection and the conditions of the habitat. The plants were delivered to the Ferdowsi University of Mashhad Herbarium (FUMH), dried, mounted on herbarium sheets, identified, and named. Original black and white drawings were done, based on the herbarium specimens, for workshop demonstration. The forage value of each plant was prepared based on the experiences of the herbarium research team, my own observation, comments by local people, nomads, and the literature. Eighteen shrub and undershrub species of Chenopodiaceae, with various forage values, were collected and identified at FUMH. The bioecological characteristics of each species were described.

Results

Shrub and undershrub species of Chenopodiaceae were collected during various expeditions. The description, distribution, and use of these species are given below.

***Anabasis eriopoda* (C.A.Mey.) Benth.**

An undershrub, 10–30 cm high, bluish, glabrous; root straight and cylindric; caudex woody, capitate, woolly-tomentose at the base of stems; numerous stems, 2–5 mm in diameter; leaves at the base of the stem are scale-like, flowers solitary in the axil, bracteols lateral; priath segment, scarious fruits, broad oroid glabular (Gharaman 1990).

A native plant; specimens were found between Mashhad and Sarakhs Ghichdar on a gravelly hillside, 700 m, 21193 (FUMH). Eaten by camels late in fall and winter.

***Anabasis setifera* Moq.**

An undershrub, 10–40 cm high; caudex woody, articulate with numerous branches and branchlets; leaves opposite, succulent, terete; flowers small and green. In the axil of branchlets, perianth segments in fruit are perfect, with 3–5 unequal wings (Mobayen 1985; Sabeti 1976).

A native plant that grows in saline soils. Specimens were found between Mazdorand and Sarakhs, 1,000 m, 21242 (FUMH) and southeast of Birjand, 900 m, 10788 (FUMH). Eaten by camels, sheep, and goats during fall and winter (Shishkin 1936).

***Atriplex canescens* James.**

A shrub, 40–250 cm high, strongly branched from the lower part, erect: dioecious, grayish-green with silvery-gray branches; branchlets divergent; leaves broad and alternate, 1–5 cm length, almost without petiol, linear or obovate; flowers dioecious; bracts underneath the fruit are involcrate, fruit 4–5 mm, July–September.

An exotic plant widely distributed, found south of Sabzavar, 900 m, 21027 (FUMH); eaten by camels and goats in late fall.

***Atriplex griffithii* Moq.**

An undershrub, 30–100 cm high; semi-woody, gray or whitish; numerous branches from the base, branches articulate; leaves alternate, tapering ends and broad; flowers green, small, in the shape of short racemes or spikes; calyx or green segments remain in fruit, broad; September–October (Sabeti 1976).

A native plant that grows in salt and sandy areas. Specimens were seen in Kashmar, between Reyvash and Attaeyeh, 1,200 m (FUMH). A source of forage for livestock including camels, sheep, and especially goats; winter forage.

***Eurotia ceratoides* C.A.Mey.**

A shrub, 30–60 cm high; numerous branches; leaves are broad, thick, oval, oblong, with a very short petiol. Male and female flowers are on the same spike, piniculate with short petiol, fruit obovoid, 3 mm long, July–September (Ghahraman 1990).

A native plant that grows on gravelly areas, desert steppes, and nitrose regions. Specimens were seen in Ghochan, 1,550 m, 1738G (FUMH); Daragaz, south side of Allah Akbar mountains, 1,430 m, 15457 (FUMH); Bajgiran, 1,650 m, 19875

(FUMH); and western Kalat, between Khakestar and Liennow, 1,350 m, 13807 (FUMH). May be a source of food for camels.

***Halothamnus glaucus* (Bieb.) Botsch.**

An undershrub, 30–75 cm high; gray branches ascending obliquely from the base; leaves alternate, terete; bracts broader at base, perianth segments; winged in fruit below the middle, May–August (Tutin et al. 1964).

A native plant that grows in gravelly gypsiferous slopes. Specimens were seen in Bojnord, between Ashkaneh and Shahrabad, Shirvan, Kalat, Mazdavand, and Sarakhs. A forage plant used by goats and sheep.

***Halothamnus subaphyllus* (C.A.Mey) Botsch**

An undershrub and shrub 30–200 cm high; numerous branches from the lower part; leaves alternate, thick, linear, deciduous; flowers sessile or subsessile, perianths exceeding bracteoles, fruiting perianth including wings 10–20 mm across; May–August (Rashed 1992).

A native plant that grows in the central desert and nitrous places; specimens were seen from Mazdavand to Mashhad, 700 m, 21248 (UFMH); south of Sabzavar, 800 m, 21025 (UFMH); southwest of Kashmar, 750 m, 21159 (UFMH); and from Gonabad to Torbate-Haydareyeh, 900 m, 17952 (UFMH).

This is a native and polymorphic species that occurs under a wide variety of ecological conditions (Rashed 1992). Eaten by camels and sheep.

***Halocnemum strobilaceum* (Pall.) M.B.**

An undershrub or small shrub, 50–180 cm high, stem woody; branches somewhat articulate, shoots terete, succulent; leaves reduced to scales and connates at base enclosing the stem, which appears articulate; flowers are green, small, three-perianth segments united at the lower part, bracts comprised of three flowers each with single stamen. July–September (Mobayen 1985; Davis 1967).

A native plant that grows in saline deserts and dry areas; specimens were seen from Esphragen to Sabzavar, 1,000 m, 19146 (FUMH), south of Sabzavar, 800 m, 21029 (FUMH); and east of Torbat-e-Jam Kale Melloo, 650 m, 21237 (FUMH). Eaten by camels and goats in late fall and winter.

***Halostachys caspica* (Pall.)**

A shrub or small tree, 350 cm high; erect many-branched trunk, ultimate branches articulate; leaves are scale-like, triangular at apex; inflorescence racemous opposite, flowers in threes subtended by scale-like bracts, perianth fleshy, distinctly three-angled, in fruit; July–September (Shishkin 1936).

A native plant that grows in saltland areas. Specimens were seen between Sarakhs and Mashhad, 500 m, 21260 (FUMH); and at Esphrayen, 1,500 m, 11460 (FUMH). Forage of low quality. Eaten by camels, sheep, and goats, especially in winter.

***Haloxylon aphyllum* (Mink) Iljin**

A tree, profusely branched stem, with dark gray bark; branches light gray, ultimate branches drooping; leaves reduced to opposite acute tubercles with short axillary bracts; flowers small, solitary in the axils of scale-like bracts, perianth segment membranous, winged in fruit; April–May (Shishkin 1936; Moyaben 1985).

A native and introduced plant. Specimens were seen in southeast Kashmar, 950 m, 21150 (FUMH); and from Taybad to Torbat Jam, 700 m, 21117 (FUMH). Rehabilitated in flat desert saline areas forming a *Haloxylon* forest. Source of forage for camels, sheep, and goats, especially in winter.

***Salsola aucheri* Bunge**

A shrublet, 30–80 cm high; profusely branched, branches are whitish and covered with short dense hairs, branchlets brittle; leaves alternate 2–3.5 cm, light green, fleshy, deciduous, initially with linear hairs; flowers solitary on spiciform inflorescence, bracteate, and bractecolate, perianth remains on fruit, obovate, red to smoky; August–October (Shishkin 1936).

A native plant found on gravelly slopes; specimens were seen between Bojnord and Ashkhaneh, 900 m, 21080 (FUMH); at Esphragen, 1,400 m, 19083 (FUMH); and between Mashhad and Sanganeh, 1,050 m, 21358. A forage crop for camels, sheep, and goats.

***Salsola dendroides* Pall**

An undershrub, 50–150 cm stem, 5–10 cm in height; branching only at the end, the ends of twigs are branched; leaves alternate; fleshy, deciduous; bracteate and bractecolate; flowers solitary, forming a dense panicle, perianth 7–9 mm in diameter in fruit, August–October (Tutin et al. 1964; Davis 1967).

A native plant that grows widely in gypsiferous clay and saline argillaceous areas between 300 and 1,750 m altitude. Found in Bojnord, Daragaz, northeastern Mashhad, Kalat, Fariman, Kashmar, Sarakhs, and Mashhad. Specimens preserved at FUMH. Eaten by goats, sheep, and camels, especially in winter.

***Salsola orientalis* S.G.Gme1**

An undershrub, 15–50 cm high; branches rough, whitish to gray, woody; leaves alternate, 1–2 cm long, pubescent, linear, semiterete, bracteols broad, keeled; flowers solitary in panicle inflorescences; perianth segments ovate, 7–10 mm across; winged in fruit; July–October.

A native plant that grows in gravelly and saltland areas. Specimens were seen from Mashhad to the Sarakhs hillsides, Bande Salami in Khaf, east of Forbate Jom. Eaten by livestock, namely goats, sheep, and camels, especially in winter.

***Salsola richteri* Kar.**

A tree or shrub, bark light gray; ultimate branches milky white; leaves alternate, terete, 40–80 mm long, bracteols much shorter than leaves and flowers; flowers solitary, winged in fruit, fruiting perianth including wings 10–20 mm in diameter; flowers August–October (Shishkin 1936).

A native plant found in steppe communities and saline sandhill areas. Specimens were seen in southern Sabzavar, 800 m, 21028 (FUMH); and from Taybad to Torbat-e-Jam, 700 m, 21113 (FUMH). Eaten by camels throughout the year, and by sheep and goats in fall and winter.

***Salsola tomentosa* (Moq). Spach.**

An undershrub, 20–40 cm tall; numerous branches, stem covered with whitish hairs; leaves slightly fleshy, light green; perianth membranous, bracteate, and bracteolate, perianth membranous, winged in fruit below the middle, fruiting perianth including wings 6–8 mm in diameter. September–October (Rashed 1992).

A native plant widely distributed in desert and semi-desert areas of Khorasan. Specimens were collected through Khorasan at altitudes of 300–1,600 m: 21086, 21242, 21295, 21363, 21359, 21306, 21314, 21338, 21141, 21269, 21273, 2141, 21122, 21260, 21152, 21037, 21127, 21238, 21109, 21040, 21276, 21057, 21067, and 21280. All preserved at FUMH. According to the local people, it is an acceptable winter forage for camels.

***Salsola zehzadi* Akhani**

A small undershrub, 30–60 cm high; numerous branches at woody base, completely glabrous even when young, stem erect, shining; leaves fleshy, linear, 3–5 leaves connate at base, flowering tepals membranous, 3–3.7 mm long, 1–1.4 mm wide, 1 or 2 fruiting perianths including wings 7–10 mm in diameter, pale yellow to pink, smoky when old (Akhani and Ghorbani 1993).

For the first time, fruiting specimens were collected on 22 October 1991 in Khorasan, east of Torbate Jam, between Mohammad Abad and Malloo, 700 m, 21222 (FUMH). Local people say it is eaten by livestock.

***Sedlitzia rosmarinus* (Her.) Bunge**

A shrub, 80–150 cm high, grayish bark; numerous branches, whitish in color, smooth, opposite, shining; leaves opposite, fleshy, linear; flowers green, pubescent, perfect, with 2 bracts, 5 perianths, connate at base, membranous wings in fruit, wings smoky or brownish when dry, fruit 2–2.5 mm in diameter, September–October.

A native plant of sandy areas. Specimens were seen from Taybad to Torbate Jam, 100 m, 21112 (FUMH). Local people say it may be eaten by camels.

***Suaeda microphylla* Pall**

A small halophytic shrub, 30–75 cm high; numerous branches; leaves small, fleshy, 10–30 mm long, terete; flowers bluish-green, short pedicels adhere to flowering stalk; perianth segments in fruit united only at base; September–October.

A native plant of saltland areas. Specimens were seen from Shrabad to Ashkhaneh, 600 m, 21081 (FUMH). A forage plant, mainly for camels.

Results and Discussion

The Chenopodiaceae saltbushes are important plants on salty desert areas, and are grazed by domestic animals. In many cases, they supply emergency feed during unfavorable conditions (Koocheki and Mohalati 1994). Animals prefer to graze on them only when other, more desirable, forages are not available. However, the nutritional value of some of these halophytes is relatively good and has been recognized for many years. Halophytes contain high levels of salt. Blending halophytes with other mixtures in prepared food will solve these problems (Koocheki and Mohalati 1994). Reports indicate that salinity may act as a fattening feed. Chenopodiaceae are late-flowering plants; they are a valuable

forage source in fall and winter. Most are also an important source of fuel and potash for soap production. Because of heat and drought conditions governing Khorasan, and the high heat and salt tolerance of these bushes, it is advisable to cultivate suitable species for use when needed. They also may be use for sand dune fixation and for changing the landscape to a more desirable situation. *Salsola zehzadi* is a newly identified species. A specimen is preserved at FUMH. Besides Chenopodiaceous shrub and undershrub species, there are many woody plants from other families in Khorasan that possess forage value. Examples are: *Crataegus*, *Rosa*, *Amygdalus*, *Cotoneaster* (Rosaceae), *Zygophyllum*, *Calygonum* and *Convolvulus* (Convolvulaceae).

In conclusion, given their acceptable forage value under harsh conditions, and the other uses for shrub and undershrub halophyte Chenopodiaceae, more research on these types of plants in the salt-affected soils of Khorasan and similar areas is recommended.

Acknowledgment

This project is supported by the Ferdowsi University of Mashhad, Herbarium. The author wishes to appreciate Mr Faghihnia, Mr Rafei, Mrs Safavi, and Mrs Shakoori for their kind assistance and help.

References

- Akhani, H. and M. Ghorbani. 1993. A contribution to the halophytic vegetation and flora of Iran. Pages 35–44 *in* Towards the Rational Use of High Salinity Tolerant Plants (H. Lieth and A. Al Massom, eds.). Kluwer, The Netherlands.
- Davis, P.H. 1967. Flora of Turkey and the East Aegean Islands. Vol. II. Edinburgh University Press.
- Fazly Bazzaz, B.S., G. Haririzadeh, S.A. Imami and M.H. Rashed. Survey of Iranian Plants for Alkaloid S. Flavenoids, Saponins, and Tanins (Khorasan province). Int. Crude Drug. Res. (in press)
- Gharaman, A. 1990. Flore de l'Iran. Public Par Société Nationale pour la Conservation des Ressources Naturelles.
- Koocheki, A. and M.N. Mohalati. 1994. Feed value of some halophytic range plants of arid regions of Iran. *In* Halophyte as a Resource of Livestock and for Rehabilitation of Degraded Lands. Kluwer, The Netherlands.
- Mobayen, S. 1985. Flora of Iran, Vascular Plants. Vol. Tehran University Publications.
- Rashed, M.H. 1992. Khorasan Vegetation. A report on Plant Collection and Identification of Khorasan Province (1982–1987). Ferdowsi University of Mashhad Publications.
- Sabeti, H. 1976. Forest Trees and Shrubs of Iran. Min. of Information and Tourism Press.
- Shishkin, B.K. 1936. Flora of the USSR (Flora SSSR). Vol. 6. Centrospermae. 12 dtle, stro Akademii Nauk SSSR. Moskva-Leningrad.
- Tutin, T.G., V.H. Hegwood, N.A. Burges, D.H. Valentine, S.M. Walters and D.A. Webb. 1964. Flora Europa. Vol. I. Lycopodiaceae to Plantanceae. Camb. U. Press.

Intérêt des Plantes Spontanées des Zones Arides et Désertiques pour la Réhabilitation des Milieux Dégradés en Tunisie Présaharienne : Cas de *Periploca laevigata* Ait. et de *Rhus tripartitum* (Ucria) DS

M. Neffati

Institut des Régions Arides Médenine, Tunisie

Résumé

Periploca laevigata Ait. et *Rhus tripartitum* (Ucria) DC. sont deux espèces arbustives spontanées qui présentent un grand intérêt pour la réhabilitation des milieux dégradés en zones arides et désertiques. Elles sont, cependant, peu connues et menacées de disparition. Dans cet article, des résultats de travaux de recherche se rapportant aux aspects morpho-biologiques de ces deux arbustes sont alors présentés. Des différences au niveau des mécanismes de dissémination des semences de ces deux espèces et au niveau de leur comportement germinatif ont été observées. Caractérisées par leur maturation échelonnée et leur propagation sur de grandes distances, les semences de *P. laevigata* présentent de bonnes performances germinatives. A maturation synchrone, les semences de *R. tripartitum* présentent une inhibition d'origine tégumentaire qui peut être levée par trempage des semences scarifiées dans l'eau pendant 24 heures. Des différences ont été également observées, entre les deux espèces étudiées, au niveau de leurs cycles biologiques et au niveau de la mise en place de leur système racinaire aux premiers stades. La tolérance de *R. tripartitum* au froid permet l'étalement de la production pastorale sur la période hivernale. L'aptitude de *P. laevigata* à se développer à des températures élevées permet à cette espèce de valoriser les pluies précoces et/ou tardives.

Mots-clés : milieu aride, germination, arbustes fourragers autochtones, réhabilitation, parcours.

Introduction

Face à l'accroissement de la pression anthropologique, sur le couvert végétal naturel, observé au cours des dernières décennies, à la lenteur de la régénération naturelle de ce couvert et aux résultats peu encourageants de l'introduction d'espèces exotiques, le recours aux espèces végétales autochtones pour la réhabilitation des milieux dégradés en zone aride tunisienne est devenu aujourd'hui une nécessité. En conditions écologiques égales, ces espèces se caractérisent, en effet, par un meilleur développement que les espèces exotiques

(Zaafouri 1993). Très peu de données concernant le mode de reproduction de ces espèces, leur régénération et leur dynamique en milieu naturel, leur aptitude à la domestication, leurs potentialités génétiques sont, cependant, disponibles. A cet effet deux plantes spontanées, parmi les rares espèces arbustives assez bien représentées en Tunisie méridionale, ont été retenues dans cette étude. Il s'agit de *Periploca laevigata* Ait (famille des Asclépiadacées) et de *Rhus tripartitum* (Ucria) DC (famille des Anacardiacees). Des résultats de recherche consacrées à l'étude de certaines caractéristiques biologiques de ces deux arbustes, susceptibles d'être utilisées pour la réhabilitation des milieux dégradés, sont présentés dans cet article. L'étude de ces caractéristiques s'avère, en effet, indispensable pour assurer la sauvegarde et l'utilisation de ces deux espèces dans les programmes de revégétalisation.

Des données relatives aux exigences écologiques, à la répartition géographique et aux différents usages de ces deux arbustes, empruntées principalement à la littérature, sont également synthétisées dans cet article.

Biologie, Écologie et Utilisation des Espèces Étudiées

***Periploca laevigata* Ait.**

Répartition géographique

Cette espèce est répandue en Afrique du Nord (de la Tripolitaine jusqu'au Maroc), en Espagne, en Sicile et en Syrie (Pottier-Alapetite 1981). Sa présence dans les montagnes du Sahara septentrional et central a poussé Le Floc'h *et al.* (1989) à la considérer comme espèce méditerranéo-saharienne. En Tunisie, cette espèce est présente du nord-est jusqu'à l'extrême Sud (Dhiba et Sidi Toui).

Exigences écologiques

D'après Le Houérou (1969) *P. laevigata* appartient au groupe écologique lié aux hivers tempéré à chaud ($m > 3$). Le Floc'h *et al.* (1989) mentionnent que l'aire de répartition de cette espèce recouvre l'ensemble des bioclimats, depuis le sub-humide jusqu'au saharien dans les variantes chaude à tempérée. Gintzburger *et* Bayoumi (1977) signalent la présence de cette espèce au sud du Jebel Neffousa (en Libye) sous une pluviométrie moyenne annuelle de 50 mm. Du point de vue édaphique *P. laevigata* colonise essentiellement des substrats caillouteux, souvent en situation de pente, ainsi que certains lambeaux de croûte calcaire. D'après Nègre (1962) cette espèce n'est pas spécialisée du point de vue édaphique. Zaafouri *et al.* (1994) ont, cependant, remarqué que lorsqu'elle est plantée sur substrat gypseux *P. laevigata* se trouve dans un état faible à moyen alors qu'elle est en bon à très bon état sur les sols sableux profonds.

Intérêt économique et utilisation

P. laevigata est incontestablement une espèce à usages multiples dans les régions arides. Outre un intérêt pastoral (Nègre 1962 ; Le Houérou et Ionesco 1973 ; Gintzburger et Bayoumi 1977 ; Chaieb 1985) et anti-érosif, le "hellab" est connu par ses nombreuses vertus thérapeutiques (Le Floc'h 1983).

Rhus tripartitum (Ucria) DC

Répartition géographique

Considérée par Quezel et Santa (1963) comme espèce saharo-méditerranéenne, *R. tripartitum* est, d'après Pottier-Alapetite (1981) répandue en Afrique du Nord (jusqu'au Hoggar), en Sicile et en Asie Occidentale. Le Floc'h et al. (1989) mentionnent la présence de ce taxon au Moyen Orient. En Tunisie l'espèce est répandue dans la Dorsale, au centre et au sud du pays.

Exigences écologiques

D'après Le Houérou (1969) *R. tripartitum* appartient au groupe écologique des étages bioclimatiques du semi-aride inférieur au saharien supérieur ($50 < P < 400$ mm) et au groupe édaphique calcicole, thermophile et héliophile des dépressions alluviales recevant un appoint de ruissellement. Les sols colonisés par le "J'deri" sont le plus souvent soit caillouteux, soit squelettiques calcaires ou encore limoneux ou limono-argileux (Le Floc'h et al. 1989).

Intérêts économiques et utilisation

R. tripartitum est l'une des espèces à usages multiples en zone aride (Neffati et Akrimi 1991). Outre le rôle anti-érosif en cas de reboisement des talwegs (Le Floc'h et al. 1989) cette espèce présente aussi un intérêt pastoral (Le Houérou et Ionesco 1973) étant surtout appréciée par les caprins et les camélidés. Le Floc'h (1983) mentionne d'autres usages, du "J'deri," qui se rapportent à la consommation des drupes par les humains, l'emploi de l'écorce pour le tannage et l'utilisation du bois pour la fabrication de charbon de bois. Birouk et al. (1991) considèrent *R. tripartitum* comme espèce pastorale, médicinale et alimentaire.

Phénologie et Morphologie

Méthode

Les données relatives aux modèles de croissance des deux arbustes étudiés résultent d'observations, échelonnées dans le temps, effectuées sur des individus installés en peuplement monospécifique et en absence de pâturage. Elles concernent aussi bien la partie aérienne que la partie souterraine. La description du

système racinaire a été effectuée à partir d'une tranchée creusée dans le sol sur 120 cm de profondeur progressivement dégagé jusqu'au niveau du collet. Cette méthode descriptive a été appliquée, avec succès, par Bendali (1987) à d'autres plantes spontanées du sud tunisien.

Résultats

Periploca laevigata

Cette espèce perd presque complètement ses feuilles durant la saison estivale. Au moment du démarrage végétatif, des verticilles foliaires se développent d'abord tout au long des anciennes tiges puis des nouvelles pousses volubiles, appelées par Ferchichi (1990) "pousses longues," se développent surtout au niveau de la partie sub-terminale de ces tiges. Ces pousses volubiles se développent suivant une trajectoire rotative lui permettant de s'enrouler autour d'un tuteur qui est généralement une ancienne branche ou une autre pousse du même individu. *P. laevigata* a un port dit en diabolos lorsqu'elle est pâturée. Les structures reproductives, (cimes axillaires) peuvent prendre naissance soit au niveau des verticilles foliaires soit sur les jeunes pousses volubiles de l'année. Le mode de ramification de cette espèce et le type de croissance de ses tiges lui confèrent une bonne résistance au pâturage étant donné qu'une bonne partie des jeunes pousses, très appréciées par le bétail, se trouve toujours protégée par les anciennes structures. Neffati (1994) a classé *P. laevigata*, parmi les espèces dont l'arrêt de croissance, à la fin du printemps, est imposé par l'épuisement des réserves hydriques du sol. De plus les fortes températures ne semblent pas affecter la croissance de cette espèce. *P. laevigata* est caractérisée par des racines pivotantes pouvant atteindre 1 mètre de profondeur et des ramifications horizontales relativement peu nombreuses.

Rhus tripartitum

Comme pour *P. laevigata* ; nous avons distingué chez cette espèce deux types de pousses :

- Des pousses dites "longues" qui partent de la partie basale de la plante et de la face supérieure des branches obliques. Elles sont vigoureuses, relativement peu feuillées et de couleur rougeâtre. Elles ne se développent généralement qu'après les pluies.

Les autres pousses, beaucoup plus courtes, se développent sur les noeuds au moment du débourrement qui se produit même avant la saison pluvieuse. Ces pousses qui rappellent les "bourres" de certains arbres fruitiers se terminent par une inflorescence en grappe. Chez cette espèce la floraison se produit peu de temps après le débourrement et la maturation des semences est assez synchrone.

Le démarrage végétatif de cette espèce en automne ne paraît pas être directement induit par la pluie et son développement végétatif se poursuit même en hiver. Une différence de précocité a été en outre observée entre les pieds mâles et femelles. Ces derniers étant plus précoces. Du type mixte, le système racinaire de cette espèce est très développé, tant en profondeur que latéralement. Les réitérations proximales, qui peuvent prendre naissance à partir de 10 cm de profondeur, sont aussi développées que les racines pivotantes qui peuvent atteindre plus d'un mètre de profondeur.

Vitesse d'Élongation des Racines au Stade Jeune Plantule

Méthode

La cinétique racinaire des deux espèces étudiées a été suivie au cours des trois premiers mois du stade jeune plantule. Pour cela, des rhizotrons d'une contenance de 54 litres (hauteur 0,90 m, longueur 0,40 m et largeur 0,15 m) ont été utilisés. Cette méthode a été, en effet, appliquée, avec succès (Ourcival 1992), à deux autres plantes spontanées du sud tunisien. Le semis des deux espèces a eu lieu en période hivernale près de la face inférieure des bacs qui est vitrée. Le suivi de l'élongation des racines des jeunes plantules a été effectué deux fois par semaine à travers la face vitrée. Les bacs sont irrigués à chaque observation sauf en cas de pluie.

Résultats

Les résultats du suivi de la croissance du système racinaire des deux espèces étudiées sont présentés à la Figure 1 et synthétisés dans le Tableau 1.

Tableau 1. Caractéristiques des parties aérienne et souterraine des jeunes plantules de *P. laevigata* et de *R. tripartitum*.

Espèce	Jour de germination	a	b	c	d	Longueur cumulée des racines (cm)	
						1er mois après germination	2ème mois après germination
<i>P. laevigata</i>	16 ème	6	21	à partir de 10 cm	7	17,5	45
<i>R. tripartitum</i>	13 ème	5	12	à partir de 5 cm	7	10	30

a = longueur (cm) de la radicule à l'émergence de la plantule.

b = profondeur atteinte par le pivot au moment de sa ramification (en cm).

c = position privilégiée des ramifications sur le pivot.

d = durée (jours) du stade cotylédonaire (de l'émergence jusqu'à l'apparition de la 1ère feuille et/ou l'élongation de la tigelle).

L'examen des données de ce tableau montre que les deux espèces étudiées présentent des différences importantes au niveau de la mise en place de leur système racinaire. C'est ainsi que durant le premier mois, la longueur du système racinaire n'atteint que 10 cm chez *R. tripartitum* alors qu'elle est de 17,5 cm chez *P. laevigata* et ce malgré une germination plus tardive de cette dernière espèce. Ces différences sont observables également au niveau de la profondeur atteinte par le pivot au moment de sa ramification et de la position privilégiée des ramifications sur le pivot. Chez *P. laevigata*, le pivot ne se ramifie que lorsqu'il a atteint une profondeur de 21 cm alors que chez *R. tripartitum* les ramifications, qui sont plus superficielles (5 cm), se développent alors que le pivot n'atteint que 12 cm de profondeur. Cette dernière espèce est donc apte à valoriser les petites pluies dès son jeune stade. Les jeunes plantules de *P. laevigata*, dont le pivot se ramifie en profondeur, sont capables de survivre même lorsque les précipitations sont espacées dans le temps. La durée du stade cotylédonaire est d'une semaine chez les deux espèces. Cette phase transitoire entre la phase hétérotrophe et la vie autotrophe des végétaux (Jones 1985) s'achève avec le développement des ramifications secondaires chez *R. tripartitum* et par une croissance plus rapide de la racine principale chez *P. laevigata*. La faible vitesse d'élongation des racines des deux espèces au cours du premier mois, pourrait être due au facteur thermique. Il s'agit là, en effet, d'espèces à optimum thermique élevé pour la germination alors que le semis a été effectué sous des températures relativement basses. En conclusion, on peut dire que les espèces étudiées présentent des différences dans la mise en place de leur système racinaire aux premiers stades de leur développement. Ces différences, qui pourraient être dues, en partie aux conditions de l'expérimentation et qui traduisent des différences d'aptitudes d'installation des jeunes plantules dans les conditions naturelles doivent être prises en considération lors de la production de plants en pépinière.

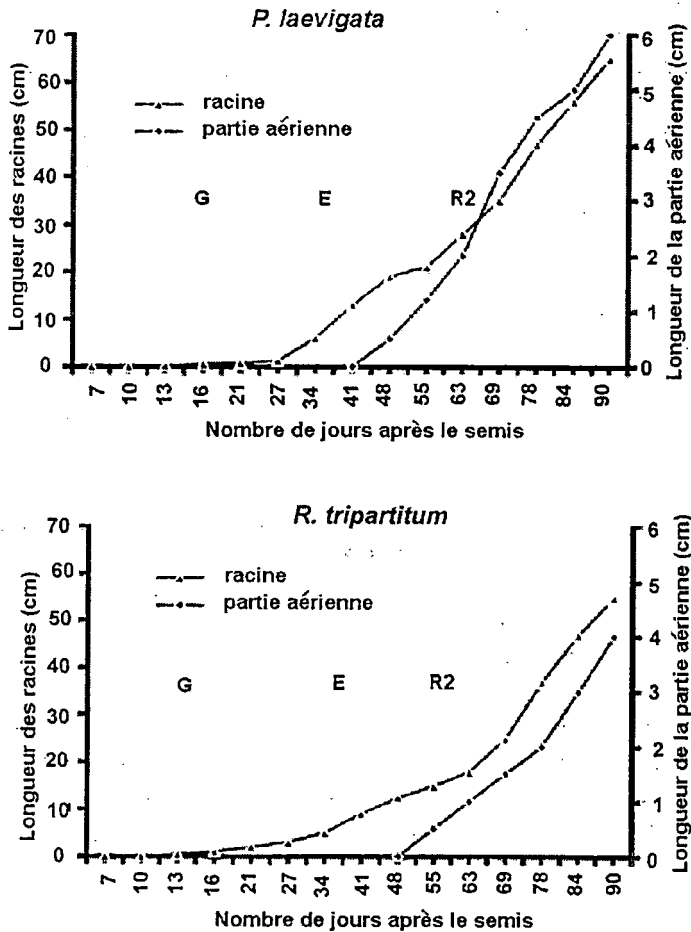


Figure 1. Longueur cumulée des racine et de la partie aérienne des jeunes plantules de *Periploca laevigata* et de *Rhus tripartitum* pendant les trois premiers mois après le semis (G = germination ; E = émergence ; R2 = ramification secondaire des racines).

Morphologie des semences et Mécanismes de Dissémination des Diaspores

La taille des semences, leur constitution et leur caractéristiques de déhiscence influent énormément sur les mécanismes de leur dissémination (Jordano 1992 ; Stiles 1992 ; Willson 1992) et permettent de raisonner les techniques et les périodes de leur collecte ainsi que les techniques de leur semis. Les capacités reproductives des deux arbustes étudiés ainsi que les caractéristiques de leurs semences sont consignées au Tableau 2.

Tableau 2. Capacités reproductives des espèces étudiées et quelques caractéristiques de leurs semences.

Espèce	Poids de 1,000 graines	Nombre moyen de semences par pied : moyenne et valeur extrêmes (en milliers)	Nature de l'unité de dispersion
<i>P. laevigata</i>	11,940	9,9 (4,3–18,9)	Graine + aigrette
<i>R. tripartitum</i>	46,172 [†]	3,8 (2,4–7,9)	Fruit (drupe)

[†] Il s'agit du fruit tout entier (drupe) dont la semence proprement dite ne représente qu'une faible proportion.

Exprimée par le nombre de graines produites par individu, la capacité reproductrice (CR) a été déterminée sur des pieds adultes bien installés. Le comptage des semences a été effectué sur 12 individus installés en peuplement monospécifique.

Le fruit de *P. laevigata* est formé de deux (et rarement de trois) follicules lisses opposés renfermant de 7 à 25 graines (par follicule) munies d'une aigrette de poils. A la déhiscence du fruit, qui commence à partir de la base, les graines munies de leurs aigrettes de poils en forme de parachute sont transportées par le vent.

R. tripartitum n'offre aucun mécanisme de dissémination. Les drupes globuleuses, de couleur marron noirâtre, se détachent de la plante mère aussitôt après le dessèchement de leurs pédoncules.

Étude Expérimentale des Propriétés Germinatives des Semences

Matériels et Méthodes

Ayant pour but de définir les conditions optimales de germination des deux espèces-cibles, cette étude a porté sur les effets des facteurs thermique et hydrique et sur l'effet de la lumière. Différentes techniques de pré-traitement, visant à améliorer les performances germinatives des semences de *R. tripartitum*, ont été également testées. Les semences de *P. laevigata* ne présentent, en effet, aucune inhibition. Pour l'étude du facteur thermique les essais ont été effectués aux températures, 5, 10, 15, 20, 25, 30, 35, et 40°C pour *P. laevigata* et aux températures, 15, 25, 30, et 35°C pour *R. tripartitum*. L'étude des effets du stress hydrique et de la lumière sur la germination de *P. laevigata* a été effectuée à la température optimale.

Les semences ont été mises à germer dans des boîtes de Pétri en verre de 9 cm diamètre où étaient disposées deux couches de papier filtre humectées avec 4 mL d'eau distillée. Dans le cas des essais relatifs à l'influence du potentiel hydrique, les semences ont été immergées dans 10 ml des solutions correspondant aux

différents niveaux de stress hydrique simulés par des solutions de polyéthylène glycol 6000 (PEG 6000) de concentrations croissantes. Les concentrations en PEG 6000 calculées sur la base de l'équation formulée par Michel et Kaufman (1973) à la température de 25°C sont consignées dans le (Tableau 3).

Tableau 3. Concentration en PEG 6,000 (g/l) à tous les niveaux de potentiel hydrique testés (bar) pour la température de 25°C.

Potentiel hydrique (bar)	0 (témoin)	-1	-3	-7	-10	-16
Concentration en PEG 6000 (g/l)	0	78,49	151,55	243,48	295,71	380,52

Les essais ont porté sur 4 lots de 50 graines par espèce et par traitement. La durée de chaque expérimentation est de deux semaines au cours de laquelle des comptages étaient effectués tous les deux jours avec élimination des graines considérées comme ayant germé (radicule ayant percé le tégument [Come 1970]).

Des analyses de variance pour l'ensemble des traitements ont été effectuées et la comparaison des moyennes a été faite par le test de Newman-Keuls au seuil de 5% si la valeur du F de l'analyse de variance est significative au seuil $P < 0,05$. Sur les figures, les valeurs ayant le même indice appartiennent au même groupe homogène d'après le test de Newman-Keuls.

Résultats

Les résultats concernant le comportement germinatif des deux espèces en terme de capacité germinative et de temps moyen de germination sous l'effet de différents traitements, apparaissent sur la (Fig. 2).

L'analyse des données de cette figure (graphique a) permet de dire que *P. laevigata* est caractérisée par un optimum thermique plus strict que *R. tripartitum*. Chez *P. laevigata*, seules les températures 20 et 25°C ont permis un taux de germination supérieur à 80%. Chez *R. tripartitum* même si le taux de germination le plus élevé est atteint à 30°C, des taux supérieurs à 80% ont été obtenus aux températures 15 et 25°C.

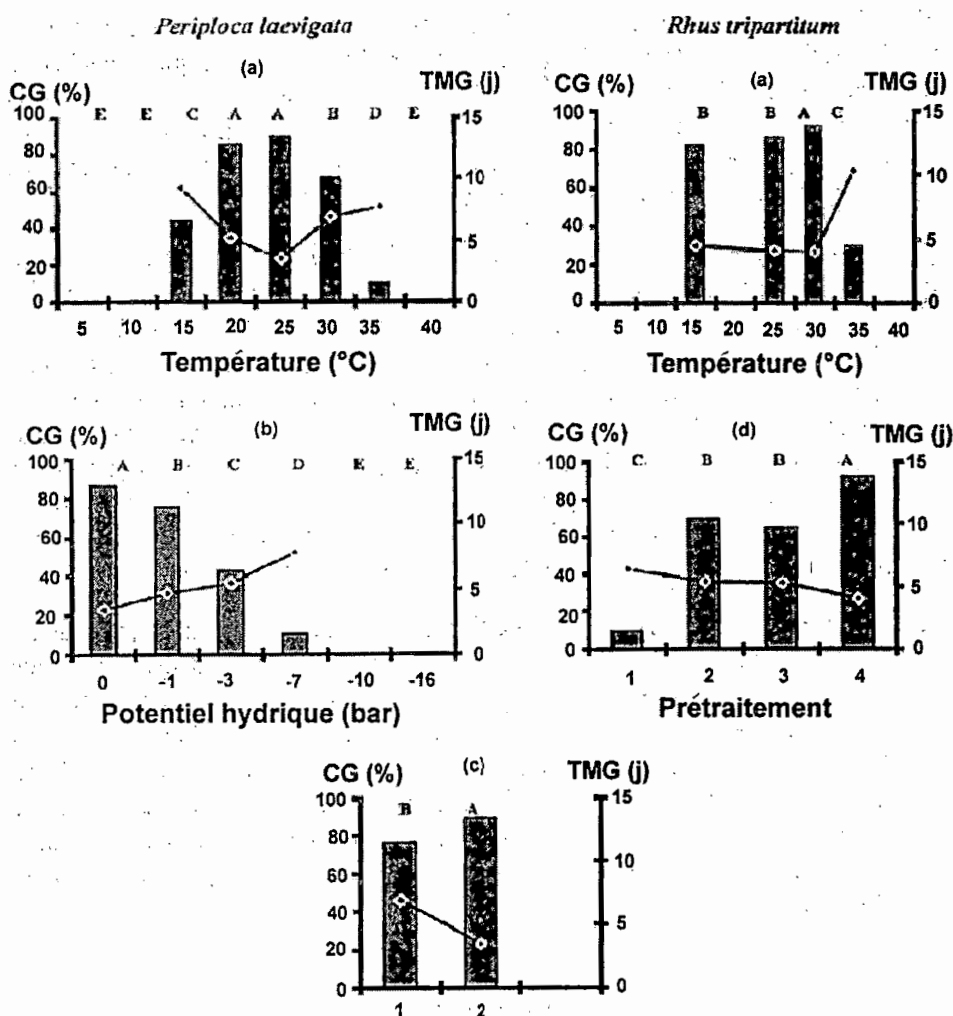


Figure 2. Influence de différents traitements sur la capacité germinative (CG%) et le temps moyen de germination (TMG en jour) de *P. laevigata* et de *R. tripartitum*. (a) = température ; (b) = potentiel hydrique ; (c) = photopériode, 1 = lumière, 2 = obscurité ; (d) = prétraitement, 1 = témoin, 2 = graines scarifiées (sans péricarpe), 3 = scarification + vernalisation (-5°C pendant 15 jours), 4 = trempage des semences scarifiées dans l'eau pendant 24 heures. Au niveau du même graphique, les traitements portant des lettres différentes sont statistiquement différents ($P < 0,05$) ; test Newman keuls.

L'examen du graphique (b) montre que, chez *P. laevigata*, le stress hydrique entraîne une réduction non seulement de la capacité germinative mais aussi de la vitesse de germination. La valeur limite du potentiel hydrique permettant une germination est de -7 bars. Comparativement aux autres plantes de la Tunisie

méridionale *P. laevigata* peut être considérée comme sensible au stress hydrique. De plus Neffati (1994) a démontré que cette sensibilité est d'autant plus élevée que les semences sont fraîchement récoltées. La sensibilité de cette espèce au stress hydrique, en phase de germination, permet d'éviter la germination dans des conditions marginales à la suite des petites pluies qui ne sont pas suivies d'événements pluvieux favorables à l'établissement des plantules.

Le graphique (d) montre que la germination de *R. tripartitum* est fortement stimulée par le trempage des semences scarifiées dans l'eau pendant 24 heures. Les taux de germination obtenu par les pré-traitements 2 et 3 (scarification et scarification + vernalisation) ne sont pas statistiquement différents même si la vernalisation a provoqué une légère diminution de la capacité germinative. Ces résultats suggèrent que l'inhibition de la germination de cette espèce est surtout d'origine tégumentaire. Deux obstacles s'opposent, en effet, à la germination de cette espèce. Un obstacle physiologique induit par le péricarpe qui peut être levé par ablation de celui-ci et un obstacle mécanique, que constitue la coque, et dont l'effet peut être diminué par trempage des semences scarifiées dans l'eau.

Les résultats relatifs à la capacité germinative et à la vitesse de germination de *P. laevigata*, en présence et en absence de lumière, sont illustrés par les histogrammes du graphique (c). Ces données indiquent que la lumière inhibe la germination de cette espèce. Cette inhibition se manifeste par une diminution de la vitesse et de la capacité de germination. La photo-inhibition constitue selon Pons (1992), une forme de résistance à la sévérité des conditions écologiques puisqu'elle empêche une germination massive des semences placées à la surface de sol étant donné que c'est à ce niveau que les variations thermiques et hydriques sont les plus importantes.

Conclusion

L'étude des caractéristiques biologiques de deux arbustes fourragers spontanés du sud tunisien (*Periploca laevigata* et *Rhus tripartitum*) a permis d'obtenir des résultats significatifs tant sur le plan scientifique que sur le plan de leur application au développement :

- La morphologie des semences de ces deux espèces et leurs mécanismes de dissémination sont à prendre en compte pour la collecte de celles-ci. La maturation assez synchrone des semences de *R. tripartitum* et les forts risques de prédation auxquels ces semences sont soumis réduisent la période optimale de collecte des semences de cette espèce. La collecte des semences de *P. laevigata* est rendue difficile par leur maturation échelonnée et leur dissémination sur des grandes distances.

- Alors que la résistance de *P. laevigata* aux fortes températures, en phase de croissance, permet à cette espèce de valoriser les pluies précoces et/ou tardives qui coïncident avec la période des fortes chaleurs, la tolérance de *R. tripartitum* au froid permet l'étalement de la production pastorale sur la période hivernale et de combler ainsi les déficits durant les périodes de soudure.
- Les différences observées, entre les deux espèces étudiées, au niveau de la mise en place de leurs systèmes racinaires aux premiers stades de leur développement doivent être prises en considération lors de la production de plants en pépinière. On peut penser soit aux dimensions des contenants, qui doivent être plus larges pour *R. tripartitum* et plus longs pour *P. laevigata*, soit à la période séparant la date de semis de ces deux espèces en pépinière de celle de leur plantation. Chez *P. laevigata*, caractérisée par une vitesse de croissance racinaire plus importante, cette période doit être plus courte que chez celle de *R. tripartitum*. De plus les irrigations doivent être plus fréquentes chez cette dernière espèce.
- Caractérisée par un optimum thermique assez strict, la température constitue le facteur régulateur majeur de la germination de *P. laevigata*. Chez *R. tripartitum* c'est surtout l'inhibition tégumentaire qui semble jouer un rôle de première importance au niveau du contrôle de sa germination. L'ablation du péricarpe et le trempage des semences dans l'eau permet d'améliorer considérablement les performances germinatives de cette espèce.

L'interprétation des résultats du comportement germinatif de ces deux espèces vis-à-vis de la température et leur confrontation avec les données sur leur écologie permet de confirmer les conclusions de certains travaux (Bell et Bellairs 1982 ; Jordan et Haferkamp 1989 ; Probert 1992) qui considèrent que la température optimale de germination d'une espèce correspond à la température de son développement normal. Caractérisée par sa croissance hivernale, *R. tripartitum* tolère, en effet, des températures plus basses, au moment de sa germination, que *P. laevigata*.

Références

- Bell, D.T. and S.M. Bellairs. 1992. Effects of temperature on the germination of selected Australian native species used in the rehabilitation of bauxite mining disturbance in Western Australia. *Seed Science and Technology* 20: 47–55.
- Bendali, F. 1987. Dynamique de la végétation et mobilité du sable en Jeffara tunisienne. Thèse de Doctorat USTL. Montpellier, France.
- Birouk, A., J. Lewalle et M. Tazi. 1991. Le patrimoine végétal des provinces sahariennes du Maroc. Actes Editions. Inst. Agron. et Vétér. Hassan II Maroc.
- Chaieb, M. 1985. Etude de l'amplitude écologique de quelques espèces pastorales pérennes du sud tunisien en vue du resemis des parcours. DEA Ecologie terrestre, USTL

Montpellier.

- Come, D. 1970. Les Obstacles à la Germination. Masson et Cie, Paris.
- Ferchichi, A. 1990. *Periploca laevigata* Ait.: Écologie, et aptitudes germinatives. DEA Ecol. Végét. Univ. Tunis-II.
- Gintzburger, G. and M. Bayoumi. 1977. Survey of the present situation and production of the Libyan range lands. Tripoli Agr. Res. Centre.
- Jones, A.C. 1985. C₄ grasses and cereals: Growth, development and stress response. A Wiley-Interscience Publication. John Wiley & Sons. New York.
- Jordan, G.L. and M.R. Haferkamp: 1989. Temperature responses and calculate heat units for germination of several range grasses and shrubs. *Journal of Range Management* 42(1): 41–45.
- Jordano, P. 1992. Fruits and frugivory. Pages 105–106 in *Seeds, the Ecology of Regeneration in Plant Communities*. Michael Fenner. CAB International.
- Le Floc'h, E. 1983. Contribution à une Étude Ethnobotanique de la Flore Tunisienne. Publ. Sci. Tunisiennes, Programme "Flore et végétation tunisiennes." Imprimerie Officielle de la République Tunisienne.
- Le Floc'h, E., A. Schoenenberger, M.A. Nabli et G. Valdeyron. 1989. Biologie et écologie des principaux taxons. Pages 51–193 in *Essai de Synthèse sur la Végétation et la Phyto-écologie Tunisienne: I. Eléments de botanique et de phytoécologie* (M.A. Nabli ed.).
- Le Houérou, H.N. 1969. La Végétation de la Tunisie Steppique avec Références au Maroc, à l'Algérie et à la Libye. *Annales de l'INRAT, Tunisie*, Vol 42.
- Le Houérou, H.N. et T. Ionesco. 1973. Appétabilité des Espèces Végétales de la Tunisie Steppique. *Projet FAO/TUN 71/525*.
- Michel, B.E. and M.R. Kaufmann. 1973. The osmotic potential of polyethylene glycol 6000. *Plant Physiology* 51: 914–916.
- Neffati, M. et N. Akrimi. 1991. Espèces Autochtones à Usage Multiple Susceptibles d'Être Utilisées pour la Revégétation des Parours Dégradés en Zone Aride. *Revue des Régions Arides*, No. 2.
- Neffati, M. 1994. Caractérisation Morpho-biologique de Certaines Espèces Végétales Nord-Africaines: Implications pour l'Amélioration Pastorale. Thèse de Doctorat en Science Biologique Appliquées. Université d'état de Gent, Belgique.
- Nègre, R. 1962. Petite Flore des Régions Arides du Maroc Oriental, Tome II.
- Ourcival, J.M. 1992. Réponses de Deux Chaméphytes de la Tunisie Pré-Saharienne à Différentes Contraintes et Perturbations. Thèse de Doctorat. USTL, Montpellier.
- Pons, T.L. 1992. Seed responses to light. Pages 259–284 in *Seeds, the Ecology of Regeneration in Plant Communities* (M. Fenner, ed.). CAB International.
- Pottier-Alapetite, G. 1979/1981. Flore de la Tunisie: Angiospermes, Dicotylédones, Apétales, Dialypétales, Gamopétales. Première et deuxième partie. Ministère de l'Enseignement Supérieur et de la Recherche Scientifique et Ministère de l'Agriculture, Tunisie.
- Probert, R.J. 1992. The role of temperature in germination ecophysiology. Pages 285–325 in *Seeds, the Ecology of Regeneration in Plant Communities* (M. Fenner, ed.). CAB International.
- Quezel, P. et S. Santa. 1963. Nouvelle Flore de l'Algérie et des Régions Désertiques Méridionales. Tome I et II. Centre National de la Recherche Scientifique France, Paris 7.

- Stiles, E.W. 1992. Animals as seed dispersers. Pages 87–104 in *Seeds, the Ecology of Regeneration in Plant Communities* (M. Fenner, ed.). CAB International.
- Willson, M.F. 1992. The ecology of seed dispersal. Pages 61–85 in *Seeds, the Ecology of Regeneration in Plant Communities* (M. Fenner, ed.). CAB International.
- Zaafouri, M.S. 1993. Contraintes du milieu et réponses de quelques espèces arbustives exotiques introduites en Tunisie pré-saharienne. Thèse de Doctorat. Univ. de Droit et d'Economie. et des Sciences, Aix-Marseille III.
- Zaafouri, M.S., N. Akrimi, C. Floret, E. Le Floc'h et R. Pontanier. 1994. Les plantations sylvo-pastorales en Tunisie pré-saharienne. *Sécheresse* 5: 265–275.

Discussion: Ecology and Biology of Fodder Shrub

Chair: H.N. Le Hou  rou (France)

Rapporteur: E. Correal (Spain)

Question by L. Tahtaci  glu: Considering the experiences which have been developed in WANA, is there any reasonable potential for transferring these technologies to the colder areas?

Comment by A.E. Osman (ICARDA): Seed viability of fodder shrubs can vary, especially during storage. Recent research on seed storage at ICARDA indicates that storing *Salsola vermiculata* seed at low temperatures improves viability over time. The effect on *Atriplex* is low.

Answer by E. Correal: I agree with your statement. It is well documented by the scientific literature on seed technology that the conditions under which seed is stored (moisture content, temperature, light, etc.) affect the viability and further performance of the seed.

S. Belkhair: Since 1985/86, fodder shrubs (especially *Atriplex* spp. plantations) in Libya have been subject to highly destructive invasion by rodents (*Psammomys* spp.) with clear impact on and damage to the nearby barley crop. Does that mean the newly created ecosystem is unbalanced because of shrub introduction? Is there any study about the effects of introducing large plantations of fodder shrubs into a range ecosystem?

Answer by G. Gintzburger (ICARDA): The introduction of fodder shrubs, whose leaves are rich in nitrogen, certainly benefited the local population of rodents in Libya. The same problem was observed in the Jeffara plain when the ley farming system with annual medics was developed, especially with *Medicago truncatula* cv Cyprus, near the Wadi Abu-Shayba and Bir-El-Ghanem sites. The rodent population exploded due to the very profitable rich diet, and soon destroyed large areas of medic pasture. The new systems were certainly unbalanced and the population of rodent predators (such as foxes and snakes) increased on the newly developed cropping or range sites in the following years. To my knowledge, there have been no qualitative or quantitative ecological studies carried out on the impact of such new systems on the local fauna. This is certainly a research area worthy of our attention in such a fragile environment.

M. Bounejmate (ICARDA): There are still some climax ecosystems such as *Acacia radiana* in Tunisia, and *Argania spinosa* in Morocco. Some attention should be given to these ecosystems before they are completely degraded.

Answer by M. Tazi (Morocco): This is being taken care of.

A. Bouchaane (Morocco): Nous devons renforcer les recherches sur la biologie florale des arbustes fourragers pour améliorer la production des semences.

Answer by E. Correal: No studies on the floral biology of fodder shrubs have been presented to this meeting. Local conditions under which shrubs flower affect fruit production and thus the amount and quality of seed. However, seed production is usually carried out under optimal conditions. Flower biology is more important for breeding, but we have seen that, for *A. canescens*, intraspecific hybridization of selected parental materials gave poorer germination results than mass selection within adapted populations.

M. Jamil (Jordan): There is a need to tackle the monoculture in fragile environments. Therefore, a gradual introduction of exotic types, accompanied by integration of native plant species, is needed to avoid the effect of catastrophic disease or mismanagement.

S. Mirza (Pakistan): We need to have complete information about the seed source, its ecotype, genetic characteristics, registration number and available source to know exactly what species we are working with.

Answer by E. Correal: Your comment is correct; sometimes species are confused, but besides that, there is usually a lot of genetic variability within species. So, it is very important to identify the particular accession we are working with, because its adaptation to particular biotic and abiotic factors may be related to the origin of the plant material.

S.M. Gamal (Egypt): Does the inoculation with *Rhizobium* bacteria increase the production of green forage of *Acacia saligna*?

Answer by E. Correal: There are no references in this workshop, nor are there in the scientific literature, indicating the need to inoculate *Acacia saligna* with *Rhizobium* to get good nitrogen fixation. Thousands of hectares of *A. saligna* have been planted, and its growth does not seem to be hampered by nitrogen deficiency. M. Ismaili of Morocco indicates in his paper that 41% of the *A. saligna* plant's nitrogen comes from fixation.

Question by M. Ismaili: In different papers (Papanastasis, de Kock, Malcolm, and Le Houérou), the important issues of nitrogen deficiency and organic matter are discussed. I would like to add phosphorus to the list and recommend that we speak about soil fertility problems in rangelands. So, what is the best solution to this problem? Adding N and P fertilizers to the soil, or using good management practices, plant-microorganism interactions (e.g. nitrogen fixation, mycorrhiza), or rock phosphate?

Answer by E. Correal: It is usually uneconomic to apply commercial fertilizers to arid and semi-arid rangelands. The best alternatives are to use animal manure to build up soil fertility on the best soils (e.g. camping animals on these sites) and to grow plants living in symbiosis with microorganisms such as *Rhizobium* and mycorrhiza that improve their efficiency to get nutrients from soil and atmosphere. The use of rock phosphate may be all right in acid soils, but it is not a good alternative for the high pH soils that dominate arid areas.

Comment by Guerin: There is a call to focus on a few species (the rapporteur's suggestion) and to work with native species (participants' suggestion). For example, *Acacia raddiana* is present from Senegal to Pakistan (including Tunisia, Egypt, etc.). It produces feed and wood, and is a traditional fodder tree. Its supplementation includes flowers, pods, and leaves. I suggest that we improve the knowledge of its biology, genetic variability, productivity, and impact on browsing in terms of the management of native stands and its reintroduction.

Answer by E. Correal: I fully agree with your comments and suggestion. A species like *A. tortilis*, subsp. *raddiana*, with wide distribution, good drought tolerance, and multiple uses, fully deserves more research to make better use of it, and to expand its present area.

Comment by M. Diouf (Senegal): Les zones semi-arides couvrent une proportion importante de la superficie du territoire sénégalais. Dans les zones à vocation pastorale, les arbres et arbustes fourragers (cas particulier de *Acacia raddiana*) jouent un rôle important fourrage de saison sèche (8 à 9 mois). Nous avons pris bonne note en ce qui concerne la suggestion de E. Correal sur l'extension de cette étude à un gradient climatique Nord-Sud par exemple. Quant à la viabilité génétique de cette plante, une thèse a été réalisée à l'ORSTOM par Mlle Cardoso Catherine en 1995: Variabilité génétique de populations d'*Acacia* au Sénégal.

Comment by H.S. Oushy (Egypt): Is it the time to have registered seed of fodder shrubs in WANA or southern Europe? The improvement program for fodder shrubs should pay attention to selection, screening, and production.

Answer by E. Correal (Spain): The opinion of many participants at this seminar is that registered seed is not yet a priority—market price and breeding difficulties will probably deter its use by potential consumers. According to your paper on *Atriplex canescens*, mass selection within adapted populations seems to be the right way to get the best germplasm for each ecological site with similar environmental conditions. This is something that can be done at low cost. Consequently, we must first harvest and screen more germplasm from our local environments, as well as from similar environments, where successfully introduced species are native.

Question by B. Boulanouar (Morocco): Plant adaptation and animal production do not always correlate. How do we detect problems early enough in the selection process? When do we stop working on a plant that has problems?

Answer by E. Correal: In my opinion, the basic criteria to screen plant species for a particular environment and livestock system should be the following: (i) adaptation to the environment, (ii) edible biomass production, (iii) feed value for livestock, and (iv) recovery after grazing. To be sure that we select plants valuable for animals, we can first use cafeteria or palatability trials (small plant samples from many species). As the number of plant species is reduced, we can start working on pen-feeding intake trials. Finally, when only a few species are left, grazing trials should take place. The use of plant analysis may be risky if fodder shrub species contain secondary metabolites that interfere with their palatability and intake values.

Question by M. Acherkouk (Morocco): L'atelier n'a pas montré de diversité large d'arbustes fourragers; diversifier! Il faut focaliser les recherches plus sur les espèces autochtones (eg. ressemis d'arboise blanche, *Helianthemum*, *Atractylis*, *Teucrium*, etc.).

Answer by E. Correal: It is true that we work with too few species (mainly *Atriplex*, *Acacia*, and *Opuntia*), and it is highly desirable to further diversify our plant fodder resources, especially when dealing with complex and diversified environments.

M. Bounejmate (ICARDA): I would agree that there is a need to work with more genetic variability. As herbaceous species contribute a lot to animal nutrition, don't you think that associated flora also need to be explored as well as fodder shrubs?

Answer by G. Gintzburger (ICARDA): Clearly, research carried out on Australian rangelands demonstrates the positive role associated herbaceous species growing between or under *Atriplex* and other useful fodder shrubs has on animal production (mostly on wool production).

A. Abdelguerfi (Algeria): Je souhaite revenir sur les remarques de Bounejmate et Gintzburger en ce qui concerne la flore herbacée poussant sous les arbres et arbustes fourragers. A mon avis, il faut rechercher des arbres et des arbustes qui permettent une remontée biologique globale. Les éleveurs, lors de la sortie de terrain, ont vivement insisté sur l'intérêt des espèces herbacées. Par ailleurs, compte tenu du coût d'installation et des pressions d'utilisation dans les régions marginales, il sera judicieux de rechercher les mécanismes et les moyens ainsi que les espèces qui permettent le ressemis, la régénération et le maintien durable des arbres et des arbustes.

Comment: by M. Tazi (Morocco): I would like to congratulate the rapporteur, E. Correal, for the good job he did summarizing all the papers. I have two relevant points for discussion. First, I think that everybody is aware that one species might be good in one area but not so good in another with a similar environment. Second, it seems that research falls behind extension and development. For example, work at the field level is mainly concentrated on two species of the *Atriplex* genus, but we have observed that there are problems with parasites, and that we don't know enough about low-cost direct seeding techniques, etc. I think more research is needed on these points.

Answer by E. Correal: It is true that research falls behind the needs of arid and semi-arid areas. Because saltbush fodder shrub plantation represents one of the few solutions to providing fodder during dry periods, developers and extensionist recommend it as a solution to farmers. However, we don't know enough about it (e.g. low-cost establishment techniques), and have not tested enough germplasm of each species to be sure we have chosen the right accession for a particular environment (e.g. tolerant to local pests or parasites). Certainly, more research is needed, and that is a common task for the whole scientific community working on arid environments

L. Tahtacioglu (Turkey): Considering the experiences that have been seen in WANA region, is there any reasonable potential to transfer these technologies to the colder areas?

Answer by E. Correal: In my opinion, cold arid environments need more research and development, because past experiences on fodder shrubs have been carried out mainly in mild winter areas (e.g. North African and Middle Eastern countries). The work done in western USA (e.g. Utha, *Atriplex canescens*, *A. lentiformis*, etc.) could be transferable.

Answer by G. Gintzburger (ICARDA): Most of the WANA work is in mild to cool winter zone (with occasional minimums of -8 to -10 C° for a few days). For colder environment, please see the experience in the cold Syrian steppe that is easily available. You also do have the range improvement work done by the Karakul Sheep Research Institutes in Samarkand (Uzbekistan), in Chimkent (Kazakstan) and by the Desert Institute from Ashkabat (Turkmenistan) with saxaoul and other species.

Question by R. Von Holdt (South Africa): Have we any reliable transinternational figures available on cost vs benefits for any particular fodder plantation. How much extra income can be derived from the project?

Answer by E. Correal: The President of this session, Dr. Le Houérou, wrote an article on this subject: An Assessment of the Economic Feasibility of Fodder Shrubs Plantations (With Particular Reference to Africa), which you can find in

the book edited by C.M. McKell on The Biology and Utilization of Shrubs (Academic Press). In my opinion—expressed also by Dr. Le Houérou in his main paper, Perspective on Fodder Shrubs—planting shrubs is usually too costly, except in countries where labor is cheap, and hence, it limits the general use of fodder shrubs.

L. Karroumi (Farmer, Morocco): In his presentation, Dr Correal indicated that exotic shrubs are more productive than native shrubs. Don't you think that, if we protect native shrubs, the result will be reversed in biological and economical terms?

N. Murad (Syria): Do you have any information on insect attack on shrubs during germination and after emergence, or on the loss of seed viability of fodder shrubs such as *Salsola*?

Answer by G. Gintzburger (ICARDA): Very little has been done on this last topic.

Plant–Animal Interface

Nutritive Value of Fodder Shrubs Used in Mediterranean Sylvo-Pastoral Systems and their Use by Grazing Animals

T.G. Papachristou

Range Management Laboratory, Forest Research Institute,
National Agricultural Research Foundation, Vassilika, Thessaloniki, Greece

Abstract

Native and exotic fodder shrubs in Greece were reviewed in terms of nutritive value, acceptance, and nutrient use by grazing goats and sheep. The species involved were: *Amorpha fruticosa* L., *Carpinus orientalis* Mill., *Colutea arborescens* L., *Corylus avellana* L., *Fraxinus ornus* L., *Ostrya carpinifolia* Scop., *Pyrus amygdaliformis* Vill., *Quercus pubescens* Willd., *Quercus sessiliflora* Salich, and *Robinia pseudoacacia* L. When the leguminous species (*Robinia pseudoacacia*, *Amorpha fruticosa*, and *Colutea arborescens*) are compared with the remaining species, they show a higher crude protein content (19.0 vs 12.0%; $P < 0.05$) and a higher IVOMD value (58.1 vs 52.0%; $P < 0.05$). According to the relative acceptance index, only *Robinia pseudoacacia* is classified as a species of high preference (18%), while *Amorpha fruticosa* and *Colutea arborescens* are not (2.1%). When these fodder species are offered as supplements to free-grazing goats (1.7 kg/head per day), nitrogen intake is relatively high—from 3.7 (*Colutea arborescens*) to 9.1 (*Robinia pseudoacacia*) g/head per day. Results from digestion trials indicate that the use of nutrients of foliage from such species was relatively high. Nitrogen digestibility for *Robinia pseudoacacia* was 64% and retained N was 9.1 g/goat per day. However, goats digested N more efficiently than sheep (55.7 vs 41.7%; $P < 0.05$) when *Carpinus orientalis* and *Fraxinus ornus* were the tested species. N retention was greater for *Carpinus orientalis* (4.7 vs 2.6 g/d, respectively; $P < 0.05$) but similar for *Fraxinus ornus* (goats = 2.7 g/d; sheep = 3.8 g/d; $P < 0.05$).

Key words: digestibility, fodder shrubs, goats, intake, preference, sheep.

Introduction

There is growing evidence that shrubs and trees play an important role in the nutrition of grazing animals in areas with a prolonged dry season, such as those found in the Mediterranean basin (Le Houérou 1993; Papanastasis 1993). During the dry months, they produce forage of high nutritive value (Nastis 1993; Papanastasis 1993), which is the only available feed. However, some woody species have a high fiber and lignin content and high levels of soluble phenolics and tannins that can reduce nitrogen digestibility and retention (Van Soest 1994).

These chemical components, in combination with morphological characteristics (spines, stout stems, etc.), lead the animals to eat some woody species in preference to others. The nutritional properties of woody species, which are spontaneous in shrublands or introduced in artificial fodder stands, and their acceptance by grazing animals, are critical to assessing their validity as animal feeds. In Greece, there has been increasing interest in some exotic and native deciduous woody fodder species as the most promising for livestock (Platis and Papanastasis 1993; Papachristou and Nastis 1996).

In this article, we present experimental evidence that woody fodder plants have the potential to be an effective source of nutrients for grazing goats. We then show that they may be used as supplements, from a nutritional point of view, for goats during the critical period. Finally, we present experimental data that indicate the true nutritional value of some browse species for goats and sheep.

Forage Value

Studies in Greece have shown that some deciduous woody species, e.g. *Quercus coccifera* L. (Papachristou et al. 1993) and herbaceous species (Yiakoulaki 1987) may play a significant role as an animal feed during summer, when other forages are of low nutritive value. Therefore, the introduction of such species into the grazing system was suggested as an economical way of meeting the demands of grazing animals (Papachristou and Nastis 1993b). To assess the contribution of such introduced deciduous woody fodder plants to grazing systems, their forage quality and acceptance by goats were investigated (Papachristou and Papanastasis 1994).

The experiment involved 10 woody fodder species: *Amorpha fruticosa* L., *Carpinus orientalis* Mill., *Colutea arborescens* L., *Corylus avellana* L., *Fraxinus ornus* L., *Ostrya carpinifolia* Scop., *Pyrus amygdaliformis* Vill., *Quercus pubescens* Willd., *Quercus sessiliflora* Salich, and *Robinia pseudoacacia* L. (for details on experimental procedures see Papachristou and Papanastasis 1994).

The forage quality (Table 1) of foliage from the woody fodder species studied was evaluated in terms of CP, IVOMD, NDF, and lignin content. The CP content of foliage of the three leguminous species, *Amorpha fruticosa*, *Robinia pseudoacacia*, and *Colutea arborescens*, was much higher ($P < 0.05$) than the other species.

Amorpha fruticosa had the highest foliage protein, followed by *Robinia pseudoacacia*, while *Pyrus amygdaliformis* had the lowest. The three leguminous species were more digestible than the other seven species (*Colutea arborescens* > *Robinia pseudoacacia* > *Amorpha fruticosa*). *Corylus avellana* and *Pyrus amygdaliformis* were equally digestible, but they had the lowest IVOMD.

The NDF content of woody fodder species ranged from 35.2% in *Colutea arborescens* to 48.9% in *Corylus avellana*. Lignin content of all species was relatively high, ranging from 6.6% (*Robinia pseudoacacia*) to 10.9% (*Ostrya carpinifolia*).

According to the Relative Acceptance Index (RAI) values recorded in preference trials (Papachristou and Papanastasis 1994), the species studied were classified in three acceptance categories (Fig. 1.). In the first category, only *Robinia pseudoacacia* was included. *Fraxinus ornus*, *Quercus sessiliflora*, *Carpinus orientalis*, *Quercus pubescens*, *Ostrya carpinifolia*, and *Pyrus amygdaliformis* showed no difference in their acceptance by goats and they were classified in the same category. In the third category (RAI <4%), *Colutea arborescens*, *Corylus avellana*, and *Amorpha fruticosa* were included.

Table 1. Crude protein content (CP, dry matter basis), *in vitro* organic matter digestibility (IVOMD), neutral detergent fiber (NDF, dry matter basis), and lignin content (dry matter basis) of 10 fodder shrubs used in Mediterranean sylvo-pastoral systems.

Species	CP	IVOMD	NDF	Lignin
<i>Amorpha fruticosa</i>	21.0 ^{a1}	56.0 ^c	45.0 ^d	8.3 ^a
<i>Carpinus orientalis</i>	11.8 ^{ef}	50.7 ^{ef}	40.7 ^f	9.6 ^{cd}
<i>Colutea arborescens</i>	17.1 ^c	60.0 ^a	35.2 ^h	9.1 ^d
<i>Corylus avellana</i>	12.2 ^a	47.5 ^g	48.9 ^a	10.2 ^b
<i>Fraxinus ornus</i>	13.3 ^d	51.6 ^{de}	36.0 ^g	7.6 ^f
<i>Ostrya carpinifolia</i>	13.1 ^d	52.8 ^d	47.4 ^c	10.9 ^a
<i>Pyrus amygdaliformis</i>	10.5 ^g	47.3 ^g	46.8 ^c	10.1 ^{bc}
<i>Quercus pubescens</i>	11.6 ^f	51.3 ^e	48.2 ^b	8.0 ^{ef}
<i>Quercus sessiliflora</i>	13.1 ^d	49.7 ^f	43.3 ^e	10.3 ^b
<i>Robinia pseudoacacia</i>	20.6 ^b	57.8 ^b	43.2 ^e	6.6 ^g

¹ Means in the same column with different superscripts are significantly different (P < 0.05).

Adapted from Papachristou and Papanastasis (1994).

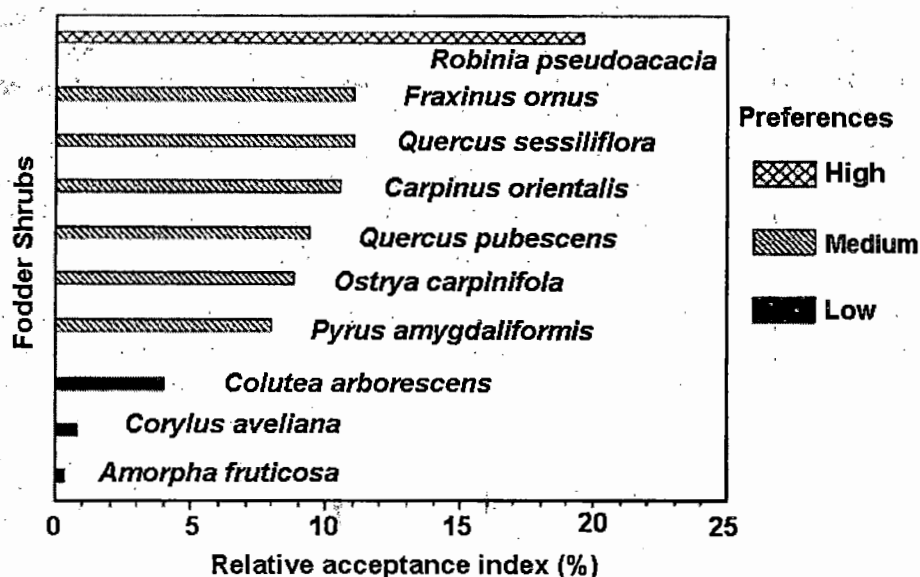


Fig. 1. Relative acceptance indexes (RAI%) of 10 fodder shrubs used in Mediterranean sylvo-pastoral systems. Means separated by more than 3.8% differ (LSD_{0.05}). Adapted from Papachristou and Papanastasis (1994).

Diet Supplementation

The woody fodder species reported on above are an integral component in the natural shrublands (Papachristou and Nastis 1996) and are dominant in artificial woody stands (Platis and Papanastasis 1993). It has been proposed (Papachristou and Papanastasis 1994) that artificial stands of such fodder species should be treated as reserves for supplementary feeding only during the critical summer period. This management scheme for artificial stands encompasses proper browsing during specific periods of the year, as well as the cutting off of branches, which are then offered to animals as a supplement.

A study was conducted in Greece (Forest Research Institute, unpublished data) to determine if some woody fodder species are useful as supplements for goats grazing kermes oak shrublands during the critical summer period (Papachristou and Nastis 1993b). *Amorpha fruticosa*, *Carpinus orientalis*, *Colutea arborescens*, *Fraxinus ornus*, *Ostrya carpinifolia*, and *Robinia pseudoacacia*, considered the most promising in terms of productivity, establishment (Platis and Papanastasis 1993), and nutritive value (Papachristou and Papanastasis 1994), were tested. Thirty-two local meat-type goats, about 18 months old and averaging 32.9 kg, were used. Goats were grouped by liveweight, and four individuals were allocated to

each treatment. Treatments were: 1–6, kermes oak shrubland plus branches of one of the above fodder shrubs as a supplement; 7, kermes oak shrubland plus 0.5 kg alfalfa pellets/animal per day; and 8, kermes oak shrubland. Branches of each fodder species were harvested daily and offered fresh to goats (1.7 kg/head per day) in August and September 1994. During the day (08:00–18:00 hours), all goats grazed the same kermes oak shrublands with cover ranging from 50 to 70% (for details see Papachristou and Natis 1993a, b). Every evening (18:00 hours), goats were separated and penned according to treatment group.

Intake of *Amorpha fruticosa* and *Colutea arborescens* was lower than the other feeds (Table 2), indicating their low acceptance by goats, as found in the previous experiment (Fig. 1). Although changes in body weight are not a reliable parameter for a small number of animals over a short testing period, animals fed supplements (alfalfa or foliage of fodder species except for *Ostrya carpinifolia*) gained weight in contrast to animals grazing kermes oak shrublands only, whose weight decreased.

The data indicate that fodder shrubs provided goats with nitrogen ranging from 3.7 (*Colutea arborescens*) to 9.1 (*Robinia pseudoacacia*) g/head per day. However, this evidence can serve as a guide in assessing their true nutritional value to particular animals, because not all nitrogen is available to animals due to anti-quality factors which may reduce its digestibility.

Table 2. Dry matter intake (DMI, g/head per day) of fodder shrubs and alfalfa used as supplements by free-grazing goats and its effect on body weight (BW, g/animal/d) during August–September.

	DMI	BW
<i>Amorpha fruticosa</i>	284.7 ^{cl}	42.5 ^{bc}
<i>Carpinus orientalis</i>	398.6 ^b	175.0 ^a
<i>Colutea arborescens</i>	233.2 ^c	50.0 ^{bc}
<i>Fraxinus ornus</i>	513.3 ^a	100.0 ^{ab}
<i>Ostrya carpinifolia</i>	388.0 ^b	-12.5 ^c
<i>Robinia pseudoacacia</i>	424.3 ^{ab}	112.5 ^{ab}
Alfalfa (control supplement diet)	397.9 ^b	187.5 ^a
Control (grazing only)		-25.0 ^c

¹ Means in the same column with different superscripts are significantly different; (P < 0.05). Forest Research Institute (unpublished data).

Nitrogen Use

An accurate assessment of the true forage value of such woody fodder species, especially when they are suggested for introduction into sylvo-pastoral systems, can only be made from feeding and digestion trials. It is also important to determine the nutritional relevance for each livestock species. We quantified the nitrogen use of *Carpinus orientalis* and *Fraxinus ornus* browse by goats and sheep (Papachristou 1996) and *Robinia pseudoacacia* by goats in digestion trials

(Papachristou unpublished data). These species were chosen because they are native to the Mediterranean sylvo-pastoral system and often introduced into open grazing lands, creating artificial woody fodder stands. A description of the metabolism cages and details for the experimental procedure are given elsewhere (Papachristou 1996).

DMI for the three tested species ranged from 65.0 (*Fraxinus ornus*) to 89.5 (*Robinia pseudoacacia*) g/kg BW^{0.75}/day. Sheep browsing *Carpinus orientalis* and *Fraxinus ornus* had much lower DMI than goats (Papachristou 1996). However, nitrogen intake was similar ($P > 0.05$) for goats and sheep fed oriental hornbeam browse, and higher for sheep than for goats when fed manna ash (Table 3).

Table 3. Nitrogen use by goats and sheep fed browse of *Carpinus orientalis* and *Fraxinus ornus* during summer.

	<i>Carpinus orientalis</i>		<i>Fraxinus ornus</i>	
	Goats	Sheep	Goats	Sheep
N intake (g/d)	17.2 ^{a1}	19.2 ^a	14.2 ^b	19.3 ^a
N digested (g/d)	9.1 ^a	7.0 ^a	8.4 ^a	9.1 ^a
N retained (g/d)	4.7 ^a	2.6 ^b	2.7 ^a	3.8 ^a
N digestibility (%)	52.9 ^a	36.5 ^b	59.2 ^a	47.2 ^b

¹ Superscripts indicate when the mean values within the same browse species are significantly different ($P < 0.05$).

Source: Papachristou (1996).

The foliage of *Robinia pseudoacacia* appears equal to alfalfa pellets (which served as the control diet) as a source of nitrogen for goats. According to the results of our study (Table 4; Papachristou unpublished data), goats consumed 27.3 g N when fed *Robinia pseudoacacia* and 20.3 g N when fed alfalfa. Nitrogen retention was similar for both diets (9.1 and 10.1 g, respectively).

Table 4. Nitrogen use by goats fed browse of *Robinia pseudoacacia* and alfalfa during summer.

	<i>Robinia pseudoacacia</i>	Alfalfa
N intake (g/d)	27.3 ^{a†}	20.3 ^b
N digested (g/d)	17.5 ^a	16.8 ^a
N retained g/d)	9.1 ^a	10.1 ^a
N digestibility (%)	64.1 ^b	82.8 ^a

[†] Superscripts indicate when the mean value is significantly different ($P < 0.05$).

Source: Papachristou (1996, unpublished data).

Implications

Based on our data, these browse species are promising for the Mediterranean sylvo-pastoral system because they can be an effective protein supplement for small ruminants consuming low-quality forage during summer. They produce

forage of high quantity and quality during this period, while it is well established that herbaceous plants or kermes oak (the dominant evergreen browse on shrublands) provide much lower protein.

Our findings also suggest that the species maintained crude protein levels approaching or in excess of goat and sheep needs for maintenance and production. Results from the digestion trials indicate that the foliage of fodder shrubs may contribute to maintenance and production requirements of goats (*Carpinus orientalis*, *Fraxinus ornus*, and *Robinia pseudoacacia* in excess of maintenance; NRC 1981) and sheep (*Carpinus orientalis* and *Fraxinus ornus*, approaching maintenance; NRC 1985) during the dry period of the year.

The species discussed are intended for use as supplementary feeds during the summer. For this reason, when they are present on grazing lands (e.g. shrublands), proper grazing management must be practiced to avoid their destruction. When artificial stands of fodder species, treated as reserve pastures during the critical summer period, are created, only species of similar preference should be included in the same plantations. Thus, selective use of some species at the expense of others will be avoided.

For fodder shrubs to make a successful contribution to grazing systems, they must be considered in terms of their nutritive value to the animals (e.g. feeding and digestion trials), not just in terms of chemical partitioning of dry matter (which does not always accurately predict forage value). The cases of *Amorpha fruticosa* and *Colutea arborescens* reported in this article represent a characteristic paradigm. Both species had high CP and IVOMD. A high preference was expected as well, but did not occur. However, these species need to be studied in digestion trials before any conclusions can be drawn. Finally, management techniques must be developed to maximize production and resistance to grazing of fodder shrubs used in Mediterranean sylvo-pastoral systems.

Acknowledgments

This paper is based on the results of experiments supported by grants from the Forest Research Department, Ministry of Agriculture, Greece, and the European Union (CAMAR project No. 8001-CT90-0030).

References

- Le Houérou, H.N. 1993. Environmental aspects of fodder trees and shrubs plantation in the Mediterranean basin. Pages 11–33 in *Fodder Trees and Shrubs in the Mediterranean Production Systems: Objectives and Expected Results of the EC Research Contract* (V.P. Papanastasis, ed.). Agriculture, Agrimed Research Programme, Commission of the European Communities, EUR 11459 EN.

- Nastis, A.S. 1993. Nutritive value of fodder shrubs. Pages 75–81 in *Fodder Trees and Shrubs in the Mediterranean Production Systems: Objectives and Expected Results of the EC Research Contract* (V.P. Papanastasis, ed.). Agriculture, Agrimed Research Programme, Commission of the European Communities, EUR 11459 EN.
- NRC. 1981. Nutrient Requirements of Goats: Angora, Dairy and Meat Goats in Temperate and Tropical Countries. No. 15. National Academy Press, Washington, DC.
- NRC. 1985. Nutrient Requirements of Domestic Animals. No 5. Nutrient Requirements of Sheep. National Academy of Sciences. National Research Council, Washington, DC.
- Papachristou, T.G. 1996. Intake, digestibility and nutrient utilization of oriental hornbeam and manna ash browse by goats and sheep. *Small Ruminant Research* (in press)
- Papachristou, T.G. and A.S. Nastis. 1993a. Diets of goats grazing oak shrublands of varying cover in northern Greece. *Journal of Range Management* 46: 220–226.
- Papachristou, T.G. and A.S. Nastis. 1993b. Nutritive value of diet selected by goats grazing on kermes oak shrublands with different shrub and herbage cover in Northern Greece. *Small Ruminant Research* 12: 35–44.
- Papachristou, T.G. and A.S. Nastis. 1996. Influence of deciduous broad-leaved woody species in goat nutrition during the dry season in Northern Greece. *Small Ruminant Research* 20: 15–22.
- Papachristou, T.G. and V.P. Papanastasis. 1994. Forage value of Mediterranean deciduous woody fodder species and its implication to management of silvo-pastoral systems for goats. *Agroforestry Systems* 27: 269–282.
- Papachristou, T.G., A.S. Nastis and P.D. Platis. 1993. Nutritive value of five browse species in different phenological stages in Northern Greece *Animal Science Review* 17: 69–81. (in Greek with English abstract)
- Papanastasis, V.P. 1993. Review of papers on woody forage plants. *Herba* 6: 28–33.
- Platis, P.D. and V.P. Papanastasis. 1993. Productivity of deciduous fodder trees and shrubs in relation to the year of cutting. Pages 134–136 in *Management of Mediterranean Shrublands and Related Forage Resources*. REUR Technical Series 28. FAO, Rome.
- Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant (2nd ed.). Cornell University Press, Ithaca, New York.
- Yiakoulaki, M.D. 1987. Nutritive value of range species as determined with laboratory procedures and their contribution to meet animal demands MSc Dissertation. Aristotle Univ. of Thessaloniki, Greece. (in Greek with English abstract)

Etude du Pâturage de Caprins en Sous-bois de Chênes Liège dans les Pyrénées Orientales, France

J.J. Rochon et J.P. Goby

Institut Universitaire de Technologie de Perpignan, Perpignan, France

Résumé

Le piémont du massif des Albères au sud des Pyrénées-Orientales en France est couvert de suberaies qui présentent des *risques d'incendies* élevés en raison du développement non maîtrisé de formations arbustives (*Erica arborea*). L'élevage caprin peut être un moyen de limiter la prolifération de ces broussailles. La connaissance de la contribution du maquis à l'alimentation des animaux est un élément de base de la maîtrise par les éleveurs des systèmes d'élevage. Les suivis comportementaux ont mis en évidence une relation entre le niveau de production des chèvres et la quantité ingérée sur parcours. La composition de la ration est liée à la disponibilité des différents constituants de la végétation. Des observations de dégradabilité ruminale, et de digestibilité montrent que le parcours fournit en grande quantité des éléments glucidiques solubles, riches en énergie qui favorisent l'utilisation des composants ligneux.

Mots-clés : maquis, bruyère, chèvre, alimentation, environnement.

Abstract

The foothills of the Massif des Albères, in the southern part of the Pyrénées Orientales district of France, are covered with fire-prone cork-oak forests. Goat husbandry and grazing are the means of bush (*Erica arborea*) control. Understanding the contribution of the *maquis* to the feed requirement of the animals is of particular relevance to the mastering of the production system by the pastoralist. Behavioral analysis highlights the relationship between goat production levels and the amount of rangeland feed ingested. The composition of the diet is linked to the resource availability of the paddocks. Observations of feeding behavior plus measurements of rumen degradability show that the rangeland provides a large amount of energy-rich soluble carbohydrates which favor the use of ligneous plants. Three years of monitoring show that goat grazing overcomes bush encroachment.

Key words: shrubs, heather, goats, feeding, and environment.

Introduction

La suberaie du piémont du massif des Albères, au sud des Pyrénées Orientales, en France, couvre 15 235 ha, indice d'une intense activité humaine au cours du siècle passé.

L'embroussaillage, conséquence de la disparition des chantiers d'éclaircies et de l'exploitation du liège entraîne des risques d'incendies élevés. En effet, la progression du feu se fait du sol vers la cime des arbres, d'autant plus rapidement qu'elle est favorisée par l'étagement des strates végétales.

Le développement d'élevages, notamment caprins, dans ces zones, est un moyen de protéger ces massifs boisés grâce à leur intégration dans le système d'alimentation des animaux qui rend possible le contrôle des broussailles.

La connaissance de la contribution du maquis à l'alimentation des animaux, en complément de l'utilisation de fourrages de qualité et d'aliments concentrés, est un élément de base de la maîtrise par les éleveurs des coûts de production, de la pérennité des systèmes d'élevage, et de l'efficacité du rôle des animaux dans l'entretien de l'espace naturel.

Le rôle nutritionnel du pâturage est établi par l'observation du comportement alimentaire des animaux dans un milieu hétérogène et face à une offre fourragère variée et en évolution tout au long de l'année. La contribution alimentaire des arbustes est l'objet d'une étude approfondie.

Matériels et Méthodes

Le Site Expérimental

L'étude s'est déroulée dans une exploitation caprine en relation étroite avec l'éleveur qui a participé à l'élaboration des différentes expériences qui ont été menées.

Localisé au piémont du massif pyrénéen des Albères (47° 32' N et 2° 59' E), à une altitude de 50 à 150 mètres, le site, d'une surface de 50 ha, intègre une suberaie implantée à la fin du XIXe siècle. L'embroussaillage très dense empêche toute pénétration humaine et en particulier rend impossible l'exploitation du liège.

La suberaie a été compartimentée en 8 parcs de 1,5 à 8 hectares débroussaillés sur environ un tiers de leur surface. Dans 4 parcs la partie débroussaillée a été semée de trèfle souterrain (*Trifolium subterraneum*).

La composition de la végétation présente une strate herbacée très pauvre, en raison des obstacles à la pénétration de la lumière au niveau du sol dus à la présence

d'arbustes, seules quelques touffes de *brachypodium ramosum* réussissent à se développer. Dans les zones débroussaillées la production annuelle de phytomasse aérienne atteint 1400 kg de matière sèche/ha.

L'espèce arbustive dominante sur ces zones est la bruyère arborescente (*Erica arborea*). Celle-ci s'est développée sous les arbres et occupe le volume compris entre 0 et 3 mètres de haut. On trouve aussi des cistes de Montpellier (*Cistus monspeliensis*), des cistes à feuille de sauge (*Cistus salvieae-folius*) et en moindres quantités des ajoncs épineux (*Ulex parviflorus*), et des genêts épineux (*Calycotome spinosa*).

La strate supérieure est composée de chênes-lièges (*Quercus suber*). L'offre fourragère sous forme de tiges et feuilles est négligeable en raison de leur inaccessibilité. Cependant par leur production de glands, ils représentent une source alimentaire importante pour les animaux.

On peut estimer la partie consommable du maquis initial entre 5 et 6 T MS/ha.

Dans les zones débroussaillée la présence des arbustes est limitée à celle de leur repousses.

Le troupeau est composé de 62 chèvres laitières de races Alpine et Saanen. Les mise bas ont lieu en hiver, et les adultes ont une production moyenne de 800 litres de lait par lactation de 300 jours. Les meilleures productrices arrivent à 1,000 kg de lait par an avec un pic de lactation à 6 litres/j.

L'alimentation repose d'une part sur le pâturage du maquis l'après-midi pendant 5 à 6 heures par jour, et d'autre part sur la distribution de 1 kg de foin de première coupe de prairie naturelle, de qualité moyenne, et pour les chèvres en lactation d'une quantité de concentrés (orge, tourteau de tournesol) variable en fonction du niveau de production (de 600 à 800 g/j). Cette ration est distribuée en deux fois, le matin pendant et après la traite, 1 à 2 heures avant la sortie au pâturage, le soir à la rentrée des animaux en chèvrerie.

L'été les animaux ne sortent pas sur le parcours.

Méthodes de Mesures

Les mesures de comportement alimentaire ont été effectuées sur un échantillon de 12 chèvres (4 forte productrices de plus de 900 litres/an, 4 de 900 à 700 litres/an et 4 inférieures à 700 litres/an) et 4 chèvres porteuses de fistules ruminales.

Les quantités ingérées sont mesurées par l'observation directe des animaux pendant toute la durée du pâturage, et quantifiées par la méthode des coups de dents (Bourbouze 1980).

L'utilisation de chèvres en production en condition d'élevage comme animaux d'observation n'a pas permis de réaliser des mesures d'ingestibilité classique des différents aliments constituant la ration. En effet nous n'avons pas voulu courir le risque d'offrir des rations trop déséquilibrées. Cependant les observations ont montré la composition des rations pâturées au cours de l'année et lors de la mesure de digestibilité de la bruyère son ingestion volontaire en complément de foin a pu être comparée à l'ingestion de foin seul.

La qualité des aliments ingérés est établie grâce à des analyses des constituants pariétaux (Goering et Van Soest 1970) et des matières azotées totales par micro-kjeldhal complétées par des mesures de dégradabilité ruminale selon la méthode *in sacco* (Demarquilly et Chenost 1969) effectuées sur les chèvres fistulées et des mesures de digestibilité *in vivo*.

L'apport nutritif du maquis est évalué en UFL à partir de l'estimation des besoins des chèvres selon les normes INRA (Jarrige 1988) et des apports contrôlés de foin et de concentrés.

Résultats et Discussion

Activité et Comportement des Chèvres sur le Parcours

Le troupeau reste groupé tout au long de la journée et les changements d'activités synchronisés, même dans les zones où les broussailles réduisent le contact entre les animaux.

Dans les parcs améliorés, quelle que soit la saison, le temps de prise de nourriture représente 69% du temps de sortie quotidienne du troupeau, les déplacements 8%, les repos debout 17% et couché 6%.

La prise de nourriture est fractionnée en trois repas d'une durée de 1 à 1.5 heures séparés de périodes de déplacements ou repos de 20 à 30 minutes.

Le temps de présence des chèvres dans le maquis (30% du temps de sortie) et dans les zones débroussaillées (70%) varie peu au cours de l'année.

Au début du pâturage les chèvres pénètrent dans le maquis, puis se déplacent vers la zone débroussaillée et y séjournent jusqu'à la sortie du parc.

Dans les parcs qui ne comprennent pas de zones débroussaillées, le temps de séjour des chèvres dans le maquis est identique à celui observé dans les parcs mixtes. A la fin de cette période d'alimentation les chèvres se regroupent près de la porte et attendent l'éleveur.

Quantités Ingérées et Qualité de la Ration sur le Parcours

Les observations réalisées lors de l'entrée des animaux dans chacun des parcs permettent de définir de façon précise la ration prélevée (Tableau 1).

Tableau 1. Compositions chimique et botanique de la ration ingérée sur parcours.

	Nov	Déc	Jan	Fev	Mars	Mai	Juin
Composition chimique de l'ingéré (%)							
NDF	46	26	18	25	16	46	54
MAT	11	19	5	5	9	9	7
MAT/NDF	0.24	0.74	0.28	0.22	0.59	0.20	0.13
Quantités ingérées des divers constituants botaniques (g/jour)							
Total	940	630	1150	630	1340	1090	600
Chênes	122	19	95	107	0	185	24
Bruyère	300	0	0	107	0	425	558
Cistes	348	50	23	0	13	0	0
Herbacées	170	498	12	6	429	404	12
Glands	0	63	920	403	898	0	0
Autres	0	0	0	7	0	76	6

Remarque: Les résultats indiqués sont les moyennes des observations effectuées sur les 12 chèvres suivies à une époque donnée.

Les quantités ingérées sur parcours varient dans une large mesure. Cette variation est liée à la combinaison des facteurs : nature des aliments disponibles, état physiologique des chèvres et diversité de l'offre.

L'ingestion élevée de janvier alors que les chèvres sont en fin de gestation correspond à une offre de glands facilement disponible dans les zones débroussaillées, l'absence d'herbe explique sa faible ingestion.

En février, le parc dans lequel se trouvent les chèvres présente une densité de chênes faible (100 arbres/ha) la consommation de glands est réduite en raison d'une offre limitée. En l'absence d'herbe les animaux broutent les repousses ligneuses dans la zone débroussaillée mais l'ingestion totale reste faible.

En mars, les animaux, au pic de lactation et à capacité d'ingestion élevée, pénètrent dans le maquis à la recherche des glands, délaissent les ligneux et complètent leur repas en fin de journée en consommant de l'herbe dont la croissance est forte.

La présence de glands de janvier à mars influe sur la composition qualitative de la ration et déprime la consommation de fourrages ligneux. Lorsque les glands font défaut mais que les animaux ont accès au maquis (novembre et mai), la quantité ingérée est un peu réduite mais la ration est plus variée comprenant des herbacées en relation avec leur disponibilité et des ligneux qui représentent plus de la moitié de la matière sèche ingérée.

La faible ingestion de juin provient de la disparition des aliments autres que les arbustes.

Selon Bourbouze et Donadieu (1987) la régulation de l'ingestion fait appel à trois mécanismes :

- Pour les fourrages dont la digestibilité est supérieure à 0,7, la régulation est de type métabolique ; les quantités ingérées sont alors limitées par les besoins exprimés par les animaux. Ce type de régulation se manifeste de janvier à mars lorsque les glands sont présents et les chèvres sont en début de lactation. De plus indépendamment des variations saisonnières de quantités ingérées les chèvres fortes productrices consomment en moyenne 42% de plus de matière sèche que les plus faibles productrices (Tableau 2).
- Pour les fourrages dont la digestibilité est inférieure à 0,7, la régulation est de type physique puisque l'ingestion est limitée par le volume du rumen. Ceci se confirme avec les résultats obtenus lors des mesures de digestibilité effectuées sur des animaux maintenus en cage. L'ingestion de foin distribué à volonté s'est élevée à 1,680 g de MS/jour, et dans le cas d'une ration mixte distribuée ad libitum foin et bruyère arborescente elle a été respectivement de 837 g de MS/j et 835 g de MS/j.
- Sur parcours, ces deux types de régulation jouent ainsi que d'autres facteurs tels que la rareté de l'offre, la régulation est alors de type comportemental.

Tableau 2. Ingestion comparée de MS entre les chèvres fortes et faibles productrices (kg de MS l/j/chèvre).

Production	>900 litres/an	<700 litres/an
Mars	1.36	0.97
Avril	0.81	0.57
Mai	1.15	1.03
Juin	0.75	0.43

Valeur Nutritive de la Ration Prélevée sur le Maquis

Tableau 3. Cinétique de dégradabilité ruminale de la bruyère arborescente (BA), du chêne-liège (CL) en pourcentage de la MS.

	8 H	24 H	48 H
BA	29 ± 5	36 ± 6	39 ± 5
CL	31 ± 5	37 ± 7	41 ± 8

Grâce à leur capacité de tri les chèvres prélèvent les parties les plus digestibles des végétaux. La dégradabilité des aliments issus d'arbustes est élevée entre 0 et 8h après leur consommation, elle correspond à la disparition de la fraction soluble riche en sucres. Ensuite on observe un ralentissement important de la disparition

de la matière sèche qui indique que les fibres contenues dans ces aliments sont faiblement digestibles.

La digestibilité de la matière sèche de bruyère mesurée *in vivo* est évaluée à 43%.

En moyenne pour le troupeau la contribution du parcours évolue entre 0,53 et 0,93 UFL/jour. L'apport le plus faible correspond aux mois de décembre et janvier, période pendant laquelle les animaux éprouvent des problèmes de déplacement sur parcours en raison de leur gestation avancée. Le maximum correspond au printemps lors de la croissance active de la végétation du maquis.

Sur l'ensemble de l'année le maquis couvre 39% des besoins énergétiques des chèvres.

Conclusion

Dans une zone marginale aux potentialités agronomiques réduites l'utilisation du maquis par des chèvres laitières de bonne productivité représente un avantage technique pour l'éleveur. Sur le plan nutritionnel la couverture d'une part importante des besoins et l'amélioration de la qualité de l'alimentation réduisent la dépendance vis-à-vis des ressources achetées. Cependant la gestion du pâturage et de l'alimentation doivent être raisonnées avec soin afin de prendre en compte la complexité du comportement alimentaire des animaux dans un milieu hétérogène et des interactions digestives des aliments. Le comportement des chèvres est expliqué en partie par l'importance de la ration distribuée avant la sortie des animaux, et par l'observation d'une règle de préférence. Les chèvres qui ne sont pas à jeun sont calmes à l'entrée du pâturage et recherchent en priorité les aliments les plus appréciés qu'elles savent disponibles à chaque époque. La consommation des herbacées suit en général cette phase d'exploration et de recherche.

Les aliments ligneux prélevés sur le maquis et en particulier la bruyère arborescente ne sont pas des apporteurs de fibres mais plutôt de sucres qui stimulent temporairement l'activité microbienne du rumen.

Références

- Bourbouze, A. 1980. Utilisation d'un parcours forestier pâture par des caprins. *Fourrages* 82: 121-144.
- Bourbouze, A. et R. Donadieu 1987. L'élevage sur parcours en région méditerranéenne. *Option Méditerranéenne*, CIHEAM/IAM Montpellier.
- Demarquilly, C. et M. Chenost. 1969. Étude de la digestion des fourrages dans le rumen par la méthode des sachets de nylon. *Annales de Zootechnie* 18: 419-436.
- Goering, H.K. et P.J. Van Soest. 1970. Forage Fiber Analysis. USDA Agric. Res. Serv. Handbook 379.
- Jarrige, R. (ed.). 1988. Alimentation des Bovins, Ovins et Caprins. INRA, Paris.

Browse Foliage as a Supplement to Wheat Straw for Sheep

A. Chriyaa and B. Boulanouar

Aridoculture Center, INRA, Settat, Morocco

Abstract

Cereal stubble and straw are widely used as animal feed for sheep in the arid areas of Morocco. Their low protein concentration limits their intake and therefore their production potential. A 15-week feeding trial was conducted to investigate the effect of supplementation with browse foliage on wheat (*Triticum aestivum* L.) straw intake, and ewe lamb liveweight. Diets were wheat straw, wheat straw plus alfalfa (*Medicago sativa* L.) hay, wheat straw plus oldman saltbush (*Atriplex nummularia* Lindl.) foliage, and wheat straw plus blue wattle (*Acacia cyanophylla* Lindl.) foliage. Alfalfa and urea levels were set to provide a crude protein (CP) concentration of 90 g DM/kg in the diet. Shrub foliage was offered *ad libitum*. *Atriplex* and *Acacia* foliage supplementation resulted in the highest and lowest straw intake increases, respectively. These findings help to explain why animals receiving *Atriplex* foliage in addition to wheat straw were the only ones to maintain weight over the 15 weeks. These results show that foliage from palatable shrubs can be an effective protein supplement for livestock consuming wheat straw. Implementing such strategies requires farmers to plant oldman saltbush (*Atriplex nummularia* Lindl.) shrubs on their land.

Key words: straw, shrub, *Atriplex*, *Acacia*, supplementation, sheep.

Introduction

In Morocco, there are approximately 8 million hectares of arable land, half of which is used for cultivation of cereals. About 25% of the arable land is left fallow or uncultivated and used for grazing every year. Rangelands occupy about 20% of the 71 million hectares of land in Morocco.

Wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) are the major cereal crops grown in the rainfed farming regions. In these areas, sheep are an important component of the mixed crop/livestock system. Of the 16.3 million head (MAMVA 1994), 70% are found in rainfed cereal-producing zones, with half in the arid and semi-arid areas (>400 mm rain/year). Following harvest in May/June, sheep graze on cereal stubble until the start of the rainy season in October or November. This usually coincides with the gestation period of ewes. During late gestation and until the start of the grazing season, cereal straw is the major component of the diet. Low birth weight, high lamb mortality, and slow lamb

growth are very common during this time (Ismaili 1983; Bouhafrà 1987; Guessous et al. 1987; Guessous et al. 1991; Outmani et al. 1991). Low animal performance in these areas is mainly due to protein and energy deficiencies of available forages.

Forage shrubs such as oldman saltbush (*Atriplex nummularia* Lindl.) and blue wattle (*Acacia cyanophylla* Lindl.) have been shown to be adapted and ecologically appropriate to arid and semi-arid areas (Arif 1992). The foliage of these fast-growing browse species has a similar composition to herbaceous legumes and can be expected to have a similar supplementary role. Throughout Morocco, more than 30,000 ha of communal rangeland have been planted to oldman saltbush. What makes this shrub especially interesting is its ability to be used in autumn and winter, when other forage resources are scarce or of low quality. Several grazing studies conducted in Morocco have shown that the introduction of oldman saltbush shrubs, compared to unimproved range as a means of range improvement, increases liveweight gain (LWG) of sheep and goats (ORMVAT 1991; ORMVASM 1992). One confined feeding study with oldman saltbush, as a supplement for sheep in Morocco, demonstrated that it was palatable and resulted in substantial improvements in LWG (ORMVAT 1991). The nutritive value of *Atriplex* and *Acacia* foliage has been investigated mainly as a sole diet (Bhattacharya 1989; Wilson 1977). Relatively few studies to evaluate shrub foliage as a supplement for low quality roughage have been carried out (Boutouba et al. 1990; Arthun et al. 1992).

The objectives of this study were to: (i) compare the supplemental feeding value of oldman saltbush and blue wattle foliage for sheep receiving wheat straw as a sole diet; and (ii) study the effect of different sources of supplemental N on the performance of ewe lambs receiving wheat straw as a basal diet.

Materials and Methods

Thirty Timahdite ewe lambs, weighing 30–36 kg at the start of the experiment, were used in the trial. All lambs received an A-D₃-E vitamin drench every four weeks during the trial. The treatments were: (i) wheat straw alone, later supplemented with urea and sodium sulfate at 1.35 and 0.13% dry matter, respectively; (ii) wheat straw supplemented with saltbush foliage; (iii) wheat straw supplemented with blue wattle foliage; and (iv) wheat straw supplemented with alfalfa hay. Six replicates were used according to a randomized complete block design. The blocking criterion was the liveweight of the animals. Wheat straw and alfalfa hay were milled in a large-capacity mill with a coarse (38 mm) screen. The saltbush and blue wattle foliage was harvested weekly from two- and three-year-old plantations, respectively. Only leaves and tender twigs were fed to the animals. Alfalfa hay and urea were fed at various levels to provide 90 g CP/kg DM in the diet. Straw and the other supplements were fed *ad libitum*. Straw was fed at 08:00

hours and supplements around 17:00 hours. Animals had free access to water. Refusals were weighed in the morning, and air-dry matter intake calculated. The straw and supplements were sampled each day and composited weekly. A sample was then taken to represent the forage fed during the previous week. All samples were dried at 55°C for 48 hours, ground in a Wiley mill to pass a 1 mm screen, and stored. Sheep were weighed every 15 days in the morning for two successive days after an overnight shrink. Forage samples were analyzed for DM, ash, CP, acid detergent insoluble nitrogen (ADIN) (AOAC 1984), neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) (Robertson and Van Soest 1981). The IVDMD was determined by the Tilley and Terry assay (1963). Tannin concentration was assessed according to Burns (1963). Variables collected (i.e., animal weight and dry matter intake) were analyzed using the repeated measures technique (SAS 1988). Chemical composition and IVDMD were analyzed following a random design assuming no forage/week interaction. Significant differences were examined with the LSD test (Steel and Torrie 1980).

Results and Discussion

Chemical Composition and IVDMD

Average chemical composition and IVDMD of the different forages used in this feeding trial are summarized in Table 1.

Based on the CP concentration and IVDMD, three groups of forages were identified. Alfalfa hay and saltbush foliage had the highest values, blue wattle foliage was intermediate, and wheat straw had the lowest values. The 52 g/kg DM CP concentration of wheat straw was lower than the 69 g/kg DM threshold required for adequate rumen microbial activity (ARC 1980). Saltbush foliage had the highest ash concentration (308 g/kg DM). NDF concentration was the lowest in saltbush and blue wattle foliage. ADL concentration varied among forages. Blue wattle foliage had the highest concentration, with 132 g/kg DM. Alfalfa hay was intermediate (92 g/kg DM), and *Atriplex* foliage and wheat straw were the lowest with 80 and 69 g/kg DM, respectively.

The proportion of total N, which was tightly bound to the ADF fraction (ADIN) and thus made unavailable for the microorganisms in the alimentary tract, varied from 3.5% for alfalfa hay to 11.54% for blue wattle foliage. This N fraction, except for alfalfa hay, seemed to be more related to the ADL than the ADF concentration. Alfalfa hay and saltbush foliage were more efficient sources of N for rumen microbes.

Table 1. Chemical composition and *in vitro* digestibility (g/kg DM) of forages used to supplement wheat straw in sheep feeding.

	Forage				SEM
	Wheat straw	Alfalfa hay	Oldman saltbush	Blue wattle	
CP [†]	52 ^c	136 ^a	137 ^a	109 ^b	3.9
Ash	85 ^e	106 ^d	308 ^a	129 ^c	9.7
NDF	703 ^a	466 ^c	348 ^d	342 ^d	16.7
ADF	421 ^a	307 ^b	152 ^d	209 ^c	13.4
ADL	69 ^c	92 ^b	80 ^c	132 ^a	3.4
IVDMD	447 ^c	586 ^a	622 ^a	488 ^b	9.5
Tannins	-	0.13 ^b	0.07 ^b	11.20 ^a	0.3
Total N (DM %)	0.83 ^c	2.18 ^a	2.19 ^a	1.74 ^b	0.04
ADIN [§] (N %)	9.99 ^b	3.52 ^d	7.30 ^c	11.54 ^b	0.78

[†] Crude protein; neutral detergent fiber; acid detergent fiber; acid detergent (lignin); *in vitro* dry matter disappearance.

[§] ADIN = acid detergent insoluble nitrogen.

^{a,d,c,d,e} Means within rows followed by different symbols are different ($P < 0.05$).

Wheat Straw and Supplement Intake

Total (Table 2) and straw (Table 3) intakes varied significantly over time for all treatments. There were also significant differences among supplements.

Table 2. Daily dry matter intake ($\text{g kg}^{-0.75}$) of ewe lambs fed wheat straw alone or with an N supplement.

Supplement	Dry matter intake		
	October	November	January
Wheat straw	38.3 ^b	40.0 ^{b,f}	47.7 ^{a,f}
Alfalfa hay	43.4 ^b	50.0 ^{a,e}	53.5 ^{a,ef}
Oldman saltbush foliage	41.2 ^c	59.0 ^{b,d}	64.3 ^{a,d}
Blue wattle foliage	42.9 ^b	44.9 ^{b,ef}	48.5 ^{a,f}
SEM	0.83	1.50	1.60

^{a,b,c} Means within rows followed by different symbols are different ($P < 0.05$).

^{d,e,f} Means within columns followed by different letters are different ($P < 0.05$).

Throughout the trial, total and straw intakes ($\text{g kg}^{-0.75}$ LW/d) increased for all treatments. The increase in total intake during the first seven weeks was the fastest for the saltbush foliage treatment, followed by the alfalfa hay. Straw and blue wattle treatments did not result in a total intake increase over the same period. The proportion of straw in this increase was highest for the treatment with saltbush, followed by those treatments supplemented with alfalfa and blue wattle. Digestible dry matter intake for the unsupplemented wheat straw treatment averaged $17.5 \text{ g kg}^{-0.75}$ LW (Table 4).

Table 3. Daily straw dry matter intake ($\text{g kg}^{-0.75}$) of ewe lambs fed wheat straw alone or with an N supplement and percentage of straw in diet.

Supplement	Straw dry matter intake					
	October		November		January	
	Straw	% Tot [†]	Straw	% Tot	Straw	% Tot
Wheat straw	38.3 ^{b,d}	100.0	40.0 ^{b,d}	100.0	47.7 ^{a,d}	99.0
Alfalfa hay	28.1 ^{b,e}	64.7	31.8 ^{b,f}	63.6	36.1 ^{a,f}	67.5
Saltbush foliage	30.6 ^{c,e}	74.3	36.5 ^{b,e}	61.9	43.5 ^{a,e}	67.6
Blue wattle foliage	29.9 ^{c,e}	69.7	33.2 ^{b,ef}	73.9	35.5 ^{a,f}	73.2
SEM	0.88	-	0.94	-	1.30	-

[†] % Total intake.^{a,b,c} Means within rows followed by different symbols are different ($P < 0.05$).^{d,e,f} Means within columns followed by different symbols are different ($P < 0.05$).**Table 4.** Digestible dry matter intake ($\text{g kg}^{-0.75}$) of ewe lambs fed with straw alone or with an N supplement.

Supplement	Digestible dry matter intake		
	October	November	January
Wheat straw	17.1 ^{b,e}	17.9 ^{b,g}	20.9 ^{a,f}
Alfalfa hay	21.5 ^{b,d}	24.8 ^{a,e}	26.3 ^{a,e}
Oldman saltbush foliage	20.3 ^{b,d}	30.3 ^{a,d}	32.3 ^{a,d}
Blue wattle foliage	19.7 ^{b,de}	20.5 ^{b,fg}	22.2 ^{a,f}
SEM	0.45	0.89	0.90

^{a,b,c} Means within rows followed by different symbols are different ($P < 0.05$).^{d,e,f,g} Means within columns followed by different symbols are different ($P < 0.05$).

This result is similar to that reported by Capper et al. (1986), but in other trials, higher values were reported (ICARDA 1986). However, Dryden and Kempton (1983) found that Border Leicester wethers offered barley straw consumed only $8.8 \text{ g DM kg}^{-0.75}$ per day. Such differences in straw intake could be due to the effect of species, variety, growing conditions, or harvesting method (Capper et al. 1985). Alternatively, different breeds of sheep may have different capacities for using poor-quality diets. During the last seven weeks of the trial, total intake increased for all supplements except alfalfa. The highest increase occurred with the urea supplement. Saltbush ranked second. Straw intake increased for all supplements during the same period. The highest increase occurred for the urea-supplemented straw treatment, followed very closely by the saltbush treatment.

Over the whole trial, the highest increase in total intake was recorded for the treatment in which wheat straw was supplemented with saltbush foliage. Straw represented about 55% of that increase. Saltbush foliage was not only well consumed, but it also increased the amount of wheat straw consumed from 420 to about 600 g DM, an average increase of 635 g DM of wheat straw intake for each kilogram of saltbush dry matter consumed. The most likely reason for the increased intake was that it corrected the protein deficiency of the straw. The CP

concentration of the total diet was increased from 52 to 74 g/kg DM. Goodchild et al. (1992) report similar results in a study where barley straw was supplemented with *Atriplex halimus* L. foliage (150 g CP/kg DM). For each kilogram of saltbush dry matter fed, voluntary barley straw intake increased 340–630 g DM.

The blue wattle supplement ranked last in terms of increasing total intake over the whole period of the trial. This increase was, however, represented by straw, indicating that blue wattle foliage was not very palatable to the animals. The reason could be the existence of anti-nutritional factors, such as condensed tannins in the foliage (Table 1). Working with the same species, Reed et al. (1990) report a negative effect of tannins on feed intake and N digestibility.

As with all pen-feeding work, the relevance of previous intake and digestibility records to results found in the field may be questioned because of the selectivity of the grazing sheep, but it may be assumed that in no circumstances would they be lower than those recorded. The effect of the supplements on straw intake can be explained by the increased rate of digestion of the basal diet following enhanced microbial activity (Cheeson and Orskov 1984).

Animal Performance

Animals receiving all supplements lost weight during the first seven weeks of the trial (Table 5).

Table 5. Periodic liveweight gain (kg) and average daily gains (g/d) of ewe lambs fed wheat straw with an N supplement.

Period	Supplement				SEM
	WS	AH	SB	BW	
Periodic LW gain					
0–7 wk	-4.65 ^c	-1.81 ^a	-1.75 ^a	-3.23 ^b	0.46
7–14 wk	-0.65 ^b	0.27 ^b	2.00 ^a	-1.82 ^c	0.36
0–14 wk	-5.29 ^c	-1.54 ^b	0.25 ^a	-5.04 ^c	0.49
Average daily gain					
0–7 wk	-132.7 ^c	-51.8 ^a	-50.0 ^a	-92.3 ^b	13.0
7–14 wk	-18.5 ^c	7.7 ^b	57.1 ^a	-51.8 ^d	10.4
0–14 wk	-75.6 ^c	-22.0 ^b	3.6 ^a	-72.0 ^c	7.1
Total weight change (%)	-15.9 ^c	-4.6 ^b	0.8 ^a	-15.6 ^c	1.4

WS = wheat straw; AH = alfalfa hay; SB = oldman saltbush fol.; BW = blue wattle fol.

^{a,b,c,d} Means within rows followed by different symbols are different ($P < 0.05$).

During the following seven weeks, only the animals that received saltbush foliage as a supplement regained weight. Except for the blue wattle treatment, the two remaining treatments reduced liveweight losses relative to the control. Animals that received saltbush foliage as a supplement were the only ones that gained weight over the whole period of the trial (Table 5). These results are in accordance

with those reported by Wilson (1966). Blue wattle supplementation resulted in the largest weight loss, amounting to about 50 g/day. Dumancic and Le Houérou (1980) and Le Houérou (1987), however, fed blue wattle foliage as a supplement to penned and grazing sheep for 79 and 238 days, respectively. They concluded that this was enough to meet maintenance energy needs, but not production requirements. Blue wattle foliage consumption in their trials was enough, however, to meet the protein requirements of maintenance and production. Most of the liveweight decrease occurred in the first half of the trial, perhaps due to the reduced intake of straw and supplements during the same period. Digestible DMI (Table 4), after a three-week adaptation period, averaged 17.1 and 20.4 g kg^{-0.75} LW/d for the wheat straw treatment and the other treatments, respectively. The highest liveweight loss was observed for the unsupplemented wheat straw and wheat straw supplemented with blue wattle foliage (Table 5). Urea and S supplementation of wheat straw stopped the liveweight loss and maintained it for the remaining period of the trial. Daily decrease of liveweight dropped from 75 before to 33 g/day during urea and S supplementation. Hadjipanyiotou et al. (1975) report similar liveweight losses (80–90 g/day) of sheep offered only chopped or long straw and a mineral supplement for 91 days.

The estimated net energy intake of sheep offered straw alone (380 Kcal) was about half the amount needed (771 Kcal) to cover maintenance requirements (NRC 1985). Therefore, it is not surprising that they lost weight. However, although losses were large at first, they were small during the last seven weeks of the trial, which coincided with urea and S supplementation. This suggests that the sheep were approaching energy balance. If this was the case, then their maintenance requirements may have been substantially lower than estimated from the published data. Lower maintenance requirements in the Timahdite breed would save feed during periods of scarcity, which occur frequently in semi-arid areas. Similar net energy intake and liveweight loss were reported for Awassi sheep offered unsupplemented barley straw over a period of 122 days (ICARDA 1985). The liveweight losses of sheep receiving supplements other than saltbush foliage indicated that their nutrient intakes were below the maintenance level.

Implications

Saltbush foliage was shown to be effective in maintaining the liveweight of ewe lambs receiving wheat straw as a basal diet, which is very common in the arid and semi-arid areas of Morocco during autumn and early winter. To benefit from these results, farmers should reserve some of their land to plant oldman saltbush shrubs. This could be land of low agricultural potential, usually left uncultivated. Use of an alley-cropping system could also be adopted on land usually cropped to barley. Another technique is to plant shrubs as windbreaks to spare the land for other

crops and help protect the soil from wind erosion. The government could provide farmers with shrub plants and advise them on how to manage the plantations.

References

- AOAC. 1984. Official methods of analysis (14th ed.). Assoc. Official Analy. Chemists, Washington, DC.
- ARC (Agricultural Research Council). 1980. The Nutrient Requirements of Ruminant Livestock. Commonw. Agric. Bur. Slough, UK.
- Arif, A. 1992. Essais d'adaptation de différentes espèces d'arbustes fourragers. Rapport annuel du CRRA, INRA, Settat, Maroc.
- Arthun, D., J.L. Holecheck, J.D. Wallace, M.L. Galyean, M. Cardenas and S. Rafique. 1992. Forb and shrub influences on steer nitrogen retention. *Journal of Range Management* 45: 133-136.
- Bhattacharya, A.N. 1989. Nutrient utilization of *Acacia*, *Haloxylon*, and *Atriplex* species by Najdi sheep. *Journal of Range Management* 42: 28-31.
- Bouhafra, L. 1987. Contribution à la caractérisation de l'organisation des productions ovines en relation avec le bovin laitier dans le périmètre irrigué de Tadla. Mémoire de 3ème cycle Agron. Hassan II Inst. Agron. Veter. Rabat, Morocco.
- Boutouba, A., J.L. Holecheck, M.L. Galyean, G. Nunez-Hernandez, J.D. Wallace and M. Cardenas. 1990. Influence of two native shrubs on goat nitrogen status. *Journal of Range Management* 43: 530-534.
- Burns, R.E. 1963. Methods of tannin analysis for forage crop evaluation. Georgia Agric. Exp. Stn. Tech. Bull. No. 32: 1-14.
- Capper, B.S., S. Rihawi, M. Mekni and E.F. Thomson. 1985. Factors affecting the nutritive value of barley straw for Awassi sheep. Pages 842-844 in Proceedings of the 3rd. Animal Science Cong. Asia-Australasian Anim. Prod. Soc., Seoul, Korea.
- Capper, B.S., E.F. Thomson, S. Rihawi, A. Termanini and R. McCrae. 1986. The feeding value of straw from different genotypes of barley when given to Awassi sheep. *Animal Production* 42: 337-342.
- Cheeson, A. and E.R. Orskov. 1984. Microbial digestion in the digestive tract. Pages 305-339 in Straw and other Fibrous By-products as Feed (F. Sundstol and E. Owen, eds.). Elsevier Sci. Publ. Comp., Amsterdam/Oxford/New York.
- Dryden, G.M. and T.J. Kempton. 1983. Digestion of organic matter and nitrogen in ammoniated barley straw. *Animal Feed Science Technology* 10: 65-75.
- Dumancic, D. and H.N. Le Houérou. 1980. *Acacia cyanophylla* Lindl. as supplementary feed for small stock in Libya. Pages 321-325 in Browse in Africa: The Current State of Knowledge (H.N. Le Houérou, ed.). International Livestock Centre for Africa, Addis Ababa, Ethiopia.
- Goodchild, A., T. Treacher, S. Rihawi and A. Termanini. 1992. Review of recent work at ICARDA on the quality of feeds and supplementation strategies. Workshop on Increased Productivity of Barley, Pasture and Sheep under areas with 200-350 mm rainfall. Amman, Jordan, 13-15 Dec 1992.
- Guessous, F., J.M. Luginbuhl, N. Rihani and K.R. Pond. 1991. Influence of supplementation on the performance of gestating ewes grazing wheat stubble pastures. *Animal Feed Science Technology* 35: 95-103.
- Guessous, F., A. Outmani, E. Dahbi, J.E. Garrett and W.L. Johnson. 1987. Utilization of

- wheat stubble by sheep: effect of protein supplementation on intake, diet composition and animal weight. 38th Ann. Meeting of the European Associ. Ani. Prod., Lisbon, Portugal.
- Hadjipanayiotou, M., A. Louca and M.J. Lawlor. 1975. A note on the straw intake of sheep given supplements of urea-molasses, soybean meal, barley-urea and barley. *Animal Production* 20: 429–432.
- ICARDA (International Center for Agricultural Research in the Dry Areas). 1986. Annual Report for 1985. Aleppo, Syria.
- ICARDA (International Center for Agricultural Research in the Dry Areas). 1985. Annual Report for 1984. Aleppo, Syria.
- Ismaili, D. 1983. Caractérisation de l'élevage ovin dans une zone bour de Tadla (commune de Beni Oukil). Mémoire de 3ème cycle Agro. Hassan II Inst. Agro. Vet. Rabat, Morocco.
- Le Houérou, H.N. 1987. Consommation volontaire de ligneux fourragers et performances animales chez le mouton Barbarin. Cinquième Réunion du Sous-Réseau FAO des herbages Méditerranéens, Montpellier, France, 13–17 Oct.
- MAMVA (Ministère de l'Agriculture et de la Mise en Valeur Agricole). 1994. Secteur de l'élevage en chiffres. Direction de l'élevage. Rabat, Maroc.
- Milford, R. and D.J. Minson. 1965. Intake of tropical forage species. *Proceedings of the International Grasslands Congress* 9: 815–822.
- NRC (National Research Council). 1985. Nutrient Requirements of Domestic Animals, Nutrient Requirements of Sheep (6th ed.). National Academy Press, Washington, DC.
- ORMVASM (Office Regional de Mise en Valeur Agricole de Sous Massa). 1992. Essai d'exploitation d'un parcours amélioré. Communication présentée lors des journées d'étude sur les arbustes fourragers organisées à Oujda, Morocco, 28–29 May.
- ORMVAT (Office Regional de Mise en Valeur Agricole de Tafilalet). 1991. *Atriplex nummularia*: production et utilisation dans l'alimentation des ovins. Rapport d'Activités.
- Outmani, A., J.M. Luginbuhl, F. Guessous and W.L. Johnson. 1991. Utilization of wheat stubble pastures by gestating ewes. *Small Ruminant Research* 4: 257–267.
- Reed, J.D., H. Soller and A. Woodward. 1990. Fodder tree and straw diets for sheep: Intake, growth, digestibility and the effects of phenolics on nitrogen utilization. *Animal Feed Science Technology* 30: 39–50.
- Robertson, J.B. and P.J. Van Soest. 1981. Analysis of fiber by the detergent system. In *The Analysis of Dietary Fiber* (W.P.T. James and O. Theander, eds.). Marcel Decker, NY.
- SAS. 1988. SAS User's Guide: Statistics. SAS Institute., Inc., Cary, NC.
- Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. McGraw Hill, New York.
- Thomson, E.F. and F.A. Bahhady. 1988. A note on the effect of liveweight at mating on the fertility of Awassi ewes in semi-arid north-west Syria. *Animal Production* 47: 505–508.
- Tilley, R.A. and J.M. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. *Journal of British Grasslands Society* 18: 104–111.
- Wilson, A.D. 1977. The digestibility and voluntary intake of the leaves of trees and shrubs by sheep and goats. *Australian Journal of Agricultural Research* 28: 501–508.

Chemical Composition and *In Vitro* Digestibility of Browse Plants in a Semi-arid Region of Spain

F. Muñoz, J.D. Andueza, I. Delgado and M.J. Ochoa

Servicio de Investigación Agroalimentaria, DGA, Zaragoza, Spain

Introduction

Animal management is one of the best ways to develop many marginal Spanish areas (Boza 1993), especially those that have been abandoned or affected by desertification. Yields are low on many of these areas due to low and irregular rainfall, poor soils, and uneven topography. All this limits the vegetation cover. Consequently, the flora has adapted to the environmental conditions, retaining characters for dry or cold seasons as well as developing those which make it resistant to disease and other environmental factors. This affects flora development and its feeding value (Van Soest 1994; Ibrahim 1981).

Shrubs are the only feed in the dry season in arid regions (Le Houérou 1989). They furnish a protein complement to the dry forage of grass plants. Sometimes, the recovery of an area includes the introduction of exotic species (Correal et al. 1986), but the natural flora is always the best resource for the long term (Montserrat 1985), given that many of these plants are high yielding.

The areas in Aragón included in this study experience long dry periods throughout the year, as well as great variability between years. This influences the vegetative activity of the plants available as forage. Stubbles and straws from cereal crops, which have low yields that vary greatly between years, are fed to the flocks. Other forage resources should be encouraged as an alternative to cereal by-products to optimize animal yields and avoid desertification, erosion, and land abandonment (Correal et al. 1992). The Monegros region in Aragón has salty soils which determine, in an important way, the existing vegetation (Ochoa 1982). In order to use it as a forage resource, it is necessary to know its feeding value throughout the year, the amount available as feed, and the most suitable methods of exploitation.

This work studies the chemical composition and *in vitro* digestibility of shrubs with forage potential throughout the year.

Material and Methods

An inventory of the existing vegetation in the area of Monegros, Aragón, was carried out. From the results of this inventory, carried out on 5 × 5 km plots at 96 locations, and from data obtained from farmers of the area, the dominant species with high forage interest were selected: *Thymus vulgaris* L., *Rosmarinus*

officinalis L., *Artemisa herba-alba* L., *Salsola vermiculata* L., *Retama sphaerocarpa* L., *Genista scorpius* L., and *Atriplex halimus* L.

Samples of the browse parts of these species were collected. Four out of the 96 locations were sampled as representative of area characteristics, and samples of the browse parts of the species were taken in the four seasons of the year.

Chemical Analysis

Samples were analyzed for dry matter (DM), ash, and protein (CP) using conventional methods (AOAC 1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin (ADL) were prepared using standard procedures (Goering and Van Soest 1970). *In vitro* dry matter digestibility (IVDMD) was analyzed according to the technique of Tilley and Terry (1963).

Data were submitted to variance analysis, and a comparison of means was made by Duncan's test using the SAS package (1987)

Results and Discussion

Table 1 shows the chemical composition of shrubs in spring, summer, autumn, and winter. Results show that there were no significant effects among the values found in the five sampled locations. Some factors, such as soil characteristics and climate, which could affect directly the chemical composition of the shrubs (Van Soest 1996), are similar.

The chemical composition of each species was significantly different among samples (Table 2), due to differences in the vegetative state of the species (intraspecies and interspecies) during the year, as can be deduced from the dry matter values (Table 1). According to Ibrahim (1981), shrub nitrogen content changes with environmental factors, type of tissue, age, development, and season. Most of the N in the leaves goes to the stems in the autumn when the leaves fall. The changes in N in the forage depend on the N and on sulfur available in the soil. However, the composition and the scarce organic material available in the soils where these shrubs usually grow indicate that some of them can synthesize N compounds independently from N concentration in the soil. According to Benjamin (1986), the level of N synthesis in *A. halimus* depends mainly on the age and the salt concentration in the plant.

In this study, *G. scorpius* and *A. halimus* had maximum N content in spring (Table 1). For the first species, this was because its browse part was made up of young shoots with low dry matter content in this season. The change in *A. halimus* is related to N increase in the leaves, produced by the formation of a compound of

quaternary ammonia, glycinebetaine, which counteracts the high osmotic pressure produced by salt accumulation (Yaron et al. 1985).

The chemical composition of these species during the different seasons has not been widely studied. Studying *R. officinalis* and *R. sphaerocarpha*, Robles et al. (1993) found similar results in samples taken in spring to those obtained in the present study. Molina et al. (1993), in a study on the use of *R. officinalis* in animal production, indicated that this plant has an anti-nutritional factor that affects its potential nutritive value.

The high N content in *S. vermiculata* and *A. herba-alba* is outstanding, but with only small differences between the seasons. *Thymus officinalis* had the lowest protein content of all the shrubs, with only slight variations throughout the year. Moreno Rios et al. (1981) found lower N content (5.4%) in samples of this species taken in autumn and winter than those obtained in this work.

Table 1. Chemical composition (DM%) and *in vitro* dry matter digestibility (IVDMD) of the browsing fraction for shrubs in spring, summer, autumn, and winter.

Shrub	Season	DM	Ash	CP	NDF	ADF	ADL	IVDMD
<i>Thymus vulgaris</i>	1	46.13	8.60	8.89	46.22	31.57	14.38	41.37
	2	78.39	9.00	8.02	45.92	33.60	14.29	42.19
	3	40.75	11.97	10.35	55.89	38.57	17.83	40.57
	4	45.37	7.75	9.60	49.12	35.80	16.42	46.75
<i>Rosmarinus officinalis</i>	1	46.09	6.85	7.13	43.70	30.60	18.17	36.68
	2	63.11	6.53	6.30	42.31	31.40	18.89	40.53
	3	43.26	6.22	8.85	49.26	33.42	19.73	34.56
	4	45.85	6.87	9.38	38.30	27.87	17.19	44.66
<i>Artemisia herba-alba</i>	1	46.72	8.93	16.96	43.79	28.63	12.16	52.83
	2	67.34	7.75	12.34	47.04	32.92	15.16	43.36
	3	36.63	11.49	18.86	50.03	32.05	15.15	47.49
	4	39.30	10.34	21.29	38.24	25.31	11.21	56.77
<i>Salsola vermiculata</i>	1	33.34	18.93	19.00	49.24	18.64	6.42	68.51
	2	39.74	17.17	16.71	45.04	19.02	6.36	62.54
	3	42.09	17.58	15.06	57.63	25.66	9.91	57.40
	4	38.23	17.26	18.83	50.25	17.97	7.16	67.57
<i>Retama sphaerocarpha</i>	1	45.18	4.10	14.71	49.06	33.23	11.87	66.53
	2	43.75	3.93	16.27	51.44	38.27	12.47	63.80
	3	46.45	3.42	13.78	56.88	42.22	13.45	63.34
	4	50.62	3.44	15.16	52.56	38.50	12.59	63.02
<i>Genista scorpius</i>	1	48.20	3.64	13.09	58.50	37.71	13.48	56.40
	2	67.73	2.68	8.00	74.85	54.59	17.96	36.35
	3	70.70	2.28	7.97	77.87	55.39	21.12	29.42
	4	71.40	2.17	7.65	76.53	55.50	22.01	26.24
<i>Atriplex halimus</i>	1	24.40	26.00	20.11	41.05	21.30	12.29	72.69
	2	25.70	26.15	18.36	42.73	23.71	11.32	61.89
	3	34.30	17.67	15.98	53.74	29.25	14.74	53.69
	4	38.15	12.26	13.41	66.28	41.40	14.68	40.46

1 = spring; 2 = summer; 3 = autumn; 4 = winter.

The low energy content of these plants prohibits the correct use of their high N content. The N balance is negative when such shrubs are the only feed source (Muñoz et al. 1996), and supplementation is needed (Valderrabano et al. 1996). The NDF, ADF, and ADL of the browse part show, as with protein, no significant differences among the four locations where samples were taken. However, all of them changed significantly ($P < 0.001$) according to season (Table 2). Nefzaoui et al. (1991) also found changes of the chemical composition of shrubs grown in Tunisia throughout the year.

The average content in the cell wall of the browse part is mainly dependent on the phenology and recovery state of the plant (Lailhacar 1990), and on environmental characteristics. Consequently, in the months when plants are latent, there is a predominance of stems, resulting in the highest content of cell tissue and lignin and the lowest difference among seasons (Table 2). *Thymus vulgaris* L., *Rosmarinus officinalis* L., and *Genista scorpius* L. showed a higher lignin content with only slight variations among seasons. *Retama sphaerocarpa* stands out because of its low percentage of lignin and high fiber content. Lignin content is related in all cases with digestibility. Hence, *R. sphaerocarpa*, *S. vermiculata*, and *Artemisa herba-alba* had the lowest lignin content and the highest digestibility. According to Van Soest (1996), there is a narrow relationship between light and temperature. Light favors the formation of carbohydrates, while temperature induces their use and the formation of other compounds such as lignin.

Table 2. Significance of the effect of species, season, and place on some parameters.

	MO	CP	NDF	ADF	ADL	DSS in vitro
Species	*** 7a 4b 3c 1c 2d	*** 4a 7a 3a 5b 1c 6c 6a 7b 5b 4bc 1c 3d 6a 5b 1c 2d 7d 3d	*** 6a 5b 1c 2d 7d 3d	*** 6a 2a 1b 7c 3c 5c	*** 5a 4a 7b 3c 1d	*** 5a 4a 7b 3c 1d
Season	*** 5f 6f	*** 2d	*** 2d	*** 4f	*** 4d	*** 2d 6f
Place	2a 3a 1a 4b	1a 4ab 3bc 2c	3a 4b 1c 2c	3a 4b 2c 1d	3a 4b 2c 1c	1a 2b 4bc 3c
Species*season	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Place*season	n.s.	n.s.	n.s.	n.s.	*	**
Species*place	n.s.	n.s.	n.s.	n.s.	**	n.s.

Species: 1 = *Thymus*, 2 = *Rosmarinus*, 3 = *Artemisia*, 4 = *Salsola*, 5 = *Retama*, 6 = *Genista*, 7 = *Atriplex*.

Season: 1 = spring, 2 = summer, 3 = autumn, 4 = winter.

Place: 1 = Vedado, 2 = Sariñena, 3 = Peñalba, 4 = Monegrillo.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. a≠b≠c≠d≠f≠P. <0.05.

The apparent digestibility of dry matter by *in vitro* methods did not reproduce the absorption and excretion of salt in the digestive track (Benjamin 1992). Therefore, when plants such as *Atriplex halimus* and *Salsola vermiculata* are at their maximum salt concentration, their dry matter digestibility is higher due to the high solubility of the salt.

Conclusions

Chemical composition of the shrubs varied. It was affected by factors such as season of exploitation.

The *in vitro* and *in situ* methods to assess dry matter digestibility applied to shrub species can only be considered indicative. Consequently, and given the interest of these plants in dry and semi-dry areas, more *in vivo* studies should be carried out using animals.

References

- AOAC. 1990. Official Methods of Analysis (15th ed.). Association of Official Analytical Chemistry. Arlington, USA.
- Boza, J., 1993. Uso ganadero de las zonas áridas del suroeste ibérico. Seminario sobre desertificación y la utilización del suelo en la cuenca Mediterránea. Almería, España.
- Benjamin, R.W. and E. Oren. 1986. Apparent Digestibility of *Atriplex barclayana* and the Nitrogen Balance of Sheep Consuming this Shrub. Progress Report. No. BGUN-ARI-41-87. The Institutes for Applied Research. University of the Negev, Beer-Sheva, Israel.
- Benjamin, R.W. 1992. The apparent digestibility of *Atriplex barclayana* and its effect on nitrogen balance in sheep. *Animal Production* 54: 175–181.
- Correal, E., J.H. Silva, J. Boza y C. Passera. 1986. Valor nutritivo de cuatro arbustos forrajeros del genero *Atriplex*. *Pastos* 16(1-2): 177–189.
- Correal, E., A. Robledo y S. Rios. 1992. Recursos forrajeros herbáceos y leñosos de zonas áridas y semiáridas. 43rd Annual Meeting of the EAAP. Madrid. Spain.
- Goering, H.K. and P.J. Van Soest. 1970. Forage fiber analysis. USDA, ARS Agric. Handbook No. 379.
- Ibrahim, K.M. 1981. Shrubs for fodder production. Pages 601–642 in *Advances in Food-Producing Systems for Arid and Semiarid Lands* (J.T. Manassah and E.J. Briskey, eds.). Academic Press. London.
- Lailhacar, S. 1990. Efecto del corte en la producción y en la calidad del forraje de *Atriplex nummularia* L. *Simiente* 60(3): 208–209.
- Le Houérou, H.N. 1989. An assessment of the economic feasibility of fodder shrubs plantation (with particular reference to Africa). Pages 604–631 in *The Biology and Utilization of shrubs* (M. McKell, ed.). Academic Press, NY.
- Molina, E., M.R. Weisbjerg and T. Hvelplund. 1993. Carbohydrates fermentation from shrubs: Effect of supplementation with urea or sunflower cake. 44th Annual Meeting of the EAAP. Aarhus. Denmark.
- Montserrat, P. 1985. Dactilos y alfalfas en la prateria española. Aspectos ecológicos relacionados con su variabilidad y selección. *Pastos* 15(1-2): 1–7.
- Moreno Rios, R., E. Ocio, E. Sanchez-Vizcaino y M.D. Moreno. 1981. Pastos espontaneos del suroeste Español: Composición químico-bromatológica, digestibilidad *in vitro* y valores nutritivos del *Rosmarinus officinalis* L., *Thymus vulgaris* L., *Cistus clusii*, *Dunal* in DC, *Artemisa campestris* L., *Fumana thymifolia* L., *Foeniculum vulgare* Miller, *Lygeum spartum* L. y *Juniperus oxycedrus* L. XXI Reunión Científica de la

SEEP. León. Spain.

- Muñoz, F., M. Joy, J. Pardo and J.D. Andueza. 1996. *In vivo* digestion and *in situ* degradability of *Atriplex halimus*. EEAP Publication No. 83.
- Nefzaoui, A. et A. Chermiti. 1991. Place et rôles des arbustes fourragers dans les parcours des zones arides et semi-arides de la Tunisie. Options Méditerranéennes. Serie A. 16: 119–125.
- Ochoa, M.J. 1982. Relaciones entre el medio y comunidades vegetales del Sabinar Continental Arido en el valle del Ebro. Comunicaciones INIA, Serie: Recursos Naturales, No. 14.
- Robles, A.B. y J. Boza. 1993. Flora forrajera autóctona del suroeste español: II. Valoración nutritiva. *Pastos* 23(1): 47–60.
- Tilley, J.M.A. and R.A. Terry. 1963. A two-stage technique for *in vitro* digestion of forage crops. *Journal of the British Grassland Society* 18: 104–111.
- Valderrabano, J., F. Muñoz and I. Delgado. 1996. Browsing ability and utilization by sheep and goats of *Atriplex halimus* L. shrubs. *Small Ruminant Research* 19: 131–136.
- Van Soest, P.J. 1994. Nutritional Ecology of the Ruminant (2nd ed.). Cornell University Press. Ithaca, NY.
- Van Soest, P.J. 1996. A critique upon the problems of predicting feed quality for ruminants. 47th Annual Meeting of the EAAP. Lillehammer, Norway.
- Yaron, A.Y., Y. Lavie, M. Forti and R.W. Benjamin. 1985. *Atriplex nummularia*, *Atriplex canescens* and *Cassia sturtii* grown under dryland conditions in the Negev. Value as feed and as a nitrogen supply for ruminants. Progress report. No. BGUN-ARI-72-85. The Institute for Applied Research. Ben-Gurion University of the Negev, Beer-Sheva, Israel.

Forage Use of Native *Atriplex halimus* L. in the Rainfed Areas of Aragón, Spain

I. Delgado and F. Muñoz

Servicio de Investigación Agroalimentaria, DGA., Zaragoza, Spain

Abstract

The forage use of autochthonous populations of *Atriplex halimus* in Aragón was studied and compared with *A. halimus* INRF 70100 and *A. nummularia* when browsed by Rasa Aragonesa ewes. Autochthonous populations showed less development, smaller leaves, and lower feeding value than the controls, although sheep accepted them well. *Atriplex halimus* as a sole animal feed produced liveweight losses.

Key words: saltbushes, growing, browsing, feeding value, fattening.

Résumé

On a étudié l'utilisation fourragère des populations autochtones d'*Atriplex halimus* d'Aragon en comparaison avec *A. halimus* INRF 70100 et *A. nummularia* amélioré, sous pâturage par des brebis de la race Rasa Aragonesa. Les populations autochtones ont montré une croissance inférieure, des feuilles plus petites et une valeur fourragère inférieure que les témoins malgré sa bonne acceptation par le bétail. L'utilisation de *A. halimus* comme unique alimentation a occasionné des pertes de poids chez les animaux.

Mots-clés: arbustes fourragers, croissance, pâturage, composition chimique, engraissement.

Introduction

The Aragón Autonomous Community, in the central region of Spain, is a rainfed area (300–400 mm rain/year with a P/PET ratio of 0.41–0.53), with mainly gypsic or moderately salty soils. Under these conditions, it is difficult to introduce new forage species. The natural grazing lands are depleted, and forage must be supplemented during the year with fallow lands and stubble, particularly in and autumn and winter.

Saltbushes have been suggested as a possibility for these areas because they are suitable for rainfed conditions and stay green all year long. (McKell 1975). Among the species evaluated, *Atriplex halimus* stood out because of its development and tolerance to low winter temperatures (Delgado 1992), which can reach -12°C. In

addition, *A. halimus* is a spontaneous species in the region, growing in the banks of the fields and ravines of the areas most affected by soil salinity.

Studies have proved the suitability of the bred variety, *A. halimus* INRF 70100, as a browse for local breeds of goats and sheep in the autumn, although it should only be considered a maintenance diet. An energy supplement is needed during fattening and pregnancy periods (Valderrábano et al. 1996).

This paper looks at the use of native populations of *A. halimus* browsed by ovine flocks under cropping conditions on non-salty soils.

Material and Methods

The experiment took place in Zaragoza in 1992 and 1993 on a plantation established in the autumn of 1990 with six-month-old plantlets. The following populations were studied: 11 Aragón autochthonous *A. halimus*, one bred *A. halimus* INRF 70100, and one bred *A. nummularia* from South Africa.

Shrubs were planted on one hectare divided into five paddocks of 2,000 m². Each plot comprised 15 shrubs/populations, spaced 4 × 2 m apart in three random blocks. Four paddocks were devoted to grazing, each in a different season of the year, and the fifth was left ungrazed to study the development of the bushes.

The offer was estimated from the volume of a shrub considered as a theoretic cylinder ($r = 0.92^{***}$) (Valderrábano et al. 1996), measured before and after grazing. In the second year, the leaf offer was evaluated by defoliating nine shrubs of average volume: three at the beginning of grazing and six at the end (three of which were protected by fences). The flock was made up of dry Rasa Aragonesa ewes with pre-trial liveweights of 58.3 ± 2.4 kg. The first year, between six and 18 ewes/paddock were introduced, according to the forage offer, using animals with no previous experience on *A. halimus* shrubs. Ewes remained continuously in the paddock, with free access to water and mineral blocks. In the second year, 12 ewes were placed in each paddock. The animals were weighed before entering the spring paddock, and every fifteen days thereafter. In the second year, body condition was scored by feeling the lumbar vertebrae (Russell et al. 1969). Palatability was measured every fifteen days during grazing.

In the non-browsed paddock, chemical analysis of the browsable part of the shrub was carried out every two months in the first year. The following were measured: dry matter (DM), ash (AS), and crude protein (CP) (AOAC 1990); acid-detergent fiber (ADF), neuter-detergent fiber (NDF), and acid-detergent lignin (ADL) (Goering and Van Soest 1970); Na, K, and Ca by spectrophotometry of atomic absorption; Cl by a Butcher chloridimeter; and digestibility of *in vitro* DM (IVDDM) according to Tilley and Terry (1963).

Results

Climate Data

During the study, the average maximum, minimum, and absolute minimum temperatures were 20.9, 9.0 and 6.0°C, respectively in 1992, and 20.1, 7.4 and -5.5°C in 1993. Total rainfall was 304.8 and 281.9 mm in 1992 and 1993, respectively.

Shrub Development

The development of the shrubs was estimated by the evolution of volume, as shown in Figure 1. The final average value per shrub was 4.2 m³ in *A. halimus* INRF 70100, 2.5 ± 0.3 m³ in autochthonous *A. halimus*, and 1.3 m³ in *A. nummularia*. Differences were significant ($P < 0.001$) among populations and species (Table 1). Some autochthonous populations showed a rather prostrate habit (Table 1).

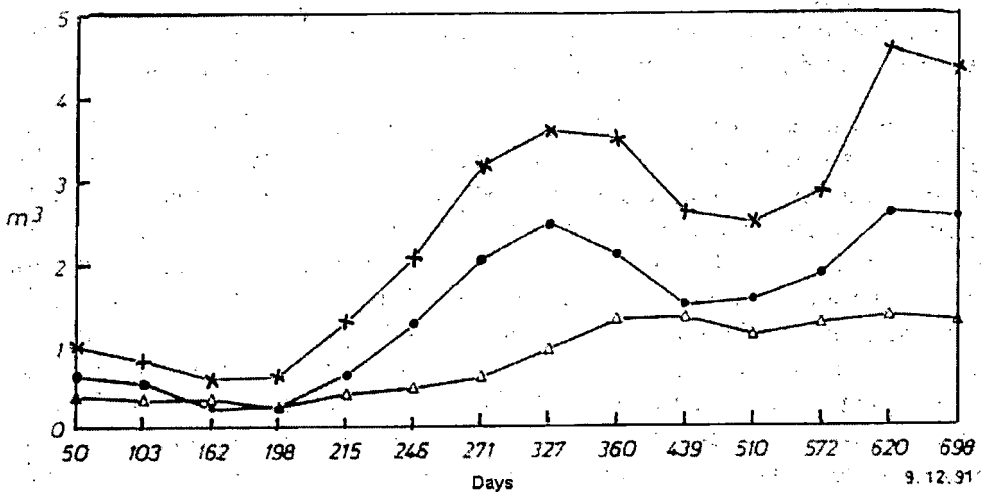


Figure 1. Evolution of saltbush volume. + = *A. halimus* INRF 70100; • = *A. halimus* autochthonous; Δ = *A. nummularia*

Table 1. Measure of saltbushes at the end of the trial and mean waste percentage of the browsing fraction over two years.

Species	Control						Browsing mean					
	Height (cm)		Volume (m ³)		h/Ø ratio		Height (cm)		Volume (m ³)		Browsing (%)	
<i>A. halimus</i> authocht.												
Population 1	119.0	ab	2.55	bc	0.72	bc	100.9	abc	2.08	ab	81.4	bcd
Population 2	116.3	b	2.92	b	0.66	c	95.4	bcd	1.85	ab	91.3	bcd
Population 3	114.0	b	2.43	bc	0.78	b	98.2	abc	1.86	ab	81.2	bcd
Population 4	109.7	b	2.26	bc	0.68	bc	98.7	abc	1.66	bc	80.7	bcd
Population 5	111.7	b	2.36	bc	0.68	bc	97.3	bcd	2.00	ab	74.6	cd
Population 6	116.7	b	3.05	b	0.64	c	100.2	abc	2.09	ab	77.8	bcd
Population 7	111.3	b	2.55	bc	0.66	c	93.2	bcd	1.82	ab	81.0	bcd
Population 8	111.3	b	2.75	bc	0.65	c	95.7	bcd	1.84	ab	74.0	d
Population 9	108.3	b	2.37	bc	0.65	c	94.5	bcd	1.97	ab	85.5	abc
Population 10	118.0	b	2.45	bc	0.74	b	104.0	ab	2.11	ab	79.3	bcd
Population 11	111.0	b	1.79	cd	0.78	b	85.5	d	1.15	cd	87.2	ab
<i>A. halimus</i> INRF 70100	133.0	a	4.29	a	0.72	bc	109.9	a	2.43	a	83.4	abcd
<i>A. nummularia</i>	109.0	b	1.22	d	0.90	a	89.7	cd	1.00	d	92.3	a
Significance	**		***		**		***		***		***	

*= P<0.05; **= P<0.01; numbers with the same letter are not significant (P>0.05)

Table 2. Chemical analysis and feeding value of the browsing fraction of autochthonous *A. halimus*, *A. halimus* INRF 70100, and *A. nummularia*, at different times of the year.

Species	Date	Ca (%)										
<i>A. halimus</i> autochthonous	January	38.5 a	14.4 e	15.8 d	48.1 b	30.6 a	14.4 b	2.4 a	2.0 e	3.0 c	2.9 d	59.8 c
	February	23.1 d	21.0 c	23.5 b	38.5 c	21.6 c	7.8 d	2.4 a	3.1 c	4.3 b	4.0 c	76.5 b
	May	16.8 e	26.1 a	26.3 a	36.4 c	18.7 c	9.7 c	1.4 b	2.7 d	6.2 a	8.5 a	80.7 a
	July	26.9 c	24.1 b	21.0 c	39.1 c	21.6 c	9.1 cd	1.5 b	3.7 a	8.3 a	8.3 a	74.1 b
	September	31.1 b	20.9 c	15.4 de	47.3 b	25.6 b	11.2 bc	1.6 b	3.3 b	6.3 b	6.3 b	60.4 c
	November	40.4 a	17.2 d	13.6 e	54.2 e	32.7 a	14.8 a	14.8 a	1.8 e	3.8 c	3.8 c	50.8 d
Significance												
<i>A. halimus</i> INRF 70100	January	32.0	18.3	18.3	44.4	25.9	9.4	1.0	2.9	3.5	2.7	75.5
	February	20.0	24.4	24.4	30.1	15.7	6.2	2.0	2.9	5.2	4.8	88.0
	May	22.3	25.7	25.7	35.9	20.0	9.3	1.4	2.7	6.0	8.8	73.0
	July	29.0	21.3	21.3	37.1	20.6	8.9	1.4	3.1	5.2	8.4	78.6
	September	31.2	21.3	21.3	43.1	22.5	9.7	1.4	3.0	4.2	6.5	69.4
	November	30.8	20.0	20.0	48.9	26.2	13.8	2.7	2.6	3.1	3.9	55.7
<i>A. nummularia</i>	January	28.9	16.0	20.7	36.9	18.7	7.4	1.8	3.1	2.4	5.0	75.5
	February	25.4	18.9	23.8	30.7	13.8	5.8	1.6	2.0	4.2	4.0	88.0
	May	24.3	23.7	19.1	36.4	17.5	7.7	1.7	2.3	4.0	6.4	64.1
	July	27.2	21.9	18.8	39.0	19.1	7.7	1.5	3.9	5.3	6.0	73.9
	September	23.8	19.0	39.1	39.1	20.3	9.2	1.4	2.4	5.1	7.0	70.5
	November	19.8	18.3	37.8	37.8	31.3	17.4	1.7	3.3	3.0	3.9	72.0

*= P<0.05; **= P<0.01; numbers with the same letter are not significant (P>0.05)

The average length and width of leaves was 3.0 and 1.8 cm, 3.8 and 2.3 cm, and 3.3 and 2.0 cm for autochthonous *A. halimus*, INRF 70100, and *A. nummularia*, respectively. Differences were highly significant between species ($P < 0.001$), highlighting the larger leaf size of INRF 70100 in relation to native populations. No significant differences were found among native species ($P > 0.05$).

Flowering in *A. halimus* lasted from the end of June (flower bud formation) to the end of October (seed ripening). Full flowering took place between the last week of August and the first week of September. There were differences of up to fifteen days between populations in terms of the appearance of flower buds and full flowering, with INRF 70100 the latest. Flowering started in *A. nummularia* at the end of January and finished in June; full flowering occurred in mid May.

Use by the Animal

The average bush height did not surpass 1.20 m, thus the ewes had access to the whole plant.

Palatability was low. In the autumn of 1993, we estimated that the intake of ewes accustomed to browsing shrubs was 1,159 g DM/ewe per day. In the autumn of 1992, when the animals had been in the paddock for 27 days, it was 762 g. With free choice in the paddock, ewes ate bushes according to their proximity to the water (located at the extreme end of the paddock). Thus, while block 1 was mostly eaten, block 3 remained almost untouched. No differences indicating individual preferences were found. The estimated average defoliation at the end of grazing was highest ($P < 0.001$) in *A. nummularia* (92.3%), while INRF 70100 came next (83.4%), and autochthonous *A. halimus* last ($80.4 \pm 4.0\%$). Shrubs recovered after the hard browsing; their volumes and heights at the end of the experiment are given in Table 1.

Ewes lost weight during all seasons in the two-year experiment. In 1992, the average liveweight lost was 4.6 kg (7.8%). In the first two months of 1993, a loss of 10.5% was seen in the same flock. Later on, weight stabilized, without increasing, until the end of the experiment. Body condition was reduced by 0.9 (26.5%) (Fig. 2).

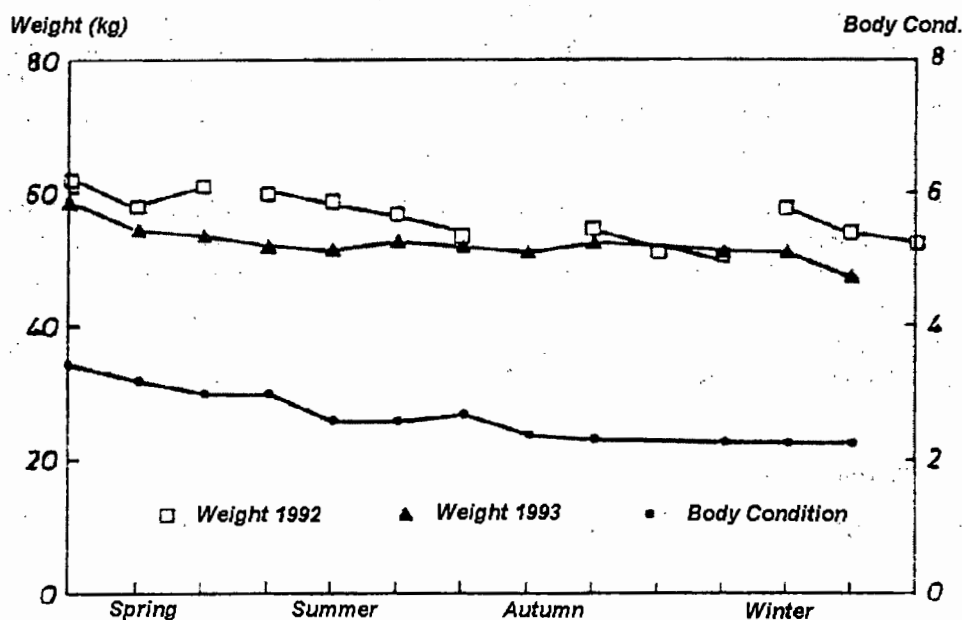


Figure 2. Liveweight gains in ewes in 1992 and 1993, and body condition in 1993.

Chemical Composition of the Browseable Fraction

The chemical composition of the browseable fraction did not show significant differences ($P > 0.05$) among different populations. Yearly average percentages, on a dry matter basis, for the autochthonous species were: DM, 29.5 ± 8.9 ; ash, 20.6 ± 4.5 ; calcium, 1.9 ± 0.7 ; potassium, 2.8 ± 0.8 ; sodium, 4.4 ± 1.4 ; chlorine, 5.6 ± 2.4 ; CP, 19.2 ± 5.5 ; NDF, 43.9 ± 7.9 ; ADF, 25.1 ± 5.3 ; ADL, 10.7 ± 2.5 ; and IVDDM, 67.0 ± 11.2 .

The mean values for *A. halimus* INRF 700100 were: DM, 27.6 ± 7.0 ; ash, 21.8 ± 3.6 ; calcium, 1.7 ± 0.4 ; potassium, 2.7 ± 0.5 ; sodium, 4.4 ± 0.9 ; chlorine, 5.7 ± 2.4 ; CP, 21.8 ± 3.6 ; DNF, 39.8 ± 6.9 ; ADF, 21.8 ± 4.0 ; ADL, 9.5 ± 2.4 ; and IVDDM, 72.0 ± 11.0 . The mean values for *A. nummularia* were: DM, 25.1 ± 3.5 ; ash, 19.5 ± 2.1 ; calcium, 1.7 ± 0.3 ; potassium, 3.0 ± 0.3 ; sodium, 3.9 ± 0.7 ; chlorine, 5.3 ± 2.3 ; PB, 19.9 ± 3.5 ; NDF, 36.7 ± 3.1 ; ADF, 20.1 ± 5.9 ; ADL, 9.2 ± 4.1 ; and IVDDM, 74.0 ± 7.8 .

When the 11 autochthonous populations of *A. halimus* are considered as individual repetitions of the same collective, highly significant ($P < 0.001$) differences between the different seasons of the year appear (Table 2). In general, the spring samples had minimum values of DM, NDF, ADF, and ADL, and maximum values of ash, CP, and IVDDM. These results were reversed in the autumn. Potassium,

sodium, and chlorine contents were at their lowest in spring/summer and highest in autumn/winter. Calcium content was exactly the opposite.

Discussion

The palatability of the *A. halimus* from Aragón was closest to the control, although, due to its wild origin, its volume and feeding value were lower, and its leaves were smaller. With proper breeding, more productive autochthonous varieties, with a prostrate habit and higher feeding value, could be obtained (Correal 1991).

The average CP content (20.0%) is, in theory, enough to meet the animals' needs, but cannot be considered an indicator of forage quality. The bibliographic review by Le Houérou (1992) shows that 65% of N is digestible, but only 55% of that amount is assimilated. The flock lost weight while grazing. This may be attributed to the lower quality and palatability of the autochthonous populations, which resulted in lower intake than the amount suggested by other authors (1.2–1.5 kg DM/ewe per day) as essential for maintenance (Gomez et al. 1991; Le Houérou 1992; Valderrábano et. al. 1996).

Conclusions

Autochthonous populations of *A. halimus* are useful as forage, although their quality and intake are insufficient for flock maintenance. Further study is needed to show how these species, a valuable resource so well adapted to rainfed land conditions, may best be supplemented by other feeds.

References

- AOAC. 1990. Official methods of analysis. Association of official analytical chemists (15th ed.). Washington, DC.
- Correal, E. 1991. Grazing use fodder shrub plantations. EEC Workshop on Fodder Trees and Shrubs. Thessoloniki, Greece.
- Delgado, I. 1992. Nota técnica sobre la introducción de arbustos forrajeros en el secano aragonés. *ITEA* 88A: 129–132.
- Gomez, V., J.I. Perez y C. Torres. 1991. Valoración del arbusto forrajero *Atriplex halimus* pastado por ganado ovino. XVI Jornadas de la Sociedad Española de Ovinotecnia, Pamplona.
- Goering, H.K. and P.J. Van Soest. 1970. Forage fiber analysis. USDA, ARS Agric. Handbook 379.
- Le Houérou, H.N. 1992. The role of saltbushes (*Atriplex* spp.) in arid land rehabilitation in the Mediterranean basin: A review. *Agroforestry Systems* 18: 107–148.
- McKell, C.M. 1975. Shrubs: A neglected resource of arid lands. *Science* 187: 803–809.

- Russell, A.J.F., J.M. Doney and R.G. Gunn, 1969. Subjective assessment of body fat in live sheep. *Journal of Agricultural Science, Cambridge* 72: 451–454.
- Tilley, J.M. and R.A. Terry. 1963. A two stage technique for the in vitro digestion of forage crops. *Journal of the British Grassland Society* 18: 104–111.
- Valderrábano, J., F. Muñoz and Delgado, I. 1996. Browsing ability and utilization by sheep and goats of *Atriplex halimus* L. shrubs. *Small Ruminant Research* 19: 131–136.

Développement Morphologique et Biomasse Apétable d'*Acacia cyanophylla* Lindl. en Réponse aux Différentes Modalités d'Exploitation Pastorale dans les Zones Arides en Tunisie

Y. Ammari¹ and M.S. Lamhamedi²

¹*Institut National de Recherche en Génie Rural, Eaux et Forêts
Ariana, Tunis, Tunisie*

²*Institut Agronomique et Vétérinaire, Hassan II, Département de Foresterie et des
Ressources Naturelles, Rabat, Maroc*

Résumé

La présente étude a été menée sur des peuplements d'*Acacia cyanophylla* Lindl. de deux âges différents (3 et 6 ans), plantés dans les zones arides de la Tunisie. L'objectif est d'analyser la réponse morphologique de cette espèce vis-à-vis un certain nombre de modalités d'exploitation pastorale à savoir :

- Des coupes totales des arbustes à 20, 40, et 60 cm du sol.
- Des coupes partielles de 30, 60, et 100% par le haut et par le bas des branches secondaires situées à une hauteur supérieure ou égale à 2 m, et des branches secondaires situées à une hauteur inférieure ou égale à 1 m du sol.
- Des coupes combinées par le haut et par le bas des branches secondaires sous les mêmes intensités de coupe utilisées dans les coupes partielles.

Les résultats obtenus ont montré que l'évolution des paramètres morphologiques est intimement liée à la hauteur et à l'intensité de coupe. L'effet coupe a été hautement significatif. Plus la coupe est élevée du sol, plus la réponse est importante en terme du nombre de rejets, de phyllodes, de l'allongement des rejets et de la biomasse sèche.

Abstract

The present study was conducted on plantations of *Acacia cyanophylla* Lindl. of two different ages (3 and 6 years) planted in the arid areas of Tunisia. The objective was to follow the morphological responses of this shrub in relation to different harvesting terms:

- Cutting shrubs at 20, 40, and 60 cm from the ground.
- Partial cutting (30, 60, and 100%) of secondary branches located at a height of 2 m or more, and 1 m or less, from the ground.

- Combination cutting of secondary branches from the top and bottom at the same cutting intensities described under partial cuts.

The evolution of morphological parameters was directly linked to cutting height and cutting intensity. Cutting effect was highly significant. Increasing the height of cutting from the ground resulted in a more important response in terms of sprout and phyllod numbers, dry matter production, and sprout elongation.

Introduction

En Tunisie, les zones arides s'étendent sur une superficie de 55000 km², soit 34% du territoire national. Dans ces zones, l'élevage extensif occupe une place importante dans l'économie des exploitations agricoles de subsistance et de marché. Dans le gouvernorat de Kairouan, objet de notre étude, l'effectif du cheptel est estimé à 1112970 UPB (unités de petit bétail), soit 9% du cheptel national. Les besoins fourragers du cheptel de ce gouvernorat sont évalués à environ 340 10⁶ UF/an alors que la production fourragère totale ne dépasse guère 29 10⁶ UF/an, soit un déficit fourrager de 311 10⁶ UF/an (Anonyme 1995). Une partie de ce déficit est couverte par les produits issus des exploitations agricoles et par les aliments subventionnés achetés sur le marché.

La rareté des ressources pastorales a conduit à une surexploitation par le pâturage et à l'intensification des coupes illicites. Cette rareté est aggravée durant les années de sécheresse où la production fourragère dans cette zone ne peut atteindre que 60 UF/ha/an (Anonyme 1993). Face à cette situation, le gouvernement tunisien a entrepris des programmes de grande envergure en matière d'amélioration pastorale complétés par des programmes d'amélioration génétique et des campagnes prophylactiques en vue d'améliorer la couverture du déficit fourrager et d'accroître les performances de reproduction et de croissance des troupeaux. Par comparaison aux plantations fourragères à base d'*Atriplex* et de *Cactus*, l'*Acacia cyanophylla* Lindl. est de loin l'arbuste fourrager le plus couramment planté dans le gouvernorat de Kairouan puisqu'il représente à lui seul 57% de la superficie totale plantée (Anonyme 1995).

Plusieurs espèces d'*Acacia* ont révélé une bonne croissance dans les zones arides et une tolérance à la salinité (Nasr et al. 1986 ; Le-Lakany 1987 ; Thomson 1987 ; Aswathappa et al. 1987 ; Zaafouri et al. 1994). Dans le gouvernorat de Kairouan, l'*Acacia cyanophylla* peut assurer une production fourragère entre 600 et 800 UF/ha (Anonyme 1993) avec une bonne valeur nutritive (matière azotée totale : 14 à 15%) et une appétabilité relativement remarquable (Nefzaoui et Chermiti 1990). A cet effet, l'*Acacia cyanophylla* peut être exploité et utilisé comme supplément fourrager durant les longues périodes de soudure et les mauvaises années climatiques caractérisées par une faible production de la strate herbacée. Cette

essence peut subvenir aussi en partie aux besoins de la population riveraine en matière de bois de feu et peut jouer un rôle capital dans la conservation et la restauration de la fertilité des sols. Pour maintenir une production foliaire appréciable et pour assurer la pérennité de cette essence, une connaissance approfondie des réponses morphologiques en fonction de l'intensité de coupe, de la hauteur des coupes et de la combinaison des deux s'avère nécessaire. Jusqu'à présent, nos connaissances restent limitées quant à la variabilité de la réponse morphologique de l'*Acacia cyanophylla* évaluée sur la base du nombre de rejets, du nombre de phyllodes, de la longueur des rejets et de la biomasse sèche. Les objectifs assignés à cette étude consistent à évaluer la réponse morphologique et la biomasse appréciable des peuplements d'*A. cyanophylla* soumis à différentes modalités d'exploitation pastorale tout en tenant compte de la qualité de la station et de l'âge des peuplements.

Matériels et Méthodes

Situation Géographique et Climat du Domaine Pastoral d'Étude

Les quatre sites d'étude sont situés dans le sud tunisien au sein du domaine pastoral d'Ennasr qui couvre 4471 ha (39° N lat. 46' ; 8° 68' E long.). Ce domaine est limité au sud par la ville de Kairouan et à l'est par la route GPZ-Sfax.

Du point de vue climatique, le domaine pastoral d'étude est soumis à un climat aride à hiver tempéré. La pluviométrie moyenne est de 291 mm. Durant la période d'étude (janvier 1994–février 95), les précipitations enregistrées ont atteint 282 mm. Cette zone est exposée aussi au vent chaud qui prend naissance au sud (le sirocco) et peut accentuer fortement l'évapotranspiration potentielle (ETP) qui peut dépasser 1345 mm/an. La température moyenne annuelle est de 19,1°C. Les températures minimale et maximale absolues enregistrées durant le mois de janvier et de juillet sont respectivement de 4,5°C et de 49°C.

Pédologie et Caractéristiques des Quatre Sites d'Étude

Dans chacun des quatre sites d'étude, un profil pédologique a été creusé dont la description et l'analyse granulométrique sont décrites en détail par Ammari (1995). Les sols sont généralement squelettiques et halomorphes, utilisés principalement pour des plantations sylvo-pastorales et pour le parcours extensif. Les principales caractéristiques de ces sites sont consignées dans le Tableau 2.

Modalités d'Exploitation Pastorale: Intensité et Hauteur de Coupe

Le domaine pastoral d'Ennasr a été divisé en quatre sites homogènes en tenant compte de la nature et de la profondeur des sols, de la situation topographique, et l'âge et de la vigueur des peuplements d'*Acacia*. Dans chacun des sites, une parcelle "homogène," d'une superficie de 500 × 500 m, a été délimitée et trois arbustes d'*Acacia* représentatifs par MEP ont été choisis. Les différentes modalités d'exploitation pastorale (MEP) expérimentées sont :

Modalité 1

Exploitation totale (ET) à différentes hauteurs : 20, 40, et 60 cm.

Modalité 2

Exploitation partielle (EP) par le haut (EPH) et par le bas (EPB).

L'EPH a été pratiquée chez les arbustes qui dépassent 2 m de hauteur avec des intensités de coupe qui correspondent à l'élimination de 30, 60, et 100% de la biomasse. L'EPB n'a concerné que les arbustes ayant une hauteur inférieure à 1m tout en gardant les mêmes intensités de coupe. Dans le site 4, l'EPH n'a pas été pratiquée car les arbustes ne dépassaient pas 2 m de hauteur.

Modalité 3

Exploitation mixte (Tableau 1) qui regroupe toutes les différentes combinaisons issues des deux types d'exploitation partielle (EPB et EPH).

Tableau 1. Combinaisons entre les différentes intensités des exploitations partielles par le bas (EPB) et par le haut (EPH).

	30%	EPB-60%	100%
30%	H30-B30	H30-B60	H30-B100
EPH-60%	H60-B30	H60-B60	H60-B100
100%	H100-B30	H100-B60	H10-B100

Paramètres Mesurés et Traitement des Données

Pour chaque modalité d'exploitation pastorale et après sept mois de croissance (novembre 94-mai 95), trois arbres ont été choisis pour effectuer les mesures suivantes :

- Le nombre de rejets.
- La longueur et le nombre de phyllodes pour chaque rejet.
- La biomasse appétable sèche à la fin du cycle végétatif. Le séchage a été effectué dans une étuve à 75°C pendant 48 heures.

Tableau 2. Principales caractéristiques des quatre sites étudiés.

Caractéristiques	Site 1	Site 2	Site 3	Site 4
Situation topographique	Bas fond	Bas fond	Bas fond	Crête
Pente (%)	1 à 2	1 à 2	1 à 2	3 à 4
Âge des peuplements (ans)	6	6	3	3
Végétation naturelle	<i>Eragrostis papposa</i> <i>Ziziphus lotus</i> <i>Artemisia campestris</i> <i>Atriplex halimus</i> <i>Salsola tetrandra</i> <i>Salsola vermiculata</i>	<i>Atriplex halimus</i> <i>Atriplex malvana</i> <i>Salsola tetrandra</i> <i>Salsola vermiculata</i> <i>Plantago crassifolia</i> <i>Plantago lagopus</i> <i>Cynodon dactylon</i> <i>Mesembryanthemum nodiflorum</i>	<i>Atriplex halimus</i> <i>Atriplex malvana</i> <i>Hordeum maritimum</i> <i>Plantago crassifolia</i> <i>Plantago lagopus</i> <i>Filago sp.</i> <i>Mesembryanthemum nodiflorum</i>	<i>Ajuga iva</i> <i>Artemisia comprestis</i> <i>Artemisia herba-alba</i> <i>Atractylis serratuloides</i> <i>Plantago albicans</i> <i>Thymelea hirsuta</i>
Salinité	Conductivité électrique; élevée : 30-45 mmho/cm	Conductivité électrique; faible = 5 à 10 mmho/cm	Conductivité électrique; faible = 5 à 10 mmho/cm	Conductivité électrique; faible = 5 à 10 mmho/cm

Les données recueillies concernant les 18 modalités d'exploitation pastorale ont été traitées sur la base d'un dispositif en bloc aléatoire complet avec trois répétitions. Des transformations mathématiques des données ont été effectuées en vue d'atteindre la normalité et l'homogénéité des variances. La comparaison multiple des moyennes entre les différentes modalités a été déterminée par le test de Newman-Keuls (Steel et Torrie 1980). Les différences sont considérées significatives à $P < 0,05$.

Résultats

La modalité d'exploitation pastorale (exprimée en terme d'intensité et de hauteur de coupe), l'âge, la qualité du site et les différentes interactions ont un effet significatif ($P < 0,05$) sur la majorité des paramètres mesurés à savoir le nombre, la longueur des rejets et la biomasse appétable sèche.

Modalité 1 : Exploitation Totale à 20, 40, et 60 cm du Sol

Dans le cas de l'exploitation pastorale totale (modalité 1), les rejets étaient plus abondants lorsque la coupe est pratiquée à une hauteur de 60 cm du sol par comparaison aux deux autres exploitations pastorales totales pratiquées à 40 et à 20 cm (Fig. 1A). Les arbustes du site 2 exploités à 60 cm du sol ont donné le plus grand nombre de rejets (138 rejets). Les exploitations pastorales totales à 60 et à 40 cm ont eu un effet remarquable sur la formation de nouvelles phyllodes et la biomasse sèche appétable chez les arbustes d'*Acacia* croissant dans les sites 2 et 3 (Fig. 1B, D). Dans les quatre sites, la longueur des rejets mesurée chez les arbustes exploités à 60 cm dépassait légèrement celles mesurées chez les arbustes exploités à 40 et à 20 cm du sol (Fig. 1C).

Modalité 2 : Exploitation Partielle par le Haut et par le Bas

L'EPH a consisté à l'élimination de 30, 60, et 100% des branches d'*A. cyanophylla* à une hauteur supérieure ou égale à 2m. Les meilleurs résultats concernant le nombre de rejets, le nombre de phyllodes, la longueur des rejets et la biomasse sèche appétable ont été obtenus avec l'EPH à 100% avec une grande influence de la qualité du site (Fig. 2). En effet, le nombre de rejets le plus élevé a été observé chez les arbustes du site 2 avec 2,058 rejets versus 1775 et 1298 rejets respectivement dans les sites 1 et 3 (Fig. 2A). La formation des phyllodes était favorisée par l'EPH à 100% dans les trois sites avec un maximum de 12,500 phyllodes/arbuste dans le cas du site 2 (Fig. 2B). Pour la longueur des rejets, la meilleure réponse a été obtenue avec l'EPH à 100% dans le site 1 (Fig. 2C). Les moyennes concernant la longueur des rejets ont été de 23, 18, et 17,5 cm respectivement pour les sites 3, 2, et 1. L'EPH à 100% a engendré une bonne production de matière sèche allant de 1,1 à 1,8 kg/arbuste (Fig. 2D).

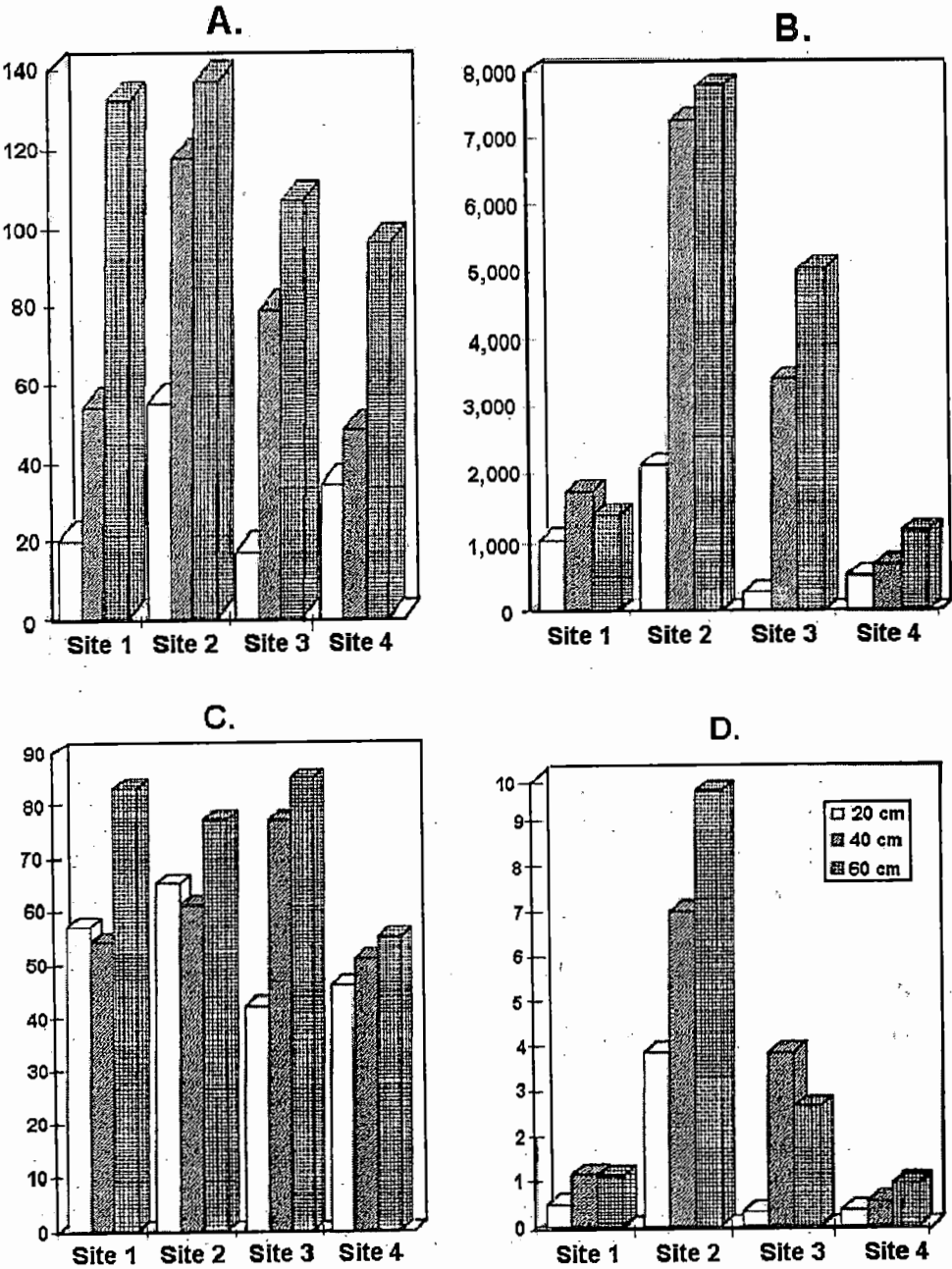


Figure 1. Effet de l'exploitation pastorale totale (modalité 1) pratiquée à différentes hauteurs (20, 40 & 60 cm) sur (A) le nombre de rejets, (B) le nombre de phyllodes, (C) la longueur des rejets (cm) et (D) la biomasse appétable sèche (kg/arbuste).

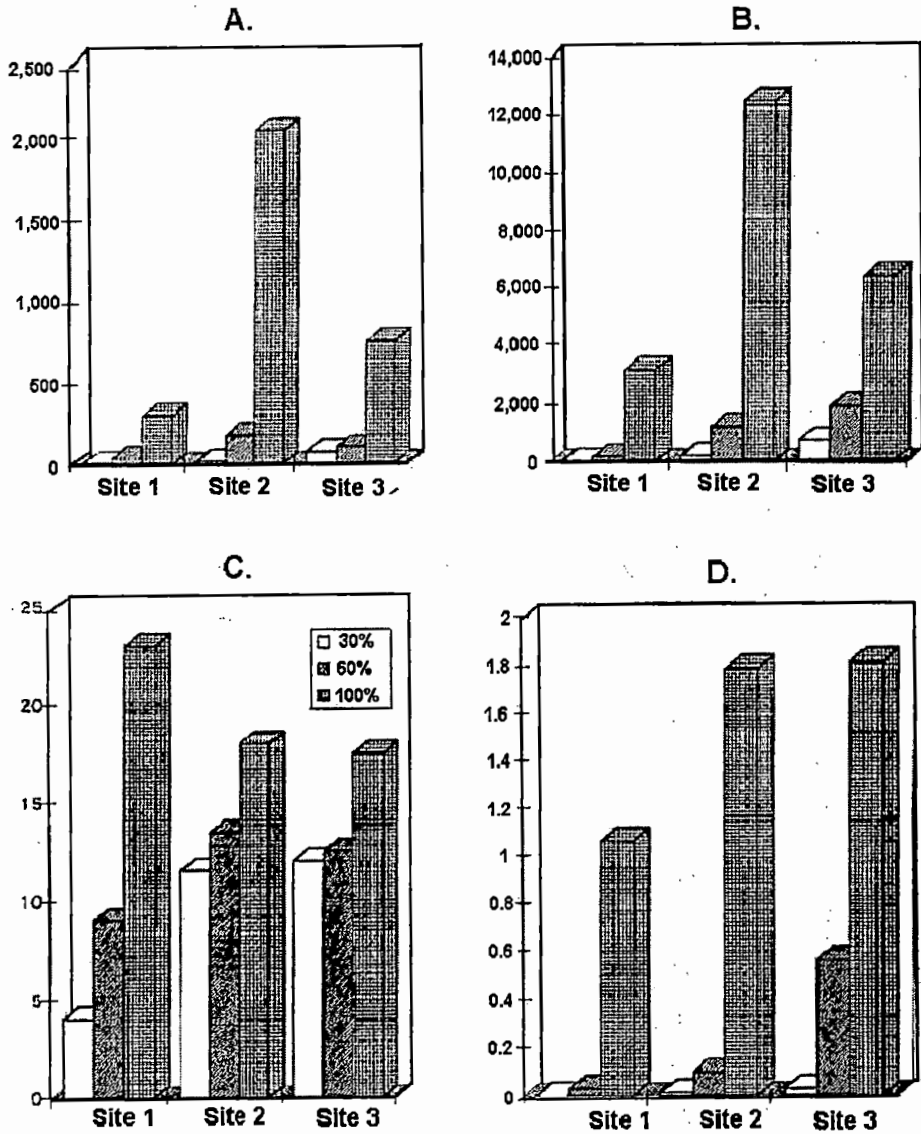


Figure 2. Effet de l'exploitation pastorale partielle (modalité 2) pratiquée par le haut à une hauteur supérieure à 2m et à différentes intensités (élimination de 30, 60 et 100% de la biomasse) sur (A) le nombre de rejets, (B) le nombre de phyllodes, (C) la longueur des rejets (cm) et (D) la biomasse appétable sèche (kg/arbuste).

L'EPB n'a pas engendré une nette amélioration de la biomasse et des paramètres morphologiques (Fig. 3). Seule l'EPB à 100% pratiquée chez les arbustes croissant dans le site 3 où l'effet était tangible concernant le nombre de rejets, le nombre de phyllodes, la longueur des rejets et la biomasse sèche (Fig. 3A, B, C, D).

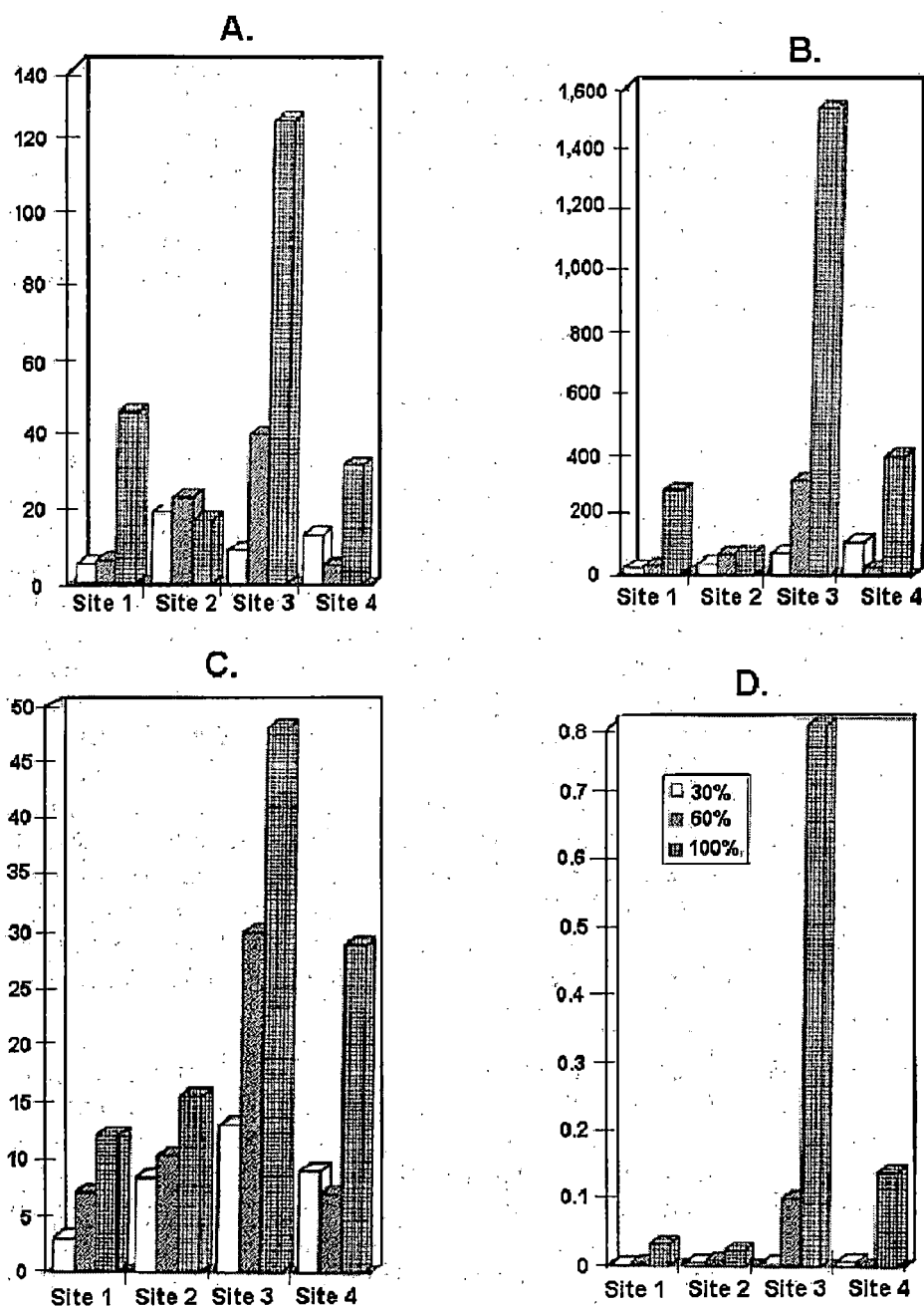


Figure 3. Effet de l'exploitation pastorale partielle (modalité 2) pratiquée par le bas à une hauteur inférieure à 1m et à différentes intensités (élimination de 30, 60 et 100% de la biomasse) sur (A) le nombre de rejets, (B) le nombre de phyllodes, (C) la longueur des rejets (cm) et (D) la biomasse appétable sèche (kg/arbuste).

Modalité 3 : Exploitation Mixte

Dans le cas de cette modalité, les réactions des arbustes étaient variables en réponse à une même modalité. En fonction de la qualité du site, chaque combinaison entre les deux exploitations (EPH-EPB) a amélioré un paramètre morphologique donné. Par exemple, le nombre de rejets, le nombre de phyllodes et la longueur des rejets étaient favorisés respectivement par les combinaisons (EPH_{100%}-EPB_{60%}), (EPH_{100%}-EPB_{100%}), (EPH_{100%}-EPB_{100%}). Seule la combinaison (EPH_{100%}-EPB_{100%}) a favorisé une bonne production de matière sèche indépendamment de la qualité du site.

Discussion

L'intensité et la hauteur de l'exploitation pastorale des arbustes d'*Acacia cyanophylla* ont eu un effet déterminant sur le développement morphologique et la production de biomasse sèche appréciable. La réponse des arbustes aux différentes modalités d'exploitation pastorale était influencée par la qualité du site (salinité, profondeur et réserves hydriques). Nos résultats laissent suggérer que la formation de nouveaux rejets et la production de biomasse étaient intimement liées à la quantité de phyllodes restantes sur l'arbuste après coupe et à l'importance du rayonnement photosynthétique actif (intensité et qualité de la lumière) à différentes hauteurs dans la partie restante de l'arbuste. Contrairement aux exploitations pastorales totales sévères (à 20 et à 40 cm du sol) et partielles par le bas, les exploitations totale à une hauteur de 60 cm et partielle par le haut à 100% (>2m) ont engendré une nette amélioration de la croissance et de la biomasse de nouveaux rejets. Ces deux types d'exploitations assurent aux arbustes une architecture horizontale et une amélioration de la quantité et de la qualité de la lumière (400–700 nm) reçues par les phyllodes restantes. L'amélioration du régime lumineux à l'intérieur de la canopée a certainement pour effet d'augmenter le taux de photosynthèse de ces phyllodes.

En plus de l'effet de la défoliation ou de la coupe sur l'amélioration du régime lumineux (Senock et al. 1991), d'autres travaux ont attribué l'augmentation du taux de photosynthèse du feuillage restant suite à une défoliation partielle à l'effet de compensation par le plant et à l'augmentation de la concentration en azote (Senock et al. 1991 ; Hoogesteger et Karlsson 1992). Cette compensation est due en partie au retard observé dans la sénescence du feuillage restant (Nowak et Caldwell 1984). L'augmentation de photosynthèse chez les plants partiellement défoliés a été attribuée aussi à l'augmentation des conductances stomatale et du mésophyle au CO₂ (Wallace et al. 1984). La croissance des nouveaux rejets pourrait être assurée par la translocation de quantités appréciables des sucres contenus le feuillage âgé restant vers le nouveau feuillage en développement. Kozłowski (1992) a montré que lors de la croissance du nouveau feuillage, il y a

une translocation des sucres stockés dans les feuilles âgées vers les jeunes feuilles. Ces dernières constituent un léger siphon des sucres jusqu'à ce que leur développement atteigne un stade d'autonomie.

Sur le plan physiologique, les différentes parties (phyllodes, tiges et racines) des arbustes d'*Acacia* reçoivent les différents stimuli émanant des différents stress environnementaux (sécheresse et salinité) et répondent d'une façon intégrée en vue de contrôler la croissance et le développement de l'arbuste en entier. Dans ce sens, ce sont les réponses métaboliques du système foliaire aux stress environnementaux qui régularisent la croissance et le développement de la partie aérienne et racinaire. Dans le site 1, la présence du sable en surface et l'accumulation de sels en profondeur (CE = 31 à 45 mmho/cm) affectent les réserves hydriques dans la rhizosphère et limitent par conséquent la production de la matière sèche. La présence de sols argileux peu salés dans les sites 2 et 3 a certainement amélioré le statut hydrique, les échanges gazeux et par conséquent la croissance des arbustes en réponse à certaines modalités d'exploitation. Dans ces sites, le système racinaire est bien développé et probablement les réserves en sucres sont relativement importantes. Ces réserves seront utilisées par les nouveaux rejets et régulariseront leur vigueur.

Pour une meilleure gestion rationnelle des peuplements d'*Acacia* à vocation pastorale, il paraît judicieux de pratiquer, en fonction de la vigueur du peuplement, des exploitations pastorales totales à 60 cm ou des exploitations partielles par le haut (>2m, 100%). Pour mieux approfondir nos connaissances, des investigations supplémentaires sur le statut hydrique et sur l'épuisement de la souche en fonction de l'intensité et de la hauteur de coupe s'avèrent nécessaires.

Références

- Ammari, Y. 1995. Contribution à l'étude des réponses morphologiques et écophysiologiques de l'*Acacia cyanophylla* Lindl. aux techniques d'exploitation dans un but de valorisation, gestion et aménagement sylvo-pastoral. (Domaine pastoral "Ennasr", Gouvernorat de Kairouan, Tunisie). Mémoire de troisième cycle. École Nationale d'Ingénieurs, Salé. Maroc.
- Anonyme 1993. Projet de développement agricole intégré de Kairouan. Volume I: Rapport principal. Document du Fonds international de développement agricole. Direction Générale des Forêts. Tunisie.
- Anonyme 1995. Résultats de l'inventaire pastoral national. Direction Générale des Forêts. Tunisie.
- Aswathappa N., N.E. Marcar and L.A.J. Thomson. 1987. Salt tolerance of Australian tropical and subtropical acacias. Pages 70–73 in *Australian Acacias in Developing Countries*. Proceedings of an International Workshop (J.W. Thurnbull ed.). Forestry Training Centre, 4–7 Aug 1986, Gympie, Qld., Australia.

- Hoogesteger, J. and P.S. Karlsson. 1992. Effects of defoliation on radial stem growth and photosynthesis in the mountain birch (*Betula pubescens* ssp. *tortuosa*). *Functional Ecology* 6: 317-323.
- Kozlowski, T.T. 1992. Carbohydrates sources and sinks in woody plants. *Botanical Review* 58: 107-222.
- Le-Lakany, M.H. 1987. Use of Australian acacias in North Africa. Pages 116-117 in *Australian Acacias in Developing Countries. Proceedings of an International Workshop* (J. W. Thurnbull ed.). Forestry Training Centre, 4-7 Aug 1986, Gympie, Qld., Australia.
- Nasr, H., R. Sghari, A. Mhiri et M.J. Elloumi. 1986. Comportement d'*Acacia cyanophylla* Lindl. dans un sol salé: résultats préliminaires. in *Colloque sur les végétaux en milieu aride*, 8-10 Sept 1986, Jerba, Tunisie.
- Nefzaoui, A. et A. Chermiti. 1990. Place et rôle des arbustes fourragers dans les parcours des zones arides et semi-arides de la Tunisie. Pages 55-69 in *Séminaire Maghrébin d'Agroforesterie. Actes du Séminaire*, 23-27 Oct 1989, Jebel Oust, Tunisie. Ministère de l'Agriculture, Tunisie.
- Nowak, R.S. and M.M. Caldwell. 1984. A test of compensatory photosynthesis in the field: implications for herbivory tolerance. *Oecologia* 61: 311-318.
- Senock, R.S., W.B. Sisson and G.B. Donart. 1991. Compensatory photosynthesis of *Sporobolus flexuosus* (Thurb.) Rydb. following simulated herbivory in the northern Chihuahuan desert. *Botanical Gazette* 152: 275-281.
- Steel, R.G.D. and J.H. Torrie. 1980. *Principles and Procedures of Statistics. A Biometrical Approach*. McGraw-Hill Publishing Company, New York, USA.
- Thomson, A.J. 1987. Australian acacias for saline, alkaline soils in the hot, dry subtropics and tropics. Pages 66-69 in *Australian Acacias in Developing Countries. Proceedings of an International Workshop* (J. W. Thurnbull ed.). Forestry Training Centre, 4-7 Aug 1986, Gympie, Qld., Australia.
- Wallace, L.L., S.J. McNaughton and M.B. Coughenour. 1984. Compensatory photosynthetic responses of three African graminoids to different fertilization, watering, and clipping regimes. *Botanical Gazette* 154: 151-156.
- Zaafouri, M.S., N. Akrimi, C.F.E. Le Floc'h et R. Pontanier. 1994. Les plantations sylvo-pastorales en Tunisie pré-saharienne. *Sécheresse* 5: 265-275.

Nitrogen Supplementation of Cactus-based Diets Fed to Barbarine Yearlings

A. Nefzaoui¹, H. Ben Salem¹ and L. Ben Salem²

¹Laboratoire de Nutrition, INRA de Tunisie, Tunisie

²Office de l'Elevage et des Pâturages, Tunis, Tunisie

Abstract

Spineless cactus (*Opuntia ficus indica* var. *inermis*) has low crude protein (3–5% of DM) and fiber (10–15% of DM) contents. The objective of this study was to investigate the effect of nitrogen supplementation (urea, soybean meal, *Atriplex halimus*, *Atriplex nummularia*) on voluntary intake and growth of Barbarine yearlings fed cactus-based diets. Four isonitrogenous and isoenergetic diets (D1–D4) were each offered to six Barbarine yearlings for 60 days (summer 1995). For all diets, freshly cut cactus was fed *ad libitum* in addition to a limited amount of hay (170 g/d). Diets were supplemented with 8 g/d urea (D1), 770 g/d *A. halimus* (D2), 740 g/d *A. nummularia* (D3), and 65 g/d soybean meal (D4). The relatively low intake of cactus and the poor nitrogen content of *Atriplex* spp. were probably due to the drought conditions during the year of the study. Results showed that cactus-based diets may be efficiently supplemented with *A. nummularia*. Urea and *A. halimus* supplementation led to low growth rates compared to soybean meal or *A. nummularia*. Voluntary dry matter intake was 694, 844, 858, and 674 g/day, for D1, D2, D3, and D4, respectively. The average daily gains were 55, 58, 74, and 70 g for D1, D2, D3, and D4 respectively. Diets using low proportions of cereal (28%) and forage (17%) are recommended to cope with feed deficiency in the arid and semi-arid areas prevailing in North Africa.

Introduction

In the Tunisian arid and semi-arid zones, animal feed resources are fluctuating and insufficient. Small ruminants are mainly fed on rangelands. Rangelands met about 80% of the total livestock requirement during the 1950s, but only 20% in the 1990s. Recently, large-scale plantation of shrubs and fodder trees (*Acacia* spp., *Atriplex* spp.), and cacti has been undertaken to reduce the increasing deficit in feed resources and prevent rangeland degradation.

The benefits of these plant species include high biomass yield, evergreen habit, drought resistance, salinity tolerance, and soil adaptability.

The importance of *Opuntia* spp. in arid and semi-arid regions is increasingly acknowledged, not only because of its abundance and palatability but also because of its 4–5 fold water-use efficiency (Russell and Felker 1987), ability to grow on

marginal lands (Le Houérou and Corra 1980), ability to serve for human consumption (Barbera 1995), ability to produce more as CO₂ concentrations increase (Nobel 1995), and uses in the cosmetic, medical, dye, and honey industries (Cantwell 1995; Saenz-Hernandez 1995).

Cacti are widespread in arid and semi-arid Mediterranean regions. According to Le Houérou (1992), cacti are mostly abundant in Tunisia and Sicily. Recently, a large-scale plantation of spineless cactus (*Opuntia ficus indica* var. *inermis*) was undertaken in Tunisia to establish fodder reserves in arid and semi-arid zones and to reduce rangeland degradation. Benefits of cacti include high biomass yield, high palatability, evergreen habit, drought resistance, salinity tolerance, and soil adaptability (Monjauze and Le Houérou 1965; Le Houérou 1992; Nefzaoui et al. 1993). Recent data (Ben Salem et al. 1996) indicate that over the year, terminal and sub-terminal pads of spineless cactus have a low content of crude protein (20–50 g/kg dry matter) and crude fiber (80–150 g/kg dry matter). They have a high ash content (150–250 g/kg dry matter) and are rich in vitamin A and in readily available carbohydrates.

On the other hand, poor-quality diets may be adequately supplemented with cacti. Our work showed that the intake of straw increased significantly with the amount of cactus in the diet. Moreover, cactus is a good supplement to ammonia- or urea-treated straw, because it provides the carbohydrates needed for the efficient use of non-protein nitrogen (Nefzaoui et al. 1993).

The objective of this study was to compare the efficiency of various nitrogen sources when used as supplements for cactus-based diets fed to ewe lambs.

Material and Methods

Diets

Four isonitrogenous and isoenergetic diets (Table 1) were formulated to meet the maintenance requirements of ewe lambs and to allow an average daily gain of 100 g. Because of its high price and scarcity during dry years, hay was included in the diets at the minimum-required level.

Diets were supplemented with four nitrogen sources: urea, soybean meal, and two types of *Atriplex*.

- D1: cactus *ad libitum* + 170 g hay + 355 g barley + 8 g urea.
- D2: cactus *ad libitum* + 170 g hay + 280 g barley + 740 g *A. halimus*.
- D3: cactus *ad libitum* + 170 g hay + 280 g barley + 770 g *A. nummularia*.
- D4: cactus *ad libitum* + 170 g hay + 280 g barley + 65 g soya bean meal.

Experimental Procedures

Diets were distributed to 4 lots of 6 individually housed ewe lambs (Barbarine breed, 20 kg BLW). The trial lasted 60 days. Feed intake and refusal were recorded daily. Animals were weighed biweekly.

Results

Table 1 shows the chemical composition of dietary ingredients. The dry matter content of the cactus varied between 10 and 24%, which is relatively high for *Opuntia* spp. This is easy to understand because the year was extremely dry. Crude protein content (4.3% DM) was in the normal range. Indeed, an average value of 4% CP is often mentioned (de Kock 1980). Such content depends on the cladode age, cultivar, and fertilization.

The chemical composition of the two types of *Atriplex* was quite similar. The only significant difference was in crude fiber content, which was higher for *A. nummularia* (Table 1).

Table 1. Chemical composition of feeds (% of DM).

Feed	OM	CF	CP
Cactus	80.0	9.2	4.3
<i>Atriplex nummularia</i>	78.8	23.0	14.3
<i>Atriplex halimus</i>	75.8	15.0	14.7
Soybean meal	92.5	6.0	43.2
Barley	97.3	5.0	12.7
Oat hay	91.2	24.3	10.6

OM = organic matter; CF = crude fiber; CP = crude protein (N*6.25).

Table 2. Diet composition (% of dry matter).

Diet	D1	D2	D3	D4
Cactus	34.1	29.2	28.1	33.5
Hay	21.1	16.6	17.2	22.1
Barley	43.7	28.2	28.4	35.8
Urea	1.1	0	0	0
Soybean meal	0	0	0	8.5
<i>Atriplex nummularia</i>	0	0	26.3	0
<i>Atriplex halimus</i>	0	26.0	0	0

Except for cactus, which was fed *ad libitum*, all dietary ingredients were controlled. Compared to other experiments (Nefzaoui et al. 1993; Ben Salem et al. 1996), the amount of cactus consumed was low for all diets, probably because of the low quality of the cladodes (high dry matter content). Analysis of the effect of the other dietary components on voluntary intake of cactus, using the contrast method, showed that there was no significant difference among diets (Table 5.).

On the other hand, the two types of *Atriplex* were equally consumed and seemed to be equally palatable (Table 3.). On a dry matter basis, they represented 26% of the consumed feed.

Table 3. Intakes and liveweight gains.

Diet	D1	D2	D3	D4
Intake (g DM/d):				
Cactus	241	252	241	228
<i>Atriplex halimus</i>	0	224.2	0	0
<i>Atriplex nummularia</i>	0	0	225.8	0
Soybean meal	0	0	0	57.6
Barley	308.8	243.6	243.6	243.6
Hay	149.0	142.9	147.5	150.6
Urea	8	0	0	0
Total intake	706.8	862.7	857.9	679.8
Average daily gains (g/d)	55	58	74	70

Average daily gains were lower than expected (<100 g/day). The highest performance was obtained when cactus was supplemented with *A. nummularia* (74 g/d) or with soybean meal (70 g/d). The lowest was obtained with urea supplementation (55 g/d). Although CP content and intake level were similar for the two types of *Atriplex* (D2 vs D3), animal performance was not the same for both *Atriplex* species. *Atriplex halimus* seemed to be of lower quality than *A. nummularia*. This could be due to the difference in crude fiber content. In fact, all the diets were lacking fiber. The higher amount of fiber supplied by *A. nummularia* may have favored a greater efficiency of rumen bacterial activity through the stimulation of cellulolytic activity. This hypothesis has to be confirmed.

Table 4. Effect of nitrogen source on yearling daily gain and voluntary intake of cactus.

Diet	D1	D2	D3	D4	SEM
Daily gain	54.8	57.0	73.7	70.0	2.35
Cactus voluntary intake:					
g DM/day	241	252	241	228	8.70
g DM/LW ^{0.75}	20.3	21.1	20.7	20.4	0.67

Statistical analysis, using the contrast method to test the source of nitrogen supplement on growth performance, showed that there was a significant difference ($P < 0.05$) between *A. nummularia* and urea. Average daily gains (Table 5) were 56 and 74 g for urea and *A. nummularia*, respectively.

Table 5. Probability values (Pr > F) obtained by the contrast method related to the effect of nitrogen source on daily gain and voluntary intake of cactus.

Contrast	Daily gain	Cactus voluntary intake	
	g DM/d	g DM LW ^{0.75}	
Urea-SBM	0.107	0.697	0.484
A. halimus-A. nummularia	0.074	0.722	0.701
SBM-A. halimus	0.179	0.471	0.447
SBM-A. nummularia	0.666	0.688	0.679
Urea-A. halimus	0.769	0.737	0.951
Urea-A. nummularia	0.041	0.996	0.749

SBM: soybean meal.

Conclusion

Cacti are widespread in arid and semi-arid Mediterranean regions. Large-scale plantations of spineless cactus were established in Tunisia to promote fodder reserves and to reduce rangeland degradation in arid and semi-arid zones. Terminal and sub-terminal pads of spineless cactus have low crude protein (20–50 g/kg DM) and crude fiber (80–150 g/kg DM) contents. They have a high content of ash (150–250 g/kg DM). The dry matter content of cactus varied between 10 and 24%, which is relatively high for *Opuntia*, probably because of the extreme drought during the year of study. This dry matter content may explain the observed low voluntary intake of cactus. Cactus cannot be fed as a sole feed and needs to be supplemented with fiber and protein. The nitrogen sources tested showed that the two types of *Atriplex* may replace soybean meal in such diets to meet the nitrogen requirements of ewes.

It is possible to get almost standard performances by feeding sheep diets based on limited amounts of hay and barley grain, spineless cactus, and *A. nummularia*, *ad libitum*. Such diets are strongly recommended when feed is scarce.

Acknowledgments

Research conducted with the contribution and the financial support of Office de l'Élevage et Pâturages (OEP/INRAT Research for Development contract) and SERST (PNM contract NY PS94BIRD 6).

References

- Barbera, G. 1995. History, economic and agro-ecological importance. Pages 1–11 in *Agro-ecology, Cultivation and Uses of Cactus Pear* (G. Barbera, P. Inglese and E. Pimienta-Barrios, eds.). FAO Plant Production and Protection Paper 132.
- Ben Salem, H., A. Nefzaoui, H. Abdouli and E.R. Orskov. 1996. Effect of increasing level of spineless cactus (*Opuntia ficus indica* var. *inermis*) on intake and digestion by sheep given straw-based diets. *Animal Science* 62: 293–299.
- Cantwell, M. 1995. Post-harvest management of fruits and vegetable stems. Pages 120–136 in *Agro-ecology, Cultivation and Uses of Cactus Pear* (G. Barbera, P. Inglese and E. Pimienta-Barrios, eds.). FAO Plant Production and Protection Paper 132.
- de Kock, G.C. 1980. Drought resistant fodder shrub crops in South Africa. Pages 109–114 in *Browse in Africa. The Current State of Knowledge* (H.N. Le Houérou, ed.). ILCA, Ethiopia.
- Le Houérou, H.N. and M. Corra. 1980. Some browse plants of Ethiopia. Pages 109–14 in *Browse in Africa. The current state of knowledge* (H.N. Le Houérou, ed.). ILCA, Ethiopia.
- Le Houérou, H.N. 1992. The role of *Opuntia* cacti in the agricultural development of Mediterranean arid zones. Segundo Congreso Internacional de Tuna y Cochenilla, Santiago, Chile, 22–25 Sept.
- Monjauze, A. et H.N. Le Houérou. 1965. Le rôle des opuntia dans l'économie agricole Nord-Africaine. *Bulletin de l'ENSA de Tunis* 8(9): 85–164.
- Nefzaoui, A., A. Chermiti and H. Ben Salem. 1993. Spineless cactus (*Opuntia ficus indica* var. *inermis*) as a supplement for treated straw. Pages 130–133 in *Management of Mediterranean Shrublands and Related Forage Resources* (A. Nikolaidis and V. Papanastasis, eds.). FAO Rome.
- Nobel, P.S. 1995. Environmental biology of cactus pear. Pages 36–48 in *Agro-ecology, Cultivation and Uses of Cactus Pear* (G. Barbera, P. Inglese and E. Pimienta-Barrios, eds.). FAO Plant Production and Protection Paper 132.
- Russel, C.E. and P. Felker. 1987. The prickly pear (*Opuntia* spp., Cactaceae): A source of human and animal food in semi-arid regions. *Economic Botany* 41: 433–445.
- Saenz-Hernandez, C. 1995. Food manufacture and by-products of prickly pear. Pages 137–142 in *Agro-ecology, Cultivation and Uses of Cactus Pear* (G. Barbera, P. Inglese and E. Pimienta-Barrios, eds.). FAO Plant Production and Protection Paper 132.

Nutritive Value of Spineless Cactus- (*Opuntia ficus indica* var. *Inermis*) and Atriplex- (*Atriplex nummularia*) based Diets for Sheep

A. Nefzaoui

Laboratoire de Nutrition Animale, INRA, Ariana Tunisie

Abstract

Fifteen Barbarine wethers were randomly allotted to three equal groups, and fed diets based on cactus (*Opuntia ficus indica* var. *inermis*; 80% of the diet) and atriplex (*Atriplex nummularia*). Fixed amounts of wheat straw (180 g/d) and a commercial mineral and vitamin supplement (30 g/d) were also distributed. Animals were housed in metabolic cages during the experiment (30 days of adaptation, and 9 days of measurement). Dry matter (DM) intake was similar for all groups (930–983 g DM/d, 70–73 g DM/kg LW^{0.75}). The relative intakes of atriplex and cactus were 59 and 21%, 41 and 38%, and 25 and 56%, for Diets 1, 2, and 3, respectively. Digestibility coefficients of organic matter (OMD) and crude protein (CPD) were relatively high for all diets, averaging 68, 74, and 75%, respectively. In contrast, fiber digestibility was low, probably because of the soluble carbohydrates in cactus, which may have depressed cellulolytic activity in the rumen. Nitrogen retention was 4.1, 3.9, and 4.1 g/d, for diet 1, 2, and 3, respectively. The diets allowed for about 1.7 times the maintenance of sheep energy and digestible CP (DCP) requirements. Diet 1 met 1.65 and 2.3 times the energy and DCP requirements of sheep. It therefore had an excess of nitrogen and could be supplemented with an energy source like barley grain. Diet 2 was relatively well balanced for energy and nitrogen, while Diet 3 was high in energy and needed to be supplemented with a nitrogen source (non-protein nitrogen), like urea. In conclusion, sheep may be fed diets based on cactus (rich in energy) and atriplex (rich in nitrogen). Both feeds are available during drought years and may therefore reduce feed imports.

Introduction

The main characteristic of arid and semi-arid zones in North Africa is the increasing degradation of rangelands and the consequent decline in feed supply for ruminants. For several reasons, there is a limited number of technologies capable of improving range productivity. Attempts to adopt management practices that would sustain the productivity and quality of the rangeland go back to the 1950s and probably earlier. Prominent among these practices are: reseeding with "improved" drought-tolerant grasses, resting a part of the area under management each year following a grazing period to allow the regeneration of desirable species,

and increasing the seed bank in the soil. Seeding and overseeding of forage species are rarely successful in the arid zones (Le Houérou 1981). An alternative approach coming into favor is the plantation of various introduced and native shrubs. Thus, plantations of fodder shrubs have been established as a drought-evading strategy. The main species used are, in decreasing order: *Opuntia ficus indica*, *Acacia cyanophylla*, *Atriplex nummularia*, and *Atriplex halimus*.

From 1956 to 1989, about 272,000 ha were planted with these species, mainly in the Tunisian arid and semi-arid zones. The strategy for rangeland improvement (1990–2000) calls for the establishment of 600,000 ha of these shrub species.

Cactus is widespread in Tunisia (>200,000 ha). It has been planted in order to prevent erosion and to create a permanent feed resource.

Spineless cactus has low crude protein (20–50 g/kg DM) and crude fiber (80–150 g/kg DM) contents. It is high in ash (150–250 g/kg dry matter), rich in vitamins A and C, and high in readily available carbohydrates. Naturally, cactus cannot be used as a single feed, and needs to be supplemented with fiber and nitrogen. *Atriplex* spp. are a good nitrogen source (Le Houérou 1986; Colomer 1986; Correal et al. 1986) and may also provide the needed fiber.

The objective of this study was to estimate the nutritive value of various diets based on cactus and atriplex.

Material and Methods

Diets

Spineless cactus (*Opuntia ficus indica* var. *inermis*), chopped in little pieces, and edible parts of *Atriplex nummularia* (leaves and twigs) were offered at various levels. Fixed amounts of straw (200 g) and a mineral mix (30 g), corresponding to 20% of total dry matter intake, were added to all diets. The level of cactus in the diets was 21, 38, and 56% of DM for D1, D2, and D3, respectively. The level of atriplex was 59, 42, and 24% of DM for the same diets, respectively.

Feed was distributed daily at 08:00 hours for the straw, 10:00 for the cactus, and 16:00 for the atriplex.

Measurements

Amounts of food offered, refusals, and urine were recorded daily. Feces and urine were collected each day over the experimental period to determine digestibility and nitrogen retention. Samples of food, refusals, feces, and urine were taken daily and bulked by animal for the whole collection period, for subsequent analysis.

Food, refusals, and feces were ground to pass through a 1 mm screen and analyzed for ash, crude protein, and crude fiber contents by conventional procedures (AOAC 1975).

Digestibility and nitrogen balance were determined on Barbarine wethers (5 head/diet, 20 days for adaptation, 7 days for fecal collection, LW 27–35 kg) using metabolic cages.

Results and Discussion

Cactus and atriplex showed high mineral content. Ca was high (5–7% DM). The crude-protein (CP), and crude fiber (CF) contents of cactus were very low. The DM, ash, CP, and CF contents (Fig. 1) for *Atriplex nummularia* and cactus were in agreement with earlier reports (Nefzaoui et al. 1993; Siebert et al. 1968; Wilson 1966; Ben Salem et al. 1996). Figure 1 shows the chemical composition of straw, cactus, and atriplex.

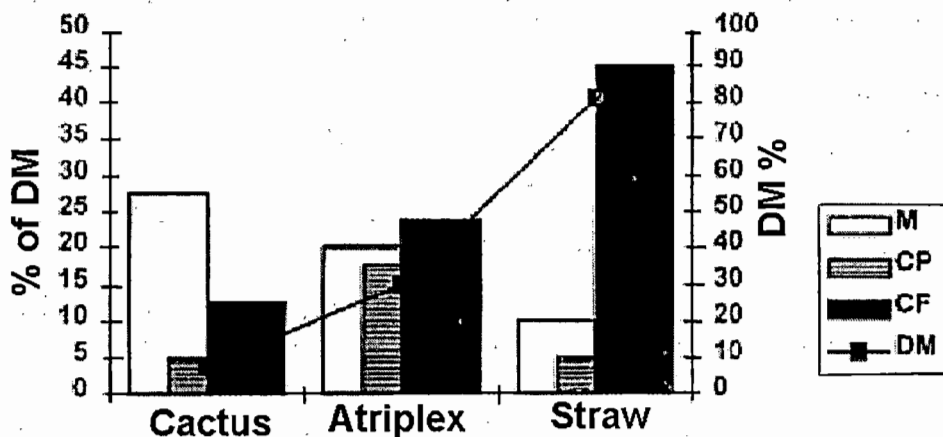


Figure 1. Chemical composition of cactus, atriplex, and straw.

Voluntary intake (Table 1) of cactus was high (6.8 kg/day, equivalent to 550 g DM/day for D3), suggesting that there was no digestive disturbance with dietary cactus levels up to 56% DM. Ben Salem et al. (1996) report similar data. Indeed, sheep given straw *ad libitum* were able to consume up to 560 g DM of spineless cactus, about 50% of the total DM intake, with no digestive disturbance. This is in agreement with earlier findings (Cordier 1947). The pattern of responses to the spineless cactus supply, with respect to fibrous feed intake (straw), is in agreement with the response generally observed for soluble-carbohydrate-rich diets. Thus, the effect of cactus may be similar to that of molasses. These observations were confirmed by the decrease in rumen cellulolytic activity.

Table 1. Feed intake[†].

Diet	D1		D2		D3	
	g DM	%	g DM	%	g DM	%
Cactus	197	21	353	38	550	56
<i>Atriplex</i>	554	59	391	42	236	24
Straw	160	17	159	17	167	17
Minerals mixture	30	3	30	3	30	3

[†] g DM per day, and percentage of total DM intake.

The high value observed in this trial for *Atriplex nummularia* intake is in agreement with earlier observations. Wilson (1977) reports that the palatability of *A. nummularia* is moderate, averaging 550 g DM per day for adult sheep.

Total dry matter intake was high for all diets (Table 2). Values (70–73 g DM/kg metabolic weight) were similar to those usually observed with conventional feeds.

Table 2. Nutritive value of diets.

Diets	D1	D2	D3
Intake [†] (g DM/d)	941 (70)	930 (72)	983 (73)
OMD (%)	67.7	69.3	74.4
CPD (%)	74.5	76.6	75.5
Nitrogen balance (g/d)			
N intake	19.7	15.6	14.0
Fecal N	5.0	3.6	3.2
Urinary N	10.5	8.0	7.2
Retained N	4.1	3.9	3.7

[†] Values () correspond to intakes given in g of DM per kg of LW^{0.75}.

Organic matter (OMD) and crude protein (CPD) digestibility for the three diets were high. The OM digestibility (Table 2) increased with the level of cactus: 67.7% for D1 to 74% for D3.

The CP digestibility was also high for all diets. It ranged from 74.5% for D1 to 76.6% for D3. The OM and CP digestibility figures of cactus and *Atriplex* suggest satisfactory feeding values for these types of diet.

For *A. nummularia*, average digestibility values reported in the literature are quite similar to our results. The average OM digestibility coefficient reported by Wilson (1977) is 72%. Colomer et al. (1986) obtained a calculated value of 77.5% for CP digestibility in *Atriplex nummularia*.

Nitrogen retention (Nr) was positive for all diets (Table 2). Values were satisfactory and varied from 3.7 to 4.1 g/day, which may indicate the relative high quality of nitrogen supplied by *Atriplex*.

With diets rich in *Atriplex* (1 and 2), nitrogen retention did not increase along with the amount of nitrogen intake, because of the higher losses of nitrogen in feces and

urine. These higher losses were probably due to the lower amounts of energy available.

Nutritive value (Fig. 2), calculated according to INRA France methodology (Alimentation des Ruminants 1978), shows that the three diets meet at least 170% of maintenance requirements for energy and nitrogen. Diet 1 has an excess of DCP, while D3 needs to be supplemented with a nitrogen source.

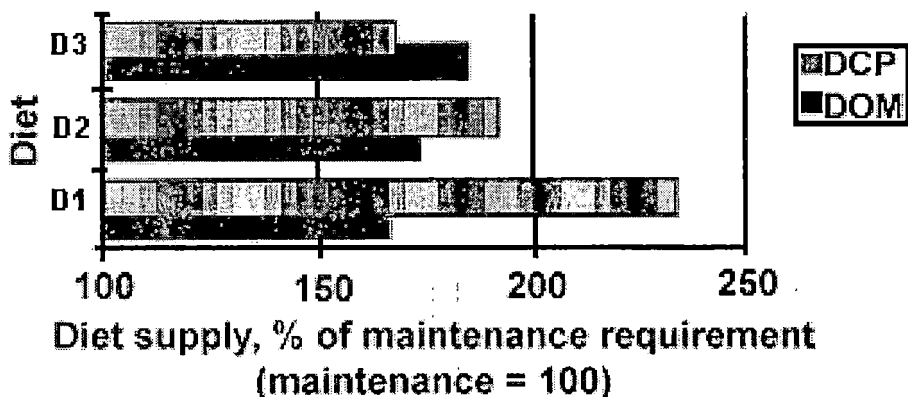


Figure 2. Feeding value of experimental diets, expressed in percent of sheep requirements in energy (digestible organic matter intake, DOM) and nitrogen (digestible crude protein intake, DCP).

These results are very encouraging. According to Le Hou  rou (1992) and to recent observations (Nefzaoui, unpublished), cactus is a buffer feed reserve which may be used during long periods (1–3 years) of drought. In 1946–1948, and more recently in 1993–1995, Tunisian farmers who had established large buffer reserves of fodder cacti went through this event virtually without harm. Le Hou  rou (1992), speaking wisely about this matter, coined the term “drought insurance” to describe the fodder reserve.

Conclusion

Cactus is a good source of energy and atriplex is a good source of nitrogen. Diets based on these two feeds may meet the energy and N requirements of sheep. Voluntary intake of cactus is high, and may reach 7 kg of fresh material for sheep, without any subsequent digestive disturbance. Nevertheless, a small amount of fibrous feed (straw, hay) must be fed to animals before the feed on cactus. The experimental diets, based mainly (80%) on spineless cactus and *A. nummularia*, had high intakes (about 70 g DM/kg metabolic weight). They also had high OM and CP digestibility and a positive nitrogen balance. These diets met about 170%

of the maintenance requirements of sheep in energy and nitrogen; their efficiency would be better if their mineral balance was improved.

In conclusion, these results are encouraging, and diets based mainly on cactus supplemented with atriplex constitute an appropriate solution for feed scarcity in arid and semi-arid zones. These two species can be considered as buffer feed reserves for prolonged drought. They can help farmers prevent destocking and reduce feed costs through the use of on-farm available resources.

Acknowledgments

Research was carried out with the contribution and financial support of the OEP (Research/Development contract) and SERST (PNM contract No. PS94BIRD 6).

References

- AOAC (Association of Official Analytical Chemists). 1975. Official Methods of Analysis (12th ed.). Washington DC.
- Ben Salem, H., A. Nefzaoui, H. Abdouli and E.R. Orskov. 1996. Effect of increasing level of spineless cactus (*Opuntia ficus indica* var. *inermis*) on intake and digestion by sheep given straw-based diets. *Animal Science* 62: 293–299.
- Colomer, S., J. Fonolla, J. Raggi and J. Boza. 1986. Valoración nutritiva del *Atriplex nummularia* en ganado caprino. *Rev. Agr. Prod. Anim.* 6(11/12): 661–665.
- Cordier, G. 1947. Composition de quelques fourrages et leur digestion par le mouton. *Annales du Service Botanique et Agronomique de Tunisie* 20: 25–108.
- Correal, E., J. Silva, J. Boza y C. Passera. 1986. Valor nutritivo de cuatro arbustos forrajeros del género *Atriplex* (*A. nummularia*, *A. cynerea*, *A. undulata* y *A. lampa*). *Pastos* 16: 177–189.
- Le Houérou, H.N. 1981. Impact of man and his animals on Mediterranean vegetation. Pages 479–521 in *Mediterranean-type Shrublands* (F. Di Castri, D.W. Goodall and R.L. Specht, eds.). *Ecosystems of the World*, 11. Elsevier, Amsterdam.
- Le Houérou, H.N. 1986. Salt tolerant plants of economic value in the Mediterranean basin. *Reclamation and Revegetation Research* 5: 319–341.
- Le Houérou, H.N. 1992. The role of *Opuntia cacti* in the agricultural development of Mediterranean arid zones. In *Segundo Congreso Internacional de Tuna y Cochenilla*, 22–25 Sept. Santiago, Chile.
- Nefzaoui, A., A. Chermiti and H. Ben Salem. 1993. Spineless cactus (*Opuntia ficus indica* var. *inermis*) as a supplement for treated straw. Pages 130–133 in *Management of Mediterranean Shrublands and Related Forage Resources* (A. Nikolaidis and V. Papanastasis, eds.). FAO, Rome.
- Siebert, B.D., D.M.R. Newman and D.J. Nelson. 1968. The chemical composition of some arid zone pasture species. *Tropical Grasslands* 2: 31–40.
- Wilson, A.D. 1966. The value of *Atriplex* (salt-bush) and *Kochia* (bluebush) species as food for sheep. *Australian Journal of Agricultural Research* 17: 147–153.
- Wilson, A.D. 1977. The digestibility and voluntary intake of the leaves of trees and shrubs by sheep and goats. *Australian Journal of Agricultural Research* 28: 501–508.

Palatability of Mediterranean Shrubs: Comparison between Browsing and Cafeteria Techniques using Goats

A. Nefzaoui¹, H. Ben Salem¹, H. Ferchichi¹ and H. Abdouli²

¹INRA de Tunisie, Laboratoire de Nutrition Animale, Ariana, Tunisia

²ESA, Mateur, Laboratoire de Nutrition Animale, Mateur, Tunisia

Abstract

This study was conducted to compare two methods of estimating palatability, free browsing, and cafeteria-style feeding. Trials took place on approximately 20 hectares in the semi-arid rangelands of central Tunisia, characterized by the presence of herbaceous and woody species. There were seven dominant woody species present at various covering rates: *Artemisia campestris* (13.7%), *Artemisia herba-alba* (0.8%), *Cistus libanotus* (6.1%), *Cistus salvifolius* (3.8%), *Globularia alypum* (7.2%), *Pistacia lentiscus* (5.1%), and *Rosmarinus officinalis* (5.9%). Alpine × local-bred goats were used. Browsing showed a wide variation among shrubs and months. Goats spent an average of 60% of their browsing time on woody species. There was no significant difference between morning and afternoon browsing. Relative palatability of shrubs changed widely between March and May. Palatability was not correlated with the chemical composition of shrubs. Browsing and the cafeteria technique were not well correlated in terms of palatability. Confined goats showed constant preferences for shrubs, while browsing goats showed a great variation according to the month. The choice of an accurate method for palatability determination remains unclear.

Introduction

Shrublands in the arid and semi-arid regions are subject to high animal and human pressures. Their durable management requires a good knowledge of plant-animal interactions. Knowledge of palatability is therefore an important tool in determining management practices. The meaning of palatability is not well defined in the literature. The subcommittee on Range Research Methods defined palatability as "the quality in a forage plant that makes it preferred when a choice of various plants is available" (Marten 1970). Two methodologies are commonly used to measure forage palatability: (i) the free-browsing trial, which involves continuous observation of browsing animals, eye examination of swards before and after browsing, and weighing of clippings or esophageal canulae; (ii) and the stall-feeding trial, based on consumption time or quantitative measurement of forage consumed. Results obtained in free-browsing trials do not always agree with those found with confined animals, since many factors may interfere with

animal preference in both methods. This paper deals with a direct comparative study with goats between the free-browsing and stall-feeding methods for palatability measurement of range species.

Material and Methods

Study Area

This investigation was performed from March to May 1993, at the Oueslatia Experimental Station of the National Agricultural Research Institute of Tunisia, located in a semi-arid zone (average annual rainfall 400 mm) at 35° 51' N latitude and a 9° 35' E longitude. Mean monthly temperatures during the experimental period were 13.5, 17.2, and 24°C, for March, April, and May, respectively. The experimental rangeland covered approximately 20 ha. In addition to herbaceous species, seven dominant woody species were present at various covering rates: *Artemisia campestris* (13.7%), *Artemisia herba-alba* (0.8%), *Cistus libanotus* (6.1%), *Cistus salvifolius* (3.8%), *Globularia alypum* (7.2%), *Pistacia lentiscus* (5.1%), and *Rosmarinus officinalis* (5.9%).

Free-browsing trial

Three Alpine × local-bred goats (17 months old, 30 kg average liveweight) were marked with three different colors and allowed to browse with a 200 head flock on the rangeland for three consecutive days each month. During this period, animals were on pasture from 09:00 to 16:00 hours each day. The time spent by each goat consuming a particular plant species (T) was recorded during a 30 minute period, according to a 3 × 3 Latin square design (3 animals × 3 observation orders). Daily observations of the experimental animals were carried out in the morning and in the afternoon. Thus, total observation time of goats per day was 180 minutes (90 minutes in the morning and 90 minutes in the afternoon). Animals were watered twice daily. In the barn, each animal received a supplement of 400 g barley grain and 200 g barley hay.

Stall feeding trial

Palatability of shrubs was also determined for stall-fed goats during the same period (March, April, and May). From the same flock, we choose nine Alpine × local—bred goats (17 months old, 30 kg average liveweight) for the study. Animals were split into three homogenous groups and confined by group in covered boxes, equipped with eight troughs each. Before the start of the study, animals were adapted to the experimental conditions for one week. Shrub palatability was measured during a 15 day period each month. At 09:00 hours on days 1 to 15, the experimental goats received freshly cut shrubs (seven shrubs) *ad libitum* and a supplement of 400 g of barley grain per head. The shrubs were cut

daily from the same experimental rangeland, as in the free-browsing trial. The distribution of shrubs in the troughs was changed daily to avoid a “habit reflex” of the animals. Approximately 200 g/head of barley hay was offered to animals at 09:00 hours during the first five days of the trial. During days 16 to 30, animals were fed barley/hay-based diets supplemented with 400 g of barley grain. Water was continuously available.

For each group, amounts of feed offered and refused were recorded daily and sampled for dry matter determination (105°C for 24 h). Samples of each feed offered were taken daily and stored for subsequent analysis. Feed samples were pooled and dried at 50°C. They were then ground to pass through a 1 mm screen and analyzed for ash, crude protein, and crude fiber contents by conventional procedures (AOAC 1975). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) contents were also determined (Van Soest 1963). *In sacco* degradability of each shrub was determined using the nylon bag technique on two ruminal fistulated cows. Each shrub was incubated in the rumen for 4, 8, 16, 48, 72, and 96 hours.

Definitions and Calculations

- I1D: shrub intake on day 1, expressed as a percentage of the amount of shrub offered.
- I5D: average shrub intake for the first five-day period, expressed as a percentage of the average amount of shrub offered for the first five-day period.
- I10D: average shrub intake for the second five-day period, expressed as a percentage of the average amount of shrub offered for the second five-day period.
- I15D: average shrub intake for the third five-day period, expressed as a percentage of the average amount of shrub offered for the third five-day period.

Results and Discussion

Stall-fed Results (Cafeteria Technique)

There was no significant correlation between the initial choice of shrubs and the adapted choices (I1D and I5D, I1D and I10D, I1D and I15D). Such results seem to show the effect of animal species on plant palatability, since they are different from our previous data obtained with sheep and camels (Ben Salem et al. 1994). Results for goats suggest that it would be more appropriate to measure palatability after a 10-day adaptation period. Figure 1 shows the effect ($P < 0.001$) of month (season) and plant species on relative intake of shrubs (I15D) and, presumably, on

palatability. *Artemisia campestris* was the most palatable species, regardless the month. This observation does not agree with the generally accepted opinion that this species is not palatable. In contrast, *Rosmarinus officinalis* showed low palatability, mainly in May, probably due to its high content of volatile oils.

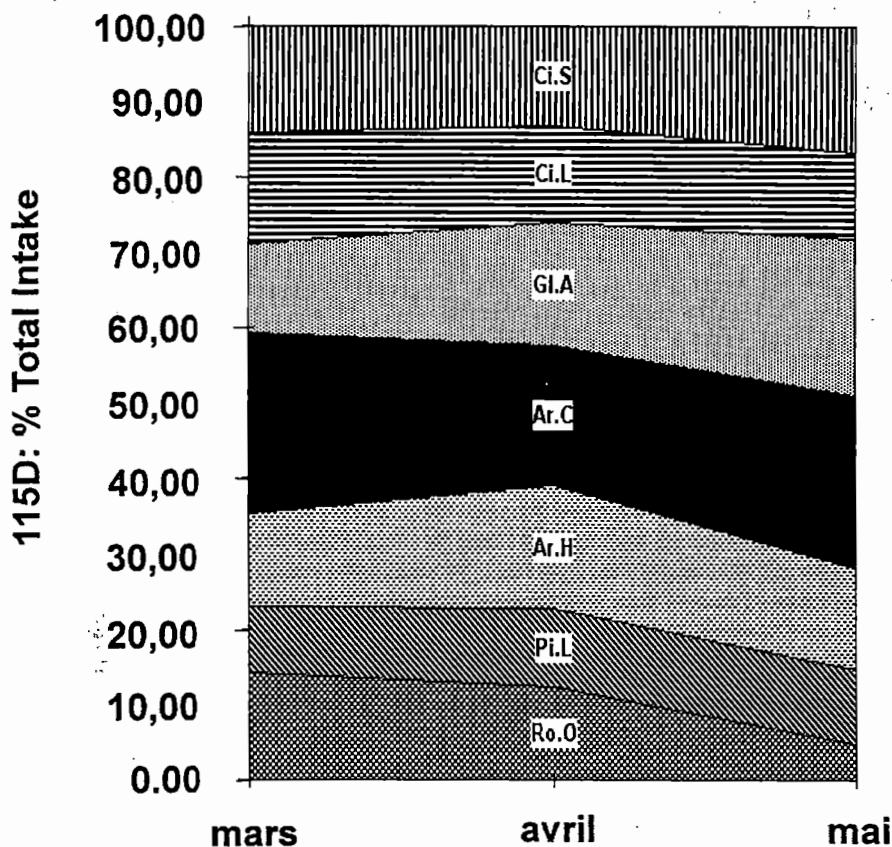


Figure 1. Monthly variations of relative intake of shrubs (cafeteria technique). Ci.S = *Cistus salvifolius*; Ci.L = *Cistus libanotus*; Gl.A = *Globularia alypum*; Ar.C = *Artemisia campestris*; Ar.H = *Artemisia herba-alba*; Pi.L = *Pistacia lentiscus*; Ro.O = *Rosmarinus officinalis*.

Free Browsing Results

Browsing showed a wide variation among shrubs and months. Goats spent an average of 60% of their grazing time on woody species (Fig. 2). When compared with the cafeteria technique, this suggests that the free-browsing method is different from the cafeteria technique. *Artemisia campestris* and *Rosmarinus officinalis*, which had low palatability in the pasture, were more palatable to

confined animals when compared to other shrubs. Overall, regression analysis of palatability showed no significant correlation between free-browsing and the cafeteria (I15D) technique. Such astringency represents a weakness of the cafeteria technique when used for palatability determination. Animals confined for long periods become accustomed to stall conditions. They fix their choice of feed regardless of variations in plant characteristics. To our knowledge, only Otal et al. (1991) carried out a comparative sheep study of these two methods. They conclude that both free browsing and stall feeding give similar results on palatability of shrubs, and that the former method seems more informative in terms of plant-animal interactions. This does not seem to apply for goats, probably because of their selective behavior on the pasture.

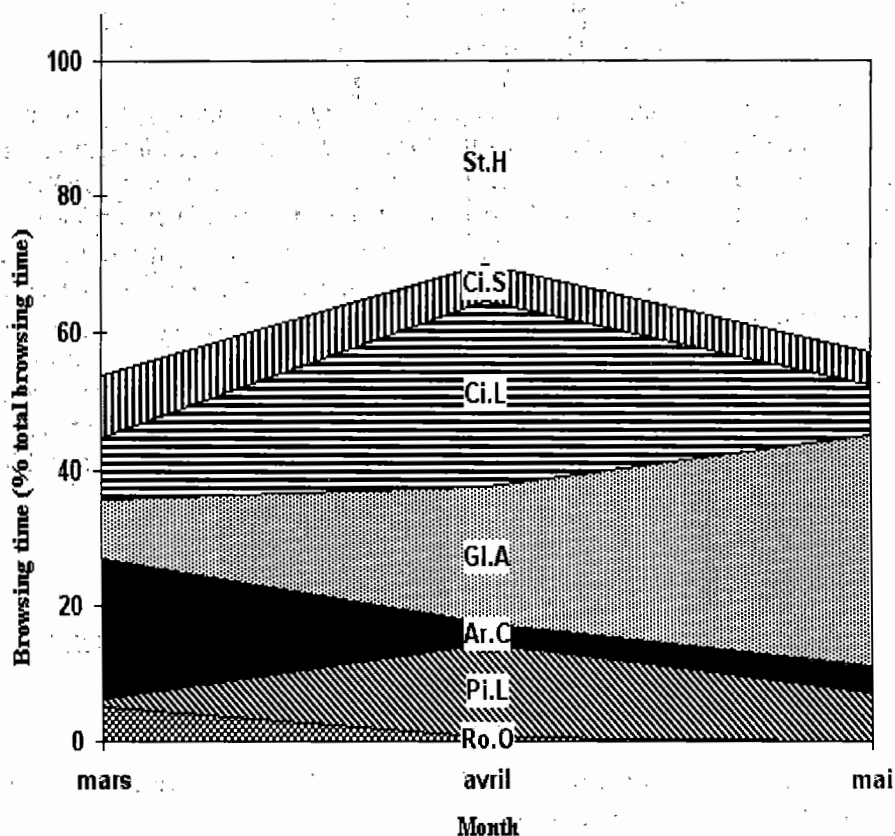


Figure 2. Monthly variation of the relative browsing time. St.H = stem herbaceous; Ci.S = *Cistus salvifolius*; Ci.L = *Cistus libanotus*; Gl.A = *Globularia alyspum*; Ar.C = *Artemisia campestris*; Ar.H = *Artemisia herba-alba*; Pi.L = *Pistacia lentiscus*; Ro.O = *Rosmarinus officinalis*.

In terms of palatability variation among shrubs, a question arises as to whether animal preferences are dependent upon plant characteristics or not. Regression analysis showed no relationship between palatability measured on free-browsing animals and nutrient content (crude protein, crude fiber, neutral detergent fiber, acid detergent fiber, and acid detergent lignin) and *in sacco* degradation parameters for shrubs. On the other hand, palatability measured on cafeteria-fed animals (I15D) was found to be significantly correlated with the fiber fractions (NDF, ADF, CF) of shrubs (Eqs. 1–3), and with the rapidly degradable dry matter fraction of shrubs (a) in the rumen (Eq. 4).

$$\text{I15D} = 0.092 + 0.0033 \text{ NDF}, r^2 = 0.2 \quad [1]$$

$$\text{I15D} = 0.105 + 0.004 \text{ ADF}, r^2 = 0.27 \quad [2]$$

$$\text{I15D} = 0.142 + 0.004 \text{ CB}, r^2 = 0.23 \quad [3]$$

$$\text{I15D} = 0.545 - 0.007 a, r^2 = 0.64 \quad [4]$$

Since it was not established that browsing time was related significantly to amount consumed, the choice of an accurate method for palatability determination remains unclear. One could ask, what is the less problematic method for palatability measurement? The cafeteria technique is relatively easy, but experimental procedures need further investigation (e.g., duration of measurement, how to avoid animal adaptation, animal species to be used, and number of plant species offered). The free-browsing technique gives different results, which often agree with shepherds' observations. Compared to the cafeteria technique, free browsing involves many behavioral factors (e.g., social, climate). Results obtained in this study fail to show any significant effect of plant nutritional characteristics on palatability. The effect of anti-nutritional compounds in shrubs on their palatability needs further investigation.

Acknowledgments

Research was conducted with the contributions and financial support of OEP.

References

- AOAC (Association of Official Analytical Chemists). 1975. Official Methods of Analysis (12th ed.). AOAC, Washington, DC.
- Ben Salem, H., A. Nefzaoui, and H. Abdouli. 1994. Palatability of shrubs and fodder trees measured on sheep and dromedaries. I. Methodological approach. *Animal Feed Science Technology* 46: 143–153.
- Marten, G.C. 1970. Measurement and significance of forage palatability. Pages 1–55 in *Proceedings of the National Conference on Forage Quality, Evaluation and Utilization*, Nebraska, 3–4 Sept 1969. Lincoln, Nebraska, USA.

- Otal, J., E. Correal y C. Belmonte. 1991. Variaciones estacionales de la palatabilidad y consumo por el ganado ovino de diversos arbustos forrajeros preseleccionados en el SE Español. XXXI reunion cientifica de la SEEP, seria congresos, Murcia 4: 353-357.
- Van Soest, P.J. 1963. Use of detergents and the analyses of fibrous feeds. II. A rapid method for determination of fiber and lignin. *Journal of the Association of Agricultural Chemistry* 46: 829-835.

Improvement of the Nutritive Value of Tannin-rich Fodder Trees: Effect of Air-drying and Polyethylene Glycol Treatment of *Acacia cyanophylla* Lindl. Foliage on Intake, Digestibility and Growth in Sheep

H. Ben Salem¹, A. Nefzaoui¹, L. Ben Salem² and H. Abdouli³

¹INRA de Tunisie, Laboratoire de Nutrition Animale, Ariana, Tunisia

²Office de l'Elevage et des Pâturages, Tunis, Tunisia

³Ecole Supérieure d'Agriculture de Mateur, Mateur, Tunisia

Abstract

The effect of air-drying and polyethylene glycol (PEG) treatment of *Acacia cyanophylla* Lindl. leaves on intake, digestibility, and growth in sheep was studied. Three diets were tested, based on acacia leaves: fresh leaves (D1), air-dried leaves (D2), and fresh acacia leaves sprinkled with a PEG solution (D3). All diets were supplemented with 400 g barley. In order to determine acacia intake and growth rate, 5 six-month-old Barbarine lambs were fed each diet for 70 days. Diet digestibility was measured on five adult Barbarine sheep using the total fecal collection technique. A decrease of condensed tannin (CT) content was observed when acacia leaves were air-dried or treated with PEG (58, 43, and 21 g/kg DM for fresh, dried, and PEG-treated leaves, respectively). Drying and PEG treatment had no effect on acacia intake in either growth or digestibility trials. Air-drying had no effect on acacia digestibility; whereas a significant ($P < 0.05$) improvement of crude protein digestibility (CPD) of acacia leaves was obtained with the PEG treatment. CP digestibility of acacia averaged 18.6, 17.2 and 68.8% for fresh, air-dried, and PEG-treated leaves, respectively. The beneficial effect of the PEG treatment was also validated by the growth trial. Lambs fed PEG-treated acacia had the highest liveweight gains when compared to lambs fed on fresh or air-dried leaves (95.3, 68.7, and 73.2 g/day, respectively). In conclusion, the nutritive value of fresh and air-dried acacia leaves is low. PEG treatment may be used to improve the productivity of sheep fed acacia-based diets.

Introduction

Acacia cyanophylla Lindl. (syn. *A. saligna*) provides valuable fodder for ruminants in arid and semi-arid regions of Tunisia. Earlier reports (Reed et al. 1990; Ben Salem and Nefzaoui 1993) conclude that *A. cyanophylla* is less suitable as a protein supplement than might be expected from its relatively high crude protein content (12–15% of dry matter). The protein digestibility of *A. cyanophylla* in sheep proved to be low due to its high levels of condensed tannins.

Attempts to improve the nutritive value of *A. cyanophylla* were made in our laboratory. Ben Salem et al. (submitted) showed that air-drying of *A. cyanophylla* foliage increases dry matter intake by sheep, but has no significant effect on digestibility and ruminal fermentation when compared to fresh foliage. In another study, Ben Salem et al. (1995) found that the improvement of rumen condition, by the supply of exogenous sources of nitrogen (urea) and energy (spineless cactus), does not improve the nutritive value of *A. cyanophylla* foliage. Therefore, the deactivation of *A. cyanophylla* tannins by the use of appropriate chemicals seems, *a priori*, the sole solution to be considered. It was demonstrated that PEG binds tannins, and is not digested by sheep (Sperber et al. 1953). The use of PEG under certain conditions was found to increase feed intake, digestibility (Larwence et al. 1984), liveweight, and wool growth by sheep fed tannin-rich diets (Barry et al. 1986; Pritchard et al. 1992). The authors are not aware of any published data on the effect of PEG supply on the nutritive value of *A. cyanophylla*-based diets. Moreover, studies on the effect of air-drying on the nutritive value of *A. cyanophylla*-based diets and performance of sheep given such diets are lacking. In this paper, we report the findings of a comparative study on intake, digestibility, and growth by sheep fed fresh, air-dried, and PEG-treated foliage of *A. cyanophylla*.

Material and Methods

Two trials were carried out simultaneously between February and April 1995. A growth trial was performed at the Pasture and Livestock Office (OEP) farm located at Jebibina, and a digestibility trial was performed at the INRA-Tunisia headquarters.

Plant Material

The *A. cyanophylla* foliage used in this study was purchased from the OEP farm at Jebibina (semi-arid region). Mean annual rainfall on the farm was 380 mm. During the course of the experiment, acacia was harvested early in the morning each day. The leaves were hand separated and immediately transported to the barn, where they were fed to animals either as fresh, PEG-treated, or air-dried material. Building on the results of a preliminary study, the 2 PEG/1 condensed-tannin ratio and the drying of acacia in the shade for 14 days were used for the digestibility and growth trials. PEG treatment of fresh acacia foliage was achieved by dissolving 9 g in 30 mL of water per 100 g of DM acacia foliage. The PEG solution was sprayed onto the acacia foliage. Treated acacia was mixed by hand at the point of feeding.

Digestibility Trial

Animals and diets

Fifteen Queue Fine de l'Ouest adult sheep, with an average initial liveweight of 50.0 ± 4.5 kg, were used. They were stratified according to liveweight and randomized to give five replicates of three diet treatments:

- D1: acacia fresh foliage *ad libitum* + 400 g barley + 30 g mineral and vitamin supplement (MVS).
- D2: acacia air-dried foliage *ad libitum* + 400 g barley + 30 g MVS.
- D3: acacia PEG-treated foliage *ad libitum* + 400 g barley + 30 g MVS.

A supplement (400 g processed barley + 30 g MVS) was distributed once a day, while acacia was distributed *ad libitum* two times a day, allowing for 20% refusals.

Animals were housed in metabolism cages. The diets were offered for an acclimatization period of 15 days, followed by a 10-day balancing period during which feces and urine were collected. Clean drinking water was continuously available.

Procedures

During the collection period, feed was weighed daily and offered at 09:00 hours to each animal, after removing the refusals from the previous day. Total feces was collected each morning at 08:00 hours, weighed, and a 10% aliquot retained and composited for each animal within the collection period. Feces were stored frozen during the collection period. Dry matter content of feed, refusals, and feces was determined daily by drying representative samples at 105°C for 24 hours. Urine was collected into containers with 100 mL 10% H₂SO₄ added to maintain pH below 3.0. A 10% aliquot of urine was retained daily and composited for each sheep within the 10 day collection period. Urine samples were stored at -20°C for laboratory analysis. Feed, refusals, and fecal samples were dried in a forced-air oven at 50°C, ground to pass through a 1 mm screen, and stored for subsequent analysis. Samples of fresh and PEG-treated foliage were obtained daily, composited for each treatment, and stored at -20°C for subsequent analysis.

Growth Trial

Animals and diets

Eighteen Barbarine wethers (4 months old, 20.0 ± 1.8 kg initial liveweight) were used. Animals were stratified based on weight and allotted in a randomized design to one of the three diet treatments listed below, resulting in six wethers per treatment. Animals were housed individually in stalls with individual feed and

water troughs throughout the experiment. The same diets (D1, D2, and D3) tested in the digestibility trial were used. Animals had free excess to fresh water.

The growth trial lasted 70 days. The first 10 days were used to adapt animals to experimental conditions. During the following 60 days, the amount of feed offered and refusals were recorded daily for each animal. Samples of feed and refusals were taken daily and dried at 105°C for 24 hours in a ventilated oven. Dry matter rates were determined and used to calculate daily feed intake. Samples of acacia foliage were prepared weekly for chemical analysis. After a 12-hour fast, animals were weighed on two consecutive days at the beginning and the end of the growth trial.

Chemical Analysis

Feeds, orts, and feces collected in the digestibility trial were analyzed for ash, crude protein (CP), crude fiber (CF) (AOAC 1975), neutral detergent fiber (NDF), and non-sequential acid detergent fiber (ADF) (Goering and Van Soest 1970). Feeds were also analyzed for acid detergent lignin (ADL) according to Goering and Van Soest. Composited samples of fresh and PEG-treated leaves of *A. cyanophylla* were ground using a refrigerated blinder. Triplicated 200 mg samples of fresh, air-dried, and PEG-treated material were extracted in aqueous methanol (50%) overnight at 4°C. Samples were analyzed for condensed tannins using the acidified vanillin technique (Broadhurst and Jones 1978). Urine was analyzed for nitrogen (N) using the Kjeldahl technique (AOAC 1975).

Statistical Analysis

Data from digestibility and growth trials were analyzed as a randomized complete design using the GLM procedures of SAS (1985). Differences in mean value among diet treatments were compared by Duncan's multiple range test.

Results and Discussion

Digestibility Trial

Chemical composition

The chemical composition of feeds offered to sheep is shown in Table 1. The OM, CP, CF, NDF, and ADF were quite similar across acacia treatments. The ADL level was high in all acacia treatments. Condensed tannins in fresh foliage accounted for 5.8% of DM. Air-drying led to a decrease (1.5 percentage units) of CT in acacia foliage. The rate of decrease of CT was more pronounced in PEG-

treated acacia (3.7 percentage units). The depressive effect of PEG on the CT level in *Lotus pedunculatus* was noted by Barry and Forss (1983).

Table 1. Chemical composition of feeds (DM basis).

	Acacia foliage			Barley
	Fresh	Air-dried	PEG-treated	
DM (%)	44.0	88.0	37.4	88.5
OM	87.2	85.3	86.3	96.9
CP	13.9	13.3	14.5	11.5
CF	21.0	21.7	19.6	7.8
NDF	43.7	44.4	45.0	28.0
ADF	27.2	26.8	28.0	6.2
Condensed tannins [†]	5.8	4.3	2.1	0.4

[†] Condensed tannins expressed as g equivalent catechin per 100 g DM.

Intake and digestibility

Data on feed intake and digestibility are shown in Table 2. DM intake of acacia foliage, reported as either absolute (g/day) or relative (g/kg LW^{0.75}), was similar ($P > 0.05$) across dietary treatments: 646–650 g/day or 33–37 g/kg LW^{0.75}. The absence of a PEG effect on acacia intake disagreed with findings of Barry and Duncan (1984) and Pritchard et al. (1992). An increase of tannin-rich forage (*Lolium pedunculatus* or *Acacia aneura*) intake was observed on sheep given PEG. DM and OM digestibility of the diet tended to increase without significance ($P > 0.05$) with air-drying and PEG treatment. The PEG treatment improved ($P < 0.05$) total diet CF, NDF, and ADF digestibility.

Table 2: Intake and apparent digestibility of diets.

	Acacia treatment			SEM [†]
	Fresh	Air-dried	PEG-treated	
DM intake (g/day)				
Acacia	650.4 ^a	659.1 ^a	646.2 ^a	31.44
Diet	1,004.2a ^a	1,013.0 ^a	1,018.5 ^a	28.07
DM intake (g/kg LW ^{0.75})				
Acacia	35.1a	36.6a	33.6a	1.44
Diet	54.3a	56.6a	52.4a	1.20
Diet digestibility (%)				
DM	57.5a	60.8a	61.9a	1.17
OM	60.6a	61.2a	62.9a	1.23
CF	48.6b	55.4ab	58.8a	1.23
NDF	46.4b	46.2b	54.9a	1.54
ADF	37.9b	37.7b	44.9a	1.73
CP	38.7b	41.5b	72.8a	0.92
DOMi (g/kg LW ^{0.75}) [‡]	29.9a	28.0a	30.3a	0.95
DCPi (g/day) [‡]	50.7b	44.9b	98.9a	2.81

[†] SEM = standard error of the mean.

[‡] DOMi = digestible organic matter intake; DCPi = digestible crude protein intake.

a, b = Means in the same row with different superscripts differ ($P < 0.05$).

Table 3. Apparent digestibility of fresh, air-dried, and PEG-treated foliage of *Acacia cyanophylla*.

	Acacia treatment			SEM [†]
	Fresh	Air-dried	PEG-treated	
Acacia digestibility (%) [‡]				
DM	40.6a	42.1a	47.3a	1.77
OM	43.1a	39.0a	46.8a	1.82
CF	43.2a	50.6a	55.1a	1.47
NDF	33.6b	34.2b	45.4a	1.93
ADF	36.9b	36.8b	44.4a	1.85
CP	18.6b	17.2b	68.8a	1.55
DOMi (g/kg LW ^{0.75})	13.4a	10.1a	14.1a	0.83
DCPi (g/day)	17.7b	11.9b	65.9a	2.81

[†]SEM = standard error of the mean.[‡]Calculated by difference.a, b = Means in the same line with different superscripts differ ($P < 0.05$).

Barry and Duncan (1984) report similar findings. In contrast, air-drying had no effect on diet digestibility. It is important to speculate that while air-drying had no effect on CP digestibility, PEG-treatment markedly increased this parameter. For the fresh acacia treatment, the rate of increase of CP digestibility obtained with the PEG-treatment was about 90%. The clear-cut positive effect of PEG on digestive use of CP has been reported (Barry et al. 1986; Nunez-Hernandez et al. 1991). The absence of variation of diet DM intake and OM digestibility, which occurred with an improvement of diet CP digestibility in the PEG treatment, resulted in no change of digestible organic matter intake (DOMi) but a significant increase of digestible crude protein intake (DCPi). The same result was observed in acacia digestibility. To estimate acacia nutrient digestibility, it was hypothesized that there were no additive effects and thus no interaction between diet ingredients (acacia and barley). Given this assumption, acacia nutrient digestibility (OM, CP, CF, NDF, and ADF) was statistically the same between fresh and air-dried acacia treatments. However, PEG-treatment increased fiber (CF, NDF, and ADF) and CP digestibility of acacia foliage significantly ($P < 0.05$). PEG seems to react with acacia tannins, resulting in an increase of CP digestibility by 50 percentage units.

Nitrogen balance

Nitrogen balances for dietary treatments are shown in Table 4. Although sheep ingested equal amounts of nitrogen (N), N excretion in feces and urine was similar in sheep fed fresh or air-dried acacia foliage.

In contrast, fecal nitrogen was markedly decreased ($P < 0.05$) in sheep fed PEG-treated acacia (5.8 and 12.7 g/day for the PEG and fresh acacia treatments, respectively). Urinary nitrogen tended to increase without significance ($P > 0.05$) with the PEG treatment. Consequently, N retention was highest in sheep fed PEG-treated acacia (8.9 g/day), compared to those receiving fresh (3.2 g/day) or air-

dried (2.3 g/day) acacia. These results confirm those obtained by Barry et al. (1986).

Table 4: Quantities of nitrogen (N) ingested, excreted in feces and urine, and retained in sheep fed fresh, air-dried, and PEG-treated *Acacia cyanophylla*.

	Acacia treatment			SEM [†]
	Fresh	Air-dried	PEG-treated	
Nitrogen (g/day)				
Intake	20.8a	20.3a	21.7a	0.69
Feces	12.7a	10.1b	5.8c	0.24
Urine	4.9a	4.9a	6.9a	0.43
Retained				
g/day	3.2b	2.3b	8.9a	0.68
N intake (%)	14.2b	13.4b	40.2a	2.74

[†] SEM: standard error of the mean.

a, b = Means in the same line with different superscripts differ ($P < 0.05$).

Growth Trial

Feed intake and growth

Data on intake and sheep performance are reported in Table 5. DM intake of acacia foliage reported in relative terms ($\text{g/kg LW}^{0.75}$) was quite similar across dietary treatments (27–33 $\text{g/kg LW}^{0.75}$). As indicated in the digestibility trial, neither air-drying nor the PEG treatment seem to influence acacia consumption by growing sheep. Sheep given PEG-treated acacia gained more (95.3 g/day) than those given fresh (68.7 g/day) or air-dried (73.2 g/day) acacia. Although acacia consumption was quite similar across dietary treatments, sheep fed PEG-treated acacia were more efficient ($P < 0.05$) than those given fresh or air-dried acacia. Daily gain-to-feed consumption ratios were 0.10, 0.10, and 0.15 for the fresh, air-dried, and PEG-treated acacia, respectively.

Table 5: Feed intake and liveweight change in growing sheep fed on fresh, air-dried, and PEG-treated *Acacia cyanophylla*-based diets.

	Acacia treatment			SEM [†]
	Fresh	Air-dried	PEG-treated	
DM intake (g/day)				
Acacia	336.6a	349.7a	277.7a	12.30
Diet	690.5a	713.5a	631.5a	11.39
DM intake ($\text{g DM/kg LW}^{0.75}$)				
Acacia	33.4ab	36.1a	27.8b	1.07
Diet	68.9ab	71.9a	63.1b	1.13
Daily gain (g/day)	68.7b	73.2b	95.3a	2.25
Gain/feed	0.10b	0.10b	0.15a	0.01

[†] SEM = standard error of the mean.

a, b = Means in the same line with different superscripts differ ($P < 0.05$).

Conclusion

Air-drying had no effect on the nutritive value of *A. cyanophylla*. However, in agreement with numerous works in the literature, PEG treatment improved the nutritive value of *A. cyanophylla*. Condensed tannins of *A. cyanophylla* seem to have an affinity with PEG. Consequently, digestive use of acacia proteins was substantially improved. Although PEG treatment improved the nutritive value of acacia foliage, it does not seem to be a viable management practice. Other PEG uses should be investigated. Special attention should be devoted to economical evaluation of this technique.

Acknowledgments

This work was financed by the Office de l'Elevage et des Pâturages de Tunisie (OEP) as a part of a Research-Development contract with OEP-INRAT and SERST (PNM contract No. PS94BIRD 6).

References

- AOAC (Association of Official Analytical Chemists). 1975. Official Methods of Analysis (12th ed.). AOAC, Washington, DC.
- Barry, T.N. and D.A. Forss. 1983. The condensed tannin content of vegetative *Lotus pedunculatus*, its regulation by fertilizer application, and effect upon protein solubility. *Journal of Science Food Agriculture* 34: 1047–1056.
- Barry, T.N. and S.J. Duncan. 1984. The role of condensed tannins in the nutritional value of *Lotus pedunculatus* for sheep I. Voluntary intake. *British Journal of Nutrition* 51: 485–491.
- Barry, T.N., T.R. Manley and S.J. Duncan. 1986. The role of condensed tannins in the nutritional value of *Lotus pedunculatus* for sheep. IV. Sites of carbohydrate and protein digestion as influenced by dietary reactive tannin concentration. *British Journal of Nutrition* 55: 123–137.
- Ben Salem, H. and A. Nefzaoui. 1993. Effect of increasing levels of *Acacia cyanophylla* on intake, digestibility and ruminal digestion on sheep fed straw-based diets. Pages 118–121 in 7th Meeting of the FAO Sub-network on Mediterranean Pastures and Fodder Crops. 21–23 April, Greece.
- Ben Salem, H., A. Nefzaoui, H. Abdouli and L. Ben Salem 1995. Energy or nitrogen supply to sheep fed *Acacia cyanophylla* Lindl. leaves based diets. Effects on intake and digestion. *Annales de Zootechnie* 44 Suppl. 76.
- Broadhurst, R.B. and W.T. Jones. 1978. Analysis of condensed tannins using acidified vanillin. *Journal of Sci. Food Agriculture* 29: 788–794.
- Goering, H.K. and P.J. Van Soest. 1970. Forage Fiber Analysis. Pages 1–9 in Agriculture Handbook No. 379. USDA, Agricultural Research Service, Washington, DC.
- Larwence, A., F. Hammouda et A. Salah. 1984. Valeur alimentaire des marcs de raisin. III. Rôle des tannins condensés dans la faible valeur nutritive des marcs de raisin chez le mouton: effet d'une addition de polyéthylène glycol 4000. *Annales de Zootechnie* 33: 533–543.

- Nuñez-Hernandez, G., J.D. Wallace, J.L. Holechek, M.L. Galyean, and M. Cardenas. 1991. Condensed tannins and nutrient utilization by lambs and goats fed low-quality diets. *Journal of Animal Science* 69: 1167–1177.
- Pritchard, D.A., P.R. Martin and P.K. O'Rourke. 1992. The role of condensed tannins in the nutritional value of mulga (*Acacia aneura*) for sheep. *Australian Journal of Agricultural Research* 43: 1739–1746.
- Reed, J.D., H. Soller and A. Woodward. 1990. Fodder tree and straw diets for sheep: intake, growth, digestibility and the effects of phenolics on nitrogen utilization. *Animal Feed Science and Technology* 30: 39–50.
- Sperber, I., S. Hyden and J. Ekman. 1953. The use of polyethylene glycol as a reference substance in the study of ruminant digestion. *K Lanthrb Hogsk Ann* 20: 337–344.

Evolution de la Composition Chimique et de la Digestibilité *in vitro* de Quatre Arbustes Halophytes dans le Sud Tunisien

T. Khorchani¹, M. Hammadi¹, H. Abdouli² et H. Essid²

¹Institut des Régions Arides Médenine, Tunisie

²Ecole Supérieure d'Agriculture Mateur, Tunisie

Résumé

Quatre arbustes halophytes (*Atriplex halimus*, *Nitraria retusa*, *Tamarix gallica*, et *Limoniastrum guyonianum*) ont été choisis parmi la liste des espèces appréciées du parcours fréquenté par le troupeau de dromadaires de l'Institut des Régions Arides de Médenine. Des échantillons de la partie consommable de ces espèces ont été prélevés le même jour, une fois par mois durant une année. Ils ont été analysés pour la détermination de leurs teneurs en matière sèche (MS), matière minérale (MM), matière azotée totale (MAT) ainsi que leur contenu en NDF et ADF. Les digestibilités *in vitro* de la matière sèche (DMS) et de la matière organique (DMO) de ces échantillons ont été déterminées en utilisant un inoculum de dromadaires munis d'une canule au niveau du rumen. Les teneurs moyennes en MS ont été de 52,2 ; 32,1 ; 47,5 ; et 51,0% respectivement pour *A. halimus*, *N. retusa*, *L. guyonianum*, et *T. gallica*. Les teneurs en MM elles ont été de 13,7 ; 17,0 ; 26,2 ; et 19,2% MS respectivement. Leurs teneurs maximales de MM ont atteints 30,8% ce qui démontre le caractère halophyte de ces espèces. Les contenus en MAT ont été de 6,8 ; 10,8 ; 7,5 ; et 7,0% MS respectivement. Les DMS moyennes ont été de 32,3 ; 44,1 ; 40,4 ; et 38,2% respectivement pour *A. halimus*, *N. retusa*, *L. guyonianum*, et *T. gallica*. La DMO a été plus faible que la DMS pour les 4 espèces. Les arbustes étudiés qui poussent sur des sols marginaux (salés, hydromorphes) ont une valeur nutritive acceptable et peuvent contribuer à la satisfaction des besoins des dromadaires surtout que ces espèces sont moins affectées par les irrégularités pluviométriques qui caractérisent les zones arides.

Mots-clés : valeur nutritive, arbustes, halophyte, dromadaire.

Abstract

Four halophytic shrubs (*Atriplex halimus*, *Nitraria retusa*, *Tamarix gallica*, and *Limoniastrum guyonianum*) were selected from the list of edible species on the rangeland grazed by dromedaries of the Arid Region Institute of Médenine. Samples of the edible parts of these species were collected on the same day, once a month, throughout one year. They were analyzed to determine dry matter (DM), mineral matter (MM), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF) contents. Dry and organic matter *in vitro* digestibility (DMD

and OMD) were determined using a dromedary inoculum. The DM ratios were 52.2, 32.1, 47.5, and 51.0% for *A. halimus*, *N. retusa*, *L. guyonianum*, and *T. Gallica*, respectively. MM ratios were 13.7, 17.0, 26.2, and 19.2% of DM, respectively. The maximum MM level reached was 30.8%, which demonstrates the halophytic character of these species. CP ratios were 6.8, 10.8, 7.5, and 7.0% of DM, respectively. DMD of shrubs was 32.3, 44.1, 40.4, and 38.2% for *A. halimus*, *N. Retusa*, *L. guyonianum*, and *T. Gallica*, respectively. The studied species grow on marginal grounds (salty and hydromorphic), have acceptable nutritional value, and can contribute to meeting dromedaries requirements, especially since they are less affected by the rainfall variation that characterizes the arid zones.

Key words: nutritive value, shrubs, halophyte, dromedaries.

Introduction

Les parcours salés couvrent en Tunisie environ 1250000 ha (Burgmeister 1975). Ces parcours sont essentiellement fréquentés par les dromadaires pendant la période hivernale. Toutefois, ils peuvent pâturer de 8 à 9 mois les parcours dominés par les plantes halophytes (Farid 1989). Moslah et Megdiche (1989) ont signalé une durée de séjour des dromadaires sur ces parcours de 3 à 5 mois selon la pluviométrie de l'année qui conditionne l'état des autres parcours qui sont utilisés pendant le reste de l'année.

Les aliments sélectionnés par les dromadaires sont généralement les plantes riches en eau et en électrolytes parmi lesquelles les plantes halophytes constituent une part importante (Wilson 1989). En Mauritanie et au Mali les dromadaires font une cure de sel grâce à leur passage à une période déterminée de l'année sur les parcours halophytes (Farid 1989).

Le troupeau de dromadaires appartenant à l'Institut des Régions Arides de Médenine (Tunisie) pâture durant toute l'année un parcours constitué principalement d'une végétation salée depuis une dizaine d'année sans constater de pathologie particulière liée à l'utilisation permanente de ce type de parcours. Au cours de la période de séjour sur les parcours salés, les dromadaires peuvent transformer une végétation d'un intérêt économique pratiquement nul en produits animaux qui ont une valeur nutritionnelle et économique certaine.

Plusieurs espèces halophytes sont bien appréciées par les dromadaires. Selon Newman (1979), qui a rassemblé les observations de plusieurs auteurs, on peut trouver parmi ces espèces : *Atriplex halimus*, *Tamarix gallica*, *Nitraria retusa*, etc., la première est la plus consommée en Mauritanie parmi 25 espèces peuplant le parcours de printemps.

Afin d'estimer l'apport nutritif de cette végétation à l'animal, les quantités prélevées ont déjà été estimées (Khorchani et al. 1992). Cependant, l'estimation de la quantité de matière sèche ingérée n'est pas suffisante pour juger du niveau des apports alimentaires de la végétation prélevée sur ces parcours. Pour cela, nous avons jugé utile le suivi de la composition chimique et de la digestibilité *in vitro* de quelques espèces du même parcours au cours de la même année.

Matériels et Méthodes

Choix du Matériel Végétal et Prélèvement des Échantillons

Quatre arbustes ont été choisis parmi la liste des espèces appréciées rencontrées dans le parcours fréquenté par le troupeau de dromadaires de l'Institut des Régions Arides de Médenine. Ce choix a été effectué soit à cause de l'abondance de l'espèce ou de son appétibilité élevée. Les 4 espèces étudiées ont été : *Atriplex halimus*, *Nitraria retusa*, *Limoniastrum guyonianum*, et *Tamarix gallica*. Les échantillons de la partie consommable de chaque espèce ont été pris une fois par mois durant 12 mois à partir du mois de janvier. Les prélèvements de toutes les espèces ont été effectués le même jour indépendamment de leurs stades physiologiques.

La pluviométrie enregistrée au cours de cette année (de janvier à décembre) a été de 70 mm durant 15 jours pluvieux. Cette quantité est inférieure à la moitié de la moyenne annuelle de la zone (183 mm sur les 8 dernières années). Les mois d'avril, mai, juillet, août, et octobre ont été complètement secs.

Animaux

Pour la mesure de la digestibilité *in vitro* de ces espèces, le contenu du rumen a été prélevé chez 2 dromadaires âgés de 4 ans environ et munis de canules au niveau du rumen. Leur ration journalière, composée de 2 kg de foin de luzerne et 1 kg de concentré, est distribuée en 2 repas égaux à 8 h et 17 h.

Analyses Chimiques

L'échantillon prélevé de chaque espèce est subdivisée en 2 parties : l'une sert à la détermination de son taux de matière sèche (MS) après séchage à 100°C jusqu'à poids constant, la seconde partie est séchée à 70°C puis broyée dans un broyeur muni d'une grille de 1 mm. Cette dernière partie a servi aux déterminations des teneurs en matières minérales (MM) et matières azotées totales (MAT = $N \times 6,25$) par les méthodes AOAC (1975). Les résidus en fibres après hydrolyse dans un

détergent neutre (NDF) ou dans un détergent acide (ADF) ont été déterminées par les méthodes de Van Soest (1963).

Mesure de la Digestibilité *in vitro*

Afin de mieux caractériser les espèces étudiées, les digestibilité *in vitro* de la MS (DMS) et de la Matière organique (DMO) ont été déterminées par la méthode de Telly et Terry (1963) mais en utilisant un inoculum constitué du contenu du rumen de 2 dromadaires fistulés ce qui paraît plus logique puisque les espèces étudiées ne sont pratiquement utilisées que par les dromadaires à l'exception de l'*A. halimus*. L'utilisation du jus du rumen des moutons pour la détermination de la digestibilité des plantes consommées par les dromadaires n'est pas appropriée (Longo et al. 1989).

Pour corriger les variations entre les séries des déterminations de la digestibilité, un échantillon de foin de luzerne, dont la digestibilité *in vivo* de la MS et de la MO a été respectivement de 60,35 et 56,12, a été intégré dans chaque série de mesure. La correction a été effectuée par la multiplication de la valeur obtenue pour chaque échantillon de la n^{ième} série par un facteur $f = \text{digestibilité } in vitro \text{ du foin dans la série } n / \text{digestibilité du foin dans la série } 1$.

Analyses Statistiques

Les valeurs moyennes et leurs écarts types des composantes chimiques et des digestibilités ainsi que les régressions entre ces paramètres pour chaque espèce ont été calculés sur 12 échantillons.

Résultats

Variations de la Composition Chimique des 4 Arbustes

Les teneurs minimales en MS sont observées au cours de l'hiver et du printemps pour la majorité des espèces. Les valeurs moyennes au cours de l'année ont été de 52,2 ; 32,1 ; 47,5 ; et 51% respectivement pour *A. halimus*, *N. retusa*, *L. guyonianum*, et *T. gallica* (Tableau 1). La valeur la plus élevée a été enregistrée chez la première espèce et la valeur la plus faible a été constatée dans le cas du *N. retusa* (24,9%). Chez *T. gallica* la teneur en MS est restée relativement constante au cours de l'année (Fig. 1).

Tableau 1. Valeurs moyennes et variations au cours de l'année de la composition chimique et des digestibilités *in vitro* de la MS et de la MO des espèces halophytes étudiées (n = 12).

Espèces	Valeurs	Composition chimique (% MS)					DMS (%)	DMO (%)
		MS ¹	MM	MAT	NDF	ADF		
<i>A. halimus</i>	Moyenne	52,2	13,7	6,8	68,4	44,9	32,3	23,8
	E. Type	8,6	4,8	1,9	7,3	7,0	10,3	8,8
	Minimale	38,6	7,4	3,7	58,3	35,5	11,8	6,7
	Maximale	63,9	22,3	9,7	82,0	58,0	44,7	39,1
<i>N. retusa</i>	Moyenne	32,1	17,0	10,8	50,9	34,0	44,1	34,2
	E. Type	5,4	3,5	2,4	6,0	6,1	8,4	7,1
	Minimale	24,9	11,2	7,6	43,1	28,5	29,4	23,2
	Maximale	42,9	21,9	15,3	62,2	49,7	55,1	46,4
<i>L. guyonianum</i>	Moyenne	47,5	26,2	7,5	39,1	30,1	40,4	31,2
	E. Type	8,2	2,6	1,4	5,6	5,4	6,9	8,6
	Minimale	36,8	21,5	5,3	29,9	22,3	24,8	11,6
	Maximale	60,4	30,8	9,9	47,1	38,0	51,8	45,4
<i>T. gallica</i>	Moyenne	51,0	19,2	7,0	46,9	29,7	38,2	27,7
	E. Type	4,1	4,7	1,6	3,8	3,3	3,9	4,0
	Minimale	44,9	13,2	3,7	40,2	23,2	31,8	17,4
	Maximale	57,7	30,1	9,6	54,3	34,9	46,8	31,3

¹ MS est exprimée en % du produit brut.

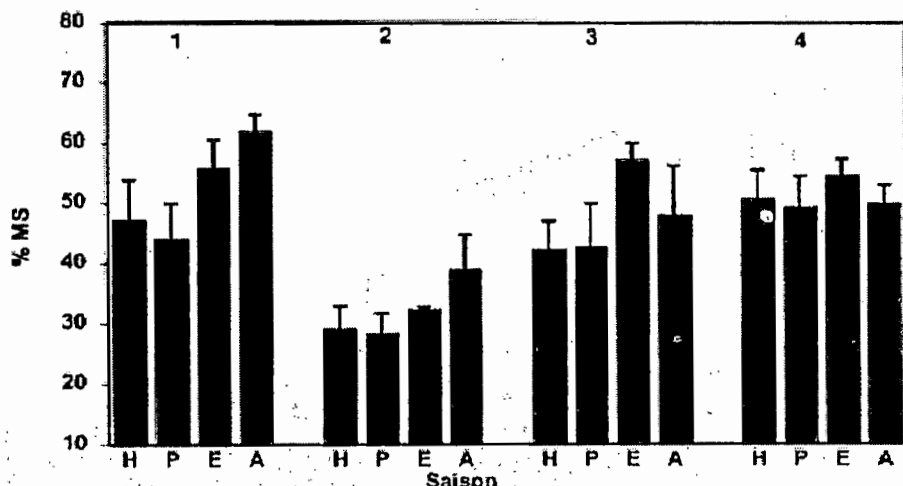


Figure 1. Variations saisonnières des teneurs en matière sèche des espèces étudiées (Espèces : 1 *A. halimus*, 2 *N. retusa*, 3 *L. guyonianum*, 4 *T. gallica*. Saisons : H = hiver, P = printemps, E = été, A = automne).

Les taux de matières minérales dans la MS sont relativement élevés pour les 4 espèces. Les valeurs moyennes au cours d'une année ont été dans le même ordre. Chez la dernière espèce, les teneurs en MM sont restées relativement constantes et élevées (Fig. 2).

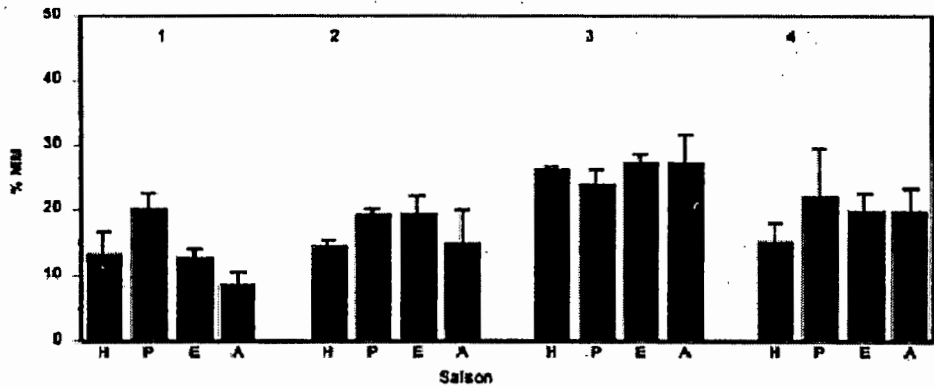


Figure 2. Variations saisonnières des teneurs en matières minérales des espèces étudiées (Espèces : 1 *A. halimus*, 2 *N. retusa*, 3 *L. guyonianum*, 4 *T. gallica*. Saisons : H = hiver, P = printemps, E = été, A = automne).

Les teneurs moyennes des MAT dans la MS ont été au cours de l'année d'étude de 6,8 ; 10,8 ; 7,5 ; et 7,0% respectivement pour *A. halimus*, *N. retusa*, *L. guyonianum*, et *T. gallica*. La valeur minimale a été observée chez *A. halimus* et *T. gallica*. Quant à la valeur maximale, elle a été constatée chez *N. retusa*. Les teneurs les plus élevées en MAT sont généralement enregistrées au cours du printemps alors que les plus faibles valeurs se situent en été ou en automne (Figure 3). Les teneurs moyennes de la MS en NDF des 4 arbustes ont été respectivement dans les même ordre 68,4 ; 50,9 ; 39,1 ; et 46,9%.

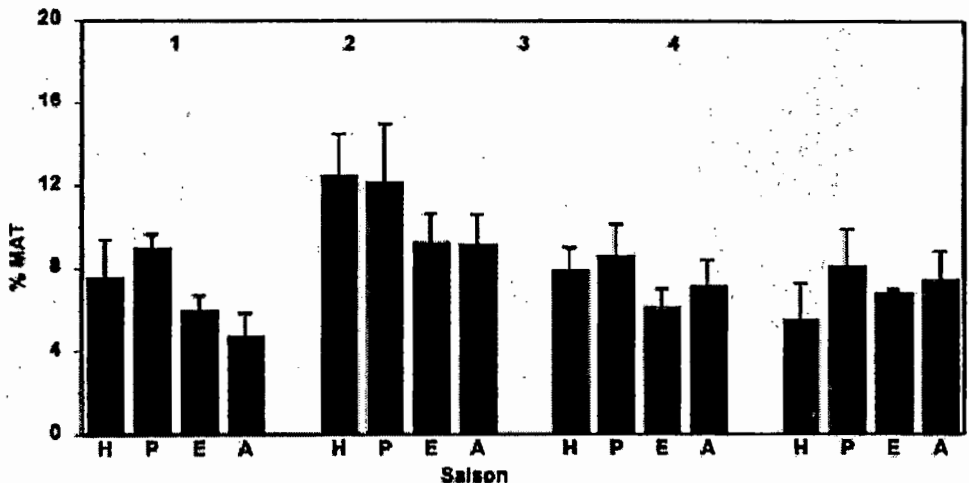


Figure 3. Variations saisonnières des teneurs en matières azotées totales des espèces étudiées (Espèces : 1 *A. halimus*, 2 *N. retusa*, 3 *L. guyonianum*, 4 *T. gallica*. Saisons : H = hiver, P = printemps, E = été, A = automne).

Ces teneurs sont relativement plus faibles au printemps dans les cas d'*A. halimus* et *N. retusa* alors que dans le cas de *L. guyonianum* la teneur en NDF s'élève au cours de cette saison et elle reste relativement constante au cours des 4 saisons chez *T. gallica*.

Evolution de la Digestibilité *in vitro* des Arbustes

Les digestibilités moyennes de la matière sèche des 4 espèces pendant la durée de l'étude ont été de 32,3 ; 44,1 ; 40,4 ; et 38,2% respectivement pour *A. halimus*, *N. retusa*, *L. guyonianum*, et *T. Gallica* (Fig. 4). La valeur maximale de la DMS a atteint 55,1% dans le cas de la seconde espèce. Les moyennes saisonnières de la DMS ont été plus élevées au printemps dans les cas des 2 premières espèces alors qu'elles ont été relativement constantes chez *T. gallica*. Chez *L. guyonianum*, elles ont progressé de l'hiver à l'automne. Les digestibilités moyennes de la matière organique ont été nettement plus faibles que celles de la matière sèche pour toutes les espèces.

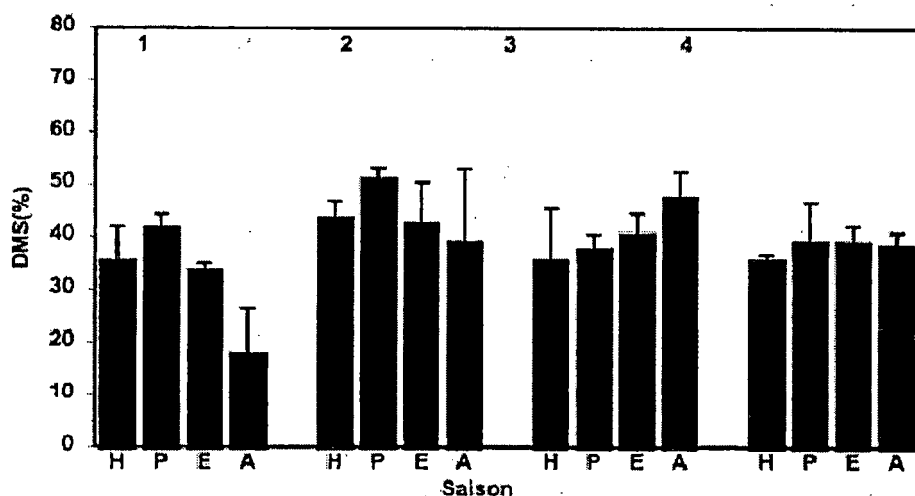


Figure 4. Variations saisonnières de la digestibilité *in vitro* de la matière sèche des espèces étudiées (Espèces : 1 *A. halimus*, 2 *N. retusa*, 3 *L. guyonianum*, 4 *T. gallica*. Saisons : H = hiver, P = printemps, E = été, A = automne).

Relations entre les Constituants Chimiques et les Digestibilités

L'établissement de relations entre ces paramètres permet la prévision de la digestibilité à partir de l'analyse chimique d'une espèce végétale. La DMS a été significativement corrélée à la teneur en NDF dans les cas d'*A. halimus* et *N. retusa* mais il fallait intégrer en plus le contenu en ADF pour atteindre une précision satisfaisante de la relation de prévision de DMS dans le cas de *L.*

Guyonianum (Tableau 2). Par ailleurs on a constaté l'absence de relation linéaire entre DMS et la teneur en NDF de *T. gallica*. Toutefois, DMS est bien corrélée avec les teneurs en MM et MS. Les seules régressions simples de la DMO ont été obtenues dans les cas de *A. halimus* et *N. retusa* avec leur teneur en NDF (Tableau 3).

Tableau 2. Equations de régression ($DMS = b + a_1 \cdot x_1 + a_2 \cdot x_2$) significatives entre la digestibilité *in vitro* de la MS et les constituants chimiques des espèces étudiées (n = 12).

Espèces	b	+ $a_1 \cdot x_1$	+ $a_2 \cdot x_2$	R	ETR	P
<i>A. halimus</i>	124,65	-1,351 NDF		0,96	3,01	0,0001
<i>N. retusa</i>	101,53	-1,129 NDF		0,81	5,17	0,0015
<i>L. guyonianum</i>	44,92	-1,222 NDF	+1,43 ADF	0,81	4,51	0,0090
<i>T. gallica</i>	8,89	+0,77 MM	+0,26 MS	0,95	1,34	0,00001

ETR = écart type résiduel.

Tableau 3. Equations de régressions ($DMO = b + a \cdot x$) significatives entre la digestibilité *in vitro* de la MO et la teneur en NDF des espèces étudiées (n = 12).

Espèces	b	+ $a \cdot x$	R	ETR	P
<i>A. halimus</i>	93,54	-1,027 NDF	0,85	4,862	0,00040
<i>N. retusa</i>	86,33	-1,024 NDF	0,86	3,737	0,00300

ETR = écart type résiduel.

Discussion

Pour les 4 espèces étudiées, le taux de MS le plus faible a été enregistré pendant l'hiver ou le printemps alors que le taux le plus élevé est enregistré pendant les saisons d'été ou d'automne. Ce taux paraît lié à la pluviométrie puisque les 2 premières saisons sont généralement les plus pluvieuses et les secondes sont les plus sèches dans les conditions du sud tunisien.

D'après Wardeh et al. (1990), les teneurs en MAT des espèces halophytes consommées par les dromadaires sont comprises entre 8,54 et 14,89% de la MS ce qui satisfait leurs besoins en protéines aux différents stades physiologiques. Les teneurs en MAT rapportées par Le Houérou (1995) sont de l'ordre de 10 à 20% de la MS dont 50% sont des protéines réellement digestibles. Comparativement aux autres espèces *N. retusa* paraît garantir une valeur azotée acceptable au cours de l'été et l'automne et assez bonne en hiver et au printemps. Les références bibliographiques traitant de la composition chimique et de la digestibilité des autres espèces sont rares. Néanmoins les plantes halophytes sont généralement considérées riches en eau, en électrolytes et en azote (Newman 1979 ; Gauthier-Pilters 1979 ; Wardeh 1990). Une forte teneur en NDF et en MS de *A. halimus* associée à une très faible teneur en MAT dans le cas de la présente étude peut en grande partie s'expliquer par la faible pluviométrie de l'année qui a handicapé le développement végétatif de cette espèce.

D'autres espèces peuvent parfois pousser près des endroits les plus humides, ce qui les rend moins sensibles aux insuffisances pluviométriques. D'ailleurs, les teneurs en MAT citées précédemment concernent des étages bioclimatiques aride supérieur ou semi-aride alors que notre parcours se situe dans l'étage aride inférieur.

Pour *A. halimus*, les variations inter-saisonnières sont importantes contrairement au reste des espèces étudiées. Cette espèce est aussi la plus riche en ADF puisqu'elle contient en moyenne 45% de la MS environ. Les niveaux des constituants énergétiques des plantes halophytes, non déterminés ici, comme les teneurs en cellulose brute, en extractif non azoté et en extrait éthéré sont d'après Wardeh (1990) assez élevés pour satisfaire les besoins d'entretien et certains besoins de production si les dromadaires peuvent consommer suffisamment de MS des espèces disponibles.

La digestibilité *in vitro* de la MS paraît très liée à la teneur en NDF puisque l'espèce la plus riche en NDF (*A. halimus*) a la DMS la plus faible. Ainsi la variation saisonnière de la DMS évolue inversement à la teneur en NDF ce qui se traduit par des valeurs de digestibilité faibles pendant l'été et l'automne. Par contre la digestibilité de la MS de *L. guyonianum* est la plus élevée pendant ces 2 saisons.

La digestibilité *in vitro* moyenne de la MS a été supérieure à celle de la MO pour toutes les espèces. Alibes et Tisserand (1990) ont aussi signalé des digestibilités *in vivo* de 75,1 et 62,8% de la MS et de la MO respectivement pour *Helianthus annuus* L. dont la teneur en MM a été de 19,8% par rapport à la matière sèche. Dans notre cas la différence la plus élevée entre les 2 valeurs de digestibilité (11,2 points) correspond à l'espèce la plus riche en MM (*L. guyonianum*). Au contraire, la différence la plus faible (8,5 points) entre ces mêmes paramètres a été enregistrée chez l'espèce la plus pauvre en MM (*A. halimus*).

Selon Le Houérou (1995), la digestibilité de la MS des plantes halophytes varie avec l'espèce, le stade phénologique et la saison. Elle peut atteindre 70% ou chuter en dessous de 40% sous certaines circonstances mais dans la plupart des cas la digestibilité de la MS est comprise entre 50 et 60%. D'après le même auteur la digestibilité de la MO de ces espèces est de l'ordre de $50 \pm 5\%$. Ces valeurs des digestibilités sont plus élevées que celles obtenues dans la présente étude mais les méthodes de mesure de la digestibilité seraient différentes dans les 2 cas ce qui rend cette comparaison difficile.

Conclusion

La composition chimique des espèces étudiées est variable avec les saisons. Certaines espèces ont des teneurs en MM qui dépassent 25% MS. En général les teneurs les plus élevées en MAT sont enregistrées pendant l'hiver ou le printemps. Les teneurs moyennes de nos espèces varient entre 7 et 11% environ mais elles

peuvent dépasser parfois 15% de la MS. Les digestibilités moyennes de la MO varient entre 30 et 46% environ. La plupart des espèces ont des valeurs nutritives acceptables surtout en hiver et au printemps, en particulier si l'on tient compte des conditions écologiques dans lesquelles ces plantes végètent. La variabilité de la composition des diverses espèces avec la saison peut être considérée comme un avantage qui permet d'assurer une certaine valeur nutritive du parcours grâce à cette compensation inter-spécifique.

Les espèces halophytes seraient moins sensibles aux irrégularités de la pluviométrie qui caractérisent les milieux arides et désertiques comparativement aux espèces non halophytes puisque les premières poussent sur des sols relativement humides en permanence. Ces espèces peuvent par conséquent satisfaire une partie non négligeable des besoins des dromadaires au moins pendant 2 saisons dans l'année. Toutefois, les études de la valeur nutritive des espèces halophytes devraient être poursuivies sur plusieurs campagnes et devraient s'étendre à d'autres espèces appréciées par ces animaux.

Références

- AOAC. 1975. Official Methods of Analysis of the AOAC (12th ed.). Washington, DC. USA.
- Alibes, X. et J.L. Tisserand. 1990. Tableaux des valeurs alimentaires des fourrages et des sous produits d'origine méditerranéenne. Options Méditerranéennes, Série B, No. 4 (X. Alibes et J.L. Tisserand, eds.). CIHAM, Zaragoza, Espagne.
- Burgmeister, R. 1975. Problèmes posés par l'élevage de dromadaire en Afrique: Un exemple, du sud tunisien. Publication de l'office allemand de coopération technique. SARL. GTZ, Eschorn, 21.
- Farid, M.F.A. 1989. Water and minerals in dromedary camel. *Options Méditerranéennes*, Série A, Séminaires, No. 2, 111-124 CIHAM, Zaragoza, Espagne.
- Gauthier-Pilters, H. 1979. Aspects of dromedary ecology and ethology. Pages 293-322 in *The Camel. Proceedings of the Khartoum Workshop on Camels*. Dec 1979, Uppsala, Sweden.
- Khorchani T., H. Abdouli, A. Nefzaoui, M. Neffati et M. Hammadi. 1992. Nutrition of the one-humped camel. II. Intake and feeding behavior on arid ranges in southern Tunisia. *Animal Feed Science Technology* 39: 303-311.
- Le Houérou, H.N. 1995. Forage halophytes in the Mediterranean basin. In *Halophytes and Biosaline Agriculture. Proceedings of the Workshop on Halophytes Utilization in Agriculture* (E. Choukr-Allah, C.V. Malcolm and A. Hamdy, eds.). Sept 1993. Morocco. Marcel Dekker, New York.
- Longo, H.F., A. Chelma et A. Ouled Belkher. 1989. Quelques aspects botaniques et nutritionnels des pâturages des dromadaires en Algérie. *Options Méditerranéennes*, Série A, Séminaires, No. 2, 47-54. CIHEAM, Zaragoza, Espagne.
- Moslah, M. et F. Megdiche. 1989. L'élevage camelin en Tunisie. *Options Méditerranéennes*, Série A, Séminaires, No. 2, 33-36. CIHEAM, Zaragoza, Espagne.
- Newman, D.M.R. 1979. The feed and feeding habits of old new word camels. Pages 172-

- 200 in Provisional Report No. 6. Camels. IFS, Uppsala, Sweden.
- Telly, J.M.A. and R.A. Terry. 1963. A two stage technique for the *in vitro* digestion of forage crops. *Journal of the British Grassland Society* 18:104-111.
- Van Soest, P.J. 1963. Use of detergents in analysis of fibrous feed. II A rapid method for the determination of fiber and lignin. *Journal of the Association of Agricultural Chemistry* 46: 829-835.
- Wardeh, M.F. 1990. Camel nutrition and grazing behaviour. Pages 113-123 in Proc. Int. Conf. Camel Prod. Improv (M.F. Wardeh, R.T Wilson and A.A. Zaied, eds.). 10-13 Dec, Tobrouk, Libya. ACSAD, Syria.
- Wilson, R.T. 1989. The nutritional requirements of camel. *Options Méditerranéennes*, CIHEAM, Zaragoza, Espagne. Série A, Séminaires, 2: 171-179.

Effect of Straw Supplementation on Intake and Browsing of *Atriplex nummularia* (Oldman Saltbush) by Segureña Ewes, under Pen-feeding and Free-grazing Conditions

E. Correal and J.A. Sotomayor

Consejería de Medio Ambiente, Agricultura y Agua, CIDA
Estación Sericícola, Murcia, Spain

Introduction

Oldman saltbush (*Atriplex nummularia*) is a native Australian shrub with good adaptation to semi-arid areas (200–400 mm rainfall), where it maintains green foliage during dry periods (Squires 1989). Because of its deep root system and C₄ metabolism, it is grazed by sheep in native stands and new plantations. It is also used as a green fodder to feed livestock during dry periods in arid and semi-arid countries such as South Africa (de Kock 1980) and Tunisia (Le Houérou and Pointanier 1987), where it was introduced a century ago.

De Kock, in South Africa, selected oldman saltbush shrubs that were best grazed by sheep. Those shrubs were used as a source of seed to produce new shrubs. The selection process continued through four recurrent cycles (personal communication). Thus, de Kock obtained a "Grootfontain" oldman saltbush cultivar, which was introduced to Murcia in the early 1980s.

The Grootfontain cv has shown good adaptation to the semi-arid dryland conditions of Murcia, and local Segureña sheep make good grazing use of oldman saltbush plantations (Otal et al. 1991). Its browsing biomass is rich in crude protein (21% CP), and its digestibility (68% DOM, 77% DDM) is quite good (Correal et al. 1990; Correal 1993). However, its energy content seems to be on the border of meeting the maintenance requirements of sheep (Belmonte et al. 1990), and is affected by the leaf/twig ratio of the diet selected by the sheep. This study was designed to see if oldman saltbush could meet the maintenance requirement of dry sheep, and to examine the effect of straw supplementation on the feeding value of oldman saltbush in sheep.

Materials and Methods

Pen-feeding Trial

This experiment, which was carried out for six weeks (26 September to 6 November) in 1990, was set up to evaluate the voluntary intake of oldman saltbush

and the effect of straw supplementation on intake values. Two feed lots were prepared, one with *ad libitum* browse of oldman saltbush (lot A), and the second with barley straw also offered (lot A/S).

To test both feed diets, two independent lots of six dry Segureña ewes were placed in small sheepfolds. Each sheepfold had a closed area containing two troughs and a graduated water tank, and an open area (120 m²) where the animals could move around.

The browse biomass of oldman saltbush comprised a mixture of leaves and young twigs (<10 mm diameter), which was harvested twice per week from a plantation at the CIDA experimental farm in La Alberca, Murcia (300 shrubs, 2.5 years old, planted at 3 m × 2 m). The edible biomass was cut and chopped into pieces 10–15 cm long to facilitate distribution in the pens, and to reduce losses to the ground during feeding periods. After chopping, the biomass was stored in sacks inside a cold room at 5°C until distribution.

Forages were offered *ad libitum* daily at 9 a.m. Amounts were increased when the proportion of surplus leaves or twigs was less than 10% of the amount offered the day before. Barley straw was offered at a rate of 1 kg/ewe per day.

Every three days, fresh and rejected oldman saltbush samples were taken from the troughs. After oven drying at 70°C, dry matter content was determined, and daily fresh matter intake was converted to DM intake values.

At the beginning of the experiment, the mean liveweight (LW) and body condition (BC) (Russel et al. 1969) of ewes were: lot A, 44.6 kg and 2.65; lot A/S, 43.7 kg and 2.58. Mean LW and BC of ewes was determined weekly.

Grazing Trial

The second study was carried out from January to March 1993 on a three-year-old *A. nummularia* plantation located at the same experimental farm in La Alberca. The shrubs, planted at 3 m × 2 m, had been grazed previously in August 1991 (18 months before the experiment). The plantation was fenced and divided in two subplots. One had barley straw in a trough, which was offered *ad libitum* to ewes every day (diet A/S). In the second subplot, ewes had access only to oldman saltbush shrubs (diet A). There were 123 shrubs in lot A and 126 in lot A/S. Each subplot was grazed by four dry Segureña ewes. Water intake was measured daily by refilling the graduated water tanks of each subplot.

Grazing of each subplot ended when shrubs were completely defoliated.

One day after the experiment ended, 40 shrubs from each subplot were chosen at random. The diameter of 50 browsed twigs from each shrub was measured with a wire gauge.

LW and BC of ewes were measured weekly. Values at the beginning of the experiment were: lot A, 49.1 kg and 2.62; lot A/S, 44.9 kg and 2.56.

Results

Voluntary Intake under Pen Feeding

Ewes on the saltbush diet consumed a mean of 1.5 kg DM/ewe per day. When barley straw was available, mean intake was 1.8 kg DM/ewe per day, around two thirds of which was saltbush and one third straw (Table 1).

Table 1. Mean DM intake and water intake for two oldman saltbush diets, and their effect on liveweight (LW) and body condition (BC) of dry ewes.

Diet	Intake/ewe per day		Change (%)	
	DM (kg)	Water (L)	LW	BC
<i>A. nummularia</i>	1.52 $\pm$ 0.047	6.5 $\pm$ 0.23	+4.9	+5.7
<i>A. nummularia</i> + straw	(1.12 $\pm$ 0.038) + (0.70 $\pm$ 0.024)	6.2 $\pm$ 0.14	+10.8	+6.6

At the end of the six-week experiment, ewes in both feed lots ended up with higher LW and better BC. This indicates that oldman saltbush browse, either alone or combined with barley straw, meets the maintenance requirement of Segureña sheep.

During the first two weeks of the experiment, ewes lost LW and BC on the oldman saltbush diet. However, if straw was included in the diet, LW increased from the first week of the experiment and BC improved from the second week. This suggests that during the first two weeks of the experiment, ewes went through an adaptation process, but with straw, the adaptation was faster.

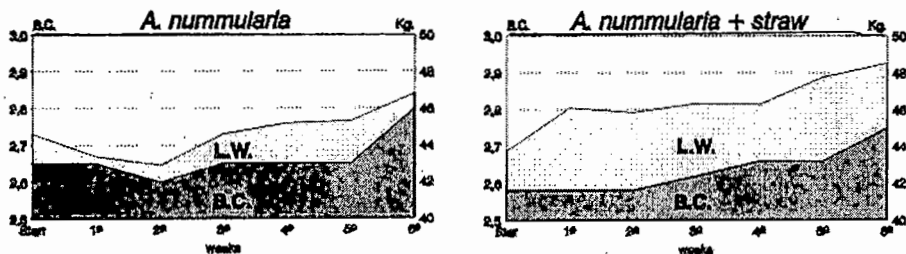


Figure. 1 Weekly evolution of LW and BC, and variation according to diet, for dry Segureña ewes.

As can be seen in Table 2, ewes consumed about 40% more oldman saltbush when fed alone than when combined with barley straw.

Dry matter intake, when related to LW (DM-intake/LW), was higher for the *Atriplex* and straw diet (3.9%) than for the oldman saltbush diet (3.4%). However, when feed intake was considered as green matter (GM) in relation to LW, the values of both diets were similar (12% GM/LW for the *Atriplex* and straw and 11.5% for the *A. nummularia*).

Water intake was similar in both feed lots, averaging 6–7 L/ewe per day.

Table 2. Mean weekly intake of *A. nummularia* and straw (g DM/kg LW^{0.75}).

Week	D1		D2	
	<i>Atriplex</i>	<i>Atriplex</i>	Straw	A + S
1	69.7	41.2	50.2	91.4
2	74.4	56.1	45.2	101.3
3	90.8	64.7	33.0	97.7
4	99.9	73.0	37.7	110.7
5	103.3	71.3	35.2	106.5
6	91.0	71.5	33.8	105.3
Average	88.2	63.0	39.2	102.2
Percent		61.7	38.3	100.0

Free-grazing Experiment

In the subplot where straw was available, ewes consumed the oldman saltbush browse in 62 days. In the *A. nummularia* subplot, the edible biomass was consumed in 46 days (Table 3). At the end of the grazing experiment, ewes in both subplots had maintained BC and increased LW (4–5 kg/ewe).

Table 3. Winter grazing of *A. nummularia*: effect of straw supplement on length of grazing period, stocking rate maintained, and diameter of grazed twigs.

	<i>Atriplex</i>	<i>Atriplex</i> + straw	Change (%)
Grazing days	46	62	+35
Annual stocking rate (extrapolated)	6.8 ewe/ha/yr	9 ewe/ha/yr	
Average diameter of browsed twigs	4.3 mm	2.9 mm	–33

It can be inferred that during the winter (January–March), ewes met their maintenance requirements from browsing oldman saltbush shrubs. If a straw supplement was available, daily intake of oldman saltbush was reduced and the grazing period extended by 35%.

At the end of the grazing period, the diameter of 2,000 twigs was measured in each subplot (Fig. 2). In the subplot where the straw supplement was available, the mean diameter of browsed twigs (2.9 mm) was smaller than in the subplot where *A.*

nummularia was the only feed available (4.3 mm). In both subplots, the diameter of browsed twigs ranged from 1 to 10 mm, but in the absence of straw, ewes browsed twigs of larger diameter (mainly 4–5 mm), and hence ingested larger amounts of fiber from oldman saltbush.

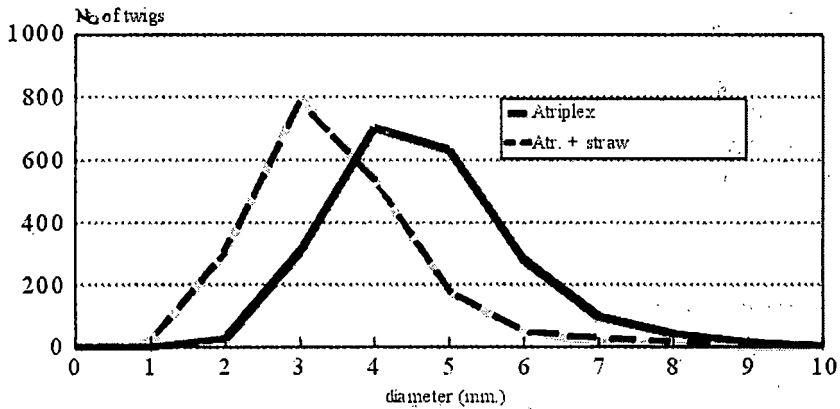


Figure 2. Diameter of twigs browsed by ewes in a free-grazing experiment.

Discussion

Voluntary Intake under Pen Feeding

Maximum daily intake of *A. nummularia* in the pen-feeding experiment (103 g DM/kg LW^{0.75}) was slightly lower than that obtained by Le Hou  rou (1991) in Libya with Barbarine sheep (117 g DM/kg LW^{0.75}). But Le Hou  rou's trial was run over 238 days, which gave the Libyan ewes a better chance to adapt to oldman saltbush feed (confirmed by a final intake four times higher than the initial rate). Libyan sheep showed an increase in LW (8.8 g/ewe per day), which is lower than that reported in our experiment (52 g/ewe per day). The larger LW gains in our experiment can be partly explained by the increments of the digestive track weight during the ingestion of a forage of low feed value/unit volume. In other words, if our DM intake is related to LW, the 3.4% (DM/LW) value obtained is close to the 3.8% maximum intake rate found by Le Hou  rou (1980).

In previous experiments where sheep were kept in boxes (Belmonte et al. 1990), voluntary intake rates for *A. nummularia* were lower: (i) 41 g DM/kg LW^{0.75} per day at the end of a five-week experiment with ewes not familiarized to oldman saltbush, but with an excessively high BC (3.5); and (ii) 88 g DM/kg LW^{0.75} per day at the end of a seven-week experiment with ewes already familiarized to *A. nummularia*, but with a BC (3.2) still too high for animals under a maintenance regime. In both these trials, ewes lost LW and BC, something we initially thought

was due to the low energy content of oldman saltbush. However, the results of our experiment are an indication that LW and BC losses were probably due to the use of overfed ewes and hence, with excessive LW and BC values for a maintenance regime. In any case, the previous experiments led to the hypothesis that oldman saltbush had to be complemented with an energy sub-product such as cereal straw (Le Houérou 1992; Le Houérou et al. 1991; Le Houérou 1980).

In our trial, ewes consuming the *Atriplex* and straw diet experienced larger LW and BC gains than those fed on *A. nummularia*. This may be partly explained by the fact that the ewes in the *Atriplex*/straw lot consumed 20% more dry matter. In any case, supplementing with straw reduced *A. nummularia* intake by 40%, and prevented losses of LW and BC during the first two weeks of the experiment.

Free-grazing Experiment

During the pen-feeding experiment, *A. nummularia* browse was harvested by hand, and a mixture of leaves and twigs of a predetermined diameter (smaller than 8 mm) was produced. For this reason, we could not test the effect of the straw supplement on the diameter of the twigs voluntarily browsed by sheep.

Starting with the hypothesis that twigs contain more crude fiber than leaves, and hence, a higher proportion of energy, we concluded that when sheep lacked the straw supplement, they consumed twigs of larger diameter to compensate for the lower energy content of their diet.

Conclusions

The oldman saltbush biomass offered to penned Segureña ewes during a six-week experiment exceeded the winter maintenance requirement of sheep. Supplementation with barley straw (two thirds *Atriplex* and one third straw) reduced *A. nummularia* intake and facilitated the adaptation of ewes to the new feed.

Free-grazing of an oldman saltbush plantation during six winter weeks also met the maintenance requirements of dry Segureña ewes. The *ad libitum* availability of barley straw increased the number of grazing days by 35%, a period equivalent to the observed reduction in *A. nummularia* intake during the pen-feeding experiment.

References

- Belmonte, C.J. Otal y E. Correal. 1990. Determinación de la capacidad de ingestión de *Atriplex nummularia* por ovejas Segureñas estabuladas en boxes. Pages 363–370 in XXX Reunión Científica de la SEEP. San Sebastian. Spain.
- Correal, E., C. Belmonte and J. Otal. 1990. Utilization by sheep of oldman saltbush

- (*Atriplex nummularia*): Palatability, browse efficiency, voluntary intake and chemical composition. Pages 165–168 in VIth Meeting of the FAO-Mediterranean Pasture Subnetwork. Bari, Italy.
- Correal, E. 1993. Grazing use of fodder shrubs. Pages 99–118 in EEC Workshop on Fodder Trees and Shrubs in Mediterranean Production Systems (V. Papanastasis, ed.) Thessaloniki, Greece. EUR 14459.
- de Kock, G.C. 1980. Drought resistant fodder shrub crops in South Africa. Pages 399–410 in Browse in Africa (H.N. Le Houérou, ed.). International Livestock Center for Africa. Addis Ababa, Ethiopia.
- Le Houérou, H.N. 1980. Browse in Northern Africa. Pages 55–82 in Browse in Africa (H.N. Le Houérou, ed.). International Livestock Center for Africa. Addis Ababa, Ethiopia.
- Le Houérou, H.N. 1991. Feeding shrubs to sheep in the Mediterranean arid zone: Intake, performance and feed value. Pages 639–644 in IVth Int. Rangeland Congress. Montpellier, France.
- Le Houérou, H.N. 1992. The role of saltbushes (*Atriplex* spp.) in arid land rehabilitation in the Mediterranean Basin: a review. *Agroforestry Systems* 18: 107–148.
- Le Houérou, H.N. et R. Pointanier. 1987. Les plantations sylvopastorales dans la zone aride de Tunisie. Notes techniques du MAB 18. UNESCO.
- Le Houérou, H.N., E. Correal and S. Lailhacar. 1991. New man-made agro-sylvo-pastoral production systems for the bioclimatic Mediterranean arid zone. Pages 383–388 in IVth Int. Rangeland Congress. Montpellier, France.
- Otal, J., C. Belmonte y E. Correal. 1991. Variaciones estacionales de la palatabilidad y consumo por el ganado ovino de diversos arbustos forrajeros preseleccionados en el SE español. Pages 353–357 in XXXI Reunión Científica de la SEEP. Murcia, Spain.
- Russel, A.J.F.; J.M. Doney and R.G. Gunn. 1969. Subjective assessment fat in live sheep. *Journal of Agricultural Science* 72: 451–454.
- Squires, V.R. 1989. Australia: Distribution, characteristics and utilization of shrublands. Pages 61–92 in *The Biology and Utilization of Shrubs* (C.M. McKell, ed.). Academic Press.

Effect of Straw Supplementation on the *Atriplex halimus* (Saltbush) Diet Consumed by Segureña Ewes

J.A. Sotomayor and E. Correal

*Consejería de Medio Ambiente, Agricultura y Agua, CIDA
Estación Sericícola la Alberca, Murcia, Spain*

Introduction

Atriplex halimus subsp. *halimus* is a Mediterranean saltbush linked, in its native habitats, to semi-arid environments and saline depressions. Besides its forage value, it retains its green foliage during dry and cold periods when other herbaceous resources are scarce or dry. Because of this, it has been used as a green fodder bank to feed livestock during seasonal feeding gaps (Franclet and Le Houérou 1971). The saltbush INRF 70100 was selected by the FAO in Tunisia as the accession best consumed by sheep under free-grazing conditions (El Hamrouni and Sarson 1975). Correal introduced it to Murcia in the early 1980s, during a fodder shrub trial promoted by the FAO-Mediterranean Pasture Sub-network (El Hamrouni 1981). From that experiment, new plant material was reproduced and propagated to new plantations and grazing experiments in several locations in southeastern Spain. It has been generally accepted that saltbush browse is rich in protein but low in energy (Le Houérou 1992). To evaluate this general statement, a pen-feeding experiment was set up to measure the voluntary intake of saltbush browse by dry Segureña ewes (diet A) and the complementing effect of barley straw (diet A/S), an abundant fodder resource in the form of cereal stubble. The feeding value of both diets was assessed by measuring the animal's performance (liveweight and body condition) and the composition of the diet (leaf/stem ratio).

Materials and Methods

Three diets were tested: (i) saltbush browse (leaves and young twigs) of the *A. halimus* accession FAO INRF 70100 (lot A); (ii) saltbush browse plus barley straw (lot A/S); and (iii) barley straw (lot S).

The saltbush feeding experiment was carried out during 28 summer days (7 July to 3 August) in 1992. Nine dry Segureña ewes were separated into three lots; each lot occupied an small sheepfold (120 m²) provided with a 2.5 m trough and a graduated water tank.

Saltbush browse (leaves and twigs <10 mm) was harvested twice weekly from a 1,300 m² plantation at the CIDA experimental farm at La Alberca, Murcia, Spain. The plantation, consisting of 154 shrubs spaced at 4 m × 2 m, was established in

February 1990. After harvest, saltbush browse was chopped into pieces 10–15 cm long to facilitate distribution in pens and reduce losses to the soil during feeding. Chopped saltbush browse was kept in a cold room at 5°C, until it was fed.

Forage diets were offered *ad libitum* every day at 9 a.m. Amounts were increased when surplus leaves or twigs were less than 10% of the amount offered. Diets were adjusted daily to assure that intake was not limited by a shortage of either leaves or twigs. Water intake was measured daily by filling up the graduated water tanks. Barley straw was offered at daily rates of 900 g DM/ewe, well in excess of the ewes' intake capacity.

Every day, fresh and rejected saltbush browse was sampled and fractioned into leaves and twigs. It was then dried in an oven (70°C) for 48 hours, from which leaf and twig dry matter content was obtained. From differences between offered and refused amounts, daily DM intake was calculated.

To estimate the nutritional value of different diets and browse fractions (leaves and twigs), the following standard analytical parameters were determined: crude fiber (CF), crude protein (CP), fat or ether extract, per minerals (ash content) and Na, K, Ca, Mg, and P.

Mean liveweight (LW) and body condition (BC) (Russell et al. 1969) of ewes at the beginning of the experiment were: lot A, 50 kg and 2.58; lot A/S, 47 kg and 2.5; and lot S, 48.8 kg and 2.75. Both parameters were measured weekly during the experiment.

Results

Table 1 shows mean data for daily dry matter intake (DMI) and water intake (WI) for each diet, and weekly variations of LW and BC. Analysis of variance showed no significant ($P > 0.05$) differences for DM intake or WI value between diets A and A/S.

Table 1. Effect of saltbush and/or straw diets on mean daily DM and water intake during summer, and on weekly variations of LW and BC.

Diet	Intake/ewe per day		Change (%)	
	DM (kg)	Water (L)	LW	BC
<i>A. halimus</i>	1.38 ± 0.043	7.5 ± 0.21	+7	-3
<i>A. halimus</i> + straw	(0.82 ± 0.026) + (0.50 ± 0.018),	7.1 ± 0.21	+14	+10
Straw	0.48 ± 0.019	1.7 ± 0.07	-2	-6

During the four-week experiment, voluntary intake was rather constant for the A/S diet, but increased in the fourth week for diet A (Table 2). Straw intake values were similar, whether consumed alone or in combination with saltbush.

Table 2. Weekly intake variations (g DM/kg LW^{0.75} per day) of dry ewes fed three saltbush and/or straw diets (g DM/kg LW^{0.75} per day).

Week	D 1	D 2		D 3	
	<i>Atriplex</i>	<i>Atriplex</i>	Straw	<i>Atriplex</i> + S	Straw
1	61.4	37.0	30.3	67.3	30.3
2	69.6	43.6	24.6	68.2	26.3
3	68.8	45.0	24.7	69.7	23.8
4	81.8	48.1	26.7	74.8	24.5
Average	70.4	43.4	26.6	70.0	26.2
Percent		62	38	100	

The intake of saltbush leaves and twigs was affected by the presence of straw in the diet (Table 3). Thus, a larger proportion of leaves was consumed in the mixed *Atriplex*/straw diet (69% leaves and 31% twigs) than in diet A (55% leaves and 45% twigs). Conversely, a larger proportion of twigs was consumed when straw was not available in the diet.

Table 3. Mean daily intake of saltbush leaves (IL), twigs (IT), and barley straw (S), and percentage and ratio (L/T) of leaves and twigs in the diet.

Diet	g DM/ewe per day			IL + IT (%)		
	IL	IT	S	L	T	L/T
<i>Atriplex</i>	762	617	-	55	45	1.24
<i>Atriplex</i> + straw	568	255	505	69	31	2.23
Straw	-	-	480			

With a saltbush diet, more leaves than twigs were consumed during the first two weeks, but in the third and fourth weeks, intake of both fractions was similar (Fig. 1). On the other hand, leaves were always consumed at a higher rate than twigs in the saltbush/straw diet.

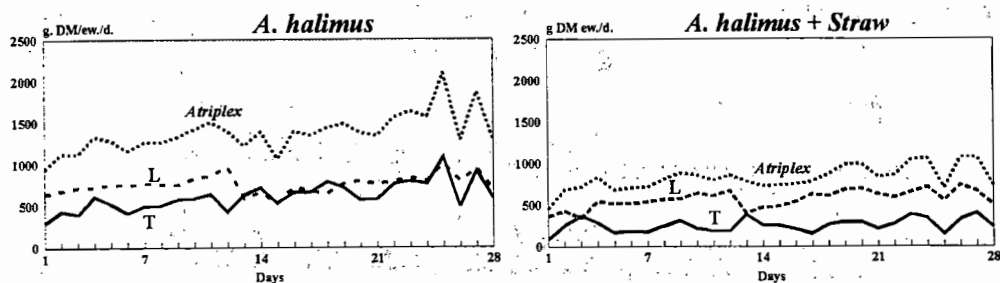
**Figure 1.** Daily variations of saltbush intake and effect of supplementing with barley straw on saltbush fraction intake (leaves and twigs).

Table 4 shows the chemical composition of leaves and twigs in the saltbush browse diets. These values were applied to the leaf/twig diet selected by ewes in each feed

lot (Table 3). We then calculated the total CF, CP, and minerals present in the real diets consumed in each feed lot (Table 5), including straw.

Table 4. Chemical composition of *A. halimus* leaves and twigs (percentage of DM).

Composition	Leaves	Twigs
OM	70.29	91.29
CF	13.92	53.21
CP	18.48	6.37
Fat (ether extract)	3.06	1.26
Minerals (ash)	29.71	8.71
Na	7.92	1.25
K	8.83	3.03
Ca	2.52	1.12
Mg	1.92	0.43
P	0.18	0.16

Table 5. Crude fiber (CF), crude protein (CP), and mineral content (g total DM intake) of daily mean saltbush diet selected by ewes in each feed lot.

Mean voluntary intake	CF	CP	Minerals
D 1 1,380 g DM of <i>A. halimus</i> per ewe	436.0	179.4	278.7
850 g DM of <i>A. halimus</i> per ewe +	215.3	121.2	190.5
D 2 505 g DM of straw	220.6 [†]	17.7 [†]	30.3 [†]
Total	435.9	138.9	220.8

[†] According to Chenost (1991).

During the 28 days of the experiment, mean CF intake was similar in both saltbush diets ($P < 0.05$). As can be seen in Figure 2, there was an increasing CF intake trend in diet A, while in diet A/S, where straw was available, CF intake was more stable. Throughout the experiment, CP intake was higher in diet A, but both diets (A and S/A) maintained parallel CP intake levels.

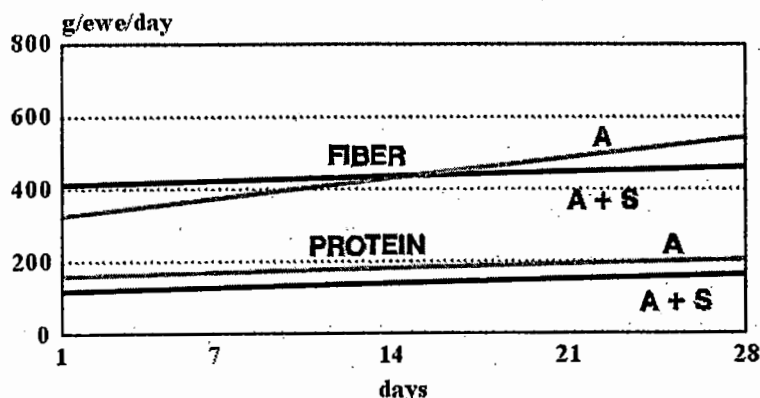


Figure 2. Total daily sheep intake of fiber (CF) and protein (CP) from two saltbush diets (with and without straw) and observed trends during the experiment.

Discussion

The mean saltbush dry matter intake obtained in our experiment, 1.38 kg DM/ewe per day (Table 1), was similar to the 1.31 kg DM/ewe per day obtained by Valderrábano et al. (1993) with Rasa Aragonsa sheep under free-grazing conditions, and to the 1.40 kg DM/ewe per day obtained by Le Houérou (1991) in Libya with Barbarine sheep. However, our saltbush intake value was higher than the 1.01 kg DM/ewe per day obtained by Alegre et al. (1993), and lower than the 2.0 kg DM/ewe per day obtained by Otal et al. (1993). Such differences can be partly explained by the fact that Alegre et al. used a wild *A. halimus* accession in their experiment, which probably had lower palatability than our FAO-INRF 70100 accession. Otal et al. used the same saltbush accession as ours, but their experiment was carried out in winter, and they used Manchega sheep, which are bigger than our Segureña breed.

If saltbush intake is considered in terms of the metabolic weight of the ewes, the average intake obtained by the fourth week of the pen-feeding experiment, 81.8 g DM/kg LW^{0.75} (Table 2), was similar to the 84 g DM/kg MW obtained by Otal et al. under similar experimental conditions, but higher than the 70.4 g DM/kg MW obtained by Valderrábano et al. under free-grazing conditions. This suggests that under pen-feeding conditions, intake values are overrated. However, when sheep become familiarized with saltbush browse, adaptation periods are shorter and final intake values higher—4.95 times higher at the end of a four month experiment run by Le Houérou (1991) in Libya, where the final Barbarine sheep intake was 90.1 g DM/kg LW^{0.75}.

Ewes with access to a mixed saltbush/straw diet consumed about one third less *A. halimus* than ewes on diet A. Saltbush intake was more stable in diet A/S. Supplementing with straw increased the leaf/twig ratio of the diet (Table 3), which produced a significant change in the fiber, protein, and mineral content of the saltbush diet (Table 5).

Conclusions

- Supplementing with straw modifies the leaf/twig ratio of the ingested saltbush and hence its nutritive value. This is due to the big difference in CF, CP, and ash content between saltbush leaves and twigs. Consequently, to determine the nutritive value of *A. halimus*, the leaf/twig ratio of the ingested browse must be known.
- The straw/saltbush diet results suggest that ewes voluntarily balanced their diet at about two thirds saltbush and one third straw. In this way, the fiber/energy of the straw compensated for the lower fiber/energy of the saltbush browse. With

the saltbush diet, ewes consumed more twigs (lower L/T rate), probably because they contain larger amounts of fiber/energy than leaves.

- Ewes feeding on the straw/saltbush diet finished the experiment with better body condition and higher liveweight, a confirmation of the fact that, with intake levels such as those reached in our experiment (-1.4 kg DM/ewe per day), the combined grazing of *A. halimus* and cereal stubble could be a good strategy to maintain dry ewes during summer periods.

References

- Alegre, J., M.A. Agudo y J.L. Sancha. 1993. Pastoreo de *Atriplex halimus* con ganado ovino. Pages 537–544 in XXXIII Reunión Científica de la SEEP. Ciudad Real, Spain.
- Chenost, M. 1991. Utilization digestive des pailles. *Options Méditerranéennes. Série Séminaires* 16: 67–72.
- El Hamrouni, A. 1981. Report on the fodder shrub trial. Pages 53–63 in 4th Meeting of the FAO-Subnetwork Mediterranean Pastures. Thessaloniki, Greece.
- El Hamrouni, A. et M. Sarson. 1975. Appétabilité de certains *Atriplex* spontanés ou introduits en Tunisie. INRF Tunisienne. Note de recherche 8. FAO Projet Tun-71/540.
- Franclet, A. et H.N. Le Houérou. 1971. Les *Atriplex* en Tunisie et en Afrique du Nord. FAO. FO.SF/TUN 11. Rapport Technique 7.
- Le Houérou, H.N. 1991. Feeding shrubs to sheep in the Mediterranean arid zone: Intake performance and feed value. Pages 623–628 in IV Congrès International des Terres de Parcours. Montpellier, France.
- Le Houérou, H.N. 1992. The role of saltbushes (*Atriplex* spp.) in arid land rehabilitation in the Mediterranean Basin: a review. *Agroforestry Systems* 18: 107–148.
- Otal, J., R.M. Barba, J.I. Perez, y V. Gómez. 1993. Valoración nutritiva de *Atriplex halimus* mediante su aprovechamiento con ovejas de raza Manchega. Pages 433–439 in XXXIII Reunión Científica de la SEEP. Ciudad Real, Spain.
- Russell, A.J.F., J.M. Doney and R.G. Gunn. 1969. Subjective assessment of body fat in live sheep. *Journal of Agricultural Science* 72: 451–454.
- Valderrábano, J., F. Muñoz y I. Delgado. 1993. Comportamiento en pastoreo de ovejas y cabras frente a *Atriplex halimus*. ITEA 12: 72–74.

Native Shrubs in Sheep Diets

S.K. Hamadeh¹, M. Abi-Said¹, K. Faour¹ and A.E. Osman²

¹Department of Animal Science, American University of Beirut, Beirut, Lebanon

²Pasture, Forage and Livestock Program, ICARDA, Aleppo, Syria

Abstract

A two-year study was conducted to determine the diet composition of 72 sheep grazing semi-arid native pastures reseeded with edible shrubs, namely *Atriplex halimus* and *Salsola vermiculata*, under three stocking rates. Botanical composition of sheep diets determined by fecal histology indicated that *Atriplex* and *Salsola* spp. can contribute up to 42% of the sheep diet in the dry season. Increasing stocking pressure, from 1 sheep/2.25 ha per year to 1 sheep/0.75 ha per year, increased *Atriplex* consumption, mainly in August. Grasses contributed consistently to sheep diets but responded negatively to the stocking rate.

Key words: shrubs, *Atriplex* spp., *Salsola* spp., sheep diet, stocking rate.

Introduction

Natural rangelands in the countries of West Asia are heavily degraded due to overstocking, cultivation, and uprooting of vegetation for domestic fuel (Pearse 1971; Osman et al. 1993).

Reseeding these lands with shrubs may help correct land degradation and provide supplemental feed for animals during periods of drought or forage maturity (Le Houérou 1992). Ongoing research at the International Center for Agricultural Research in the Dry Areas (ICARDA) indicates that the productivity of natural pastures and their capacity to sustain sheep production is improved by reseeded with two native shrubs, namely *Atriplex halimus* and *Salsola vermiculata* (Osman et al. 1993). Within this context, a collaborative study (American University of Beirut and ICARDA) was conducted to determine the contribution of these native shrubs to the botanical composition of sheep diets under low, medium, and heavy stocking rates.

Materials and Methods

The study was initiated in 1991 and included sheep grazing on 100 ha of native rangelands at Maragha (120 km southeast of Aleppo, annual rainfall 200 mm) that had been improved by direct seeding of *A. halimus* and *S. vermiculata*.

Three stocking rates, 1 sheep/2.25 ha (L), 1 sheep/1.5 ha (M) and 1 sheep/0.75 ha (H) were applied, with three replications for each treatment.

Ewes grazed the plots from early morning to sunset and were confined at night. If body weight was not sustained by grazing and during late pregnancy and early lactation, animals were supplemented with barley, cottonseed cake, and hay. Good-quality water was provided on a continuous basis for all animals. Detailed descriptions of the study site, forage, biomass production, and sheep performance over four seasons (1989–1993) can be found in Osman et al. (1993) and Osman and Shalla (1994).

Diet Botanical Composition

Fecal grab samples of 20–40 pellets were collected from 72 ewes (8 ewes/plot per treatment) over three seasons (August/November 1992, April 1993, and April, August, and November 1994). The samples were dried and ground to pass through a 1 mm Wiley screen. Composite samples were prepared for each ewe.

Samples of key forage plants, mainly shrubs, were hand plucked according to season, dried, and ground to be used for reference and identification. Fecal and plant materials were soaked in bleach to remove plant pigments, used, and mounted on slides with Hoyer's solution (Holecheck 1982; Holecheck and Valdez 1985). The botanical composition of each fecal sample was determined by microscopic observation. Twenty random fields per slide were screened for undigested plant fragments, which were recorded as frequencies and estimated as percentage of the diet for each forage species (Holecheck and Gross 1982).

Botanical components of diets were statistically analyzed using a two-way analysis of variance for complete randomized block designs. When significant *F* values were obtained, means were separated by least significance difference procedures.

Results and Discussion

The botanical composition of the diet of sheep grazing on native pastures reseeded with shrubs (Table 1 and 2) indicated that *Atriplex* and *Salsola* spp. contributed at least 7–10% of the diet during the two years of the study (1992/93, and 1994), with marked seasonal variation. During the dry season (August) of 1992/93, about half the sheep diet (42%) consisted of edible shrubs, with equal proportions of *Atriplex* and *Salsola* spp. (Table 1). The consumption of shrubs declined during the autumn (November) of that year. This agrees with Osman et al. (1993), who studied the herbage availability of the pasture. They observed that the shrubs made their maximum growth and contribution to grazeable forage during the summer of the same year, while forage, including herbaceous plants, was available in the fall and spring. In contrast, shrubs made up only 10% of the sheep diet in August 1994, compared to 38% of the diet in November 1994. Several studies show considerable

changes in forage selection by sheep according to seasonal (Holecheck et al. 1986; Posse et al. 1996).

Increasing the stocking rate from 1 ewe/2.25 ha per year to 1 ewe/0.75 ha per year resulted in more *Atriplex* consumed in August 1992 (16.7 and 25%, respectively) ($P < 0.05$). A similar trend was observed in August 1994 (Table 2). However, the influence of the stocking rate on the contribution of *Salsola* to the sheep diet was inconsistent and fluctuated according to season and year. Monitoring of available forage at the same location indicated a seasonal stocking rate interaction effect on the available forage (Osman et al. 1993). Energy supplementation during late pregnancy and early lactation may have alleviated grazing pressures under high stocking rates. Supplementation may affect the grazing behavior of sheep whenever the nutritional value of pastures is inadequate (Hamadeh et al. 1990). Grasses contributed steadily to the sheep diet, especially in April, when they constituted at least 30% of the diet. *Poa bulbosa*, a highly palatable herbaceous species, was consistently preferred by sheep in April and August, and to a lesser extent in November (27, 28, and 14% respectively, 1993 and 1994 combined). A similar preference for *P. bulbosa* was reported for sheep grazing on semi-arid steppes (Abdullahi et al. 1986; Posse et al. 1996). Sheep are known to be grazers whenever grass is abundant. However, they are characterized by dietary plasticity and seem to maintain the quality of their diet by selecting different types of forage (Schwartz and Ellis 1981; Hamadeh et al. 1990). Consumption of *P. bulbosa* responded negatively to stocking rate, mainly in August ($P < 0.05$) and, to a lesser extent, in spring. Other herbaceous species only selected in spring, i.e. on a seasonal basis, included *Helianthemum ledifolium* and *Carex stenophylla*.

Thus, edible shrubs can provide sheep grazing on semi-arid pastures with substantial green forage, especially in the dry season under high stocking pressures.

Table 1. Botanical composition (%) of sheep diets at three stocking rates on shrub-seeded, semi-arid pastures (1992/93).

Forage	Season														
	August 1992					November 1992					April 1993				
	L [†]	M	H	SE	Ave.	L	M	H	SE	Ave.	L	M	H	SE	Ave.
<i>Atriplex</i> spp.	16.6 ^a	24.3 ^b	25.2 ^c	0.2	22.0	2.6 ^{ab}	1.8 ^a	3.2 ^b	0.1	2.5	1.1	1.3	2.4	0.3	1.6
<i>Salsola</i> spp.	23.6 ^b	22.2 ^a	15.3 ^a	0.5	20.4	8.5 ^a	12.1 ^b	13.2 ^c	0.4	11.3	3.1 ^a	4.4 ^b	4.7 ^b	0.2	4.1
<i>Poa bulbosa</i>	29.2 ^c	25.4 ^b	21.6 ^a	0.4	25.4	11.2 ^a	16.1 ^b	15.4 ^b	0.5	14.2	26.1 ^b	20.3 ^a	19.8 ^a	0.6	22.1
<i>Malva</i> spp.	-	-	-	-	-	-	-	-	-	-	5.9 ^a	7.2 ^{ab}	8.6 ^b	0.4	7.2
<i>Helianthemum ledifolium</i>	-	-	-	-	-	-	-	-	-	-	32.5 ^a	30.6 ^a	40.2 ^b	0.7	34.4
<i>Artemisia herba-alba</i>	6.4 ^a	8.1 ^b	7.5 ^{ab}	0.2	7.3	12.9	10.7	18.9	0.3	14.2	-	-	-	-	-
Others [‡]	24.2	20.0	31.4		25.2	64.8	59.3	49.5		57.9	32.3	36.2	24.3		30.9

[†] L = one sheep per 2.25 ha; M = one sheep per 1.5 ha; H = one sheep 0.75 ha.

[‡] Others include *Carex stenophylla*, *Ephedra elata*, *Noea mucronata* and energy supplements in addition to unidentified species.

^{a, b, c} Row means within season with different superscripts differ ($P < 0.05$).

Table 2. Botanical composition (%) of sheep diets at three stocking rates on shrub seeded semi-arid pastures during 1994.

Forage	Season														
	April 1994					August 1994					November 1994				
	L [†]	M	H	SE	Ave.	L	M	H	SE	Ave.	L	M	H	SE	Ave.
<i>Atriplex</i> spp.	2.7	5.8	4.2	0.7	4.2	4.8 ^a	8.1 ^b	9.6 ^b	0.5	7.5	19.3	19.0	17.8	0.4	18.7
<i>Salsola</i> spp.	5.8	4.9	5.5	0.9	5.4	3.3 ^a	4.5 ^{ab}	5.5 ^b	0.4	4.4	19.0	19.0	19.8	0.2	19.3
<i>Poa bulbosa</i>	33.6	34.4	35.0	0.7	34.3	59.2 ^c	42.4 ^b	35.7 ^a	1.2	45.8	14.1	13.3	14.2	0.5	13.9
<i>Malva</i> sp	23.5 ^a	24.8 ^a	35.2 ^b	0.8	27.8	3.2 ^a	4.9 ^b	3.3 ^a	0.2	3.8	-	-	-	-	-
<i>Helianthemum ledifolium</i>	19.2	19.0	19.3	0.9	19.2	2.1 ^a	3.2 ^{ab}	3.8 ^b	0.4	3.0	-	-	-	-	-
<i>Artemisia herba-alba</i>	-	-	-	0.5	-	3.1 ^a	5.3 ^{ab}	7.9 ^b	0.6	5.4	23.1	23.7	24.4	0.4	23.7
Others [‡]	3.5	11.1	0.8	-	5.1	24.3	21.6	34.2	-	26.7	24.5	25.0	23.8	-	24.43

[†] L = 1 sheep per 2.25 ha; M = 1 sheep per 1.5 ha; H = 1 sheep per 0.75 ha.

[‡] Others include *Carex stenophylla*, *Ephedra elata*, *Noea mucronata* and energy supplements in addition to unidentified species.

^{a, b, c} Row means within season with different superscripts differ ($P < 0.05$).

References

- Abdullahi, A.N., N.I. Hassan, M.A. Bayoumi and M.A. Shourbagy. 1986. Forage preference of sheep, goats and camels in the Mediterranean type arid region of Wadil-Azieb, Syria. ACSAD, Damascus, Syria.
- Hamadeh, S.K., C.V. Hulet, R.R. Rouda and J.L. Holecheck. 1990. Supplementation effects on sheep diet and weight on semi-desert range. *SID Sheep Research Journal* 6(3): 6-13.
- Holecheck, J.L. and B.D. Gross. 1982. Evaluation of diet calculation procedures for microhistological analysis. *Journal of Range Management* 35: 721.
- Holecheck, J.L. 1982. Sample preparation techniques for microhistological analysis. *Journal of Range Management* 35: 267.
- Holecheck, J.L. and R. Valdez. 1985. Magnification and shrub stemming material influences on fecal analysis accuracy. *Journal of Range Management* 38: 350.
- Holecheck, J.L., J. Jeffers, T. Stephenson, C.B. Kuykendall and S.A. Butler-Nance. 1986. Cattle and sheep diets on low elevation winter range in north-central New Mexico. *Proc. West. Sec. Amer. Soc. Anim. Sci.* 37: 243.
- Le Houérou, H.N. 1992. The use of salt bushes (*Atriplex* spp.) in arid land rehabilitation in the Mediterranean Basin: A review. *Agroforestry systems* 18: 107-148.
- Novikoff, G. 1983. Desertification by overgrazing. *Ambio* 12: 102-105.
- Osman, A.E., F. Bahhady, N. Hassan and N. Murad. 1993. Use of fodder shrubs in the rehabilitation of degraded rangelands in Syria. Pages 136-141 in the PFLP Annual Report. ICARDA, Aleppo, Syria.
- Osman, A.E. and M.A. Shalla. 1994. Use of edible shrubs in pasture improvement under Mediterranean environment in northern Syria. Pages 255-258 in *Halophytes as a Resource for Livestock and for Rehabilitation of Degraded Lands*. (V. Squires and A. Ayoub, eds.). Kluwer, The Netherlands.
- Pearse, C.K. 1971. Grazing in the Middle East: Past, present and future. *Journal of Range Management* 24: 13-16.
- Posse, G., J. Anchorena and M.B. Collantes. 1996. Seasonal diets of sheep in the steppe region of Tierra del Fuégo, Argentina. *Journal of Range Management* 49: 24-30.
- Schwartz, C.C. and J.E. Ellis. 1981. Feeding ecology and niche separation in some native and domestic ungulates on the shortgrass prairie. *Journal of Applied Ecology* 18: 343-353.

Pâturage d'*Atriplex nummularia* dans la Zone Aride du Sud du Maroc

M. Tazi¹, A. Birouk², B. Hafidi² and M. Aghlabi³

¹Centre de Production des Semences Pastorales, El Jadida, Maroc

²Institut Agronomique et Veterinaire Hassan II, Rabat, Maroc

³Office Regional de Mise en Valeur Agricole de Souss-Massa, Agadir, Maroc

Résumé

Plus de 25000 ha de parcours dégradés au Maroc ont été réhabilités en utilisant des arbustes fourragers, notamment *Atriplex nummularia*. Dans le souci de contribuer à la détermination de la période de pâturage et aux modalités d'exploitation de parcours améliorés d'*Atriplex*, une étude a été menée durant les années 1990–1991, dans la station pastorale d'Ouled Allag (région de Taroudant) dans le sud du Maroc, au cours de la période du déficit alimentaire dans la région (15 août au 15 novembre). L'effet sur la croissance d'un troupeau ovín de 3 traitements : (i) pâturage direct de plants d'*Atriplex* ; (ii) pâturage direct de plants d'*Atriplex* supplémenté avec 350 g.d'orge/tête/jour ; et (iii) pâturage direct de plants d'*Atriplex* supplémenté avec 1 kg de paille/tête/jour, a été étudié en comparaison avec le témoin (pâturage sur parcours non amélioré). Les pesées sont effectuées tous les 3 jours.

Les animaux qui pâturent sur les parcours améliorés d'*Atriplex* ont enregistré des croissances et des gains de poids supérieurs à ceux pâturent sur les parcours non améliorés. L'*A. nummularia* se prête bien au pâturage direct. Les gains de poids les plus élevés ont été obtenus chez les animaux ayant reçu une supplémentation à base d'orge.

Mots-clés : *Atriplex*, pâturage, arbustes fourragers, Maroc

Abstract

More than 25,000 ha of degraded rangelands in Morocco have been rehabilitated by planting fodder shrubs, mainly *Atriplex nummularia*. In order to determine the grazing period and use of *Atriplex*, an experiment was carried out during 1990/91 at the Ouled Allag range experimental station (Taroudant region) in the south of Morocco. The grazing period was from 15 August to 15 November, which corresponds to the critical period of feed-resource deficit in the region. Sheep performance under three treatments: (i) *Atriplex* grazing; (ii) *Atriplex* grazing with barley supplementation (350 g/head per day); and (iii) *Atriplex* grazing with straw supplementation (1 kg/head per day), was compared to the control (sheep grazing on non-rehabilitated range). The animals were weighed every three days. Animals grazing on *Atriplex*-improved

rangelands generated higher performance and body weight gain than animals grazing on non-rehabilitated rangeland. The highest body weight gains were recorded with animals receiving barley grain supplementation.

Key words: *Atriplex*, grazing, fodder shrubs, Morocco.

Introduction

Parmi les espèces arbustives introduites en Afrique du Nord pour l'amélioration des terrains de parcours, l'espèce *Atriplex nummularia* s'est montrée adaptée aux conditions contraignantes des zones arides du Maroc (Ezzahiri et al. 1986 ; Tazi et al. 1991). Actuellement, plus de 25000 ha de parcours dégradés au Maroc ont été réhabilités par cette espèce. Quant à la production fourragère de l'*A. nummularia*, des évaluations effectuées en Tunisie ont montré qu'elle pourrait produire 1,000 à 1,500 UF/ha dans les régions recevant une pluviosité de 150 à 200 mm/an (Malet 1969). Otal et Correale (1989) ont rapporté qu'au sud de l'Espagne dans les régions recevant jusqu'à 400 mm de pluie, les plantations d'*Atriplex* âgées de 2 ans ont produit jusqu'à 1500 kg/ha/an de matière sèche consommable. Dans la Région de Taroudant au sud du Maroc, où l'actuelle étude a été menée, Tazi et al. (1991) ont enregistré une production de 460 kg/ha/an de biomasse consommable chez des plants âgés de 30 mois. Par ailleurs, il a été reporté que l'*Atriplex* est une espèce résistante à la sécheresse et peut survivre sans produire avec une pluviométrie de 50 mm durant 12 mois (Franclet et le Houérou 1971).

En outre, les *Atriplex* jouent un rôle important dans l'alimentation des animaux en particulier quand la strate herbacée est desséchée ou indisponible. Durant cette période, les arbustes maintiennent en effet une valeur nutritive adéquate. Le Houérou (1987) rapportent que *A. nummularia* peut être à l'origine de plus de 170 kg de protéines brutes/ha/an ce qui correspond à la ration protéique de 8 ovins adultes/ha/an et qu'elle peut être à l'origine de 400 UF/ha/an assurant ainsi les besoins énergétiques annuels d'entretien de plus de 1.3 ovins/ha/an.

L'*Atriplex nummularia*, peut être exploitée annuellement à partir de la troisième année de sa plantation par pacage direct durant un mois entre août et novembre (Le Houérou 1987). Toutefois, l'exploitation de cette espèce au Maroc reste peu étudiée d'où l'intérêt de cette expérimentation qui a pour but de contribuer à la détermination de la période de pâturage et aux modalités d'exploitation de parcours améliorés d'*Atriplex*.

Matériels et Méthodes

L'étude a été menée sur une plantation démonstrative de 60 ha d'*A. nummularia* dans le périmètre pastoral d'Ouled Allag, situé à 80 km à l'Est de la ville de Taroudant (30° 43' N lat. ; 8° 11' O long.). Le climat de la zone est de type aride à hiver tempéré (pluviométrie annuelle moyenne sur 55 ans $P = 220$ mm ; moyenne des températures minima du mois le plus froid $m = 5,1^{\circ}\text{C}$; coefficient pluviométrique d'Emberger $Q2 = 23,1$). Le sol est à texture limono-sableuse, moyennement profond, développé sur des alluvions à charge caillouteuse.

La plantation est âgée de 30 mois au moment de la première exploitation. La charge animale est déterminée sur la base des besoins moyens d'entretien du troupeau à savoir 0,61 UF/tête et de la production totale en UF de la strate arbustive et herbacée qui sont de 193 UF/Ha, soit une charge théorique de 3,4 têtes/ha pendant 3 mois. Le cheptel des éleveurs ayant droit du périmètre pastoral est composé de 55,5% de brebis, 38,8% d'antennais et antennaises et 5,6% de béliers. Cette composition a été respectée lors du choix du troupeau expérimental qui était de 150 têtes, correspondant à une charge animale de 2,7 têtes/ha. Cette charge est en effet inférieure à la charge théorique par mesure de sécurité.

Le premier essai de pâturage a eu lieu du 15 août au 15 novembre 1990 et le second du 1er septembre au 30 novembre 1991. Les animaux préalablement vaccinés et traités contre les parasites ont été bouclés et abrités au niveau de la station pastorale. L'abreuvement du troupeau était assuré de façon continue par le biais des abreuvoirs qui ont été construits à l'intérieur du périmètre planté.

Afin de suivre l'évolution du poids des animaux, le troupeau a été divisé en 3 lots et les pesées ont été réalisées tous les 3 jours :

- Lot 1 (P1) : constitué de 20 animaux pâturant sur le parcours amélioré d'*Atriplex*.
- Lot 2 : Vingt animaux pâturant sur le parcours amélioré d'*Atriplex* et recevant 2 types de supplémentation :
 - (P21) : 10 têtes recevant 350 g d'orge/j/tête + CMV (Composé Minéral Vitaminé).
 - (P22) : 10 têtes recevant 1 kg de paille/j/tête + CMV.
- Lot 3 (P3) : 20 animaux pâturant sur le parcours habituel non amélioré (hors de la plantation).

Resultats

Gain Total de Poids des Animaux

Les résultats de croissance au cours des 2 années sont indiqués au Tableau 1. La comparaison de l'effet de pâturage de l'*Atriplex* par les différents lots d'animaux montrent que le gain total de poids des 10 animaux recevant 350 g/tête d'orge (P21) en supplément a été de 70 kg et 54 kg pour les années 1990 et 1991 respectivement correspondant à des gains moyens quotidiens (GMQ) de 77g/tête/j et de 62 g/tête/j. Le gain de poids des 10 animaux recevant une supplémentation de 1 kg/tête de paille a été de 50 kg en 1990 et 39 kg en 1991 correspondant à des GMQ de 55 et 45 g/tête/j. Les 20 animaux pâturant sur l'*Atriplex* sans supplémentation ont enregistré des gains totaux de 80 kg et de 72 kg en 1990 et 1991 correspondant à des GMQ de 44 et 41 g/tête/j. Par contre les animaux pâturant sur le parcours non amélioré ont perdu 40 kg du poids au cours de l'année 1990 et n'ont enregistré en 1991 qu'un gain total de poids de 18 kg correspondant à un GMQ de 10 g/tête/j soit 25% de celui qui a été enregistré par les animaux sur *Atriplex* seul.

Tableau 1. Gain total de poids des animaux par lot (toutes les catégories confondues).

Année	Lot	Nombre d'animal x	Gain/total/lot (kg)	Gain/tête (kg)	GMQ (g/tête/j)
1990	P21	10	70	7	77
	P22	10	50	5	55
	P1	20	80	4	44
	P3	20	-40	-2	-22
1991	P21	10	54	5,4	62
	P22	10	39	3,9	45
	P1	20	72	3,6	41
	P3	20	18	0,9	10

Il y a lieu de signaler que l'année 1990 a été une année de sécheresse et que la biomasse de la végétation sur les parcours naturels a été faible. Les Figures 1 et 2 donnent respectivement l'évolution des gains moyens de poids des animaux (toutes catégories confondues).

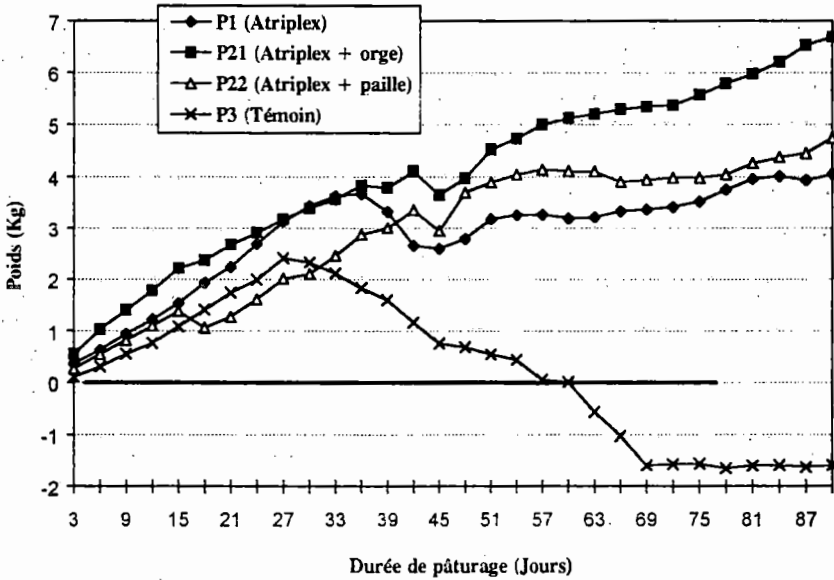


Figure 1. Volution de la moyenne du gain de poids des animaux (P,turage du 15/8 au 20/11/90).

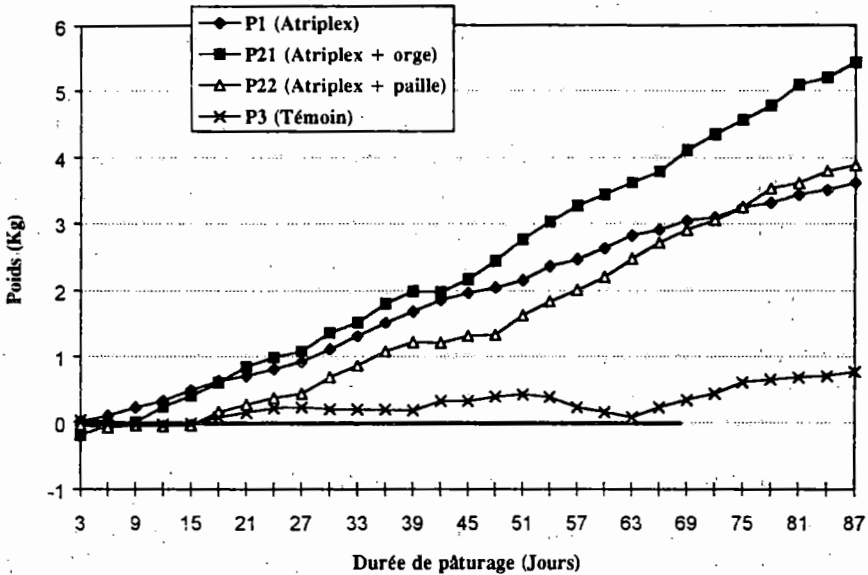


Figure 2. Volution de la moyenne du gain de poids des animaux (P,turage du 01/9 au 30/11/91).

Effet de Pacage du Parcours Amélioré sur la Croissance des Animaux

Les croissances des animaux qui pâturent sur le parcours amélioré (P1, P21, et P22) ont été nettement supérieures à celles des animaux pâturent sur le parcours non réhabilité (P3). Cet effet est significatif chez les 3 catégories d'animaux utilisés dans l'essai et ce au cours des 2 années. Cependant, seuls les résultats du second essai (1991) sont rapportés (Tableau 2).

Tableau 2. Moyenne de gain de poids et gain moyen quotidien (GMQ) des animaux (Période du 1/9 au 30/11/91).

Lot	Brebis		Bélier		Antenais	
	Gain/tête (kg)	GMQ (g/tête/j)	Gain/tête (kg)	GMQ (g/tête/j)	Gain/tête (kg)	GMQ (g/tête/j)
P21	5.86	67	8.8	101	6.13	70
P22	4.44	51	5.3	61	5.63	65
P1	2.95	34	4.5	53	4.6	56
P3	-0.21	-4.6	1.4	8	1.8	16

Ainsi et après 87 jours de pâturage :

- Le gain de poids moyen chez les brebis du lot P1 a été de 2,95 kg alors que celles du lot P3 ont perdu 0,21 kg. Ces chiffres correspondent à un gain moyen quotidien (GMQ) de 34 g/tête/j contre une perte de poids journalière de 4,6 g/tête/j, respectivement.
- Le bélier du lot P1 a gagné 4,5 kg alors que celui du lot P3 n'a gagné que 1,4 kg, soit des gains moyens quotidiens de 53 g/tête/j et 8 g/tête/j, respectivement.
- Le gain de poids moyen chez les antenais et antenaises du lot P1 a été de 4,6 kg correspondant à un GMQ de 56 g/tête/j, alors que chez ceux du lot P3, il n'a été que de 1,8 kg soit un GMQ de 16 g/tête/j. Ces résultats confirment ceux trouvés, dans la région d'Errachidia, au Maroc, à savoir un gain moyen quotidien de 67 g/tête/j chez les antenais pâturent sur l'*Atriplex* (Anonyme 1992).

Les Figures 3, 4, et 5 donnent l'évolution des gains de poids chez les différentes catégories d'animaux au cours du second essai.

Effet de la Supplémentation sur la Croissance des Animaux

La supplémentation a été donnée uniquement à des animaux pâturent sur le parcours amélioré (lot 2) pour étudier son effet par rapport à celui de l'*Atriplex* seul. Tous les animaux ayant reçu une supplémentation ont enregistré des croissances supérieures aux autres. Par ailleurs, la supplémentation à base d'orge a entraîné des croissances supérieures à celles obtenues avec la paille.

En effet, le gain de poids par tête chez les brebis ayant reçu une supplémentation de 300 g/j/tête d'orge a été de 5,86 kg, soit un GMQ de 67 g/tête/j, alors que celui des brebis ayant reçu une supplémentation de paille n'a été que de 4,44 kg correspondant à un GMQ de 51 g/tête/j (Tableau 1).

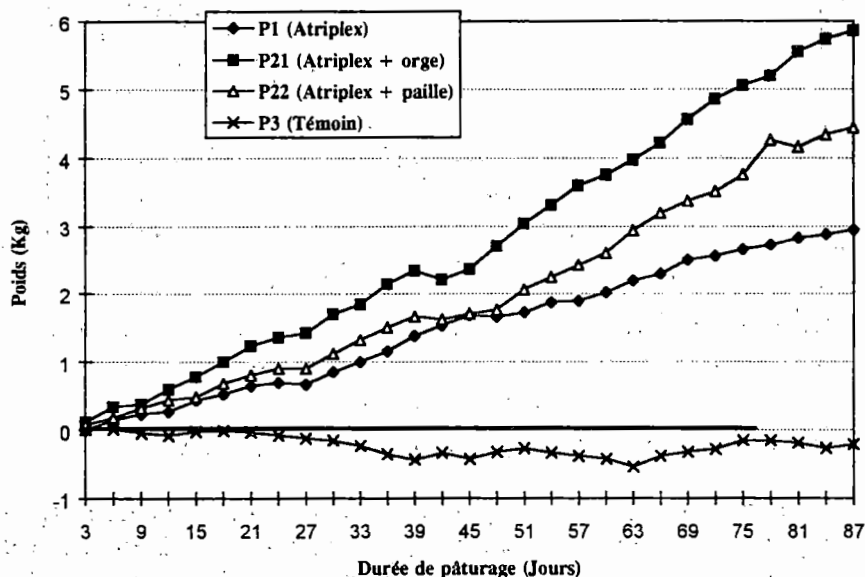


Figure 3. Evolution de la moyenne du gain de poids des brebis (1991).

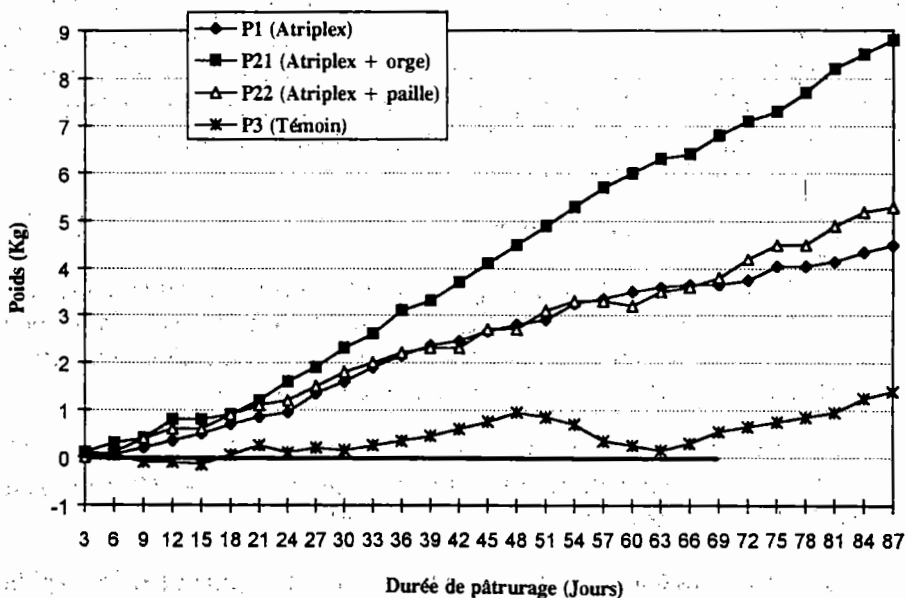


Figure 4. Evolution de la moyenne du gain de poids des antenais (1991).

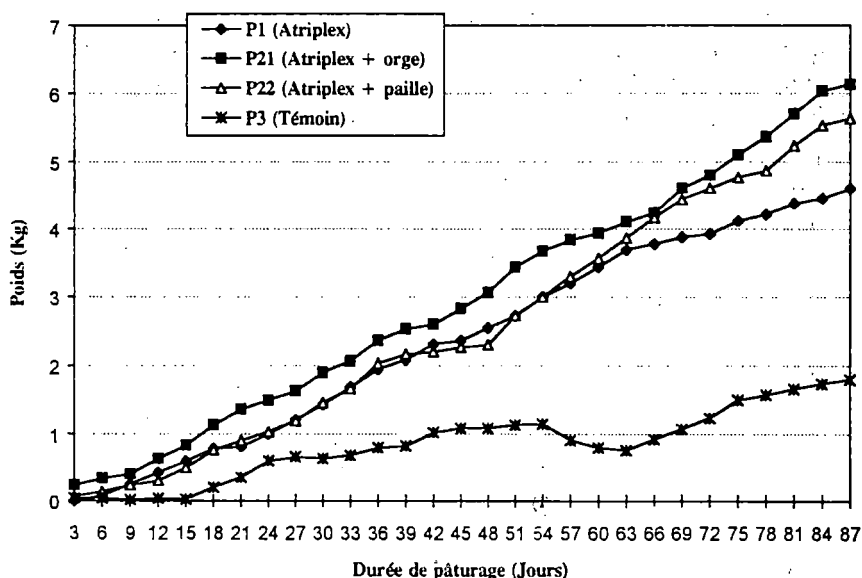


Figure 5. Evolution de la moyenne du gain de poids des bœliers (1991).

Des gains de poids par tête de 8,8 kg et 5,3 kg correspondant à des GMQ de 101 et 61 g/tête/j ont été respectivement enregistrés chez les bœliers recevant des supplémentations d'orge et de paille (Tableau 2). En outre, chez les antenais et antenaises recevant une supplémentation d'orge, le gain de poids par tête a été de 6,13 kg correspondant à un GMQ de 70 g/tête/j contre un gain de poids de 5,63 kg soit 65 g/tête/j chez celles recevant de la paille (Tableau 2). Ces résultats sont en concordance avec ceux enregistrés par les chercheurs de l'Office Régional de Mise en Valeur Agricole de Tafilalet qui ont enregistré un gain moyen quotidien de 86 g/tête/j chez des animaux recevant de l'*Atriplex* à volonté et une supplémentation de 200 g/j d'orge (Anonyme 1992).

Discussion

Au cours des 2 années d'expérimentation, le comportement alimentaire des animaux sur *Atriplex* ne laisse supposer aucun refus ; cependant, une consommation accrue d'eau d'abreuvement et une production abondante d'urine ont été observées chez les animaux pâturant l'*Atriplex*.

L'analyse des courbes d'évolution de la croissance des animaux (Fig. 1 et 2) montre que chez les animaux pâturant sur *Atriplex* (P1, P21, et P22) on peut distinguer 3 phases successives :

- Une première phase de croissance progressive avec un gain de poids rapide correspondant surtout au pâturage de la strate herbacée.

- Une seconde phase caractérisée par une chute brutale de poids chez l'ensemble des animaux. Cette phase correspond à la période d'adaptation à l'alimentation de l'*Atriplex*, la strate herbacée ayant été épuisée.
- Une troisième phase correspondant à la fin de la période d'adaptation où on constate une augmentation progressive du poids chez tous les animaux.

Toutefois, si on peut remarquer que la charge animale sur le parcours non amélioré (témoin) n'était pas contrôlée, il y a lieu de signaler que cet essai a permis de confirmer l'effet positif de l'*Atriplex* sur la croissance des différentes catégories d'animaux. D'autre part, on a constaté que l'effet de la supplémentation par la paille n'a pas été significatif par rapport à celui de l'*Atriplex* seul, par contre, la supplémentation à base d'orge des animaux pâturant de l'*Atriplex* a permis de tirer un meilleur gain de ce parcours. Cependant, une étude économique devrait être réalisée pour voir la rentabilité d'une telle supplémentation.

Conclusion

En maîtrisant la charge animale et la durée de leur exploitation, les parcours améliorés par l'*Atriplex* peuvent assurer une alimentation d'entretien des animaux surtout en automne (période critique s'étalant du mois de septembre à novembre). Le comportement alimentaire des animaux sur *Atriplex* a été jugé très bon et cet arbuste se prête bien au pacage direct à condition de mettre suffisamment d'eau d'abreuvement à la portée des animaux. Les résultats de cette étude montrent que la réhabilitation des terrains de parcours des zones semi-arides et arides du Maroc par les plantations d'*A. nummularia* est une opération qui est rentable surtout si on ajoute à l'effet qu'elle a sur l'alimentation du cheptel durant les périodes critiques, l'effet environnemental qu'elle joue dans la stabilisation des sols et la lutte contre la désertification. Par ailleurs, tous les parcours améliorés par la plantation de la seule espèce *A. nummularia* restent, toujours sous la menace de dégradation en cas d'attaque éventuelle d'insectes ou de maladies cryptogamiques, d'où l'intérêt d'utilisation de mélanges d'espèces. Dans ce cadre, les recherches menées dans la région de l'Afrique du Nord et de l'Asie de l'Ouest, sur les espèces arbustives autochtones devraient être encouragées et soutenues.

Références

- Anonyme 1992. L'*Atriplex nummularia*: Production et utilisation dans l'alimentation des ovins. Note de l'Office Régional de Mise en Valeur Agricole de Tafilalet. Séminaire sur les Arbustes Fourragers, 28–29 Mai 1992, Oujda, Maroc.
- Ezzahiri, A., A. El Maghraoui et A. El Abassi. 1986. Comportement des *Atriplex* en zone aride. Séminaire Association Nationale pour la Production Animale. 10–12

Avril, Rabat, Maroc.

- Franclet, A. et H.N. Le Houérou. 1971. Les *Atriplex* en Tunisie et en Afrique du Nord. Projet PNUD/FAO TUN 11. Rapport technique. FAO, Rome, Italie.
- Le Houérou, H.N. 1987. Consommation volontaire de ligneux fourragers et performances animales chez le mouton barbarin. Pages 91–95 in FAO-European Cooperative Network on Pasture and Fodder Crop Production, Bull. No. 5, Sub-network on Mediterranean Pastures, 5th Meeting, Montpellier. Serv. de Invest. Agrar. de Extremadura, Badajoz, Espagne.
- Malet, P. 1969. Premiers résultats d'un essai d'*Atriplex nummularia* sur le sol argileux non salé et sous pluviosité naturelle à Hendi Zitoun dans la plaine de Kairouan. Centre de Recherches en Génie Rural, Tunis, Doc. Tech. 133.
- Otal, J. et E. Correal. 1989. Productividad primaria y aprovechamiento ovino de *Atriplex nummularia* arbusto forrajero introducido en el S.E. Español. Reunión Iberica de pastos y forrajes. 10–14 Abril 1989. Badajoz, Espagne.
- Tazi, M., A. Birouk, B. Hafidi et A. Haimoura. 1991. Comportement d'*Atriplex nummularia* en zone aride du sud Marocain. IV Congrès International des Terres de Parcours, Montpellier, France.

Les Arbres et Arbustes dans les Systèmes Fourragers d'Afrique Tropicale : Élaboration de Références Scientifiques et Techniques au Service d'une Meilleure Gestion de ces Ressources

H. Guerin¹, A. Ickowicz² and B. Mallet³

¹CIRAD-EMVT, Montpellier France

²INERV-ISRA, Dakar, Senegal

³CIRAD-Forêt, Montpellier, France

Résumé

De nombreuses connaissances sont disponibles sur la biologie, la productivité et la valeur nutritive de plus de cent espèces d'arbres et arbustes fourragers des régions d'Afrique sahélienne et soudanienne. Quelques dizaines d'entre elles ont un rôle déterminant pour la couverture des besoins du bétail en saison sèche. Certaines sont intensivement exploitées par les éleveurs. Evidemment, elles fournissent aussi du bois de chauffage. Le CIRAD-EMVT, le CIRAD-Forêt et leurs partenaires des Systèmes Nationaux de Recherche Agronomique (SNRA) peuvent maintenant valoriser ces acquis et s'engagent dans des actions de recherche-développement dont le principal objectif est une meilleure gestion des ressources fourragères ligneuses des parcours sylvo-pastoraux. Ces actions sont envisagées dans le cadre d'un dialogue avec les utilisateurs des parcours et celui d'une organisation foncière naissante. Des travaux plus spécialisés à objectifs méthodologiques pour évaluer les ressources et leur évolution sous l'effet de telle ou telle pratique de gestion se poursuivent également. Les espèces exotiques concernent soit des opérations de reboisement dans des régions dégradées, soit l'aménagement de l'espace rural avec des espèces à usages multiples dans les régions où l'intégration de l'agriculture et de l'élevage s'accroît. Le texte expose les principales orientations de ces travaux.

Mots-clés : Afrique tropicale aride et semi-aride, espèces fourragères ligneuses, biologie, biomasse fourragère utile, valeur fourragère, gestion, espèces introduites à usages multiples.

Abstract

A lot of information is available on the biology, productivity, and feeding value of more than 100 native tree and shrub species found in Sahelian and Sudanese Africa. Many are very useful as animal feed during the dry season. Herders crop some of them intensively. They also produce fuelwood. CIRAD-EMVT, CIRAD-Forêt, and their NARS partners may now make good use of this knowledge in

research and development projects with the aim of better management of native fodder trees and shrubs on sylvo-pastoral ranges. Users of pastures are involved in these projects, which depend strongly on land tenure policies. More specialized topics are studied from a methodological point of view for the practical assessment of rangeland resources and their response under different management practices. Exotic species are used mainly for reforestation projects in degraded areas or in areas where livestock and cropping activities are more and more integrated. These species must be multipurpose. This paper presents a general overview on these activities.

Key words: arid and sub-arid tropical Africa, native trees, shrubs, fodder species, biology, usable fodder biomass, nutritive value, management, multipurpose exotic species.

Introduction

Les fourrages ligneux des régions sahéliennes et soudaniennes d'Afrique subsaharienne participent largement à l'alimentation traditionnelle des troupeaux transhumants et nomades depuis les temps ancestraux. Cela a été largement décrit par les premiers observateurs des pâturages, du cheptel et des pratiques d'élevage des pasteurs. Ce n'est que depuis les années 70-80 (Le Houérou 1980) que la communauté du développement rural et de la recherche s'est significativement investie en régions sahéliennes et soudaniennes pour évaluer l'importance quantitative et qualitative de ces fourrages. La mise au point de méthodes de gestion des peuplements arbustifs et arborés de ces régions dans une optique fourragère est une préoccupation actuelle.

La Stratégie du Cirad en Agroforesterie à Orientation Fourrager

Le CIRAD-EMVT en partenariat avec des SNRA d'Afrique Centrale et de l'Ouest a, comme l'ILCA/ILRI, entrepris des inventaires quantitatifs et qualitatifs des arbres et arbustes fourragers. Ces travaux ont pour but d'une part, de mieux connaître individuellement les espèces végétales ligneuses utiles à l'élevage, d'autre part, d'établir, à l'échelle des terroirs, des références techniques sur la production fourragère des peuplements ligneux et sur son utilisation par le bétail.

Ces références constituent les données de base pour la mise au point de méthodes et de normes de gestion *en zones tropicales sèches de steppes*. Cependant la restauration et/ou la réactualisation de règles d'utilisation foncière est, dans tous les cas, un préalable incontournable aux efforts coordonnés de gestion pastorale et forestière. En conséquence, les connaissances acquises dans le domaine des arbres et arbustes fourragers ne peuvent trouver leur application que dans un contexte de

développement global où la gestion de l'espace repose sur un consensus de type socio-économique dont l'obtention doit être prioritaire lors de la conception des projets de recherche et/ou de développement.

La gestion de ces espèces fourragères ligneuses doit s'inscrire dans une approche plus globale de l'aménagement des écosystèmes au sein desquels elles se trouvent, et d'une prise en compte des usages multiples de ces espèces, en particulier la production de bois de feu. Les travaux initiés par le CIRAD-Forêt au sein de divers projets en Afrique soudano-sahélienne visent à prendre en compte cette diversité tant des espèces que des usages et des acteurs en vue d'un aménagement durable de ces formations sylvopastorales.

En zones *subhumides de savanes*, l'intégration progressive des activités agricoles et d'élevage renforce l'importance de l'arbre dans des paysages de bocages et de parcs arborés à préserver ou à reconstituer. Les travaux menés par le CIRAD sur les espèces arborées et arbustives visent alors à la fois à :

- A développer les fonctions défensives et anti-érosives des haies vives, en particulier en tant qu'interfaces entre les cultures et le bétail.
- A renforcer le rôle de l'arbre dans le maintien de la fertilité des sols agricoles, de façon directe (effets microclimatiques ; apports de litière), comme de façon indirecte par les animaux (via les fèces).
- A optimiser les différentes fonctions de productions des espèces ligneuses (bois de feu et de service ; fourrage ; fruits ; éléments de pharmacopée, etc.) afin de les prendre en compte dans les modalités de gestion de ces espèces au sein des terroirs agricoles.

Le raccourcissement de la durée des jachères, assez général dans ces régions, peut également justifier des actions de boisement de celles-ci avec les espèces les plus utiles sur le plan fourrager et de la restauration de la fertilité des sols.

Le CIRAD et ses partenaires mènent aussi des actions d'agroforesterie intégrant des objectifs d'élevage dans des *régions tropicales humides de forêt et/ou d'altitude* (la Réunion, Nouvelle-Calédonie, zone forestière humide d'Afrique).

Ces travaux sont consacrés à des espèces bien connues pour leur intérêt fourrager (*Calliandra*, *Leucaena*, *Gliricidia*), dont l'introduction dans l'espace rural peut favoriser une diversification de la production des petits paysans, tout en favorisant la stabilisation de ces exploitations paysannes. Ils concernent en particulier les techniques d'implantation et de gestion, certains aspects de nature génétique (optimisation du couple rhizobium/végétal ; résistance au psylle pour le *Leucaena*). La valorisation des potentialités fourragères des espèces locales, moins connues de ce point de vue dans les régions humides, est aussi un objectif des travaux du

CIRAD encouragé par les risques pathologiques encourus par certaines espèces exotiques.

Ces problématiques se traduisent par des projets de Recherche et de Développement réalisés, en cours ou en projet, dont un bref aperçu est donné ci-dessous (Annexe 1).

Fourrages Ligneux des Parcours Pastoraux Sahéliens et Agro-pastoraux Soudaniens

L'exemple des travaux consacrés aux fourrages ligneux consommés par les ruminants sahélo-soudaniens est retenu pour illustrer l'enchaînement des connaissances et des méthodes nécessaires à l'élaboration de plans de gestion des ressources ligneuses :

- La connaissance de la contribution des ligneux aux régimes n'a de signification que par rapport à une ressource fourragère définie. Il est donc nécessaire de caractériser les *disponibilités* en préalable et en parallèle aux études de *la préférence alimentaire des animaux*. Les cycles saisonniers de croissance de l'herbe et les cycles phénologiques des espèces ligneuses sont déterminants pour les choix des animaux—ces paramètres doivent donc être étudiés dans leur dynamique temporelle (saisonnière et annuelle) et leur variabilité spatiale. De plus, seule une fraction de la production foliaire des ligneux est accessible au bétail, donc utile à celui-ci ; il est nécessaire de la quantifier.
- Aux abords de certaines villes, il existe un véritable *commerce* de rameaux feuillés et de gousses de légumineuses. Il joue un rôle significatif dans les activités d'élevage périurbain et, dans certains cas, menace les peuplements forestiers. Ce mode d'utilisation des fourrages ligneux doit aussi être pris en compte au niveau régional.
- L'évaluation du *rôle nutritionnel* des espèces ligneuses nécessite une connaissance individuelle des *espèces* et celle du *régime* des animaux. Le préalable à toute analyse est un *échantillonnage raisonné*. L'échantillonnage a d'abord pour but de caractériser une espèce dans sa diversité anatomique (tiges, feuilles, fruits, graines) et saisonnière: dans ce cas, les prélèvements concernent des organes individualisés. L'échantillonnage vise aussi à caractériser le régime des animaux, les prélèvements sont constitués d'un ensemble de fourrages représentant par exemple un repas. Le régime peut aussi être étudié de façon indirecte par l'analyse des matières fécales.
- La *valeur nutritive* des fourrages ligneux est très variable :
 - Digestibilité de la matière organique : 30 à 75 p. 100.
 - Teneur en matières azotées totales : 60 à 230 g par kg de matière sèche.

- Digestibilité des matières azotées : 14 à 82 p. 100, indépendamment de la teneur en matières azotées totales.
- Ingestion volontaire par les ovins : 25 à 90 g de matière sèche par kg de poids métabolique.
- Ces résultats sont obtenus par des *mesures sur animaux in vivo*, pour des bilans de digestion apparente, et *in situ*, pour mesurer la digestion dans tel ou tel compartiment du tube digestif (rumen, intestin grêle). Ces méthodes associées à des analyses chimiques montrent que la valeur nutritive est particulièrement dépendante :
 - Des teneurs en fibres et de leurs fractions plus ou moins digestibles.
 - De la teneur en azote digestible alors que celle en azote total est en moyenne assez élevée. La digestibilité des matières azotées dépend de facteurs physiques comme la répartition de l'azote entre les fibres des parois cellulaires et les autres compartiments des tissus ainsi que de facteurs chimiques (tannins ci-dessous).
 - Des teneurs en facteurs anti-nutritionnels comme les tannins qui affectent particulièrement la digestibilité de l'azote.
- Compte tenu du coût des méthodes *in vivo* et *in situ*, des délais d'obtention des résultats et des difficultés méthodologiques spécifiques aux fourrages ligneux, des *méthodes de prévision* de la valeur nutritive en fonction de critères analytiques sont recherchées. Les équations de prévision sont des relations mathématiques qui relient la valeur nutritive aux données du laboratoire ; leur établissement s'appuie sur des valeurs nutritives mesurées (plusieurs dizaines par espèces) ; leur application concerne des échantillons pour lesquels on ne dispose que de données de laboratoire.

Les principaux paramètres *chimiques* de prédiction de la valeur nutritive sont ceux cités ci-dessus (fractions pariétales ou fibres, fractions azotées, tannins), mais des critères plus globaux, à la fois plus synthétiques et d'obtention plus rapide, sont aussi recherchés comme la *dégradabilité enzymatique* ou *in vitro* (mesures de la digestion en condition contrôlées *in vitro* par des enzymes ou par du liquide ruminal) de la matière organique ou des matières azotées.

Une autre méthode potentiellement applicable aux espèces ligneuses est la *spectrométrie dans le proche infra rouge* (SPIR). Elle consiste à relier mathématiquement les profils spectraux des végétaux aux caractéristiques de leur matière organique (composition, digestibilité). Pour produire des résultats précis, cette méthode nécessite un étalonnage sur une centaine d'échantillons par espèce ; bien que cet effectif ait rarement été approché sur les fourrages ligneux, des critères simples (azote total, fibres etc.) peuvent cependant être prédits avec une précision acceptable compte tenu de la variabilité importante de ces fourrages et des objectifs, tels que le choix d'un niveau de complémentation par exemple.

Les analyses chimiques sont aussi appliquées aux matières fécales pour estimer, indirectement, certaines caractéristiques des régimes : digestibilité de la matière organique et teneur en azote digestible.

(a) La finalité de ces investigations sur la disponibilité, l'appétabilité et la valeur nutritive des espèces fourragères ligneuses est d'interpréter puis prévoir leur impact sur l'état nutritionnel et la production des animaux. C'est l'objet des *essais zootechniques*, qui consistent à mesurer les performances d'animaux recevant des rations complètes ou des compléments au pâturage.

Ces différents groupes de méthodes ont été mis en oeuvre dans le cadre d'un programme de recherche financé par l' Union Européenne conduit dans cinq pays d'Afrique Centrale et de l'Ouest avec la participation de 11 institutions africaines et européennes. On a pu ainsi répertorier environ trois cents espèces ligneuses sur une dizaine de parcours représentatifs de grandes régions d'élevage. La moitié d'entre elles est plus ou moins régulièrement consommée par le bétail et a été analysée plus ou moins complètement sur environ 3000 échantillons.

Les plus importantes d'entre elles, une cinquantaine, furent l'objet d'études plus complètes concernant la phénologie, la production foliaire, la digestibilité *in vivo* ou *in situ* ou encore des essais zootechniques (une quinzaine).

Ces travaux répertoriés dans un recueil méthodologique (Guerin 1994) destiné aux équipes participantes sont l'objet de valorisations et de prolongements.

(b) En matière de valorisation, la base de données issue de ce projet permet de fournir des estimations de valeur nutritive des espèces et de leur éventuelle variabilité (d'origine, géographique, saisonnière etc.). Ces estimations ont par exemple été diffusées pour *Acacia nilotica* (Audru et al. 1993) et *Faidherbia albida* (Depommier et Guerin 1995) Il est prévu aussi de les intégrer dans un recueil réunissant des informations biologiques et techniques relatives aux principales espèces ligneuses fourragères.

(c) L'ensemble des méthodes mises en oeuvre sur le terrain pour caractériser la ressource et son utilisation contribue aussi à l'élaboration de bilans fourragers sur parcours. Les travaux sur parcours sahéliens au Tchad ont par exemple permis de caractériser le niveau énergétique et azoté des rations ingérées par des ovins, des caprins et bovins. Suivant l'équilibre entre ressources herbacées et ligneuses et suivant l'espèce animale, le niveau azoté des rations est très variable. En conséquence, pour un objectif de production équivalent, la recommandation de complémentation des rations avec du tourteau varie du simple au double (Ickowicz 1995).

En complément à ces recherches sur les fonctions fourragères spécifiques des espèces ligneuses, des études ont également été menées au niveau de certains des

écosystèmes concernés, afin d'analyser la dynamique dans l'espace et dans le temps de ces espèces au sein de ces formations végétales naturelles, mais aussi leurs interactions avec les cultures dans les milieux agricoles. Ces travaux, menés en partenariat avec différents SNRA africains, en particulier en Côte d'Ivoire, au Burkina Faso, au Cameroun, portent en particulier sur :

- L'effet des feux sur l'évolution de la composition spécifique et la croissance des espèces.
- L'impact des interventions humaines (émondage ; élagage ; recépage) sur la croissance et la productivité en biomasse et en bois de ces espèces.

Ces données visent à mieux connaître la réaction des espèces forestières, et des espèces ligneuses fourragères, à l'anthropisation du milieu et aux pratiques humaines ; elles complètent les travaux conduits sur les relations entre l'arbre et la plante dans ces milieux (Grouzis et al. 1991) ; elles devraient permettre de définir des modalités d'intervention optimales en fonction des objectifs suivis tant par les pasteurs et agro-pasteurs, que par les agriculteurs et les forestiers.

Perspectives de Travaux Futurs

La généralisation de ces approches se heurte principalement à la lourdeur des méthodes nécessaires à des applications finalisées pour la gestion des parcours ou pour la complémentarité alimentaire des animaux.

Les travaux actuels ont donc pour objectif d'identifier les indicateurs les plus pertinents et les méthodes les plus économes pour les obtenir. Cette préoccupation concerne les différents niveaux d'analyse des relations plante-animal évoqués ci-dessus. Les approches à développer concernent plus particulièrement :

- La mise au point d'outils de télédétection spatiale pour caractériser les densités de peuplement ligneux à une échelle et une précision répondant aux objectifs de la gestion fourragère ne semble pas encore effective. Les dénombrements des peuplements et des espèces sur le terrain restent donc nécessaires, mêmes si des allègements dans les méthodes doivent être recherchés (niveau de précision à fixer suivant les objectifs, extrapolation grâce à la photo-interprétation etc.) ; les travaux de terrain sont de toute façon l'occasion pour le généraliste de réunir une précieuse information qualitative multiforme sur les conditions du milieu et son exploitation par l'homme et l'animal.
- La représentation cartographique des ressources et de leur utilisation par l'homme et le bétail peut maintenant s'appuyer sur les systèmes d'information géographique. Cela permet d'introduire des paramètres dynamiques tels que la distribution spatiale des cultures, des troupeaux, des points d'abreuvement, etc.

- Jusqu'ici, la production fourragère des ligneux est estimée grâce à l'observation sur le terrain de cycles phénologiques et par des mesures destructrices (même si elles sont appliquées à des échantillons des rameaux) et fastidieuses de la production foliaire. Les relations d'allométrie entre les mensurations et la production totale de feuillage constituent déjà un progrès mais ne sont pas encore disponibles pour toutes les espèces ; de plus, elles doivent être adaptées aux conditions du milieu. Plus récente, l'assimilation des arbres et arbustes à des formes géométriques permet de rendre plus rapide et plus précise l'évaluation de la biomasse fourragère utile (Ickowicz 1995). L'étape suivante consistera à modéliser la croissance des arbres grâce à une approche architecturale qui permettra d'obtenir, à partir de paramètres simples de terrain, une estimation de la dynamique de la biomasse fourragère dans l'espace et le temps. Elle pourra alors être représentée par une imagerie en trois dimensions (Cirad-Amap : de Reffye et al. 1991 ; Sabatier et Barthélème 1994). Des mesures de référence *in situ* seront ensuite nécessaires à la modélisation de l'impact du feu, de l'élagage ou du broutage.

L'enchaînement fructueux de ces travaux devrait permettre de passer de descriptions de situations particulières, certes de référence mais anecdotiques, à des scénarios plus variés et prospectifs, donc plus généralisables, dont le but sera le conseil de gestion. Plusieurs années sont prévues pour franchir ces étapes :

- Ces méthodes modernes (SIG, modélisation, imagerie) permettent de donner une représentation synthétique et évolutive des observations de terrain, mais ces dernières restent toujours nécessaires pour alimenter des référentiels de plus en plus ciblés. Cependant avec le recul actuel, des indicateurs plus pertinents de la durabilité des ressources et de l'état nutritionnel du cheptel peuvent être privilégiés et/ou confirmés : diagrammes démographiques des espèces ligneuses ; définition de critères limites d'abrutissement au delà desquels la survie ou la régénération des ligneux n'est pas assurée ; rythmes d'activités alimentaires traduisant une satisfaction globale de l'appétit ; état corporel en deçà duquel une complémentation exogène par des sous-produits est nécessaire pour garantir la survie ou mieux le potentiel de reproduction et de croissance du cheptel. Ces référentiels ne sont pas encore complets et nécessitent toujours un travail expérimental et d'observation traditionnel mais orienté par les nouveaux outils de gestion de l'information.
- La connaissance de la valeur alimentaire des espèces locales et introduites reste assez imprécise notamment sur le plan des interactions digestives entre les fourrages ligneux et les autres éléments des rations. Pour répondre aux interrogations des zootechniciens-praticiens, il est nécessaire de disposer de référentiels très divers qu'il n'est pas possible d'expérimenter individuellement sur l'animal.

- Comme pour le suivi des ressources sur le terrain, l'adaptation des méthodes rapides (SPIR) et globales (enzymatiques) d'estimation de la valeur nutritive aux spécificités des fourrages ligneux et des régimes qui en contiennent permettra d'accélérer l'acquisition des connaissances et de leur valorisation. Comme précédemment les travaux traditionnels en nutrition animale à poursuivre doivent servir de support de référence à la construction des modèles de prévision rapide de la valeur nutritive.
- Enfin, et en complément à ces recherches plus pointues, il semble important de mieux faire connaître aux "décideurs" et aux responsables de projets de développement rural la nature et la diversité des espèces ligneuses fourragères déjà utilisées de façon traditionnelle, ou potentiellement utilisables, mais également de faire ressortir leur importance pour assurer le développement et la "durabilité" de l'élevage dans de nombreuses régions tropicales.

Un ouvrage sur ces espèces forestières fourragères, précisant leurs caractéristiques tant fourragères que sylvicoles, est en cours de préparation au sein du CIRAD, associant les départements Élevage et Forêt dans une approche complémentaire sur ces espèces.

Conclusion

Dans le domaine des fourrages ligneux, on est passé au cours des deux dernières décennies d'une connaissance "naturaliste" à une connaissance "analytique et techniciste" qui reste peu opérationnelle sur les parcours extensifs. De ces acquis peuvent cependant être déduits et caractérisés les principaux enjeux tant forestiers que zootechniques liés aux relations arbres/animal dans les milieux arides.

Il est maintenant urgent d'aider les utilisateurs des parcours à maîtriser ces enjeux par des pratiques pastorales qui tiennent compte de l'évolution, tant démographique (homme, animal) que forestière et du contexte socio-économique (notamment l'accès limité mais réel à l'économie de marché tant pour l'acquisition d'intrants alimentaires que pour la commercialisation du bétail).

La recomposition socioprofessionnelle en cours dans ces régions doit être accompagnée et soutenue par la mise à disposition -urgente- d'outils qui contribueront à une gestion plus rationnelle des parcours sylvo-pastoraux sahéliens et soudaniens qui, entre autres caractéristiques, sont fragiles.

Références

- Audru, J., M. Labonne, H. Guerin et A. Bilha. 1993. *Acacia nilotica*: son intérêt fourrager et son exploitation chez les éleveurs Afars de la vallée du Magdoul à Djibouti. *Bois et Forêts des Tropiques-CIRAD-Forêt* (235): 59–70.

- Depommier, D. et H. Guerin. 1995. Emondage traditionnel de *Faidherbia albida*: production fourragère, valeur nutritive et récolte de bois à Dossi et Watinoma (Burkina Faso), Bois et Forêts des Tropiques-CIRAD-Forêt: *Numéro spécial: Faidherbia albida* 55-84.
- Grouzis, M., J. Nizinski et E. Akpo. 1991. L'arbre et l'herbe au Sahel : Influence de l'arbre sur la structure spécifique et la production de la strate herbacée et sur la régénération des espèces ligneuses. Actes du IV Congrès International des Terres de Parcours. Montpellier, France.
- Guerin, H. (ed.). 1994. Valeur alimentaire des fourrages ligneux consommés par les ruminants en Afrique Centrale et de l'Ouest. CCE-DGXII, Programme ST2.A/89/215-Allemagne (Univ. Hohenheim), Belgique (CRA-Gembloux), Cameroun (IRZV), Côte d'Ivoire (IDESSA), France (CIRAD-EMVT, CIRAD-Forêt, INRA-Theix), Mali (IER), Sénégal (ISRA-LNERV), Tchad (LRZV-Farcha).
- Ickowicz, A. 1995. Approche dynamique du bilan fourrager appliqué à des formations pastorales du Sahel tchadien. Thèse de Doctorat, Université Paris XII, Créteil, France.
- Le Houérou, H.N. (éd.). 1980. Les fourrages ligneux en Afrique: état actuel des connaissances. Colloque International. 8-12 août 1980. Addis Ababa (Ethiopia). CIPEA.
- de Reffye, P., E. Elguero and E. Costes 1991. Growth units construction in trees: A stochastic approach. *Acta Biotheoretica* 39: 325-342.
- Sabatier, S. et D. Barthélémy 1994. Premières observations sur l'architecture du cèdre de l'Atlas, *Cedrus atlantica* (Endl.) Manetti ex Carrière (Pinaceae), *Ann. Rech. For. Maroc*, 27 (spécial) 2: 362-379.

Annexe 1. Cirad forêt

Des Recherches sur les Espèces Fourragères Ligneuses Menées à des Échelles Variées

Au niveau de l'arbre :

- Études sur la productivité fourragère (feuilles et fruits)
- Évaluation de la productivité ligneuse (bois de feu)
- Recherches sur les associations symbiotiques (rhizobia)

Au niveau de la parcelle et de l'unité d'exploitation :

- Analyse des interactions arbre/sols/cultures
- Études sur les interactions arbre/animal

Au niveau du terroir agricole villageois :

- Études sur la dynamique des parcs agroforestiers
- Modalités d'intégration de haies fourragères

Au niveau de l'espace rural et forestier :

- Réaction des espèces au feu et aux interventions humaines
- Aménagements sylvo pastoraux des écosystèmes forestiers

Des Recherches sur des Espèces Fourragères Ligneuses Diversifiées, dans des Contextes Variés

Espèces arborées de parcs agroforestiers d'Afrique soudano-sahélienne :

- *Faidherbia albida* (Côte d'Ivoire ; Burkina Faso ; Cameroun)
- *Prosopis africana* (Cameroun)

Espèces arborées forestières d'Afrique soudano-sahélienne :

- *Pterocarpus* sp. (Côte d'Ivoire ; Burkina Faso)
- *Acacias* : *A. nilotica* ; *A. Senegal* (Sénégal ; Cameroun)

Espèces arbustives introduites :

- *Calliandra callothyrsus* (La Réunion ; Nouvelle Calédonie ; Cameroun)
- *Leucaena leucocephala* (La Réunion ; Côte d'Ivoire)

- *Acacia ampliceps* (Nouvelle Calédonie)

Des Activités de Recherche et de Développement Menées en Partenariat

Au sein du CIRAD :

- Départements
 - EMVT (aspects fourragers)
 - CA (interactions cultures)
- Unités de GREEN (socio-économie)
- Recherche: AMAP (modélisation)

Avec des collaborations françaises :

- NRA (écophysiologie)
- ORSTOM (phytoécologie)
- Universités (botanique ; géographie)

Avec des organismes de recherche et de développement africains :

- IDEFOR et IDESSA (Côte d'Ivoire)
- IRAD (Cameroun)
- INERA (Burkina Faso)
- ISRA (Sénégal)
- PE II (Niger)
- SONADER (Mauritanie)

Discussion: Plant–Animal Interface

Chair: V. Papanastasis (Greece)

Rapporteur: E. Thomson (ICARDA)

Oushy Hamdy (Egypt): The experimental design is important in grazing and feeding value trials, but replications across time and location are hard to find. This is especially true in grazing trials, although less so in feeding value trials.

M. Lloyd (Farmer, Australia): I believe it is important to evaluate data on a whole-farm basis, not just trial plots, as grazing management is based on whole-farm situations.

H.M. El-Shaer (Egypt): Evaluation of nutritive value should be carried out over a long feeding period and include all the criteria mentioned. Animal performance should also be tested.

J.J. Rochon (France): Looking at the plant–animal interface is a better way to study farming systems than defining methods of research. There are two points of view: (i) palatability, intake, and nutritive value must be in the context of a complete diet to take into account the interactions between the different components; (ii) animal feeding behavior and impact on vegetation must be analyzed in relation to the production cycle of flocks and fodder resources throughout the year.

L. El Bachir (Farmer, Morocco): A-t-on une idée de l'effet des arbustes sur le foetus ainsi que sur la qualité du lait et de la viande?

Answer by G. Gintzburger (ICARDA): Cela dépend de l'espèce d'arbuste utilisé. Drs. A. Osman, Thomson et Goodchild ainsi que Mr. F. Bahhadi travaillent actuellement sur l'effet du pâturage des plantations d'*Atriplex* dans la steppe Syrienne sur la production qualitative et quantitative du lait de brebis Awassi.

L. Mayer (GTZ-CRDA/DASPI/Project, Tunisia): Selection of plant species for animals has various objectives. Plant management is an important factor in deciding which plants to go for. Palatability is not considered as the most important factor for choosing species, because of the lack of optimal plant management available to all of us.

E. Correal (Spain): Anti-nutritional components (e.g. tannin) are not well-known; they vary from one species to another. I do not believe in this kind of analysis unless you have some idea of the answer beforehand.

F. Alnaoui (Livestock owner, Syria): From our experience on the Syrian steppe of Aleppo, we know that *Atriplex* spp. alone are not enough to feed the sheep. We think that *Atriplex* should be complemented by other crop residues, such as barley stubble and chopped straw (*tebben*). One option would be to grow barley between shrub rows.

H.N. Le Houérou (France): To evaluate nutritive values, I know only one method: animal performance. Everything else is blah, blah, blah.

H.N. Le Houérou (France): Shrubs are rich in N, vitamins, and minerals, and poor in fiber. Therefore, they complement fiber-rich feed: straw, stubble, poor rangeland.

H. Guérin (France): Il est important de définir la fonction des arbres et arbustes fourragers dans le système d'alimentation pour choisir les critères de valeur alimentaire (appétibilité, ingestibilité, valeur azotée, etc.).

S. Hamadeh (Lebanon): There are large individual variations in diet selections. Why not select animals instead of shrubs, in terms of preference?

B. Boulanouar (Morocco): We have carried out privilege cafeteria trials but there are problems with the microhistological technique. We should use field observations or esophageal fistula. The question is, how much do you sacrifice adaptation vs animal production and vice versa? Once we have assessed palatability, we still need to determine persistence under grazing, which is more of a mid- to long-term question.

T. Daoudi (Farmer, Morocco): We should give high importance to native species, and find ways to manage them in order to increase them in the range.

M. Acherkouk (Morocco): Le choix des espèces/écotypes d'arbustes fourragers devrait ressortir d'une étude du comportement alimentaire direct des animaux dans des arbustes fourragers, avec une étude, en particulier, sur les performances réelles de ces animaux engendrées (permises) par ces arbustes.

L. El Bachir (Farmer, Morocco): What is the best-quality shrub for sheep? What is the effect of plant parasites on plant palatability, and, consequently, the effect on animal health?

M. Boujrad (Morocco): Est-ce que les arbustes fourragers peuvent changer d'efficacité nutritive en changeant le lieu et le temps? Est-ce que les résultats de cette session vont être distribués aux éleveurs? Ce serait très intéressant pour eux et pour leur collègues sur place!

N. Murad (Syria): What is the best way to improve nutritive value? Sowing barley between rows of *Atriplex* or leaving space for annuals?

H. S. Oushy (Egypt): What techniques should we use to select the right plants? Fecal analysis and/or cytological analysis?

H.N. Le Houérou (France): The criterion for selecting individual shrubs for seed production is to use only individual shrubs that are heavily grazed and multiply them vegetatively in an isolated seed orchard. In nature, there is a genetic drift, a negative selection, towards unpalatable shrubs, because palatable individuals do not have a chance to produce seed when grazing pressure is high.

C. Malcolm (Australia): The ultimate test is whether the shrub makes money for the farmer in his farm system and with appropriate companion species or supplements. The quickest way to test this is to work on the farm with the farmer. Analysis supports this work but cannot substitute it.

H.N. Le Houérou (France): I am glad to see that what I showed 13 years ago in Libya is being confirmed: (i) the need for long-term feeding experience; and (ii) shrub intake and animal performance increase with time to 2–3 times the initial values, which are similar to those of short-term digestibility trials (600–900 g DM/h per day vs 1.5–2.5 kg DM/h per day).

H.N. Le Houérou (France): I suggest that where shrubs are concerned, we talk about total N and retained N instead of CP and DCP, since a $CP = N \times 6.25$ and some 50% of N is non-protein.

M. Bounejmate (ICARDA): I don't think there is one good answer to the question of how to evaluate the nutritive value of shrubs. We should first identify the problem and look for the best way to solve it. In Syria, for example, research indicates that milk quality decreases when sheep graze *Atriplex*, compared to natural pastures. Thus, milk composition analysis should be done.

M. Ben Diaf (Tunisia): A quel degré peut-on introduire les arbustes fourragers dans la ration alimentaire? Quelle est la période propice d'introduction des aimaux ou de la coupe? Et la période que peut couvrir cet arbuste afin d'établir un calendrier fourrager?

T. Ngaido (ICARDA): All the WANA countries have extensive experience with shrubs or cacti. There is a need to get the farmers to better understand selection and the use of shrubs. I also propose a farmer forum that will deal directly with the issues of selection and use of fodder shrubs.

M. Jamil (Jordan): The reasons and the need for research are different from the point of view of the researchers. Farmers need to improve their income, so the best way to transfer knowledge and results easily to the farmers is to do applied research on-farm.

B. Boulanouar (Morocco): Even the simplest methods call for chemicals, so intake and palatability studies should provide most of the needed information, especially if these shrubs are to be used in conjunction with other resources.

M. Acherkouk (Morocco): La question de savoir comment utiliser les arbustes fourragers par les animaux devrait prendre en considération plusieurs facteurs : disponibilité fourragère, disponibilité d'eau d'abreuvement, année climatique, végétation naturelle, etc. Il est donc nécessaire de réfléchir, plutôt, sur le pâturage direct au champ, ou à la coupe des arbustes fourragers et distribution.

Socioeconomics

Economics of Pastoral Fodder Shrubs in Jordan

K. Nesheiwat

Ministry of Agriculture, Monitoring and Evaluation
for Agricultural and Rural Development Projects, Amman, Jordan

Abstract

Native and exotic fodder shrub planting is a major activity for the MOA and JCO, both of which are concerned with range reserves. There are 20 range reserves in areas receiving 100–200 mm annual rainfall. The total area of these reserves is about 0.6 million ha. More than 13,000 ha have been planted to fodder shrubs, mainly *Atriplex nummularia* and *A. halimus*. Some areas inside these reserves were reseeded with fodder shrub seed, mainly *Salsola vermiculata*, *A. leucoclada*, and *A. halimus*. However, the reseeded of perennial forage grasses on Jordan's dry rangelands has never been very successful. Results show that developing the Badia reserve is not economically rational, while steppe reserve development based on protection and management is the most feasible option. Despite this perception, I encourage shrub planting in range reserves for the following reasons: (i) decreasing the numbers of shrubs planted per dunum will reduce costs and increase the internal rate of return; (ii) shrub planting will indicate to herders that the planted area is under development; and (iii) shrub planting will serve as an obstacle to governmental land acquisition by neighbors, even if the land is considered to be *wajihat ashairia*.

Introduction

Jordan's rangelands occupy 8.34 million ha, approximately 95% of the total land area. The rangelands extend from the highlands in the western areas which abut the Jordan (Rift) Valley, eastward to the steppe and Badia zones. Rainfall decreases from west to east. The highland rangelands cover about 200,000 ha (2.5%) in the >200 mm rainfall zone. The steppe rangelands cover about 1.0 million ha (11.5%) within the 200–100 mm rainfall zone. The Badia rangeland covers 7.1 million ha (82%) to the east of the 100 mm isohyet.

The purpose of this paper is to describe the native fodder shrubs in arid and semi-arid zones in Jordan and to examine the economics of reserve establishment with and without shrub plantation.

Vegetation Zones

Depending on the mapping system, the rangeland vegetation of Jordan can include a variety of different vegetation zones. According to IFAD (1993), there are six basic rangeland zones. These six vegetation zones characterized below.

Vegetation Zone 1

Zone 1 is located in the northeast, and makes up 67% of the land in Jordan. Characteristic shrub species are: *Anabasis articulata*, *Retama raetum*, *Zilla spinosa*, and *Artemisia herba-alba*. The zone ranges in altitude from 600 to 800 m. The climate is hot and arid, with annual rainfall of 25–75 mm.

Vegetation Zone 2

Zone 2 is located in the southeast and covers 9% of the land surface. The most common shrub species are: *Calligonum comosum*, *Haloxylon persicum*, *Haloxylon salicornicum*, and *Artemisa judaica*. The altitude ranges between 800 and 1,000 m. The climate is hot and arid with annual rainfall of 25–100 mm.

Vegetation Zone 3

This zone comprises the eastern escarpment of the Jordan Valley and covers 1% of the total land area. The common shrub species are: *Acacia tortilis*, *Artemisia herba-alba*, and *Retama raetam*. This zone is mountainous and highly dissected. It varies in altitude from 300 to 950 m. The climate is hot and dry. Annual rainfall ranges from 100 to 250 mm.

Vegetation Zone 4

Zone 4 is located in the southwest and covers 5% of the total land area. The most common shrub species are: *Retama raetam*, *Retama duriaei*, *Calligonum comosum*, *Zilla spinosa*, *Haloxylon salicornicum*, and *Acacia tortilis*. The altitude ranges from below sea surface to 300 m. The climate is hot and dry. Annual rainfall is 50–100 mm.

Vegetation Zone 5

Zone 5 is located in central Jordan and covers 7% of the total land area. Common shrub species are: *Artemisia herba-alba* and *Anabasis aphylla*. The altitude ranges from 700 to 1,200 m. The climate is hot and dry. Annual rainfall ranges from 100 to 250 mm.

Vegetation Zone 6

Zone 6 is located in the northeast and covers 4% of the total land surface. Common shrub species are: *Artemisia herba-alba*, *Salsola rigida*, *Haloxylon articulatum*, and *Achillea fragrantissima*. Altitude ranges from 650 to 800 m. The climate is hot and dry. Annual rainfall ranges from 75 to 200 mm.

In addition, the rangelands of Jordan have been categorized into agro-climatic zones as follows: highlands, steppe, and Badia, by descending order of rainfall.

Rangeland Vegetation Composition and Productivity

The available information on rangeland composition and productivity in Jordan is copious, but limited in terms of topic. Little work has been done in the rangeland areas of most of the country. Detailed information is limited to the 32 grazing reserves (established by MOA, JCO and RSCN).

The existing range reserves represent less than 1% of the rangelands in Jordan. Within the reserves, some 28% of the land has been planted with forage shrubs in an attempt to improve grazing conditions. The majority are located in the western highlands and the steppe, with a few in the arid Badia zones. The existing natural reserves also represent less than 1% of the total rangeland. Most are totally protected from grazing.

Data on plant species composition and biomass in the range reserves have been collected by professional staff at the National Center for Agricultural Research and Technology Transfer (NCARTT), and by the technical staff at the Range Division (Ministry of Agriculture). Data from the latter are generally less quantitative in nature. As noted by IFAD (1993), "Reports on rangeland forage biomass production are based on generalized values, quoted without reference to the original source, and it appears that most of the values reported are based on estimates, rather than on actual measurements." Scattered studies and research at Lajjoun in the steppe (Tadros and Salem 1993), in the northeastern Badia zones (Durham University 1994), and at Muwaqar, were carried out to improve rangeland productivity in the arid and semi-arid regions of Jordan.

Forage Shrub Planting Experience

Jordan's experience with fodder shrub planting on the range reserves is long, going back some five decades. The first reserves were established at Khanasry and Sorah in Mafraq Governorate. Today the range reserves in Jordan cover a total of about 68,000 ha and are managed either by the MOA or the JCO. About 30% (19,800 ha) of the reserve area has been planted with forage shrubs.

The forage shrub species used are predominantly *Atriplex halimus* (local) and *Atriplex nummularia* (Australian), with relatively minor stands of *Acacia saligna* and *Prosopis juliflora*. Despite the very low rainfall at some sites, the establishment and survival of shrubs have been remarkable. The shrubs are generally hand planted as seedlings into "contour" trenches that have been ripped using heavy machinery. The cost of forage shrub establishment within a reserve is about JD 724 per ha.

Despite the present shortcomings of forage shrubs, they offer considerable potential for providing strategic forage.

The palatability of *Atriplex* foliage is such that it is generally not selected by livestock in the spring, when there is a relative abundance of highly palatable annual grasses. This means that the new foliage may be carried over without special management, for use in summer or autumn when other forage components of the reserve have disappeared or are of very poor dietary quality. Good examples of the effect of shrub reserves, and especially the results of shrub planting, are found at Lajjoun in Karak Governorate and at AIRA and Al-Sahin in Balqa Governorate. Estimates of the general impact of shrub range reserves on rangeland production for the Badia and steppe are as follows:

Location	Open range	Shrub reserves
Badia	40 kg DM/ha	150 kg DM/ha
Steppe	100 kg DM/ha	450 kg DM/ha

Grazing trials at the Fujij reserve showed that average production of 8–10-year old *Atriplex* shrubs was about 950 kg DM/ha.

Forage Resources

Until the early 1950s, the Badia, steppe, and upland ranges in Jordan were covered with very different vegetation associations, including a variety of shrub species. In 1962, a Durham University team surveyed the southern highlands and stated the following: "The dominant species in the steppe is *Artemisia herba-alba* var. *Laxiflora* in association with variety grasses with intrusions into the eastern desert.... *Artemisia herba-alba* is seen to cover by far the greatest area of any species, as a broad belt running from the edge of the wooded highlands towards the more desertic terrain bordering the Desert Highway. The climax area of *Artemisia* is found in a belt running north and south between Tafila and Naqb Ishtar, where the herb exhibits vigorous growth and forms a dense cover. *Artemisia* has been found associated with *Poterium spinosum* in the Tafila-Rashadiya district." Table 1 shows the potential production increments of rangeland rehabilitation and projected increments in forage production over the next 30 years.

Table 1. Potential rangeland rehabilitation and forage production over the next 30 years.

Rangeland		Year						
		Present	Y5	Y10	Y15	Y20	Y25	Y30
Badia (desert <100 mm)	ha	7,100,00	2,990,539	2,654,326	2,572,781	2,548,205	2,548,205	2,548,205
	kg DM/ha	40	40	40	40	40	40	40
Badia (desert improved)	ha	1	4,051,871	4,386,773	4,467,920	4,492,415	4,492,415	4,492,415
	kg DM/ha	40	54	89	112	115	115	115
Badia (desert reserve)	ha	33,500	57,590	58,906	59,293	59,380	59,380	59,380
	kg DM/ha	100	109	131	145	147	147	147
Steppe (grassland 100–200 mm)	ha	600,000	268,204	174,983	163,496	159,136	159,136	159,136
	kg DM/ha	100	100	100	100	100	100	100
Steppe (grassland improved)	ha	1	279,122	366,595	377,373	381,465	381,465	381,465
	kg DM/ha	100	235	368	383	389	392	393
Steppe (shrubland 100–200 mm)	ha	400,000	185,620	118,437	110,159	107,016	107,016	107,016
	kg DM/ha	100	100	100	100	100	100	100
Steppe (shrubland improved)	ha	1	214,380	281,563	289,841	292,984	292,984	292,984
	kg DM/ha	100	235	368	383	389	392	393
Steppe (grassland reserve)	ha	34,331	52,674	58,422	59,131	59,400	59,400	59,400
	kg DM/ha	175	299	420	435	440	442	444
Highlands (grassland >200 mm)	ha	200,000	92,810	59,219	55,080	53,508	53,508	53,508
	kg DM/ha	600	600	600	600	600	600	600
Highlands (grassland improved)	ha	1	107,190	140,781	144,920	146,492	146,492	146,492
	kg DM/ha	600	780	957	978	985	989	991
Forest (natural grassland and browse)	ha	40,000	40,000	40,000	40,000	40,000	40,000	40,000
	kg DM/ha	300	345	389	394	396	397	398

Economics of Fodder Shrub Plantation

Rangeland improvement through the establishment of reserves has been undertaken in Jordan for over five decades. Technical analysis has been carried out in many research trials and demonstrations on various reserves and protected areas. In this section, we examine the economics of reserve establishment as demonstrated by the establishment of two 1,000 ha reserves in the Badia and the steppe. Two development scenarios are considered for each range type:

- Reserve based on protection and management techniques only.
- Reserve based on protection and management techniques, plus shrub planting on 500 ha (50% of the reserve area).

Incremental Benefits

The incremental benefits are based on dry matter production (Table 2). Production estimates are based on the predicted effects of de-stocking the reserves.

Table 2. Range reserve dry matter production (kg/ha).

Rangeland	Without reserve	With reserve	Incremental	Breakdown of incremental effects	
				Prod. and Mgt.	Shrub [†]
Badia	40	150	110	88	23
Steppe	100	450	350	283	68

[†] Shrub contribution to incremental production assumed at 15%.

Tables 3 and 4 show the derivation of the benefits for the Badia and steppe, respectively. The incremental values are calculated using the following methodology:

- DM production is converted to energy using the appropriate conversion factor (9.8 and 10.1 MJ ME/kg DM for Badia and steppe, respectively¹).
- Energy is converted to barley equivalent at a conversion rate of 12.9 MJ ME/kg DM.
- Barley equivalents are valued at the current farm-gate import parity price of JD 115 per tonne.
- The per-hectare values are converted to the reserve incremental value by multiplying by area: 1,000 ha for management effect and 500 ha for shrub production.

¹ MJ ME = Mega joules of metabolizable energy.

Table 3. Cost-benefit analysis for Badia reserve development over 30 years.

Description		1	2	3	4	5	6	7	8	9	10-30
Protection and management only											
Incremental benefits											
Incremental dry matter [†]	kg DM/ha	0	10	19	29	39	49	58	68	78	88
Incremental energy [†]	MJ ME/ha	0	95	191	286	381	476	572	667	762	858
Barley equivalent [‡]	kg/ha	0	7	15	22	30	37	44	52	59	66
Barley equivalent value ^{††}	JD/ha	0	1	2	3	3	4	5	6	7	8
Total inc. benefits	JD/1,000 ha	0	849	1,699	2,548	3,398	4,247	5,096	5,946	6,795	7,644
Incremental costs											
Staff	JD/ha	10.80	10.80	10.80	10.80	10.80	10.80	10.80	10.80	10.80	10.80
Supervision ^{††}	JD/ha	1.18	0.53	0.53	0.53	0.53	0.26	0.26	0.26	0.26	0.26
Total incr. costs/ha	JD/ha	11.98	11.33	11.33	11.33	11.33	11.06	11.06	11.06	11.06	11.06
Total inc. costs	JD/1000 ha	11,984	11,326	11,326	11,326	11,326	11,063	11,063	11,063	11,063	11,063
Benefits-costs	JD	(11,984)	(10,477)	(9,627)	(8,778)	(7,929)	(6,816)	(5,967)	(5,117)	(4,268)	(3,419)
NPV JD	(55,062)	@ 12%	IRR%	-100%							
Protection/management + shrub planting											
Incremental benefits											
Incremental dry matter	kg DM/ha	0	10	19	29	39	49	58	68	78	88
Incremental energy	MJ ME/ha	0	95	191	286	381	476	572	667	762	858
Barley equivalent	kg/ha	0	7	15	22	30	37	44	52	59	66
Barley equivalent value	JD/ha	0	1	2	3	3	4	5	6	7	8
Mgt. incr. benefits	JD/1,000 ha	0	849	1,699	2,548	3,398	4,247	5,096	5,946	6,795	7,644
Planted shrubs. incr. dry matter	kg DM/ha	0	3	5	8	10	13	15	18	20	23
Incremental energy	MJ ME/ha	0	25	49	74	98	123	147	172	196	221
Barley equivalent	kg/ha	0	2	4	6	8	9	11	13	15	17
Barley equivalent value	JD/ha	0	0	0	1	1	1	1	2	2	2
Shrubs inc. benefits	JD/500 ha	0	109	218	328	437	546	655	764	874	983
Total incr. benefits	JD	0	959	1,917	2,876	3,834	4,793	5,751	6,710	7,669	8,627
Incremental costs											
Total Mgt. costs	JD/1,000 ha	11,984	11,326	11,326	11,326	11,326	11,063	11,063	11,063	11,063	11,063
Shrub planting											
Shrub planting incr. costs/ha ^{§§}	JD/ha	724	0	0	0	0	0	0	0	0	0
Total shrub incr. costs	JD/500 ha	362,000	0	0	0	0	0	0	0	0	0
Total incr. costs	JD/1,000 ha	373,984	11,326	11,326	11,326	11,326	11,063	11,063	11,063	11,063	11,063
Benefits-Costs		(373,984)	(10,367)	(9,409)	(8,450)	(7,492)	(6,270)	(5,312)	(4,353)	(3,394)	(2,436)
NPV JD	(373,701)	@ 12%	IRR%	-100%							

Table 4. Cost-benefit analysis for steppe reserve development over 30 years.

Description/		1	2	3	4	5	6	7	8	9	10-30
Protection and management only											
Incremental benefits											
Incr. Dry Matter [†]	kg DM/ha	0	35	71	106	141	177	212	247	283	283
Inc. Energy [†]	MJ ME/ha	0	357	713	1,070	1,427	1,783	2,140	2,497	2,853	2,853
Barley Equivalent [§]	kg/ha	0	28	55	83	111	138	166	194	221	221
Barley Equivalent value ^{††}	JD/ha	0	3	6	10	13	16	19	22	25	25
Total inc. benefits	JD/1,000 ha	0	3,179	6,359	9,538	12,718	15,897	19,077	22,256	25,436	25,436
Incremental Costs											
Staff	JD/ha	10.80	10.80	10.80	10.80	10.80	10.80	10.80	10.80	10.80	10.80
Supervision ^{††}	JD/ha	1.18	0.53	0.53	0.53	0.53	0.26	0.26	0.26	0.26	0.26
Total incr. costs/ha	JD/ha	11.98	11.33	11.33	11.33	11.33	11.06	11.06	11.06	11.06	11.06
Total inc. costs	JD/1,000 ha	11,984	11,326	11,326	11,326	11,326	11,063	11,063	11,063	11,063	11,063
Benefits-costs	JD	11,984	8,147	4,967	1,788	1,392	4,834	8,014	11,193	14,373	14,373
NPV JD	33,897	@ 12%	IRR%	22%							
Protection/management + shrub planting											
Incremental benefits											
Incr. dry matter	kg DM/ha	0	35	71	106	141	177	212	247	283	283
Incr. energy	MJ ME/ha	0	357	713	1,070	1,427	1,783	2,140	2,497	2,853	2,853
Barley equivalent	kg/ha	0	28	55	83	111	138	166	194	221	221
Barley equivalent value	JD/ha	0	3	6	10	13	16	19	22	25	25
Mgt. inc. benefits	JD/1000 ha	0	3,179	6,359	9,538	12,718	15,897	19,077	22,256	25,436	25,436
Planted shrubs, incr. dry matter	kg DM/ha	0	8	15	23	30	38	45	53	60	68
Inc. energy	MJ ME/ha	0	76	152	227	303	379	455	530	606	682
Barley equivalent	kg/ha	0	6	12	18	23	29	35	41	47	53
Barley equivalent value	JD/ha	0	1	1	2	3	3	4	5	5	6
Shrubs inc. benefits	JD/500 ha	0	338	675	1,013	1,351	1,688	2,026	2,364	2,701	3,039
Total incr. benefits	JD	0	3,517	7,034	10,551	14,069	17,586	21,103	24,620	28,137	28,475
Incremental costs											
Total mgt. costs	JD/1000 ha	11,984	11,326	11,326	11,326	11,326	11,063	11,063	11,063	11,063	11,063
Shrub planting											
Shrub planting incr. costs/ha ^{§§}	JD/ha	724	0	0	0	0	0	0	0	0	0
Total shrub incr. costs	JD/500 ha	362,000	0	0	0	0	0	0	0	0	0
Total incr. costs	JD/1000 ha	373,984	11,326	11,326	11,326	11,326	11,063	11,063	11,063	11,063	11,063
Benefits-costs	275,171	(373,984)	(7,809)IR	(4,292)0%	775	2,743	6,523	10,040	13,557	17,074	17,412
NPV JD		@ 12%	R%								

Footnotes for Tables 3 and 4:

† See text for explanation of incremental dry matter assumptions.

‡ Energy content, Badia DM: 9.8 MJ ME/kg

§ Barley energy content: 12.9 MJ ME/kg DM.

†† Barley value: farmgate import parity price: 115 JD/tonne.

‡‡ Allowance for the overhead costs associates with reserve (MOA or JCO expense).

§§ See text for cost description; model assumes 500 ha are planted with shrubs.

The incremental costs associated with management are as follows:

- Staff costs are based on three man-years at JD 3,600, which equals JD 10.80 per ha for 1,000 ha.
- Supervision costs for facilitating reserve development (MOA or JCO) are estimated at JD 5000 per ha per day, given 45 days of supervision in the first year and 20 days/year for 4 years and 10 days/year thereafter.

The incremental costs associated with shrub planting are shown in Table 5. These rates were calculated by the JCO, based on experiences with the WFP programs in recent years. The cost assumes that a D4 caterpillar is used for contour ripping.

Table 5. Cost of shrub planting (JD/ha).

Operation	Amount	Total cost
Contour marking (m)	3,600	8
Ripping (m)	3,600	25
Digging planting holes (no.)	1,200	83
Plant distribution (no.)	1,200	6
Planting (no.)	1,200	122
Replacement and maintenance (no.)	1,200	83
Replanting (no.)	1,200	7
Seedling transport (no.)	1,320	39
Seedling cost (no.)	1,320	299
Indirect and miscellaneous (value)	-	51
Total cost		724

Source: JCO.

Results and Conclusions

Table 6 summarizes Tables 3 and 4. The net present value was calculated at an opportunity capital cost of 12%.

Table 6. Economics of reserve development.

Range type	Development Options	NPV (12%)	IRR (%)
Badia	Protection and management only	55,060	100
	Protection/management + shrub planting	373,700	100
Steppe	Protection and management only	33,900	22
	Protection/management + shrub planting	275,171	0

NPV = Net present value; IRR = internal rate of return.

A further indicator is the cost per tonne of feed produced. To undertake this calculation, an annual cost for both development options was determined by annualizing the net present value of the total incremental costs. This figure was divided by the total quantity of barley equivalent to derive the equivalent cost per tonne. The results of this calculation are shown in the following table.

Table 7. Cost of incremental production (JD/t).

Range	Development options	IRR (%)	Ann. costs	Cost/t
Badia	Protection and management only	66	11,254	170
	Protection/management + shrub planting	83	51,379	619
Steppe	Protection and management only	221	11,254	51
	Protection/management + shrub planting	274	51,379	188

Conclusion

It is clear from the results that reserve development in the Badia is not economically rational. Steppe reserve development based on protection and management only is the most feasible option, as both a reasonable rate of return and an equivalent per unit cost of barley lower than the farmgate parity price are possible.

Tables 3 and 4 show that the practice of shrub planting measured in purely incremental production terms is uneconomic. Shrub planting programs are thus pursued for reasons in addition to rangeland development. Using the valuation procedure devised here, shrub planting generated negative net present values, which indicates that the present value of the benefits is less than the present value of the costs at a certain discount rate (in this case, 12%, the opportunity cost of capital). The NPV remains negative even with a reduction of the discount rate to 6%.

The returns to planting shrubs are probably even overestimated in this analysis. Experience has shown that planted shrubs are not producing seedlings, which means that the stands are not regenerating and are therefore non-sustainable. For the increment shown to be maintained, replanting and therefore additional costs would be incurred every 10–15 years.

An alternative way to judge the economic rationality of reserve development is to consider the equivalent cost per tonne of feed produced. Given that incremental production can be valued in equivalent tonnes of barley, and that an annual incremental cost to generate this production can be determined, a cost per tonne of feed produced can be estimated. The results of this calculation are provided in Table 4.

This analysis reveals that the equivalent of one tonne of barley, produced on a Badia reserve with grazing management only, costs approximately JD 170. The same tonne produced from a Badia range reserve that includes shrub planting costs JD 619: four and a half times the import parity value (eight times the current subsidized value). The same values for the steppe reserve are JD 51 for the grazing management option, and JD 188 when shrub planting is not worth the returns.

References

- IFAD (International Fund for Agricultural Development). 1993. National program for range rehabilitation and development.
- Durham University. 1994. Conservation survey of the southern highlands of Jordan.

***Atriplex halimus* L. : Source de Bois de Feu et de Fourrage en Milieu Aride (Cas de la Région de Marrakech, Maroc)**

A. Benchaabane

Laboratoire d'Écologie Végétale, Faculté des Sciences, Marrakech, Maroc

Résumé

La rigueur du climat en milieu aride imprime souvent à la végétation un port buissonnant. Cette végétation est très souvent lignifiée et n'offre que de faibles opportunités fourragères. Elle est surtout utilisée par les populations locales comme bois de feu.

Atriplex halimus est une Chénopodiacee adaptée aux régions arides et salées. Cette espèce a le double avantage de fournir aux populations locales du bois de feu et du fourrage. Elle joue un rôle social et économique important dans les régions arides. Cependant son écologie, sa répartition géographique et l'évaluation de ses performances fourragères ne sont pas assez étudiées.

La connaissance de la biologie et de l'écologie d'*Atriplex halimus* permettra une meilleure maîtrise de l'amélioration du rendement de ces buissons afin de garantir aux populations rurales l'accès à un véritable éco-développement. Un développement qui répond aux besoins des populations locales en ressources végétales tout en assurant l'équilibre écologique de la région.

Dans le présent exposé l'auteur donne un aperçu sur la problématique posée par *Atriplex halimus* source de bois de feu et de fourrage en milieu aride dans une étude de cas de la région de Marrakech.

Mots-clés : *Atriplex halimus*, buisson, bois de feu, fourrage, région de Marrakech.

Introduction

La végétation des régions arides du Maroc se caractérise par son faible recouvrement et son aspect steppique. Parmi les buissons qui composent cette végétation, le genre *Atriplex* est très représenté et utilisé par les populations locales et son cheptel. Le genre *Atriplex* représente un grand intérêt économique pour de nombreuses régions où le bois de feu et le fourrage se font rares.

Atriplex halimus est une Chénopodiacee utilisée comme fourrage en zone aride et facultativement comme bois de feu dans les localités où les ligneux sont rares.

Dans la région de Marrakech les formations végétales à *Atriplex halimus* sont très dégradées suite à leur exploitation intensive par les riverains. Compte tenu de l'importance de cette espèce pour les populations locales ainsi que de son adaptation aux conditions contraignantes en milieu aride la restauration et la réhabilitation des espaces à *Atriplex halimus* est une urgence afin d'assurer à la région un éco-développement répondant aux attentes des populations locales tout en assurant l'équilibre écologique du milieu naturel.

La connaissance de la biologie, de l'écologie ainsi que des différentes utilisations ethno-botaniques d'*Atriplex halimus* est une étape indispensable pour l'optimisation des performances de cette espèce.

Après un bref aperçu sur l'aire de répartition du genre *Atriplex* en Afrique du Nord, l'auteur présente la répartition d'*Atriplex halimus* dans la région de Marrakech. Les différentes utilisations ethno-botaniques de l'espèce seront examinées. Une réflexion sur un projet d'aménagement des espaces à *Atriplex halimus* sera exposée.

Le Genre *Atriplex* en Afrique du Nord

Le genre *Atriplex* (famille des Chénopodiacees) est représenté par 18 espèces, (Tableau 1) en Afrique du Nord dont 3 espèces endémiques et 3 introduites d'Australie (Maire 1962).

Certaines espèces se développent sur le littoral sur des sols sableux, d'autres se développent en milieu continental sur des sols très variés (Benchâabne 1995).

Couvrant de larges espaces dans tous les pays de l'Afrique du Nord, toutefois il se caractérise pour son polymorphisme et son adaptation aux conditions écologiques très variables dans les régions arides. Au Maghreb, Bouabdellad et Dutuit (1995) ont mis en évidence l'existence de plusieurs phytocénoses caractérisées par de nombreux écotypes d'*Atriplex halimus*.

Cette large adaptation à différentes contraintes écologiques du milieu confère à *Atriplex halimus* un statut particulier ; ses utilisations pastorales et comme combustible jouent un rôle économique important pour de nombreuses populations démunies dans les pays du Maghreb.

Tableau 1. Le genre *Atriplex* en Afrique du Nord, sa chorologie et ses utilisations ethno-botaniques.

Espèce	Utilisation ethno-botanique
<i>A. chenopodioides</i> Batt (E)	Fourrage
<i>A. colerei</i> Maire (E)	Fourrage et bois de feu
<i>A. coriacea</i> Forsk.	Fourrage
<i>A. dimorphostegia</i> Kar et Kir	Fourrage
<i>A. glauca</i> L.	Fourrage et bois de feu
<i>A. halimus</i> L.	Fourrage
<i>A. hastata</i> L.	Fourrage
<i>A. hortensis</i> L.	Plante potagère
<i>A. inflata</i> F. Muell. (I)	Fourrage
<i>A. littoralis</i> L.	Fourrage et bois de feu
<i>A. mollis</i> Def. (E)	Fourrage et bois de feu
<i>A. nummularia</i> Lindl. (I)	Fourrage
<i>A. patula</i> L.	Fourrage
<i>A. portulacoïdes</i> L.	Fourrage
<i>A. rosea</i> L.	Fourrage
<i>A. semibaccata</i> R. Br (I)	Fourrage
<i>A. tatarica</i> L.	Fourrage
<i>A. tomabeni</i> Tineo.	Fourrage

(E) Plante endémique ; (I) Plante introduite.

***Atriplex halimus* dans la Région de Marrakech**

La Région de Marrakech

La région de Marrakech se caractérise par une végétation clairsemée à cause de la surexploitation pastorale et des rigueurs climatiques. Le climat de type aride est caractérisé par des températures élevées, une faible hygrométrie, une évaporation intense et une faible pluviométrie. La moyenne des précipitations pour la région de Marrakech est de 240 mm par an (Benchaâbane 1985).

Les sols sont squelettiques (Moreau 1981) et très riches en calcaire (Benchaâbane 1985). Ils subissent une intense érosion.

La moitié de la population de la région de Marrakech vit dans les campagnes. En milieu rural l'économie est de type agro-pastoral (Pascon 1977). Le pâturage est extensif, le cheptel est dominé par les ovins et les caprins (Benchaâbane 1985).

La Végétation

Les milieux halomorphes de la région de Marrakech ont fait l'objet de nombreuses études floristiques et phytoécologiques. Différentes phytocénoses *Atriplex halimus* y ont été décrites (Abbad 1993 ; Abbad et Benchaâbane 1995 ; Benchaâbane 1985 ;

et Nègre 1956, 1960, 1961). Leurs utilisations pastorales a été étudiée par Ahamdane (1994) et Benchaâbane (1985, 1996).

L'examen attentif de ces documents a permis de faire une synthèse de la structure et de la composition floristique des formations à *A. halimus* de la région de Marrakech. Cette étude bibliographique a été complétée par des relevés récents lors de la dernière mission au Maroc du programme Européen STD sur le terrain (février et septembre 1996).

Le tableau 2 donne une synthèse sur les formations à *A. halimus* de la région de Marrakech. Il donne le nom de la station, les références bibliographiques, la composition floristique, le type du substrat, le recouvrement spécifique d'*A. halimus* et le type d'utilisation ethno-botanique.

L'analyse du tableau 2. montre la diversité floristique des formations à *A. halimus* de la région de Marrakech. La biodiversité est le trait commun aux formations à *Atriplex halimus* en Méditerranée comme l'ont souligné les travaux récents de Bouabdellah et Dutuit (1995). Une variabilité morphologique (port, forme et taille des feuilles, variation du sex-ratio) ont été également relevées.

Les formations à *A. halimus* de la région de Marrakech se développent sur des sols différents et supportent des taux variables de salinité selon la texture et l'humidité du sol et ceci est possible grâce à l'enracinement différentiel d'*A. halimus* (Benchaâbane 1985).

Dans des milieux floristiquement pauvres, *A. halimus* offre une valeur pastorale très appréciable. Les formations à *A. halimus* de la région de Marrakech jouent ainsi un grand rôle écologique et économique dans la région. Elles permettent de protéger le sol, assurent une biodiversité et possèdent des performances pastorales intéressantes pour le cheptel local. Toutefois ces formations sont très dégradées. L'aménagement de ces formations est aujourd'hui une urgence.

Les Utilisations Ethno-botaniques d'*Atriplex halimus*

Atriplex halimus présente une grande variabilité morphologique surtout au niveau de l'appareil végétatif aérien. En fonction des conditions écologiques stationnelles certains écotypes ont été relevés (Bouabdallah et Dutuit 1995 ; Benchaâbane 1996).

Certains écotypes sont très lignifiés, ont un port dressé et sont alors exploités comme bois de feu. La section et l'arrachage sont les techniques de coupe de bois les plus souvent utilisées.

D'autres écotypes sont moins lignifiés et portent beaucoup de feuilles et rameaux herbacés. Ces individus sont broutés par les animaux. Dans la région de Marrakech *A. halimus* est très apprécié par les caprins et les ovins (Benchaâbane 1985).

Conclusions et Perspectives

Dans la région de Marrakech les formations à *A. halimus* présentent une grande biodiversité, une large capacité d'adaptation écologique et jouent un rôle important dans la fixation du sol. Il est dans certaines régions la seule source de bois de feu.

L'état actuel de leur dégradation est très avancé. Il convient donc de réfléchir à des programmes d'aménagement. Toutefois l'étude approfondie de la biologie et de la biodiversité de l'espèce est un passage indispensable afin de réussir toute tentative de projet d'éco-développement des formations à *A. halimus*. C'est à dire réussir l'insertion d'*A. halimus* dans son milieu naturel tout en essayant d'optimiser ses performances de productivité. C'est la seule façon de répondre efficacement aux besoins des populations locales en matière de fourrage tout en respectant l'équilibre écologique de ces milieux.

La restauration des espaces à *A. halimus* doit être accompagnée par des projets alternatifs et palliatifs offrant le bois de feu et le fourrage nécessaires aux populations locales pendant les premières phases de réinstallation ou d'installation d'*A. halimus* et par la suite utiliser ces espaces alternatifs lors de périodes de soudure. C'est une manière pour diminuer la pression actuelle sur cette espèce.

Ce projet est soutenu par le programme Européen STD, Projet STD3 No. TS3* CT 94 0264.

Tableau 2. *Atriplex halimus* dans la région de Marrakech.

Station	Auteur(s)	Les espèces dominantes	Le type de substrat	Le recouvrement spécifique d' <i>Atriplex halimus</i>	Utilization d' <i>Atriplex halimus</i>
Oued Tensift	Benchaabane (1985)	<i>Tamarix gallica</i> <i>Suaeda fruticosa</i>	Terrasse sableuse	25 à 30%	Pâturage
Sidi Ghanem	Mission Prog STD (1996)	<i>Atriplex colerei</i> <i>Ziziphus lotus</i> <i>Haloxyton scoparium</i> <i>Salsola vermiculata</i>	Sol squelettique calcaire	20 à 25%	Pâturage
Lac Zima	Negre (1952) Abbad (1994)	<i>Atriplex colerei</i> <i>Suaeda fruticosa</i>	Terrasse sableuse	rare	Pâturage
Sed El Massjoun	Benchaabane et Abbad (1995) Negre (1956)	<i>Frankenia corymbosa</i> <i>Ziziphus lotus</i> <i>Haloxyton scoparium</i> <i>Atriplex colerei</i> <i>Suaeda fruticosa</i>	Sol calcaire	35 à 50%	Pâturage Récolte de bois de feu
Dar Bellarj	Mission Prog STD (1996)	<i>Frankenia corymbosa</i> <i>Ziziphus lotus</i> <i>Haloxyton scoparium</i> <i>Asparagus albidus</i> <i>Frankenia corymbosa</i>	Sol squelettique calcaire	40 à 60%	Pâturage Récolte de bois de feu

Références

- Abbad, A. 1993. Contribution à une étude éco-pédologique et cartographique des peuplements halophiles de la région de Marrakech. (Sebkha Zima). Thèse Doctorat 3ème cycle. Fac. Sci. Semlalia, Marrakech.
- Ahamdane, B. 1994. Contribution à l'étude des potentialités pastorales de la Sebkha Zima (Bahira occidentale, Maroc). Thèse de Doctorat de 3ème cycle. Fac. Sci. SEMLALIA, Marrakech.
- Bouabdallah, E. et P. Dutuit. 1995. Apport de la typologie des phytocénoses halophiles méditerranéennes, sub-sahariennes et sahariennes à la caractérisation de la diversité biologique de l'*Atriplex halimus*. 5èmes journées scientifiques biotechnologies et ressources génétiques, Dakar, Senegal 13–15 Feb.
- Benchaabane, A. 1985. Etude de la structure et de l'exploitation de la végétation d'Ouljat Oued Tensift (Région de Marrakech, Maroc). Thèse Doctorat 3ème cycle. Fac. Sci. Marrakech.
- Benchaabane, A. 1996. Etat des atriplexaies à *Atriplex halimus* dans la région de Marrakech. 2ème séminaire du réseau *Atriplex halimus*. 29 Avril–5 Mai 1996. Paris-Bruxelles.
- Benchaabane, A. et A. Abbad. 1995. Les formations végétales d'un milieu halomorphe de la région de Tensift (lac Zima, Chemaia, Maroc). Rev. Rés. Amélior. Prod. Agr. Milieu aride, Vol. 7. Paris.
- Maire, R. 1962. Flore de l'Afrique du Nord, volume VIII. Ed. Paul Lechevallier. Paris.
- Moreau, R. 1985. Étude des matériaux superficiels dans la région de l'Oued Tensift au Nord du Haouz de Marrakech. Différenciation géomorphologique, lithologique et paléogénèse. Trav. et doc. de l'ORSTOM. Paris.
- Nègre, R. 1956. Recherches phyto-sociologiques sur Sedd-el-Messjoun, Trav. Inst. Sci. Chérifien, Série botanique, No. 10. Rabat.
- Nègre, R. 1960. Les associations végétales du lac Zima. Bull. Soc. Sci. Nat. Physi. du Maroc Inst. Chérif., T 40., Rabat.
- Nègre, R. 1961. Petite flore des régions arides du Maroc occidental. Tomes 1 et 2. Ed. CNRS, Paris.
- Pascon, P. 1977. Le Haouz de Marrakech, CURS. Rabat, CNRS, Paris et INAV. Rabat.

Use of Seawater Irrigation for Halophyte Plantation on the Arabian Peninsula

H. Wakabayashi

Department of Environmental Systems Engineering, Faculty of Engineering,
Kanazawa Institute of Technology, Japan

Abstract

CO₂ emissions, caused by desertification, including deforestation of the tropical rain forests, account for about 13% of the global warming problem. Nevertheless, reforestation is limited: only 10% of the area cut each year is reclaimed. Another growing problem throughout the world is hunger. A stable food supply is needed to feed the increasing world population. These two problems intertwine to create a new set of problems, or *problematique*, the resolution of which likewise requires a new concept, approach, and attitude. Halophytes, which are very useful as fodder, food, biomass, fuel, etc., represent one such new solution. Halophyte plantation is proposed as a way to start vegetation along the periphery of the Rub Al Khali desert in the Arabian Peninsula. Irrigation systems were designed for massive vegetation plantation along the coastline of the United Arab Emirates and the piedmont area of the Al Jabal Al Akadar facing the Rub Al Khali desert. Three areas for halophyte plantation using seawater irrigation were considered: the coast of the UAE (Concept A), the inland border (concept B), and the piedmont area (Concept C). Wider discussion and critical examination are still needed.

Key words: halophyte plantation, Arabian Peninsula, seawater irrigation, the Rub Al Khali Desert, the United Arab Emirates, Oman.

Introduction

Environmental problems on a global scale are increasing. Following recent studies on greenhouse warming, a call for greater efforts to improve energy efficiency by developed countries was urged (Wakabayashi 1992) and requested by the IPCC (Intergovernmental Panel on the Global Climatic Change) at their meeting in December 1995. As we know, today's civilization, created and motivated by the technologies of the developed countries, relies heavily on energy from fossil fuels, particularly oil. We must view the future of energy use and the environment in this context.

Carbon dioxide (CO₂) accounts for half the trace gasses that contribute to global warming. A quarter of the world's CO₂ emissions come from desertification, including deforestation of the tropical rain forest for use as either rangeland or lumbering. Nevertheless, reforestation is limited; only 10% of the area cut each

year is reclaimed. The stable supply of food for the growing world population (increasing at a rate of roughly 90 million per year, and expected to reach 6 billion by the year 2000) is another major concern. A cry for greater efforts towards a modern version of the green revolution must be raised.

Development of massive agro-forestation programs could help alleviate some of these environmental problems in an holistic way (Wakabayashi et al. 1996). Halophytes (the general term for plants that can tolerate a high level of soil and water salinity, even above that of the seawater) provide biomass in the form of fuel, animal fodder, and food (oil seed), and improve soil fertility and CO₂ fixation. In this context, the Japanese government has expressed its intention of participating in international programs to level off the CO₂ concentration in the atmosphere. This use of halophytes is supported by the data provided by the US Electric Power Research Institute (EPRI) (Douglas 1993; Glenn et al. 1991, 1994; Squires 1994; Ayoub and Malcolm 1993). Several species of halophyte are considered promising for this purpose, and the project appears technically feasible (Glenn et al. 1991, 1994).

The best halophyte species suitable for massive plantation and their specific purposes are summarized below. This list is based on data gathered by the environmental research laboratory of the University of Arizona over two years of growing crops using seawater (Alpert and Maulbetsch 1966):

- Carbon fixation rates of 5–10 tonnes of carbon/ha were realized for the five best species, i.e., *Batis maritima*, *Atriplex canescens*, *Salicornia bigelovi*, *Sueda estora*, and *Sesuvium verucosum*, representing about one-half of the organic biomass produced annually. As for production rates, *Sueda estora* may be appropriate for massive plantation in saline soils, while *Atriplex canescens*, which can grow to a height of 2–3 m, with a root length of 4 m, is appropriate for sand deserts (Glenn, personal communication).
- *Atriplex nummularia*, *Battis martima*, and *Salicornia esteroa* were twice as sensitive as other species. When salinity is higher than sea water, *Battis martima* and *Salicornia esteroa* may perform better.
- Biomass storage of 30–80% of the carbon in desert regions is feasible; dry storage is more efficient than in the irrigated fields.

Of the many potential uses for halophytes, we focus in this paper on the issue of CO₂ fixation, because it affects other areas that are also important. Sophisticated technologies for this project are not required, and thus special problems are anticipated, except for sociological ones

Study Area

This study selected desert areas that are unused and not planned for use in the foreseeable future. The Arabian peninsula was chosen on the assumption that much of the desert around 30° N longitude may become wetter as global warming proceeds. This would raise the average temperature roughly 2°C by the year 2100. This assumption is based on the evidence of pollen analysis from the Altithermal Period (about 6,000 years ago) when the earth's temperature was 2–3°C higher than it is now (Rose 1986).

Following discussions with those familiar with the UAE (Yamane, personal communication; Akai, personal communication), we examined the possibility of plantations along the coastline and further inland. The areas selected are shown in Figure 1. Concept A was on the coast of the UAE, while concepts B and C were inland in the UAE and in Oman.

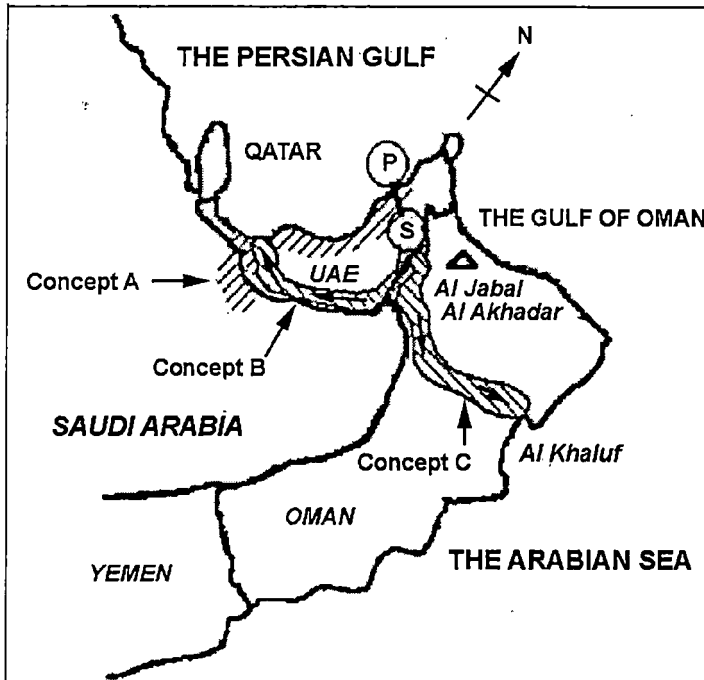


Figure 1. Development concepts for halophyte plantation in the Rub Al Khali Desert.

The local environment needs to be carefully assessed in terms of the following: the seasonal movement of nomads seeking grazing; activities such as oil tapping; oasis irrigation; the impact on the aquifers, etc. Benefits may include an increase of job opportunities for farmers, in addition to a possible increase of rainfall, which will allow increases of all vegetation. This change of focus would help people survive oil depletion in the long term.

Irrigation Along the Coastline of the UAE

Controlling salinity while irrigating farmland is obviously one of the challenges for this plantation project. A way to minimize pumping costs must be found. Pumping seawater or brackish water is one of the basic processes of irrigation. Salinity control depends on the balance of the water flow transported within the irrigation system. Although halophytes can withstand salinity over 5%, continuous leaching of the farmland is necessary to prevent excessive salinization. Adaptability depends on ground soil conditions; soil must be carefully chosen and prepared. Nutrient control is another issue to be considered (urea is usually added).

Plot Design

Figure 2 gives an example of the design of the irrigation system for an area of 50–200 ha, determined by features such as the flatness or gradient of the plot, pump capacity, accessibility, machine maneuverability, etc. The soil configuration of the plot is vertically stratified: the deepest soil is waterlogged, above that the soil is impermeable, and the top-most soil is sand or ripped permeable soil that needs irrigation for halophyte plantation. The size of a plot may be limited by increasing salinity in the direction of the water flow, due to both natural evaporation and plant transpiration. Small ponds or reservoirs are created where the seawater enters the plot, at the inlet plenum, or at the outlet plenum. Highly saline water is collected at these points to be recharged into a groundwater well or returned to the sea by a gravitational head. In the latter case, drainage water should be collected from many units to make the operation economical. Drainage water may be used for salt production if economically attractive.

The number of halophyte plots can be increased to make agro-farming a significant contributor to food and fodder production, biomass fuel production, CO₂ sequestration, etc. One of the unique features of this concept is its flexibility in terms of locating plots according to site-specific socioeconomics and politics (Cordes and Sholz 1980).

Windbreaks may be needed for plot protection, depending on the climate of the site. The coastline of the UAE experiences relatively mild winds, generally 1–3 Bft, NW (75%), up to a peak of 5–6 Bft (20%). Sand storms and blizzards occur only a few days per year and are mainly below 6 Bft. However, these winds transport sand that may render the plots useless (Al Gobaisi 1996).

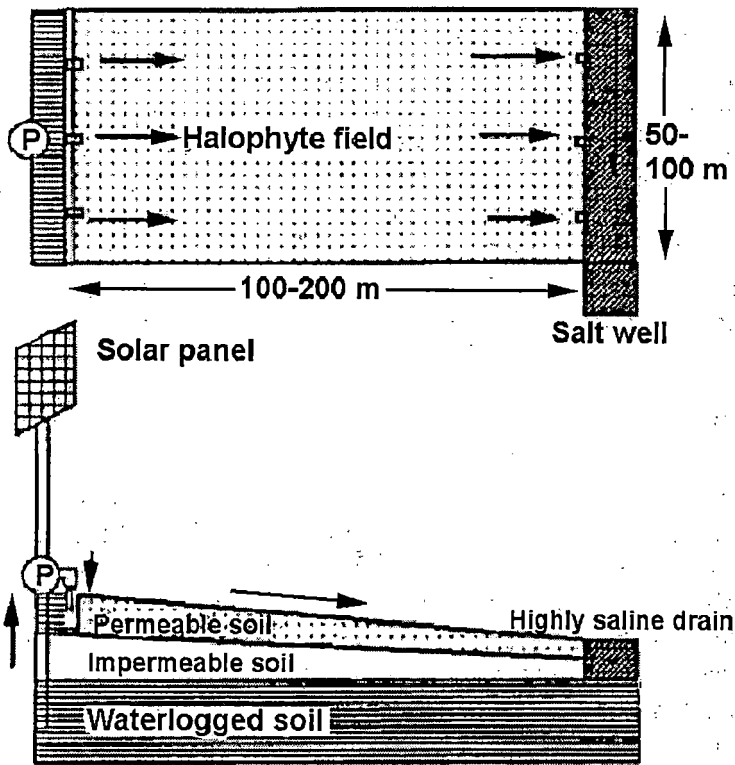


Figure 2. Irrigation system for a halophyte plantation, concept A.

Concept A: Coastline and the Sabkhat Matti (UAE)

Concept A involves the development of the *sabkhat* near and along the coast of the UAE, facing the Arabian Gulf. The elevation of the coast is generally low enough to reach the groundwater, even at a depth of 10 m. Preventive measures are required for buildings to avoid waterlogging. Thus, irrigation is relatively easy: water can be pumped up through a well. The area (20,000 km²) is around 20 km from the coast and contains large salt marshes (*sabkhat*), especially the Sabkhat Matti, located at the western end of the UAE. The main inland area of the UAE is a plain, mainly sand but part gravel desert. Elongated dune ridges with interdunal depressions and extended *sabkhat* areas form a unique environment that is only sparsely settled. The plain rises from north to south (Al Gobaisi 1996).

There are many man-made facilities such as freshwater wells, oil wells, oases, roads, etc., that must be carefully protected from the proposed halophyte plantations. Nevertheless, there is a huge space available for plantation. Towards the coast, soil varies from desert sand to finer silt soil, the surface of which is generally dry and hard, particularly in summer, as the area lies on the Tropic of

Cancer (the northern edge of the tropical climatic zone). The water and the land in this area are already highly saline and appropriate for halophyte plantation. Whether the land is ripped down to a depth of a couple of meters or soft soil is added, it will be good for halophyte plantation. Some *sabkhat* dry up in summer, with significant appearance of salt. Thus, irrigation is required for part of the year. In general, it is important to find and use impermeable base soil (silt-like) to prevent the percolation of the seawater.

Concepts B and C: Periphery of the Rub Al Khali Desert

There are two dominant mountain ranges in the southeastern part of the Arabian Peninsula, one facing the Red and Arabian Seas along the coastlines of Saudi Arabia and Yemen, and the other in the northern part of the UAE and Oman facing the Gulf of Oman. Together they fence in a large desert, the Rub Al Khali, which extends over these countries. Rainfall in the mountains of Saudi Arabia and Oman provides a good source of fresh water for drinking and irrigation in the form of groundwater or surface water around the oases of the piedmont. Wadis (dry streams), which contain a substantial amount of fresh underground water, are typical in these areas. Fossil waters, lying deep underground, are also available; rural farmers depend on them for irrigation and drinking. The supply of these waters is, however, unstable, and the gradual depletion of the groundwater is foreseen. Conservation must be practiced in the farming areas around the piedmont.

Figure 3 shows the layout of the two irrigation concepts: (i) two plots in the UAE (concept B); and (ii) two plots, one in the UAE facing the Arabian Gulf and the other in Oman facing the Arabian Sea (concept C). To make use of the low altitude piedmont situated along the coastline of Oman but facing the borders between Oman, the UAE, and Saudi Arabia, a massive introduction of seawater is envisaged via a water pump (P) from the Arabian Gulf in the UAE to a charging reservoir or pond (S) situated at the highest point (100 m) of the water transfer system in the UAE. Parallel pipelines running from the reservoir are proposed: one for supplying water to the halophyte farmland and the other as a drain for collecting used and highly saline water. The total length of both pipes is estimated at 600 km. The water runs by gravity from the source reservoir on top of a hill down to the final discharge port into the Arabian Sea facing Oman. The position of the pipes is chosen according to the gradient that best facilitates natural flow. The plots will be designed to avoid further salinization of deserts.

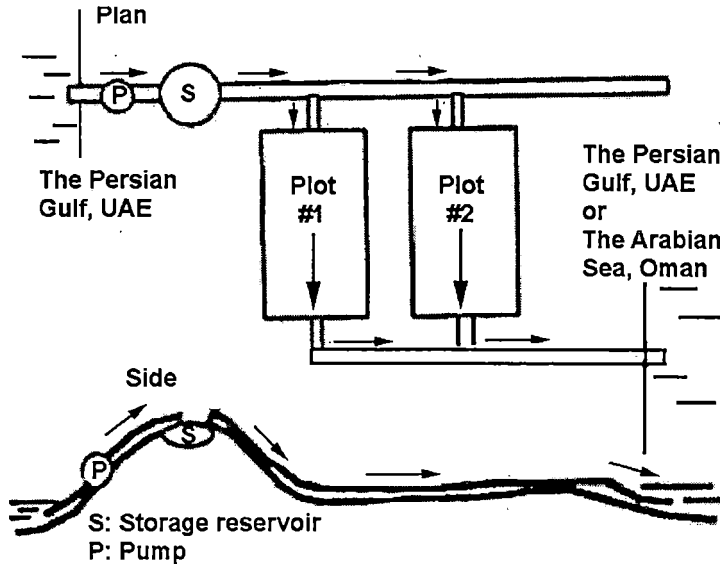


Figure 3. Irrigation system for halophyte plantation, plans B and C.

Another possible idea was incorporated into concepts B and C. It aims at increasing rainfall around the mountain areas of the UAE and Oman by introducing seawater to stimulate rainfall, starting with either natural evaporation or plant transpiration (in this case through halophytes). Humid vapor is expected to be transported by the wind from the desert toward the mountain ridges and condense as it is lifted along the mountain slope by an upwell flow. This might increase the natural circulation or convection of fresh water around the area, which in time might become so wet that the water supply from the sea might be of secondary importance. The idea is not unique (Pielke 1993; Yanagisita 1995). Doubt remains, however, as to its effectiveness in the UAE and Oman, due to the suppression of clouds and precipitation by a strong subtropical ridge in that area for most of the year. Only when there is already convective rainfall would the increase of humidity perhaps slightly increase precipitation (Pielke, personal communication). Further simulated study is necessary regarding this issue.

The technology of piping water into the desert is well-established. It is similar to the trans-Arabian pipelines (the tap-lines) for oil transportation from an oil well to the shipping port (the longest one is about 1,700 km). Care must be taken when locating the pipes to avoid interference with existing human activities and aquifers. Geologically unfavorable soil conditions for halophytes are stone/gravel desert and deep sand. Good soil for irrigation is to be found between such areas. Flattening of the plot by the introduction of new soil may be necessary.

Discussion

A special project team was set up at the Kanazawa Institute of Technology (KIT), Ishikawa Japan, with the aim of working out a realistic program for massive plantation of halophytes. The team works in collaboration with researchers from the International Center for Water and Energy Systems (ICWES), Abu Dhabi, UAE.

The collaboration between KIT and the ICWES for the benefit of the global environment and community includes the following:

- Introduction of new irrigation methods on the Arabian Peninsula. The project aims to design an optimum irrigation scheme for massive plantation of halophytes in desert areas. Difficulties are anticipated due to the vastness of the area and high salinity of the soil (30–40%). Experiments are necessary to develop dependable, high-quality irrigation/fertilizing technologies, possibly with a small-scale experimental rig.
- Sites will be identified by analyzing satellite remote sensing data along with socio-cultural information on the countries and peoples involved. This includes the political system, economic development, and social changes expected as a result of this project. Among others benefits, food and fodder production from halophytes is important because it addresses the future of the region in terms of population growth and oil depletion.
- Activities related to global climatic changes possible as a result of massive halophyte plantation include:
 - Evaluation of the effect of increased vegetation on global CO₂ circulation.
 - Simulation of the effects of global climatic change.
- Economic analysis of halophyte plantation includes:
 - Cost analysis of growing halophytes.
 - Cost comparisons among alternatives in the areas of anti-desertification measures and forestation/reforestation.
- Social and political implications of the project. The project will help to alleviate the long-standing disparity between the north and the south. The technology transfer of civil engineering and remote sensing skills will help improve the skills of people in the UAE, Oman, and other countries.
- In terms of international economics, the anticipated boom-town effect on local communities may be significant. However, possible alteration of the traditional culture of the local community may be a concern. This is part of the trade-off involved with economic development. Nevertheless, new economic development will be so sustainable, both locally and globally, that the boom-

town effect on local communities will spread to other interested regions. We must seek a compromise between these problems that results in a brand-new economy. This theme, therefore, involves both regional and international economic study.

- Technology assessment for the environment and public welfare of local communities. There are concerns about causing a new environmental problem, i.e., the possible destruction of a stable ecosystem, and about altering local community traditions. Therefore, technology assessment must be carried out on all research items relevant to socioeconomics and politics to study the possible effect on local people, as well as the global ecosystem. Social issues raised by the introduction of a new technology are associated with both positive and negative effects, on the local and national levels. Identification of the merits and demerits will be necessary for the smooth progress of the project. Efforts to achieve public acceptance (through participation in the projects) are crucial to the successful development of the project. Harmonization of the traditional culture and the new development will face difficulties (Cordes and Scholz 1980). Dialogue with nomads and Bedouins at the start of the project is the key to successful design. It is important to involve the local workforce within the framework of their traditions. Social and cultural issues are best analyzed in collaboration with researchers and policy makers from the universities and research institutions of the UAE, Oman, etc.

With the kind assistance of the ICWES, we hope to start field demonstrations, if appropriate, in collaboration with ICWES researchers and students. A small-scale (<1 ha) operation using concept A will be the first step. The transport of seawater 10 km inland, using concept B, as approved by the UAE, will also be undertaken. Concept C will follow as soon as possible.

Conclusions

Massive halophyte plantation under seawater irrigation represents one possibility for the gradual vegetation of the Rub Al Khali Desert in the Arabian Peninsula. In this paper, three different areas are considered: (i) along the coastline of the UAE (concept A); (ii) inland on the border of the UAE (concept B); and (iii) the piedmont area of the Al Jabal Al Akadar facing the Rub Al Khali Desert (Concept C). A broader discussion of the basic idea of halophyte plantation and a critical examination of these concepts are needed, and invited, from all interested parties.

Acknowledgments

A part of this paper depended upon the research proposal prepared by the research team formed within KIT at the end of 1995 (Wakabayashi et al. 1996). Discussions

with members of the project are highly appreciated. Critical reading of the manuscript, as well as comments and data, provided by Dr Darwish M.K. Al Gobaisi of the UAE ICWES are highly appreciated.

References

- Al Gobaisi, D.M.K. 1996. Personal communication.
- Alpert, S.B. and J. Maulbetsch. 1996. Global warming mitigation strategies. *Energy Conversation Management* 37(6-8): 747-750.
- Ayoub, A.T and C.V. Malcolm (eds.). 1993. Rehabilitation of Degraded Land and Sequestering Atmospheric Carbon in UNEP Environmental Management Guidelines for Halophytes for Livestock. UNEP.
- Cordes, R. and F. Scholz. 1980. Bedouins, Wealth, and Change: A Study of Rural Development in the United Arab Emirates and the Sultanate of Oman in NRTS-7/UNUP-143.
- Douglas, J. 1993. A Rich Harvest From Halophytes. *EPRI Journal* Oct/Nov: 16-23.
- Glenn, E.P., K.J. Kent and T.L. Thompson. 1991. Seaweeds and Halophytes to Remove Carbon from the Atmosphere. EPRI ER/EN-7177, Project 8011-3, Final Report.
- Glenn, E.P., M. Olsen, R. Frye and D. Moore. 1994. Use of Halophytes to Remove Carbon From the Atmosphere: Results of a Demonstration Experiment in EPRI TR-103310, Project 801103, Final Report.
- Pielke, R.A., T.J. Lee, E.P. Glenn and R. Avissar. 1993. Influence of halophyte plantings in arid regions on local atmospheric structure. *International Journal of Biometeorology* 37: 96-100.
- Rose, D. J. 1986. Learning about Energy. Plenum Press, New York.
- Squires, V. 1994. Overcoming salinity with salt water. *Search* 25(1): 9-12.
- Wakabayashi, H., S. Goto, K. Yanagisita, S. Tanimoto S. Goto, K. Yanagisita, S. Tanimoto and Y. Hori. 1996. Design and Development of an Environmentally Secured Global Society based on the Massive Vegetation in Desert-Water Areas over the World. (unpublished)
- Wakabayashi, H. 1992. Some ideas toward energy efficient society. Pages 171-180 in Making the Market Right for the Efficient Use of Energy (Kursunoglu, ed.). Nova Science Publishers, New York, USA.

Socioeconomics of Shrub Plantations in Syria

J. Rae¹, G. Arab², K. Jani³, N. Murad³, T. Ngaïdo², G. Gintzburger²
and T.L. Nordblom²

¹ School of Geography, Oxford, UK

² Pasture Forage and Livestock Program, ICARDA, Aleppo, Syria

³ Steppe and Range Directorate, Ministry of Agriculture and Agrarian Reform,
Palmyra, Syria

Abstract

Active measures to rehabilitate rangelands with fodder shrubs in Syria over the past 30 years have reached a new level of sophistication and apparent success, but not without costs and continuing challenges. Results of new surveys of plantation users in 1995 and 1996 are presented to illustrate the benefits and costs of such programs with the aim of providing timely feedback. Contrary to the idea that "open access" predominates in the Syrian steppe, natural resources are associated with particular traditional communities with continually evolving institutions for their use. To estimate what the impact of such reserves has been and will be, the surveys focused on actual land use, opportunity costs, and sheep management over the annual cycle. Costs included those of finding alternative feed sources for those dislodged and excluded from access to plantation areas for periods of 6 to 15 years. However, poor native range had probably been providing less than 20% of annual sheep diets; the remainder probably came from grazing crop residues in the higher-rainfall and irrigated areas of northwestern Syria and from feed grains and agro-industrial by-products. Additional plantation costs were counted for bulldozer ripping, shrub seedling production, planting, and care. Direct cash costs by the government were estimated at US\$ 32.68 per ha for establishing the new 7,325 ha Obaisan plantation. The costs of expensive perimeter boundary structures around the plantations could be reduced or avoided altogether if protection were legally empowered in the hands of traditional land users.

Introduction

In the arid and semi-arid areas of West Asia and North Africa (WANA) the transplanting or reseedling of shrubs is at the technological core of rangeland amelioration. The idea is not a new one; in some parts of the region similar activities were carried out during the French mandate in the first half of this century. It is, however, since the mid-1960s that shrub intervention, within larger overall action plans, has been pursued through a variety of institutional frameworks. This is no less the case in Syria, where about 52% of the land is currently considered rangeland, and the spread of this technology is taking place through government-run shrub plantation.

Two interrelated goals are being pursued by the government: first, the rehabilitation of degraded rangelands; and second, the enhancement and stabilization of agro-pastoral incomes. The objectives of our socioeconomic survey of current shrub plantations were twofold: first, assessing how the technology and its institutional aspects are being integrated into the agro-pastoral system; and second, identifying the broader economic and environmental costs and benefits of such active interventions.

Shrub intervention has had a long and checkered history in WANA. More often than not its effect has been short-lived, as it has succumbed to logistical, institutional, and technological difficulties. As a result of earlier experiences in Syria, the government has vigorously pursued publicly run shrub plantations which, since 1995, have been leased under restricted contracts to range users.

In this paper, we briefly chart the history of shrub intervention in Syria. We follow this with a summary of findings from two socioeconomic and institutional surveys of government shrub plantations in Syria conducted by the International Center for Agricultural Research in the Dry Areas (ICARDA) and the Syrian Ministry for Agriculture and Agrarian Reform (MAAR) during the spring seasons of 1995 and 1996 (Rae, in preparation). Survey methods are presented first, followed by data that illuminate the role and perceived worth of the reserves within the current agro-pastoral system.

Why a Socioeconomic Survey?

Socioeconomic research may employ a variety of methods designed to assess three broad areas in development: (i) needs assessment or surveys aimed at elucidating the opportunities and constraints for development within a community; (ii) monitoring and evaluation to determine the progress of project implementation; and (iii) studies designed to understand the impact of policy shifts. The current study is mainly accommodated within number two above, and also provides material for number three. The survey was designed to evaluate the impact of the reserves on the local agro-pastoral systems, and to identify where opportunities and constraints lie in terms of further integration of the "reserve" concept into these systems, technologically and institutionally.

A survey of Bedouin production systems in Aleppo and Hama Provinces in 1991–1993 found that *Atriplex* had a negligible role in the diet calendar of sheep at that time (Wachholtz et al. 1993; Wachholtz 1996). Similar findings were made by Leybourne (1993). As for the impact assessment of the forage reserves on the agro-pastoralists, the current socioeconomic survey was preceded by a pilot survey conducted in 1995 (Nordblom et al. 1997a). These two surveys are the first to focus on the human aspects of government shrub reserves in Syria. With the

designated forage reserve areas presently covering some 125,000 ha in Syria, and with plans for further expansion, the need for socioeconomic work (in all three areas mentioned above) and for broad, rigorous economic cost/benefit studies, becomes more pressing.

The History of Shrub Intervention in Syria

In an effort to increase the productivity of degraded arid and semi-arid areas of Syria, successive attempts have been made by the government and international agencies to transplant or reseed desert shrubs. The institutional channels used have varied but they have all, by most accounts, been at best only partially successful. It is only now, with more firm intervention by the government, that visible evidence of the sustained vitality of planted shrubs exists. The overwhelming shrub of choice by the interventionists has been one or another species of *Atriplex*. Known for their drought resistant qualities, their fast and substantial growth under harsh conditions, the species planted have come from, in descending order, Australia, the United States, and the Red Sea region¹.

Phase One: The 1970s

Initial steps to introduce *Atriplex*² into Syria were taken with the combined help of the World Food Program (WFP) and the Food and Agriculture Organization (FAO) program in the early 1970s. This initiative formed one component of a larger overall strategy for rangeland management. The planting program took two routes.

The first was through the establishment of specialized cooperatives with designated rangelands in the steppe. The second was through direct contact between the program and farmers living along the desert margins. A limited number of Sheep Breeding and Range Amelioration cooperatives, with the mandate to protect and rehabilitate their land, had been set up some years earlier with the assistance of WFP/FAO. In the archives of these two agencies, however, there is no record of transplanting or reseeding being carried out through the cooperatives; certainly no evidence of cooperative plantations existed in 1996.

The second channel for the uptake of seedlings lay in encouraging private individuals leasing state land on the margins of the steppe³ (below 200 mm annual precipitation). These were often the traditional users of the range, diversifying with barley cultivation. Initial plans were for the planting of 12,000 ha. The recommendation of the interim report was for this to be reduced to 3,000 ha. "Food for work," backed up by a tailored educational program, was considered sufficient to initiate interest among the farmers. The termination report provides no actual figures on the success of this particular scheme, although it highlights logistical problems and poor education facilities as undermining project objectives. An

important underlying assumption is drawn into relief by the design of this particular project, one that has been carried through to the present day: i.e., given sufficient exposure to the advantages of *Atriplex*, farmers would instinctively adopt it. The 3,000 ha target was never reached, and it is questionable whether traces of this intervention still remain⁴.

Phase Two: The 1980s

In terms of planting shrubs and other efforts for range amelioration and management, the period between 1975 and 1982 was a quiet one in Syria. Further cooperatives were established in the late 1970s and early 1980s, so that by 1982 they covered the majority of the steppe region. Their impact on range management was negligible at best; due to their role in delivering subsidized feeds, they contributed to expansion of the livestock population. In 1982 and 1983, however, a flurry of decrees and instructions from the Prime Minister⁵ established and refined a requirement for the planting of shrubs on 30% of each area of the steppe licensed for cropping⁶. It is not clear to the authors what kind of pressure was brought to bear, or from what quarters, for the enactment of this legislation.

The response of the Peasants' Union and its members was a request to the Higher Agricultural Council for a special committee to investigate the broader concerns of steppe resource management. The result was a committee, chaired by the Deputy Prime Minister, that was to sit for four years before publication of its final report. During the sitting of the committee, legislation on shrub establishment was postponed. Following the report to the Prime Minister and Parliament, new legislation was drafted, of which Article Five of Instruction No. 5057/M.D. is the most relevant to the present discussion:

“80% of the authorized area is to be grown to cereals...and 20% to pastures. Cereal crops and kinds of shrubs and pasture plants to be authorized will be defined in the authorization.”⁷

Deciding what shrubs to plant was undertaken by the Ministry itself, rather than by pastoralists. The authors of this paper have as yet been unable to view the above-mentioned authorization, but from what can be gauged from licenses and private plantations viewed by the authors, and from the survey conducted by Leybourne et al. (1997), the shrubs most favored by the state were again species of *Atriplex*. The latter study estimated that a weighted average of less than 3% of some 1,350 plantations, established in Aleppo, Raqqa, Deir Ezzor, and Hassakeh Provinces, survived to varying degrees four years after planting. Various reasons for this were brought forward. Prominent among which were: (i) lack of controlled grazing stemming from poorly defined tenure arrangements⁸ and fear of expropriation of traditionally-held land; (ii) patchy promised assistance (e.g. watering) and enforcement from authorities during establishment; and (iii) preference among the

population groups in the steppe for barley cultivation. An additional factor was that in 1988, in response to a foreign exchange crisis, a policy decision was made to cultivate barley to the maximum extent⁹ in the steppe regions.

Phase Three: the 1990s

A major shift in policy concerning steppe regions unfolded through the early years of the new decade. It was manifested in two related decisions: the first was a large-scale program for government-controlled shrub plantations; and the second was legislation¹⁰ bringing an end, for the first time in Syria, to cultivation on state-defined steppe lands¹¹. The latter envisaged a progressive increase of planted pasture shrubs over a five-year period on the individually held cultivated licensed areas of the steppe. In the end, with sufficient seedlings supplied by MAAR, all areas formerly licensed for cultivation would be under permanent pasture. By the 1994/95 season, cultivation in the steppe had substantially halted; estimates for illegal plowing throughout the whole country for this period have been put at 3,000 ha¹². However, the steady increase of shrub planting did not, in large part, materialize. Various probable reasons exist behind this failing, not least among them being a contradictory decision on the part of the Planning Department of MAAR to authorize pre-legislative cultivation levels to persist through the duration of the decreed five years. Nevertheless, a near-total ban on cultivation was achieved within four years. For detailed descriptions of the barley/sheep production systems in the years before barley cultivation was banned, see Thomson et al. (1989), Leybourne (1993), and Wachholtz (1996).

The government shrub plantation initiative

Until the mid-1980s, three methods were used to introduce transplanted shrubs into the steppe: cooperatives, legislation aimed at individual cultivators, and the government's own Hema and Sheep Breeding Research Centers¹³. None, apart from the last, have enjoyed the kind of success hoped for. It was largely in response to this¹⁴ that the Steppe Directorate of MAAR initiated moves for the establishment of government-controlled shrub plantations with the aim of making them available to the range users after a period of time and under "proper control." It was a dramatic departure from the previous policy, a move away from pursuing formulae incorporating private responsibility to one with direct government control.

Of the 22 shrub reserves in Syria¹⁵, 12 were established in 1990/91. Overall, the planted area of public reserves approached 125,000 ha, though a figure somewhat below this would reflect areas reseeded or replanted. Specialized government nurseries were charged with the supply of seedlings and seed. The nurseries' five-year plan (1990–1994) was to supply shrub seedlings in the proportions given in

Table 1. There is a dramatic difference between these figures and the estimates given by the Steppe Department for what was actually produced during the period.

Table 1. Seedling production from specialized government nurseries (1990–1994).

Species	Planned production (%)	Actual production (%)
<i>Salsola vermiculata</i>	70	10
<i>Atriplex nummularia</i>	10	80
<i>Atriplex canescens</i>	10	
<i>Atriplex halimus</i>	10	
Others	-	10

Source: Head of Range Rehabilitation, Sheep Centers, and Pasture Plantations.

For reasons primarily concerned with seedling production, *Atriplex* species dominated in the nurseries and consequently the reserves. Though figures were not available for the previous plan (1985–1989), it was commented that actual seedling production followed similar trends. As for the extent of direct seeding of the range, a figure of 5% was given, though it was mentioned that this share would be increased in future projects¹⁶.

After a period of establishment of around five years, the reserves have been opened for public use during restricted periods each year in the spring and winter. Theoretically, carrying capacity for the individual reserves is estimated and leases are issued accordingly. A sensible though unwritten policy has given the right of priority to lease to those groups with winter camps closest to the reserves. Among the first reserves to be opened was Maragha in Aleppo Province.

The 1995 survey of users of the Maragha plantation

The Maragha plantation was established on saline soils in the marginal steppe area of Aleppo Province. It is approximately 6,500 ha in size, much of which has been replanted with *Atriplex* species. The first leases on the reserve were offered in the spring of 1995. To find out who the actual lessees were, and to gauge their reactions and opinions, ICARDA carried out a rapid survey of ten group heads, representing all 72 households using the plantation (Nordblom et al. 1997a).

The 1995 survey focused on users of the government plantation of *Atriplex* and *Salsola* shrubs on 6,500 ha at Maragha, about 77 km southeast of Aleppo (Fig. 1). The ten Bedouin groups had taken contracts for grazing parcels on the plantation for a one-month period beginning in April 1995. Maximum stocking of 3 sheep/ha was allowed for a fee of SL 125 (about US\$ 3) per hectare¹⁷. This cost is lower than for full hand-feeding when the outside range has dried up, but before cereal stubble is available in early summer (Fig. 2).

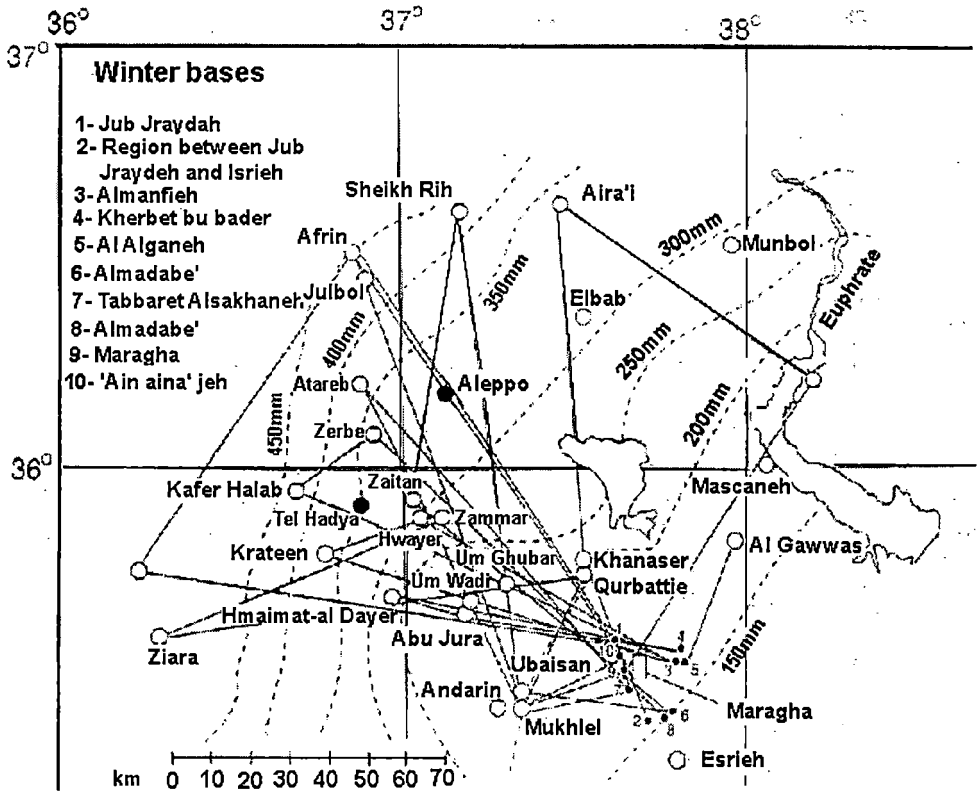


Figure 1. Movement of flocks in the 1994/95 season with winter bases near Maragha.

The relatively larger role of crop residues compared to rangelands in the annual diet calendar was already clear from the findings of Wachholtz et al. (1993) and Leybourne (1993) in adjacent study areas, and from the findings of Hamadeh et al. (1995) and Darwich et al. (1995) in Lebanon and northeastern Syria, respectively. As in Syria, livestock in Morocco, Iraq, Lebanon, Turkey, and Egypt depend more on crop residues than on rangelands; in other countries of the region, rangelands are under increasing pressures (Nordblom and Shomo 1995). This is also true in Central Asia (Nordblom et al. 1997b).

The ten groups of people surveyed had long traditional links with the plantation area. Those without experience grazing *Atriplex* ranges reported trouble with sick animals and lowered milk yields. Those who knew their sheep would require continued low levels of hand-feeding and larger amounts of low-salinity water reported no such trouble if they took the pains to provide these inputs.

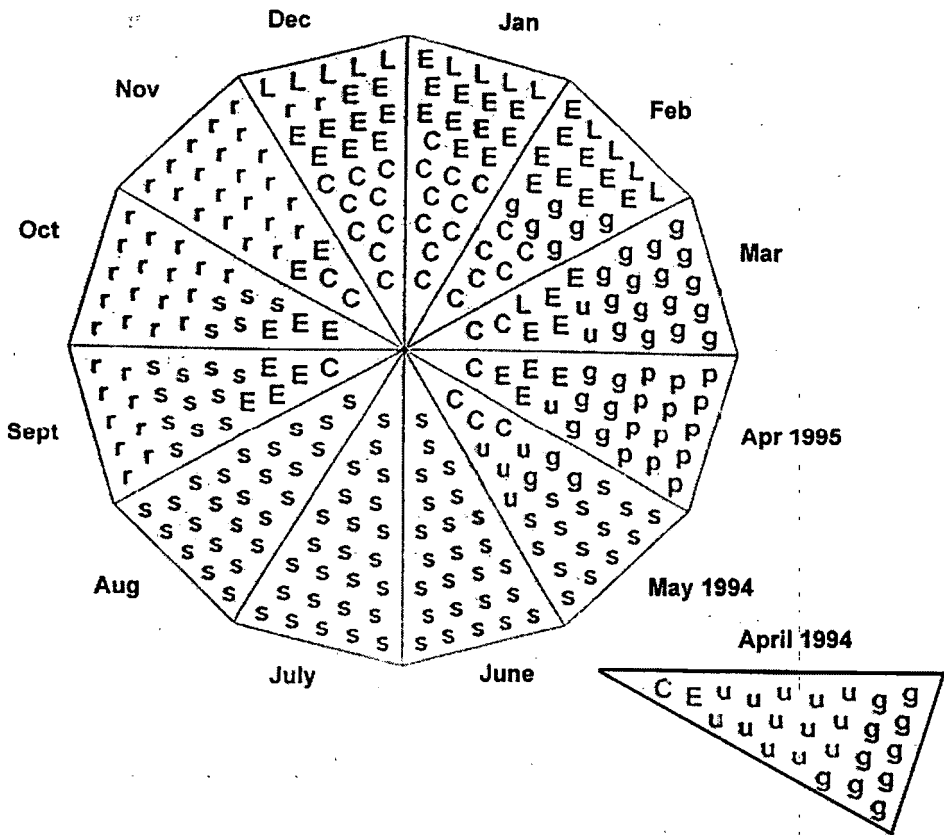


Figure 2. Small ruminant diets reported by ten Bedouin groups near Maragha, Syria (1994/95). Each character is 4% of monthly diet. Upper case symbols denote hand feeding: C + cereal straw (wheat, barley); L = legume straw (lentil, chickpea, faba bean); E = energy feeds (barley grain, cotton seed cake, cotton seed and trash, wheat bran, dry bread, sugar beets [and sugar beet pulp, leaves, and tails], cotton seed hulls, and sunflower discs).

The 1996 user survey of four plantations in Aleppo and Hama Provinces

The 1996 survey was more ambitious, covering the contract users of four government shrub plantations: Maragha, Adami (2,000 ha), Abu Al Fayad (13,500 ha), and Abu Al Natal (8,000 ha). The nearest points of the latter three to Aleppo are, in a straight line to the southeast, 60, 117, and 125 km, respectively. Travel distances are greater and involve negotiation of dirt tracks. Carried out in the spring of 1996, the new survey aimed at assessing integration of the reserves within the current agro-pastoral system, and to evaluate the potential for devolving the technology and management of the reserves to local institutions. The latter is a highly complex issue where economic, institutional, socio-political, and historic factors come to bear; the question is only explored in a preliminary way.

The 1996 survey sought to expand on the results of 1995, to venture in depth into those areas considered to be of particular importance, and to seek wider representation of the experience in Syria. Together, the four plantations cover about 30,000 ha in an area spanning a 150–200 mm mean rainfall zone.

All group heads leasing the four reserves were interviewed, with the range of questions covering group organization and institutional issues as well as practical sheep management issues. Lists detailing all households of each group were drawn up. Households for more intensive interviews were randomly chosen from these lists; the number selected from each group was proportional to the size of the group. In all, 20 group heads and 30 individual households were interviewed during the course of the 1996 survey.

Table 2. Shrub plantations and their 1996 leasing history.

Sample	Year est.	Area [†]		Months leased	Number of			Stock rate ^{††}
		Total	Leased		Groups	HH [‡]	Sheep [§]	
Aleppo Province								
Maragha	1987	6,500	1,280	2	8	25	4,450	3.45
Adami	1980	2,000	720	2	3	15	2,075	2.88
Hama Province								
Abu Alfayyad	1987	13,500	3,440	1	6	45	16,600	4.83
Abu Al Natal	1989	8,000	1,920	1	3	30	13,500	7.03
Totals		30,000	7,360		20	115	36,625	

[†] Area in hectares. [‡] HH = Households.

[§] Authorized. ^{††} Sheep/hectare.

Findings: Organizational and Institutional Arrangements

Two institutions were active throughout the leasing period: the first embodied the regulations imposed by the state over the use of the reserves; and the second embodied those combined institutional arrangements brought by the groups to clarify terms of responsibility among themselves. The basis for the latter, as already mentioned, lay in the understanding that the closest households to the reserve got first refusal. These families were, in large part, all related to each other, either through blood or long-established connections. Two large clans dominated the four reserves under study, with further concentrations taking place among the fan of families descending from either clan. All the group leaders were respected men in their communities; individual family heads acknowledged understanding through them about actions and consequences in the reserves¹⁸.

Cash security deposits were required for contract grazing of the Aleppo reserves, but not for the reserves in Hama. Where required, each household paid a deposit in proportion to its herd size. Among the self-regulations actually articulated by the groups before the start of the lease, one concerned the payment of fines for

breaches of rules. Three of the 20 groups said they would share the costs among themselves, a further 12 groups understood the adage “breaker pays,” while another group had an arrangement that with accidental damage the group pays, while with deliberate rule infringement the breaker pays. Where the infringement is not observed by government authorities, but only by the group members themselves, nine group heads said they would refuse the offending household(s) admission to the group in the next round of leasing, three group heads would expel them immediately from the group (and hence the reserve), while a further five group heads left the responsibility in the hands of the individual household heads.

Only 13 households out of 115 were reported not to have come from nearby winter encampments¹⁹. These gained access to the reserve through family channels that largely reflect how land is managed outside of the reserve among the groups: six of the thirteen were under long-term protection from one or another of the main clans; three were close relatives; three were business partners; and one a friend. There should be little surprise in the continuity of adaptable indigenous systems. This was expressed in other areas as well when it came to allowing or denying access of particular clans or groups into the reserve. With the stark situation of boundary-trenched reserves and the uncertainty of government access rules, the vitality of local institutions is bought into dramatic relief. There are inevitable teething problems with a “technically-lead” project that must find its role on the social landscape of the steppe or else go the way of so many previous, well-intentioned, steppe development programs, into history. As an add-on that must now be integrated into the fabric of the reserve concept, it is a function of socioeconomics to understand the sociopolitical and economic context of problems that have occurred in establishment, maintenance, and leasing of these reserves. The findings from such work provide essential feedback and guidance to the technical and institutional components of the program.

Opportunity Costs of the Reserves

The steppe area of Syria is close to 10.5 million ha. With only around 125,000 ha fenced-off (or rather trenched off) for the reserves, it is often concluded that traditional users could not be adversely affected by shrub plantation. Indeed, the assumption is that they could only benefit from it. The problems alluded to above would put these assertions in question, as would evidence from another recent study in the area²⁰. Contrary to the understanding that open access exists in the steppe in Syria, natural resources are managed, to varying degrees, by the continually evolving informal institutions of the local communities. It is legitimate, then, to ask what the impact of the reserves has been and will likely be in the future. As no studies were carried out prior to the establishment of these reserves, actual land use and opportunity costs can only be derived from a socioeconomic survey of this type. Table 3 details some of the more salient information.

Twelve families were dislodged from their mud-brick winter encampments with the establishment of the reserve areas. For tent-dwelling households, estimates put the number at 22. Thus, not less than 35 households (a third) had to shift their winter camps out of these areas (Table 3)²¹.

Table 3. Opportunity and other costs involved in plantation establishment.

Plantation	Total area (ha)	Land use prior to reserve estab. [†]		Transhumant household displacement [‡]
		Cultivation (%)	Pasture (%)	
Maragha	6,500	0	100	13
Adami	2,000	30	70	12
Abu Alfayyad	13,500	12	88	6 [§]
Abu Al Natal	8,000	16	84	4 [§]

[†] Means of estimates given by the individual group members

[‡] Estimated number of households with winter camps on the land prior to establishment of the reserve

[§] In addition, unspecified numbers of strangers' households had to leave.

From the time people were excluded from grazing until they were allowed to graze again, what was the impact of establishing reserves? In the case of three of the four reserves, people reported they had to crowd their camps and flocks closer to one another on their remaining land. Aside from the inconvenience and extra effort of keeping their flocks separated, the pressures of grazing and firewood (native shrub) cutting increased (for details of women's labor in firewood collection see: Pape 1994; Pape-Christiansen et al. 1997).

With grazing prohibited in the reserves and people more strongly protecting their lands outside the reserves, some families moved away and some faced conflicts with their neighbors. Where they did not prevent it, those who stayed sometimes found their lands being grazed by strangers facing similar problems. Crowded in this way, some said they felt as if they were "strangers among ourselves."

There were other adjustments in sheep management due to crowding: nearly all reported increases in supplementary feeding. The average reported increase in expenses for supplementary feeds was 37% at Adami, 41% at Abu Al-Natal, 59% at Abu Al-Fayad, and 88% at Maragha. While these values reflect increased quantities of feed, there must certainly also have been increases in transaction, credit, and transportation costs for finding, buying, and hauling this extra feed. Since this refers only to the winter/spring grazing periods on the range, these cost increases in most cases do not apply to the remainder of the year. An indirect effect of greater dependence on hand-feeding of transported material was an increase in market-orientation and a greater demand for purchased feed.

Shrub Reserves and Feed Production

There are three reasons why individuals or groups will take out leases on a reserve: (i) the reserve may occupy their traditional grazing areas and hence there is little or no alternative but to rent; (ii) they may want to establish or re-confirm a history or tradition of use of the reserve land; and (iii) the cost of the lease and the quality/quantity of the forage justify the choice over alternative feed sources. In reality, the reason may be a mix of all three. For the government, however, it is the quality and quantity of the seasonal vegetation inside of the reserve with which the cost of establishment and maintenance needs to be compared²², along with environmental-stability concerns such as soil erosion. Since *Atriplex* species have dominated planting within the reserves of Syria (it is unfortunate that we do not currently have the specific composition of the reserves included in this survey²³) we can safely assume the overwhelming use of *Atriplex*. The establishment and maintenance costs of the reserves can be set against the benefits derived from protection (exclusion of grazing for five or more years) and those benefits derived from the planting or reseeding of shrubs²⁴. In an effort to assess these, the pastoralists were asked to estimate the contribution of species found within each reserve to the diet of their animals (see Table 4). The original vegetation for Maragha and Adami reserves was dominated by *Artemisia herba-alba* communities, while for Abu Al Fayyad and Abu Al Natal it was *Haloxylon articulatum* communities²⁵. This is reflected in their relative contributions to diets of animals at the time of grazing the reserves. It should be noted that neither of these principal shrubs has, so far, been part of the planting program.

Atriplex species, despite their quantitative superiority in the reserves, were considered to contribute less than the original shrub communities to diets, an overall mean of 3.7% in the judgment of the range users. Distinction between the various *Atriplex* species cannot usefully be made, unfortunately. *Salsola vermiculata*, a much-favored forage shrub, which is both native to the reserve areas and transplanted by the authorities, shows a consistent contribution of 2.8% to animal diets. The ubiquitous perennial grass *Poa bulbosa*, accounted for the major share of grazing, according to the users, with a mean close to 40% of the overall contributions from the reserves. Again, what seems obvious from Table 4 is that the plants of most benefit to the herders are not the planted shrubs *per se* (*Atriplex* and *Salsola* spp.) but rather the natural vegetation growing under and between them. Does this reflect the beneficial effect of protection on forage production? To start with, we do not know what forage production would have been like under similar conditions before the establishment of the reserves. One indication, however, was obtained by asking the herders to estimate hand-feeding amounts for flocks grazing outside of the reserve as compared to amounts given inside (Table 5). While there were "black and white" differences for the Hama reserves, and less consistent ones for those in Aleppo province, savings in hand-feeding were noted for flocks in the reserves.

Table 4. User reports of sheep grazing sources, by plant species and location, as a percentage of total grazing in government shrub plantations in northern Syria (spring 1996).

Name of Plant	Arabic Name	Adami	Maragha	Abu Alhayyad	Abu Alnaytal	Mean
<i>Atriplex</i> (undifferentiated)	رعيل (بحر مبيد)	4.2	1.8	1.0	1.0	2.0
<i>Atriplex nummularia</i>	رعيل بيرومى الأورقي	0.6	2.3	1.6	0.0	1.1
<i>Atriplex halimus</i>	رعيل رفيع الأورقي	0.0	1.5	0.8	0.0	0.6
<i>Artemisia herba alba</i>	قنبح	3.6	3.7	1.6	0.8	2.4
<i>Noeae mucronata</i>	فسر	1.2	3.1	3.1	0.0	1.9
<i>Salsola vermiculata</i>	قرونة	2.8	2.9	2.8	2.8	2.8
<i>Haloxylon articulatum</i>	البقا	0.0	0.2	3.4	3.3	1.7
<i>Anabasis syriaca</i>	قشاني	0.0	0.0	1.0	0.8	0.5
<i>Peganum harmala</i>	قارول	0.0	0.0	0.2	0.0	0.1
<i>Achillea fragrantissima</i>	القيسوم	2.8	0.8	0.3	0.0	1.0
* Sub total for shrubs		15.2	16.3	15.8	8.7	14.1
<i>Poa bulbosa</i>	قبا	32.0	44.4	34.6	48.4	39.9
<i>Carex stenophylla</i>	قنيس	14.0	12.6	0.4	0.0	6.8
<i>Koeleria</i> sp.	قشلة	3.0	7.0	0.0	0.0	2.5
<i>Bromus</i> sp.	شوبرب	0.0	0.0	5.7	0.0	1.4
<i>Hordeum glaucum</i>	خلافور	0.0	2.2	0.7	0.0	0.7
<i>Stipa tortilis</i>	قشمة	0.0	0.2	0.0	0.0	0.1
* Sub total for grasses		49.0	66.4	41.4	48.4	51.4
<i>Anthemis syriaca</i>	الأزريق	0.0	0.2	2.7	3.3	1.6
<i>Lotus</i> sp.	رجل، قصور	16.4	3.6	0.0	0.0	5.0
<i>Helianthemum salicifolium</i>	حويبة	7.6	2.3	1.0	0.3	2.8
<i>Allium</i> sp.	بصلية	4.8	0.1	0.0	0.0	1.2
<i>Torularia</i> sp.	قسنبر	0.0	2.3	7.1	13.4	5.7
<i>Filago</i> sp.	عظينة	1.0	0.9	3.4	3.5	2.2
<i>Astragalus</i> sp.	قرونة	0.0	0.0	6.9	0.0	1.7
<i>Salsola volkensii</i>	خادوش	0.0	0.0	3.7	1.8	1.4
<i>Diptotaxis harra</i>	حارة	0.0	0.0	3.1	1.3	1.1
<i>Erodium</i> sp.	دودة البقري	1.0	2.8	1.9	0.2	1.5
<i>Mathiola bicornis oxycera</i>	شقر	0.0	0.0	1.9	3.0	1.2
<i>Malva</i> sp.	خبيز مخلوب	2.0	0.0	0.1	0.2	0.5
<i>Papaver</i> sp.	شقائق القنس	0.0	0.6	0.0	0.2	0.2
<i>Ranunculace</i> sp.	خولان	0.0	0.8	0.0	0.0	0.2
<i>Sisymbrium septulatum</i>	لمبة	0.0	0.2	0.0	0.0	0.1
<i>Matricaria</i> sp.	بجولج	0.0	0.0	0.9	0.0	0.2
<i>Ceratocephalus falcatus</i>	خشونة	0.0	0.0	0.1	0.0	0.1
<i>Serratula cerinthifolia</i>	قرونة	0.0	0.0	0.6	0.0	0.2
<i>Plantago ovata</i>	عروطة	3.0	2.3	6.2	4.2	3.9
undifferentiated others	باستط غير مميزة	0.0	1.2	3.2	11.7	4.0
* Sub total for others		35.8	17.3	42.8	43.1	34.8
* Total		100.0	100.0	100.0	100.0	100.0

Table 5. Relative intensity of hand-feeding and water use in and out of the reserves.

	Adami		Maragha		Abu Alfayyad		Abu Al Natal	
	In	Out	In	Out	In	Out	In	Out
Herders hand-feeding (%)	25	50	20	50	0	78	0	100
Not Hand-feeding (%)	75	50	80	50	100	22	100	0
Mean H-feeding, (kg/head per day)	0.6	1.2	1.2	2.0	0	1.2	0	1.1
Mean Water use, (L/head per day)	3.8	3.2	4.2	3.3	4.3	3.8	3.8	3.5

The benefits from the reduction of hand-feeding costs within the reserves are somewhat off-set by the cost of supplying additional drinking water to the flocks. The figures on water suggest that there is no substantial additional requirement for flocks on saline as opposed to non-saline soils. The herders' responses do, however, seem to confirm that additional amounts of water are needed while grazing an *Atriplex*-rich pasture. These are estimates for impact on inputs; costs and benefits may also be reflected in outputs from the herd such as milk and cheese production and lamb weight (Table 6).

Results from herders at Adami reserve were the only ones ambiguous in nature. Herders at the other reserves, especially those in Hama province, reported increases in milk production and also (for Abu Al Fayad) lamb weight gains. There are parallels between Tables 5 and 6, as might well be expected. Where all feed came from the natural pastures, there were more reports of increased milk yields.

Table 6. Percentage of households reporting decreases (-), no change (0), or increases (+) in output of sheep flocks inside the reserve vs flocks outside.

	Adami			Maragha			Abu Alfayyad			Abu Al Natal		
	-	0	+	-	0	+	-	0	+	-	0	+
Milk quantity	75	0	25	0	56	44	0	11	89	0	0	100
Cheese/milk ratio	33	34	33	23	77	0	0	87	13	0	100	0
Lamb weight	50	0	50	11	33	56	0	11	89	0	100	0
Mean of above	53	11	36	11	55	34	0	36	64	0	67	33

The Place of Plantations within the Agro-pastoral System

There is continuity and change in the migration habits of the sheep-herding tribes of northwest Syria. Change has primarily come in the form of vehicles to transport water, feed, and sheep, enabling herders to graze their flocks further from traditional watering places and move more swiftly between seasonal grazing areas (Fig. 1). Change in the form of an increased national sheep population and increased dependence on crop residues and feed grains has also been noted (Nordblom and Shomo 1995). Continuity has been maintained with that of the past

half century, however, in the particular groups' general orbit of movement both for spring grazing and their summer movements into the cultivated areas²⁶. Expanded areas of irrigation, on the other hand, have increased the quantity of crop residues and by-products available for autumn grazing and winter hand-feeding.

From the feeding calendar pie-charts in Figure 3, and their associated maps (Fig. 1), it is clear that 6–8 months of the year are spent by flocks in the cultivated areas grazing crop residues and stubble. In late autumn or early winter, flocks are moved to their winter camps in the steppe, where they feed on concentrates and straw. In spring, the flocks graze around their winter encampment areas; this when the grazing of shrub reserves could replace or complement grazing of unimproved rangeland. Summer and autumn grazing of shrub plantations has been tried experimentally by government flocks. Given the alternatives of cheap seasonal grazing of crop residues at these times of the year, however, private flocks may make the most economic use of shrub reserves in spring when other feed sources are most expensive.

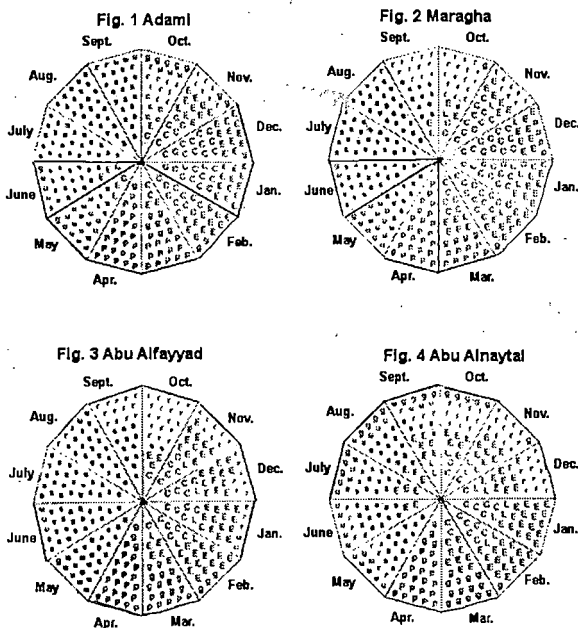


Figure 3. Small ruminant diets as reported by those Bedouin households holding spring grazing contracts at four Syrian government shrub plantations. Each character represents 4% of monthly diet. Lower-case symbols denote *in situ* animal grazing: s = cereal stubble (wheat, barley, and chickpea); r = crop residues (sugar beet, vegetable, maize, cotton, and potato); u = unharvested barley; g = rangeland grazing (range and fallow land); and p = shrub plantations (*Atriplex* spp., *Salsola vermiculata*, and grasses). Upper-case symbols denote hand feeding: C = cereal straw (wheat, barley); L = legume straw (lentil, chickpea); and E = energy feeds (barley grain and cottonseed cake).

Concluding Observations

The plantations are supposed to serve a dual purpose, that of improving and stabilizing the supply of forage in the dry areas, and that of protecting or enhancing environmental quality. This paper has addressed the former. While the latter was beyond the scope of the study, one or two observations can be made. The first concerns the shrubs being planted: from an ecological stance, there may be legitimate concerns about introducing exotic species on the scale that is observed and further planned. It may be argued that, though they are not endemic, they create a micro-environment for the recovery of native vegetation. Under management suitable to prevent complete canopy cover of the surface by the exotic species, this may well be the case. Such management, however, is not necessarily easy or cheap. It could be maintained that native shrubs and trees could better fill the role now being promoted for exotic species.

A further point can be made on the demarcation of the reserves. Two practices have been used to create semi-permanent and unmistakable boundaries which, nevertheless, can easily be crossed by sheep and shepherds on foot. The first is the digging of trenches, sometimes a meter wide and over a meter deep, around vast plantation reserve areas. The second is the building of mud walls, sometimes over three meters high, by bulldozing top soil around the reserve perimeter. Such is the scale of these works that some appear on Landsat satellite images of the area. The immediate ecological damage is obvious in terms of disruption of channel flow and loss of vegetation and soil. Considerable costs for equipment, fuel, and labor are also involved.

Government costs were summarized for the establishment of a fifth, more recent reserve, Obaisan, which covers about 7,325 ha between Adami and Maragha, about 110 km southeast of Aleppo. Costs listed for "site selection," including government employee wages and fuel, totaled US\$ 551 (US\$ 0.08/ha). Costs given for excavating the meter-deep and half-meter-wide border trench around the periphery totaled US\$ 18,000 (US\$ 2.46/ha). Site preparation costs, including bulldozer ripping and supervision, ran to US\$ 83,805 (US\$ 11.44/ha). The greatest cost was for the preparation of shrub seedlings, including seed preparation (collecting, threshing, drying), seed-bag preparation (plastic bags, soil, manure, filling labor), planting, watering, care, and eventual transport, totaling US\$ 113,826 (US\$ 15.54/ha). The planting of seedlings, including employee wages and fuel costs, totaled US\$ 16,404 (US\$ 2.24/ha). Security costs, for two guards watching over the plantation day and night for four years, were estimated at US\$ 6,700 (US\$ 0.92/ha). Total government establishment expenditures were US\$ 239,345 (US\$ 32.68/ha).

Local costs of lost grazing access were not calculated, the official line being that people can simply graze "elsewhere" during the period of plantation establishment,

before returning with limited grazing contracts they must themselves pay for. Such contracts have been negotiated at other reserves for about US\$ 2.50/ha for two months of grazing by a maximum of three or four sheep per hectare.

The damages and direct costs of boundary trenches or fences may be largely avoided where responsibilities for range protection and rehabilitation are devolved to the institutions of the traditional user groups. How this might be done in the future is among the subjects of an ongoing research component on policy and property rights within the Mashreq/Maghreb Project of ICARDA and IFPRI (International Food Policy Research Institute) in collaboration with the national agricultural research programs and the expertise of eight countries in West Asia and North Africa.

Regarding the use of plantations within the agro-pastoral system, the fact that they continue to be leased in substantial numbers suggests that they have a role to play. This may well be because of their enhanced pasture quality and, as already explained, the fact that other pastures available to the traditional users of the area for sheep grazing are insufficient. These people also have incentives to maintain their claims to use-rights on the land, short of other legal provisions, by continuing occupation at every opportunity (Ngaido et al. 1998).

This paper introduces a problem area that needs further development, dividing the assessment of costs and benefits of plantations into two categories. First, are those opportunity and direct costs associated with protecting an area from grazing for a period of five or more years and, thenceforth, coordinating seasonal grazing access to it. Second, are the costs of planting or reseeded shrubs. The evidence from our recent survey, concerning the direct and immediate benefits and costs to the pastoralist of shrub plantations, gives greater significance to the acts of protection than to those of planting. There are important caveats to consider, not least of which is the type of shrub being planted and the longer-term ecological advantages of shrub establishment. Where a seed bank is wholly lacking in desirable endemic plant species, range rehabilitation will not happen through protection alone.

One aspect that has not yet been elaborated concerns the rules for using the reserves. It is clear from the fieldwork that the flexibility of these rules to the needs of the herders differs among provinces. Regulations on grazing of leased parcels within reserves have been strict: watering, milking, camping, and firewood collection are strictly forbidden in some cases. Compliance with these rules imposes direct costs in terms of manpower, time, and finances available to user households while negatively affecting animal performance by requiring extra trekking for watering, milking, and camping. Reserves in Hama Province did provide more latitude for these activities, much to the relief of herders' households.

Perhaps the most important point to be drawn from the study is evidence of existing local institutions and their organizational counterparts: first, by way of the policy of the authorities leasing first to traditional user groups, or organizations; and second, by the institutional experience brought in by these groups to regulate among themselves for the benefit of their common interests. Indigenous organizations and their institutions not only exist in and are adapted to these vast rangeland areas, but may well be suitable for devolution of the state's managerial responsibility for range rehabilitation and control on larger scales.

The extent of traditional arrangements for rangeland management in northern Syria and other parts of WANA offers the possibility of economically efficient, equitable and environmentally sustainable development that meets and protects the interests both of the state and range users.

Acknowledgments

This study was made possible only through the cooperation and active help of the Steppe and Range Directorate, Ministry of Agriculture and Agrarian Reform, Syrian Arab Republic. The study was supported in part by the ICARDA/IFPRI Mashreq/Maghreb Project, which is funded by IFAD and the Arab Fund for Economic and Social development.

Surveys such as this are intensely participatory in nature, and the Syrian agropastoralist range users who were interviewed freely gave their ideas and experiences. They also maintained the legendary hospitality for which they are famous; the authors are sincerely grateful for their help.

The authors are particularly grateful to Dr Tony Goodchild for critical comments on an earlier draft, and to Mr Farouk Shomo for crucial help with the feeding-calendar graphics.

The authors alone are responsible for any errors and for the opinions voiced in this paper. The ideas expressed do not necessarily represent the policies or positions of any of the several cooperating or supporting institutions.

Footnotes

- ¹ *Atriplex halimus*, from the last of these three regions, is not endemic to the current land area of Syria (Battikha 1996, personal communication).
- ² *Atriplex* species were introduced in the mid-1960s on the Wadi Al Azib station in Hama Province. This, however, was done for experimental reasons, and the shrubs were not made available to the local range users (van de Veen 1967).
- ³ 200 mm average precipitation.
- ⁴ During extensive fieldwork in the Aleppo and Hama steppes, and to a lesser extent in the Homs steppe, through 1995/96, the authors did not identify one site whose roots

could be traced back to this period.

- ⁵ These principally include decisions Nos. 16/T and 27/T of 1982 and Instructions from the Prime Minister Nos. 3480/1/31, 3499/1/31, 3454/1/31, 2267/1/31, and 3026/1/31, all of 1982
- ⁶ Following Article 13 of the Agrarian Reform Law, the maximum permissible area of cultivation to either an individual or a household is 45 ha.
- ⁷ The original decision is No. 96/T Article 1 section F. However, this quote, translated by ICARDA, is an elaborated version found in a later letter of clarification, No. 5057/MD, dated 1/12/87, from the Ministry of Agriculture and Agrarian Reform. This legislation did not include "non-irrigated lands of the steppe included or [that] will be included in the 'Euphrates and Khabour Dam' projects." Art. 2 of Decision No. 96T.
- ⁸ This is a commonly cited reason for the poor performance of intervention that depends partly or wholly on local institutions for the appropriate regulation; the principal author of this paper feels, however, that this reason is given too much credit, its prominence stemming from misunderstandings of the traditional institutions themselves (see Rae, in preparation).
- ⁹ To cultivate all land cultivated in the recent past.
- ¹⁰ The legislation referred to here is decision No. 17 of the Superior Agricultural Council. Article 3 states "The area whose use is regulated under the provisions of the Law of the Steppe Protection will be transferred gradually to be planted with pasture shrubs within five years as from the 1992/1993 cropping season."
- ¹¹ This does not include those lands included or to be included within the Euphrates and Khabour Dam projects: Decision No. 17 of the 15/9/92.
- ¹² This figure was given both by the Steppe Department, MAAR, and by the Minister of MAAR during parliamentary debate (21 March 1996).
- ¹³ These will not be discussed, as the forage is not made available to traditional use groups but reserved for government flocks.
- ¹⁴ MAAR, in collaboration with ACSAD, held a two day conference in early 1987 on steppe rehabilitation alternatives in which the idea of public shrub plantations came to the foreground. The conference was unusual, in that the Minister of Agriculture and Agrarian Reform, The Head comrade of the Peasants' Union, and the Head of the Higher Agricultural Council (the Prime Minister) all attended. The first two graduated from the same class at university together.
- ¹⁵ The figures presented here do not include the seven "Hema and sheep breeding centers," which are not open to public grazing. Of the 20 public reserves, there are four reserves apiece in Hama, Homs, Raqqa, Deir Ezzor, and Hassakeh provinces, with a further five in Aleppo and three in Al Suida provinces.
- ¹⁶ Steppe Directorate Headquarters, Tadmor (Palmyra).
- ¹⁷ This figure was the same for 1995 and 1996. Initially, it was thought by MAAR that leases would be free, though this was soon altered after the large initial interest (US\$1 = 42 Syrian Lira).
- ¹⁸ Another study, carried out by some of the authors of this paper, found that this has continuity with similar arrangements outside of the reserve areas among the populations of the larger community in the steppe.
- ¹⁹ These households are defined by winter camp distances from the reserve of over 25 km. The minimum distance was 75 km, while the maximum was 100 km for nine of the households.
- ²⁰ See Rae (in preparation).

- ²¹ 13 households with former winter camps over 75 km from the reserve are not included in these calculations.
- ²² For the sake of simplicity in the upcoming discussion, the benefits of the shrubs to soil stability, micro-climate conditions, etc., and their potential use as firewood, are not considered here, although their importance is acknowledged.
- ²³ This is also the case for the government authorities.
- ²⁴ See endnote 22.
- ²⁵ A local Arabic term for *Haloxylon articulatum* is *natoon* from which the “natel,” in Abu Alnatel, is derived.
- ²⁶ See Al Ashira al Sham (1943) cited in Rae (in preparation).

References

- Darwich, M., O. Erkan, T.L. Nordblom and Kazem Dendal. 1995. The economy of livestock and pasture management in Jabal Abdul Aziz, NE Syria. Paper prepared for Science Week, organized by the Supreme Council of Sciences, Syrian Arab Republic, Latakia, 4–9 Nov 1995.
- Hamadeh, S.K., A. Goodchild, F. Shomo, T.L. Nordblom and G. Gintzburger. 1995. The role of native pasture grazing in relation to other feed sources for sheep and goat flocks in the Beqa'a Valley of Lebanon. Pages 201–202 in *Rangelands in a sustainable Biosphere*, Vol I (N.E. West, ed.). Proceedings of the Fifth International Rangeland Congress, 23–28 July, Salt Lake City, Utah.
- Leybourne, M. 1993. Links between the steppe and cultivated areas through migration: The socioeconomic organization of production of the semi-nomadic agro-pastoral society of the Syrian steppe, Institut Universitaire d'Etudes du Developpement, Diplome de Recherche No. 78, Geneva.
- Leybourne, M., F. Ghassali, A. Osman, T. Nordblom and G. Gintzburger. 1997. The utilization of fodder shrubs (*Atriplex* spp., *Salsola vermiculata*) by agro-pastoralists in the northern Syrian steppe. Pages 425–436 in *Improvement of Crop-livestock Integration Systems in West Asia and North Africa* (N.R. Haddad, E. Tutwiler and E. Thomson, eds.). Proc. Regional Symposium on Integrated Crop-Livestock Systems in the Dry Areas of West Asia and North Africa, 6–8 Nov 1995, Amman, Jordan. ICARDA, Aleppo. ICARDA-044.
- Ngaido, T., T. Nordblom, G. Gintzburger and A. Osman. 1998. A policy shift toward sustainable resource development. Pages 71–94 in *Drylands: Sustainable Use of Rangelands into the Twenty-first Century* (V.R. Squires and A.E. Sidahmed, eds.). Proceedings of a Workshop Sponsored by the International Fund for Agricultural Development (IFAD), the Meteorology and Environmental Protection Administration and the Ministry of Agriculture and Water, at Jeddah, Saudi Arabia 3–6 Nov 1996. IFAD, Rome.
- Nordblom, T.L., and F. Shomo. 1995. Food and feed prospects to 2020 in the West Asia/North Africa region. Paper prepared for the workshop on Sustainable Agricultural Growth in the Major Ecoregions of the Developing World: Prospects to 2020, Airlie House, Warrenton, Virginia, November 7–9, 1994 by IFPRI. ICARDA. Social Science Paper No. 2, ICARDA, Aleppo.
- Nordblom, T.L., G. Arab, G. Gintzburger and A.E. Osman. 1997a. Survey of Bedouin groups with contracts to graze the government rangeland plantation at Maragha, Aleppo Province, Syria. Pages 437–445 in *Improvement of Crop-livestock Integration Systems in West Asia and North Africa* (N. Haddad, R. Tutwiler and E.

- Thomson, eds.). Proc. Regional Symposium on Integrated Crop-Livestock Systems in the Dry Areas of West Asia and North Africa, 6–8 Nov 1995, Amman, Jordan. ICARDA, Aleppo. ICARDA-044.
- Nordblom, T.L., F. Shomo, and G. Gintzburger. 1997b. Food and feed prospects for resources in Central Asia. Pages 129–146 *in* Central Asia Regional Livestock Assessment Workshop Proceedings (M. Demment, ed.). Tashkent, Uzbekistan, 27 Feb–1 March 1996. Management Entity, Small Ruminant CRSP, University of California-Davis.
- Pape, Andrea. 1994. The Contribution of Women to Labor and Decision Making Processes in Bedouin Families. An Example from Syria. MSc Thesis. Institute of Agricultural Economics and Social Sciences in the Tropics and Sub-Tropics, University of Hohenheim, Stuttgart, Germany.
- Pape-Christiansen, A., W. Doppler and T. Nordblom. 1997. The contribution of women to labor and decision making processes in Bedouin farming systems of northern Syria. Pages 553–563 *in* Improvement of crop-livestock integration systems in West Asia and North Africa (N. Haddad, R. Tutwiler and E. Thomson, eds.). Proc. Regional Symposium on Integrated Crop-Livestock Systems in the Dry Areas of West Asia and North Africa, 6–8 Nov 1995, Amman, Jordan. ICARDA, Aleppo. ICARDA-044.
- Rae, J. Custom, pragmatism and opportunity in steppe administration: An analysis of formal and informal institutions and organizations on the Syrian steppe. Forthcoming PhD Dissertation, School of Geography, Oxford University, Oxford, England. (in preparation)
- Syria: The Syrian Arab Republic. Laws and Decisions of the Council of Ministers.
No. 140 of 15.7.1970.
No. 13 of 26.3.1973.
No. 96/T of 19.11.1987.
No. 17 of 15.9.1992.
- Syrian Ministry Of Agriculture and Agrarian Reform.
Circular No. 4 18.5.1976.
No. 107/DS of 23.5.1976.
No. 5057/M.D. of 1.12.1977.
- Syria: Letter of the Ministry of Agriculture and Agrarian Reform No. 1119/St of 15.8.1990
- Thomson, E.F., F.A. Bahhady and A. Martin. 1989. Sheep husbandry at the cultivated margin of the northwest Syrian steppe. ICARDA-148. ICARDA, Aleppo.
- UNDP. 1967. Range Management and Fodder Development Report to the Government of Syria. Report No. TA 2351.
- Wachholtz, R., T. Nordblom and G. Arab. 1993. Characterization of year-round sheep feeding and grazing calendars of Bedouin flocks in the NW Syrian steppe. Pages 215–236 *in* Pasture, Forage and Livestock Program Annual Report, 1992. ICARDA-070. ICARDA, Aleppo.
- Wachholtz, R. 1996. Socioeconomics of Bedouin farming systems in dry areas of northern Syria. PhD Dissertation, Hohenheim. Vol. 24 *in* Farming Systems and Resource Economics in the Tropics (W. Doppler, ed.). Wissenschaftsverlag Vauk, Kiel.

Socioeconomic Assessment: Rapporteur's Report

T.L. Nordblom

Agricultural Economist Pasture Forage and Livestock Program
ICARDA, Aleppo, Syria

Range Grazing in the Livestock Economy

The rangelands of North Africa and West and Central Asia make up a substantial but declining proportion of the livestock diet (Fig. 1). This is due to the fixed areas of rangelands in a period of increasing livestock populations, increasing crop (and crop residue) production, and increasing use of feed grains and other concentrates.

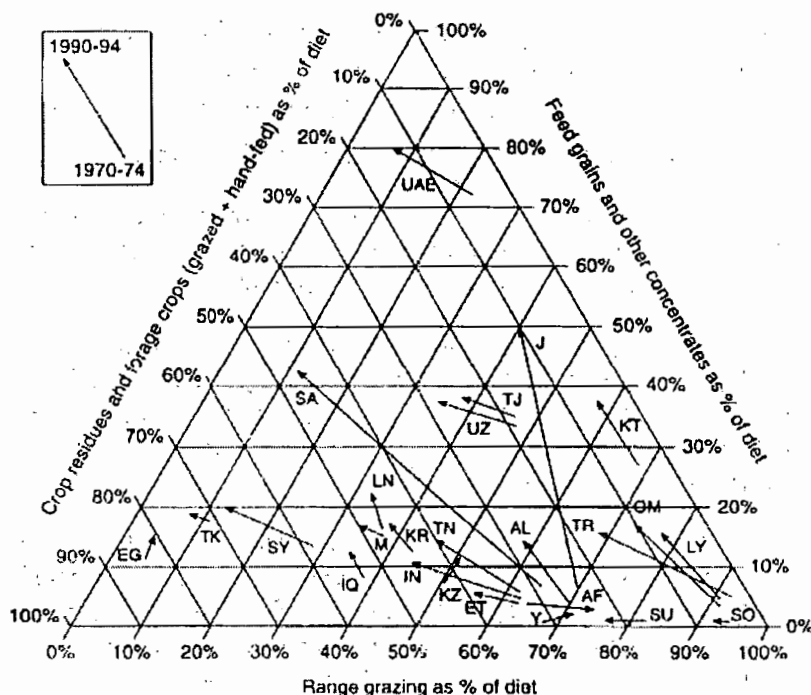


Figure 1. Trends in the composition of livestock diets by feed category in West Central Asia and North Africa (1970-1974 to 1990-1994).

Due to larger numbers of livestock, and the expansion of cropping areas, rangelands face growing pressures. While these trends have certainly caused degradation of the rangelands in all countries of the region, this is not accounted for in Figure 1, which assumes constant range areas and productivity over the past 20 years. Therefore, Figure 1 shows the most conservative estimate of declines in

rangeland contribution. Nevertheless, rangelands remain very important feed sources, and scientific interest in sustaining or enhancing their productivity is well justified.

Multiple Uses of Shrubs

The uses of shrubs, which many authors have referred to in these proceedings, can be summarized briefly:

- Shrubs can provide seasonal forage that may fill an economic feed-gap each year, or provide a strategic reserve for drought management.
- Shrubs are a means of physically marking land to assert a claim of exclusive access, or to identify an exclusion zone for deferred grazing.
- Shrubs can provide firewood, a cover for animals from wind and sun, a wildlife habitat, and control of erosion by wind and water.
- Shrubs can be used to lower groundwater tables where salinity is a problem.
- Shrubs can be aesthetically pleasing and improve land sale value.

Each of the above uses generates value from land that typically has low potential for cropping. These values are often complex and spread over many years, in contrast to the simple and quick payoffs from crop production.

Regarding seasonal grazing, recall the diet calendars presented by Rae et al. (1999) for herders with grazing contracts on government shrub plantations in Syria. Only 5–10% of the annual sheep diet came from the plantations, and only a small proportion of this amount was from shrubs. The remainder came from native grasses and other species as well as hand feeding.

Syrian herders move considerable distances (often more than 100 km) to take advantage of other feed sources, particularly residues of cereal and irrigated crops when these become available (cheap and abundant). The flexibility to move their flocks gives these herders a resilient system. Sedentary systems in such low rainfall areas are more vulnerable to year-to-year variations in weather.

Shrub Plantation is a Long-term Investment

We must deal with the fact that range rehabilitation almost always requires long-term investment. Plantations often have high initial costs and yield benefits after a recovery period stretching over many years. Figure 2 presents this investment in graphical form, with time in years on the horizontal axis and costs and benefits on the vertical axis.

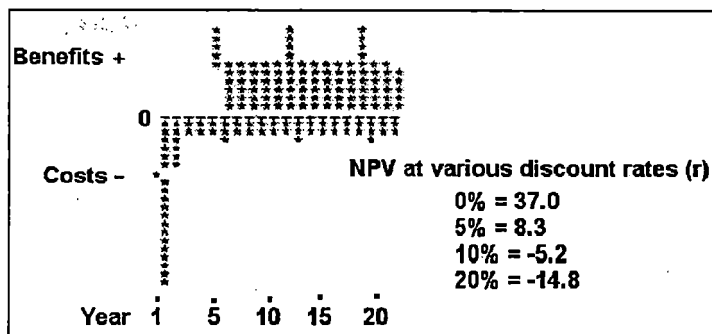
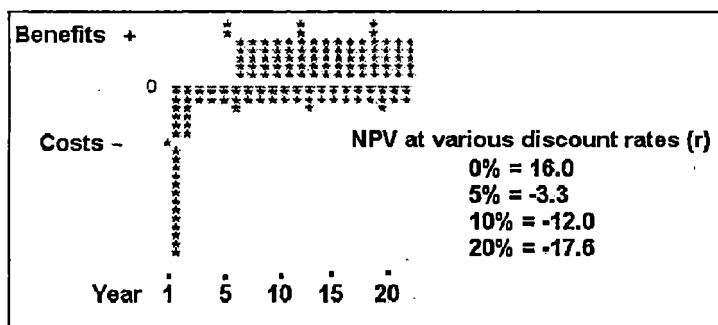
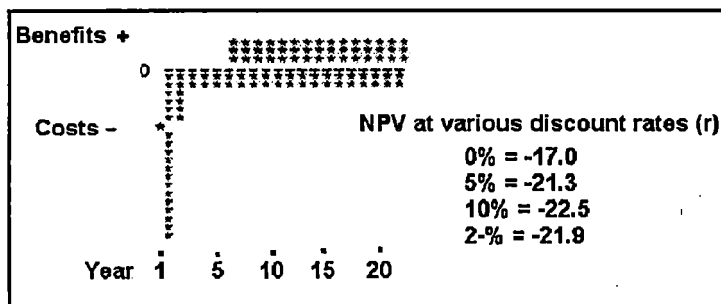
A. With large anticipated benefits**B. With modest anticipated benefits****C. With small anticipated benefits**

Figure 2. Net present value (NPV) of the flow of costs and benefits over time, with a 20 year horizon.

The attractiveness of an investment plan depends not only on the direct costs and benefits expected but on other opportunities for using the resources. This includes the need for parallel consideration of other investment options, including that of doing nothing—i.e., continuing range use as it is. It is the other opportunities for use of resources that give rise to a discount rate. With such a discount rate, we can

calculate the net present value (NPV) of a future stream of benefits and costs. A positive NPV indicates a good project that pays off better than other opportunities (as represented by the discount rate).

Consider the first investment scenario (Fig. 2a), with large initial costs, a delay of five years until the first benefits are available in the form of increased grazing off-take, and a small harvest of firewood. Here I use the cost estimate of US\$ 32/ha and a five-year establishment period based on Syria's Obaisan plantation as reported by Rae et al. (1999). Other hypothetical benefit and cost values are my own; for example, the harvest of firewood by pruning the shrubs every six years. Costs are allowed for the firewood harvest while small, regular, per-hectare costs for maintenance and protection occur each year. A 20-year horizon is used to compare investments.

With a discount rate as high as 7%, the investment in Figure 2a looks like a good one. The internal rate of return of this project is just over 7%. A farmer may consider commencing a series of such investments on poor rangeland, adding a few hectares of shrubs each year, while not having sufficient funds to rehabilitate all the land at one time.

The investment scenario in Figure 2b is clearly less attractive; the cost sequence is the same as in Figure 2a, but the stream of benefits is lower. Unless the discount rate is lower than 4%, other investment options are preferred.

The poorest investment scenario is depicted in Figure 2c. In this case, expected costs significantly exceed benefits. As in the other two scenarios, a large share of the costs occurs early in the life of the project. In this case, however, the annual benefits are too small to ever cover the establishment costs. This project is clearly uneconomic.

Most readers will catch the point that it is important to have good estimates of costs and benefits over time. For the justification of large shrub plantation projects, particularly those financed by loans, it is essential to have good quantitative estimates of the long-term flows of expected costs and benefits. Unfortunately, such reliable estimates are frequently unavailable. A challenge for us is to arrive at reasonable, un-inflated estimates of shrub use benefits.

I have seen the opposite, when the value of summer grazing of *Atriplex* shrubs was given as equal to the cost of one kg of barley grain per head of sheep per day. This was at a time when local farmers had already removed their sheep from the area to the higher rainfall areas for summer grazing of cheap and abundant cereal stubble after harvest. The appropriate measure of shrub grazing might have been the lowest cost substitute feed at that time of year; in this case the cost of stubble grazing, in the range of US\$ 1.60–2.40 per head per month, rather than US\$ 4.20 per month for barley grain. Other factors should have come into the calculation, such as the

long haul (40 km) to bring fresh water to sheep on the shrub pasture, versus the short haul for sheep grazing stubble fields in the main farming areas.

Targeting Range Research/Development

Within the domain of known and potential technologies for rangeland rehabilitation at any given site, considering the soil, climate, and other conditions, there may be one subset of technologies that is cost efficient, another subset that is regarded as equitable (fair and just), and a third subset of environmentally sustainable technologies. The target for our research should be where these three subsets overlap; that is, where we can define technologies and project applications which meet all three criteria (Fig. 3).

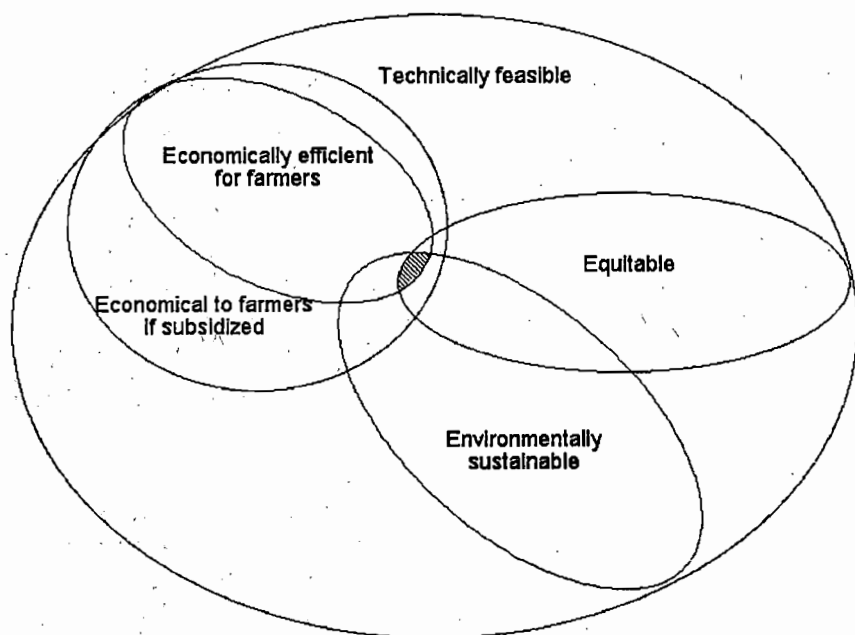


Figure 3. Overlapping goals in range improvement.

Conclusion

It is perhaps not surprising that scientists reporting at a meeting on native and exotic fodder shrubs would focus most on the biological findings and remaining mysteries and possibilities for wider use of these plants. Statements of objectives I heard this week include:

- Managing for the benefit of the land (soil, water, vegetation).
- Managing for the benefit of the animals.
- Meeting the needs of the animals.

One statement of objectives not heard is: management to meet human needs at the farm and national levels for current and future generations. To be fair, however, these objectives have been implicit in the workshop. Farmers from several countries have joined us to share their viewpoints. We have enjoyed field visits to cooperatives, government farms, and private farms in central Tunisia, affording us perspectives on how these are managed. The human side of motivations and incentives for integrating shrubs in farming systems has received more attention by this group than in many other scientific technical meetings. For this, our workshop organizers should be congratulated.

Socioeconomic Assessment: Recommendations

- Fodder shrubs may play the economic role of filling feed-gaps as a seasonal forage each year, or as a strategic reserve for drought management, in addition to providing firewood and other facilities.
- The socioeconomic contexts, as well as the biologic contexts, of fodder shrubs differ from location to location; they should be surveyed in advance as part of the process of designing new shrub research and development.
- Within the domain of technically feasible things that can be done with fodder shrubs at any location, we should seek the target subset that is economically efficient for farmers, equitable, and environmentally sustainable.
- Shrub plantations are long-term investments, differing from short-term cropping decisions in terms of risk considerations and need for security; because of high initial costs and long pay-off periods, we cannot expect farmers or communities to invest in shrubs without solid security of tenure.
- Other conditions for successful private or communal investment in range needing study include: institutional and organizational models, credit, and alternative feed sources during plantation establishment, etc.
- Sedentary crop/range/livestock systems in the arid zones are more vulnerable to weather risks than flexible nomadic ones; fodder shrub reserves may partly ameliorate these risks.
- There is a deficiency in baseline data on costs and benefits of shrub plantations. When valuing the grazing benefit of fodder shrubs, one must take into account the lowest cost substitute feed that could be used at that time of year by local farmers.

- There is a need for participatory approaches with farmers in the design and conduct of research and development on fodder shrubs.
- And, finally, a note of caution summarized by Clive Malcolm: “Shrub technology is in its infancy. The range of species in use is very poor, the methods of establishment are in general very costly, and profitability is in many cases negative. We must not subsidize poor technology; it will bring itself into disrepute and the whole concept will be discredited.”

References

- Rae, J., G. Arab, K. Jani, N. Murad, T. Ngaido, G. Gintzbürger and T.L. Nordblom. 1996. Socioeconomics of shrub plantations in Syria. These proceedings.

Discussion: Socioeconomics

Chair: N. Gaddes (Tunisia)

Rapporteur: T. Nordblom (ICARDA)

A. Hazlaoui (Tunisia): Pour les arbustes fourragers, on doit considérer la rentabilité à long terme pour un intérêt surtout du point de vue : pastoral ; ecologie ; développement durable, pour éviter la perte du sol chaque année, si ce dernier est laboré.

C. Malcolm (Australia): Shrub technology is in its infancy. The range of species in use is very poor, the methods of establishment are in general very costly, and the profitability of the technology is in most questions negative. We must not subsidize poor technology; it will bring itself into dispute and the whole concept will be discredited.

Ahmed El Mohammed (Farmer, Syria): *Atriplex* without barley is not sufficient for animals. We are intending to plant barley between rows. In some years, we have runoff which amounts to 300 mm, which helps the barley grow between *Atriplex* rows.

E. Thomson ICARDA: Today we reviewed about 40 papers in the morning, but only about 12 in afternoon. I believe that much of the research reported in the morning could be done on-farm. Maybe in five years, when we meet again, we'll see most of the research being done on-farm. This will increase the chances of shrub technology being adopted by farmers.

C. Salah (Tunisia): I think there is a risk when using barley of improperly plowing the soil.

F. Nouri (Agro-pastoralist, Syria): We are in favor of fodder shrubs, but they are costly. We are asking for help because most farmers cannot plant fodder shrubs.

K. Tadros (Jordan): The resource management scheme you suggested may be suitable and negotiable on privately owned rangelands. What resource management scheme do you suggest for state open-grazing rangelands?

B. Mustapha (Morocco): Nul ne peut nier l'importance des arbustes fourragers naturels ou importés, mais nous prions les chercheurs de bien vouloir axer leur travail sur la minimisation des coûts de plantation des arbustes, pour permettre la reproductibilité, sachant que ni les bailleurs de fonds ni l'Etat ne financeront à vie ces projets.

L. El Bachir (Farmer, Morocco): Les arbustes fourragers doivent être planté dans des régions arides ou semi-arides. Dans les terres fertiles, il faut planter autre chose, qui soit plus rentable.

L. Tahtacioglu (Turkey): In most presentations, the environmental benefit of fodder shrubs plantation is considered one of the main components. Do you really think farmers will place the same importance on the environmental aspect, without incentives?

M. Acherkouk (Morocco): Inter-cropping can be realized on degraded lands. But it cannot be recommended on lands where the natural vegetation can grow.

H.N. Le Houérou (France): In oil-rich countries, you may pay US\$ 200 or more for a local 40 kg ram (Barkhous). With irrigated *nummularia*, you may produce 20–30 tonnes DM/ha and thus draw US\$ 10,000 to 20,000 from your hectare, even with brackish water, and thus compete with any vegetable or fruit crop.

A.E. Osman (ICARDA): Is there any practical example from the papers reviewed that growing barley in areas receiving less than 200 mm will achieve the three Es: economic feasibility, equity, and environmental stability?

Answer by a Syrian farmer: We certainly know that without growing barley, we will not be able to continue raising sheep in our steppe.

A. Abdelguerfi (Algeria): Que pensez vous de la privatisation du foncier et ses conséquences sur les parcours? Ne peut-on pas penser à avoir des propriétés ayant une superficie viable? Au niveau Nord-Africain, il y a souvent confusion entre mise en culture et mise en valeur. Ne pensez-vous pas qu'il est possible d'améliorer la productivité au niveau des régions marginales sans perturber le milieu et préserver ainsi l'environnement et les ressources génétiques locales?

V. Papanastasis (Greece): Given the high cost of establishment and maintenance of fodder shrub plantations, where would you recommend planting shrubs, on good soils or on marginal soils?

A. Brayzat (Farmer, Jordan): Our purposes in fodder-shrub plantation are: to stop desertification; to produce seed; and to stop people from plowing lands under 100 mm rainfall for barley production. I'm appealing to all national and international organizations to help us in overcoming these problems.

A. Youssef (Tunisia): Considérons la rentabilité économique et financière des projets de développement sylvo-pastoraux ; la première est évidente tandis que la deuxième est incertaine ou nulle ; que pensez vous du devenir de ces investissements en l'absence du soutien de l'Etat et des bailleur de fonds?

A. Koocheki (Iran): There are still nomads in our part of the world. It would have been relevant if a mention of these people was made in this workshop.

Answer by G. Gintzburger (ICARDA): Some are present with us in this room and are taking part to our discussion.

L. Abdelali (Morocco): Le problème d'évaluation de l'impact des interventions pour l'amélioration des parcours ne peut se résumer en une rentabilité économique, mais en s'intéressant plus aux critères de l'environnement et du côté social (cas du Maroc). Assurer la mise en valeur des terres de parcours par une prime est une question difficile. Dans le cas du Maroc, l'assurance des cultures n'a commencé qu'en 1994 et pour des espaces très limités (13 communes).

L. Mayer (GTZ-CRDA/DASPI/Project, Tunisia): I believe the long-term damage done to the land in our project area that is prone to erosion and used for wheat production (with a yearly average rainfall of 150 mm) is significantly higher than the short-term benefit from poor wheat production. Do you know of any figures to support this hypothesis?

K. Laid (Farmer, Morocco): For rangeland improvement, we should distinguish among three categories of rangelands: (i) very degraded, which require projects for rehabilitation by fodder shrubs; (ii) common rangelands of moderate degradation, which require only protection and help to farmers by improving the infrastructure (water points, feed in years of drought, shelters); and (iii) private rangelands, i.e. whose owners have enough resources to improve their rangeland.

M. Boujrad (Morocco): Personne ne nie l'importance des arbustes fourragers, mais on constate qu'il y a encore un manque flagrant de recherches dans ce sens, surtout dans le domaine économique, effet sur l'animal, l'environnement, etc. Est-ce qu'on pense à la viabilité des projets après le départ du bailleur de fonds? Est-ce que les éleveurs sont capables de s'intégrer dans ce sens?

S. Mirza (Pakistan): What are the standard criteria for estimating long-term benefits from shrub plantation?

H. Guerin (France): What are the potential roles of fodder trees and shrubs in Mediterranean and middle-eastern cropping systems? What is their potential role in restoring soil fertility? These are much developed in tropical areas.

M. Ben Diaf (Tunisia): Il faut avoir une vision globale du mariage des arbustes fourragers et de l'orge (quantifier l'érosion qui revient au travail du sol).

C. Malcolm (Australia): An approach to the economic problem is to spend government money on providing better technology that is available to all. The better technology may involve higher productivity, cheaper establishment and

better species, and this may encourage the farmer to fund it himself and eliminate the need for subsidies. This also overcomes some equity problems. Farmers can also help pay for the cost of establishment by selling seed.

H.N. Le Houérou (France): There are many ways of approaching economic feasibility studies, particularly in terms of macro-economics:

- Drought-insurance, how do you quantify it?
- How do you put figures on environmental benefits?
- The cost of doing nothing.
- The cost of erosion.
- What about the technical level of the farmer as regards economic efficiency?

S. Hamadeh (Lebanon): In the context of marginal lands and in the light of the GATT Agreement, what relative weight would you give to economic feasibility, equity, and environmental sustainability.

M. Tazi (Morocco): I have a remark about the Resource Management mapping. I think you should have a precipitation gradient and I will draw the map. It should show:

- Degraded rangelands where you have to plant shrubs.
- Rangelands with some native vegetation which need some protection.
- Cultivation of barley within shrub plantation.
- Cultivation of barley alone in better areas with high precipitation.

How do you calculate the incremental cost for a shrub plantation?

M. Lloyd (Farmer, Australia): Tom has reviewed the benefits of planting fodder shrubs, and used the three Es. What is the real cost of doing nothing?

E. Correal (Spain): Do you know if there is any economic assessment of international money invested in developing projects involving fodder shrub plantations? This relates to the benefit of improving the efficiency of the money invested.

E.B. Labied (Farmer, Morocco): En cas de plantation d'une zone, cette dernière doit être protégée du pâturage pour une période donnée. Les animaux doivent donc être emmenés quelque part, où? Qui supportera les charges qui en résultent? En cas de catastrophe (mortalité d'animaux), qui va aider l'agriculteur à surmonter et supporter de tels problèmes?

**Recommendations
of
The Workshop Participants**

Recommendations

The following recommendations were brought up and accepted by the workshop participants in plenary session.

Ecology, Biology, and Germplasm

- There is a need to develop an eco-climatological base for appropriate referencing and comparison of collection and evaluation sites. Eco-zones and potential species for each zone should be defined.
- Cold arid environments need more research and development, because past experiences with fodder shrubs have focused mainly on mild winter areas.
- A larger genetic diversity should be used. Only a few species (*Atriplex* and *Acacia*) have been used in fodder shrub plantations and not enough germplasm has been screened for the most frequently used species to get a good genetic insurance against biotic and abiotic stress factors. There is a potential risk that parasites (e.g. *Cistanche* and *Cynomorum* spp.) will proliferate and damage current plantations. Hence the need to promote a germplasm bank of fodder shrubs, trees, and woody species from different environments.
- In germplasm collection, conservation, and evaluation, local and endemic shrub species should be given higher priority.
- There is a need to promote a germplasm bank of fodder shrubs, trees, and woody species from different arid areas to be tested in various environments, and to build a database on fodder shrub species located at ICARDA.
- The functioning and symbiosis of root systems (nitrogen fixation, mycorrhiza, seedling root strategy, etc.) of the most frequently used fodder shrub species deserve more attention.
- The effect of the woody plant canopy on the herbaceous layer should be considered.

Plant-Animal Interface

- The effect of shrub use on the reproductive performance of livestock needs to be investigated.
- Livestock should be involved at an early stage in the screening of shrub germplasm, since chemical analysis is usually inappropriate for selecting species and ecotypes for animal use.
- More emphasis should be given to the measurement of anti-nutritional factors in fodder shrubs and less to the measurement of fiber constituents and *in vitro* digestibility.

- The use of shrubs should be viewed in the context of the production system, so that they meet specific needs in the annual feeding calendar of the animals.
- Long-term trials that measure the yield and quality of meat, milk, and wool are desirable, since these are the best expressions of the feeding value of shrubs.

Socioeconomics

- Socioeconomic analysis should be carried out on all projects. Fodder shrubs may play the economic role of filling feed-gaps as seasonal forage each year, or as strategic reserves for drought management, in addition to providing firewood and other facilities.
- In low-rainfall rangeland ecosystems, benefits may also be evaluated in terms of soil conservation, combating desertification, and wildlife habitat.
- Shrub plantations are long-term investments, differing from short-term cropping decisions in terms of risk considerations and the need for security. Because of high initial costs and long pay-off periods, we cannot expect farmers or communities to invest in shrubs without solid security of tenure.
- Other conditions for successful private or communal investments in rangelands needing study include: institutional and organizational models, credit, and alternative feed sources during plantation establishment.
- Sedentary crop/range/livestock systems in the arid zones are more vulnerable to weather risk than flexible nomadic ones; fodder shrub reserves may reduce these risks.
- There is a deficiency in the baseline data on costs and benefits of shrub plantations.

Technology Transfer

- Research must be user-driven; whenever feasible, studies should be conducted on-farm, with the full participation of farmers and the community in the planning, management, and evaluation of the shrub plantation. Funding agencies should be strongly advised to ensure that land users are involved in range improvement programs from inception and at all stages.
- A participatory approach should be adopted to better involve the farmers and to ensure that the technology will be a response to their needs and demand.
- More attention should be given to studying the grassroots knowledge that is the prerequisite for efficient transfer. The indigenous knowledge of farmers concerning fodder shrubs needs to be examined when developing range rehabilitation studies.

- There is a need for a comprehensive education program so that technology will grow as the knowledge of farmers grows, and be progressive rather than condensed and rushed.
- State involvement is a must in producing the needed incentives and stimulating development programs.
- Cheap methods of shrubs establishment should be developed.
- Informal seed production by farmers and availability of good-quality seed in the market should be encouraged to cope with the current demand for diverse fodder shrub plantations.

Networking

- There is a need to establish a fodder shrub network for arid and semi-arid zones. Strong links should be established between the Mediterranean/West Asia shrub programs and those in Australia/Pakistan, South Africa, and South America.
- To allow scientists, farmers, and extension people to interact and build on their experiences and understanding fodder shrub prospects in rehabilitating the rangeland, periodic workshops on fodder shrubs are needed. Regional and international organizations are requested to support the organization of such workshops.
- A cooperative research program should be established to develop cheap reliable establishment methods for forage shrubs.
- The possibility of establishing networks of farmers, such as the land-care network in Australia, or the cooperative scheme in Pakistan, should be investigated.

List of Participants

List of Participants

Algeria

Aïssa Abdelguerfi
Institut National Agronomique
Dépt. de Phytotechnic
PO Box 16200
El-Harach, Algeria
Tel: 213 252 19 87/89; 229 40 36
Telex: 64143
Fax: 213 252 35 47/29 21

Noureddine Redjel
Haut Commissariat au Développement
de la Steppe (HCDS)
Cité Ezzouhour, Route El Kouif
PO Box 12005
Tebessa, Algeria
Tel: 213 847 46 30/32 12
Fax: 213 847 32 12

Atika Slimani
HCDS
Cité Ezzouhour, Route El Kouif
PO Box 12005
Tebessa, Algeria
Tel: 213 847 46 30/32 12
Fax: 213 847 32 12

Mohamed Yousfi
HCDS
Cité Ezzouhour, Route El Kouif
PO Box 12005
Tebessa, Algeria
Tel: 213 847 46 30/32 12
Fax: 213 847 32 12

Australia

Michael J. Lloyd
Newdegate Land Conservation
District Committee
Private Mail Bag
Lake Grace 6353
Australia
Tel: 61 98 71 20 41
Fax: 61 98 712 062

Clive Vincent Malcolm
RMB 1054
Denmark, Australia
Tel: 61 98 409 389
Fax: 61 98 409 389

Chile

Sergio Lailhacar
Dept. Prod. Animal
Universidad DE Chile
Fac. Sc. Agrarias y Forestales
Santa Rosa-CC 1004
PO Box 11315
La Pintana Santiago-1
Chile
Tel: 558 70 42/224
Fax: 56 2 678 58 02

Egypt

Yahia Mahmoud Omar Abd-Elwanis
Matrouh Res. Management Project,
International Project Center
Box 62
Mersa Matrouh, Egypt
Tel: 20 3 931083
Fax: 20 3 931082

Hassan M. El-Shaer
Desert Research Centre
1 Mathf el Mataria
PO Box 11753
Mataria, Cairo, Egypt
Tel: 202 243 5519/0759
Fax: 202 245 7858

Taher Hamida Kaseih
Matrouh Res. Mgt. Project,
International Project Center
Box 62
Mersa Matrouh, Egypt
Tel: 20 3 931083
Fax: 20 3 931082

Gamal Samy Mikhiel
Matrouh Res. Mgt. Project
International Project Center
Box 62
Mersa Matrouh, Egypt
Tel: 20 3 931083
Fax: 20 3 931082

Houssein Mohamed Mosaed
Matrouh Res. Mgt. Project
International Project Center
Box 62
Mersa Matrouh, Egypt
Tel: 20 3 931083
Fax: 20 3 931082

Mossa Rachid Moustafa
Matrouh Res. Mgt. Project
International Project Center
Box 62
Mersa Matrouh, Egypt
Tel: 20 3 931083
Fax: 20 3 931082

Hamdy Soliman Oushy
Field Crop Research Institute
Forage Crop Res. Dept.
ARC
PO Box 12619
Giza, Egypt
Fax: 20 2 573 84 25

Ali M. Gaber Saad
Matrouh Res. Mgt. Project
International Project Center
Box 62
Mersa Matrouh, Egypt
Tel: 20 3 931083
Fax: 20 3 931082

Nouredine Gaddes
FAO
Reg. Off. for the Near East
11 El Eslah El Zirai Street
PO Box 2223
Cairo, Egypt
Tel: 337229/337789
Fax: 20 2 3495981
Telex: 21055 FAONE UN

France

Hubert Guerin
CIRAD Montpellier, EMVT
BPS035
Campus Int'l de Baillarguet
Baillarguet
S035
Montpellier 34032, France
Tel: 33 4 675 93 707
Fax: 33 4 67 59 37 97

Henri-Noël Le Houerou
CNRS
327, rue Jussieu
Montpellier, France
Tel: 33 04 67 54 76 09
Fax: 33 04 67 52 75 39

Philippe Masson
Institut National Polytechnique,
Ecole National Supérieure
Agronomique de Toulouse
145, Avenue du Muret
Toulouse 31 076 Cedex
France
Tel: 33 62 13 15 00
Fax: 33 5 61 42 30 29

Martine Rochon
Mas Des Pentes
PO Box 66
Saint Nazaire du Roussillon
France
Tel: 33 4 68732303

Jean-Jacques Rochon
IUT
Dépt. Biologie Appliquée and
Agronomie
Chemin de la Passio Vella
PO Box 66025
Perpignan Cedex, France
Tel: 33 68 66 24 22/24 29
Fax: 33 4 68 66 24 21
Telex: 909009-FUNIPERP

Greece

Apostolos Ainalis
Forest Serv. Lagadas
Range and Wildlife Science
PO Box 54006
Thessaloniki, Greece
Tel: 30 31 998943/39424024
Fax: 30 31 998886/30394/22153

Thomas Papachristou
National Agric. Res. Foundation
Forest Res. Institute
Range Management Lab
PO Box 57006
Vassilika, Thessaloniki
Greece
Tel: 30 31 461171
Fax: 30 31 461341

Vasilios Papanastasis
University of Thessaloniki
Fac. of Forestry and Natural
Environment
Range and Wildlife Science
PO Box 236
Thessaloniki, Greece
Tel: 30 31 998 933/992721
Fax: 30 31 206 138/998 886
Telex: 0412181 AUTHGR
Email: vpapan@olymp.ccf.auth.gr

Iran

Avaz Koocheki
Ferdowsi Univ. of Mashad
College of Agriculture
PO Box 91775/1163
Mashhad, Iran
Tel: 71802123/810 863 5
Fax: 98 51 815 845
Telex: FUOM 512271 IR

Mohamad H. Rashed
Ferdowsi Univ. of Mashad
College of Agriculture
PO Box 91775 1163
Mashhad, Iran
Tel: 718021 23/810 863 5
Fax: 00 98 51 815 845
Telex: FUOM 512271 IR

Iraq

Khalid Abdelatif Mohamad
Ministry of Agriculture
Baghdad, Iraq
Tel: 961 7185264
Telex: 21 22 22
Fax: 961 7184125

Japan

Hiroaki Wakabayashi
Kanazawa Inst. Technology
7-1 Ohgigaoka Nonoichi
PO Box 921
Ishikawa, Japan
Tel: 810762 94 6712
Fax: 810 762 94 6713

Jordan

Abdel Halim Brayzat
Madaba Mleik
Amman, Jordan
Tel: 8541275

Mohamed Jamil
Queen Alia Fund for Soc. Devel.
PO Box 5118
Amman, Jordan
Tel: 962 6 825241
Fax: 962 6 827350

Abdallah Jaradat
c/o Karim Neshiewat

Karim Neshiewat
Ministry of Agriculture
Head, Monitoring and Evaluation for
Agric. and Rural Dev. Proj.
PO Box 926630
Amman, Jordan
Tel: 686151
Fax: 962 6 690683
Telex: 23278 ICARDA/JO

Kamal Tadros
NCARTT
PO Box 639
Baqa', Jordan
Fax: 962 6 725 411

Kazakhstan

Seifulla Abduraimov
Karakul Sheep Breeding Institute
Lenin Square, 3
PO Box 486011
Chimkent, Kazakhstan
Tel: 8 325 22 3 13 02
Fax: 90 312 287 8955

Lebanon

Shady K. Hammadeh
Faculty of Agricultural and Food
Sciences
American University of Beirut
c/o ICARDA Office
Beirut, Lebanon
Tel: 865250/1 4457
Fax: 212 478 1995 (ext USA)

Libya

Suliman Belkhair
AR Centre
PO Box 2480
Tripoli, Libya
Tel: 60 55 40
Fax: 218 21 60 55 41
Telex: 20320 Agres LY

Adnan Speita
Agricultural Res. Centre
PO Box 2480
Tripoli, Libya
Tel: 60 55 40
Fax: 218 21 60 55 41
Telex: 20320 AGRES LY

Morocco

Abd-Errazzak Ben Chaabane
Faculté des Sciences SEMLALIA
Lab. Ecologie vegetale
BP S 15
PO Box 40000
Marrakech, Morocco
Tel: 212 430 36 77
Fax: 212 4 43 6769

Mustapha Boujrad
Province Figuig
BP 415/Sce Aménagement-Direction
de l'Elevage
PO Box 61300
Tendrara, Morocco
Tel: 212 6 66 20 44/662039
Telex: 36932
Fax: 212 6 66 21 52

Bouchaib Boulanouar
INRA, Aridoculture Center
BP 589
Settat, Morocco
Tel: 212 3 40 32 10/40 32 18
Fax: 212 340 3209
E-Mail: CRRA-ST@MTDS.COM

Mohamed Acherkouk
INRA, CR Oriental
PO Box 428
Oujda, Morocco
Tel: 8126744660
Fax: 212 67 44 661

Abdelouahid Chriyaa
INRA, Aridoculture Center
PO Box 589
Settat, Morocco
Tel: 212 3403210/18
Fax: 212-340 3209

Tayeb Daoudi
c/o Mr A. Gharbaoui
Ministère de l'Agriculture
BP 415/Sce Aménagement Direction
de l'Elevage
Rabat, Morocco
Tel: 19 212 7 76 30 29
Fax: 212 7 76 44 04
Telex: 36932

Abderahim Arif
INRA, Aridoculture Center
PO Box 589
Settat, Morocco
Tel: 212 3 40 32 10/18
Fax: 212-340 3209
E-mail: CRRA-ST@MTDS.COM

Abdelouahed El-Gharbaoui
Ministère de l'Agriculture et de la
Mise en Valeur Agricole
BP 415/Sce Aménagement Direction
de l'Elevage
Rabat, Morocco
Tel: 19 212 7 76 30 29
Fax: 212 7 76 44 04
Telex: 36932

El-Houcine El-Mzouri
INRA, Aridoculture Center
PO Box 589
Settat, Morocco
Tel: 212 340 3209

Mohamed Ismaili
Université Moulay Ismail
Faculté des Sciences
BP 4010 Beni Mahmed
Meknes, Morocco
Fax: 212 5 53 68 09

Laïd Karroumi
Association Nationale Ovine et
Caprine
Ave. Moulay Youssef, No. 5
Guercif, Morocco
Tel: 212 7 670281/5 67 63 27
Fax: 212 5 67 63 27

Abdelali Laamari
INRA, Aridoculture Center
PO Box 589
Settat, Morocco
Tel: 212 340 32 10/18
Fax: 212-340 3209
E-mail: CRRA-ST@MTDS.COM

El Bachir Labiad
c/o Mr A. Gharbaoui
Ministère de l'Agriculture
BP 415/Sce Aménagement Direction
de l'Elevage
Tendrara Maataika, Morocco
Tel: 212 6662112
Fax: 212 7 76 44 04
Telex: 36932

Mohamed Tazi
Centre de Production de Semences
Pastorales
PO Box 79
El Jadida, Morocco
Tel: 212 3 34 4350
Fax: 212 3 344 350
Telex: 78032

Pakistan

Sarwat Mirza
Arid Zone Research Inst.
PO Box 63
Quetta, Pakistan
Tel: 92-81-841006
Fax: 92-81-84 10 06
Telex: 841006

Karim Nawaz
AZRI Forest Department
PO Box 574
Quetta, Pakistan
Tel: 444579
Fax: 92-81-84 10 06
Telex: 23072 PCOQT.PK

Senegal

Macoumba Diouf
CERRAAS/CNBA
Bambey
BP 59
Bambey, Senegal
Tel: 221 736197/323480
Fax: 221-7361970
E-mail: diouffm@dakar.orstom.sn

Mamadou Ka
(see Diouf above)

South Africa

Gerhard C. de Kock
Dept. of Agronomy
Groot Fontein, Inst. of
Agricultural Development
Private Box 529
Middelburg EC 5900 South Africa
Cape Province, South Africa
Tel: 27 4924 21212
Fax: 27 4924 22392

Anéria Heydenrych
Dept. of Agriculture
Elsenburg Agricultural Dev. Inst.
Provincial Administration
PO Box 7607
Western Cape
Private Bag X1
Elsenburg, South Africa
Tel: 27 21 808 53 20
Fax: 27 21 808 51 20

R. Von Holdt
Gablesway
Box/Posbus 202
Somerset East/OOS
South Africa
Fax: 27 424 31821

Spain

Enrique Correal
Centro de Investigacion y Desarrollo
Agroalimentario
Finca "Sericicola"
PO Box 30150
La Alberca, Murcia, Spain
Tel: 34 68 84 01 50/02 50
Fax: 34 68 84 48 02

Ignacio Delgado Enguita
Diput. Gen. de Aragón, Serv.
Investigacion Agraria-SIA
Unidad Produccion Animal. SIA
50016 c/Monatnana No. 176
PO Box 50080
Zaragoza, Spain
Tel: 34 76 576311/36
Fax: 34 76 575501/68 84 48 02

Dunixi Gabina
CIHEAM
Instituto Agronomico de Zaragoza
50016 c/Monatnana No. 177
PO Box 202
Zaragoza 50080, Spain
Tel: 976 57 60 13
Fax: 34 976 57 63 77
Telex: 58672

Fernando Muñoz-Perez
Diput. Gen. de Aragón, Serv.
Investigacion Agraria-SIA
50016 c/Monatnana No. 177
PO Box 202
Zaragoza 50080, Spain
Tel: 34 76 576311/36
Fax: 34 76 575501
E-mail: fernandom@mizar.csic.es

Syria

Amin Al-Jundi
Steppe Dir. FAO Palmyra
PO Box 10709
Damascus, Syria
Tel: 031-910855
Fax: 031-913025
Telex: 411580 FOODAM

George Arab
ICARDA
PO Box 5466
Aleppo, Syria
Tel: 331208/331263
Fax: 963 21 213490/225105

Fawaz Azmeh
Protection des Végétaux
BP 30621
Damascus, Syria
Fax: 963 11 511 6352

Addelhadi Hazaa El-Fkiki
(ICARDA/Syria through F. Bahhadi)
Fax: 963 21 225 105

Ahmed Ibn Jasem El-Mohamed
Steppe Directorate
Directorate of Agriculture
Aleppo, Syria
Fax: 963 21 225 105
(ICARDA/Syria, through F. Bahhadi)

Haitham Khaddour
Steppe Dir. FAO Palmyra
PO Box 10709
Telex: 411580FAODAM
Damascus, Syria
Tel: 031 910855
Fax: 031 913025

Nabih Murad
Steppe Directorate
Directorate of Agriculture
Aleppo, Syria
Fax: 963 21 225 105
(ICARDA/Syria, through F.
Bahhadi)

Faysal Al Ahmad Nuri
Steppe Directorate
Directorate of Agriculture
Aleppo, Syria
Fax: 963 21 225 105
(ICARDA/Syria, through F.
Bahhadi)

Abdallah Jarradat
IPGRI c/o ICARDA
PO Box 5466
Aleppo, Syria

Georges Arab
ICARDA
PO Box 5466
Aleppo, Syria
Tel: 963 21 213 477
Fax: 963 21 213490/225105
Telex: 331208/331263

Faik Bahhadi
ICARDA
PO Box 5466
Aleppo, Syria
Tel: 963 21 213 477
Fax: 963 21 213490/225105
Telex: 331208/331263

Mustafa Bounejmate
ICARDA
PO Box 5466
Aleppo, Syria
Tel: 963 21 213 477
Fax: 963 21 213490/225105
Telex: 331208/331263

Gustave Gintzburger
ICARDA
PO Box 5466
Aleppo, Syria
Tel: 963 21 213 477
Fax: 963 21 213490/225105
Telex: 331208/331263
gustave.gintzburger@cirad.fr

Anthony Goodchild
ICARDA
PO Box 5466
Aleppo, Syria
Tel: 963 21 213 477
Fax: 963 21 213490/225105
Telex: 331206/331208

Tidiane N'gaido
ICARDA
PO Box 5466
Aleppo, Syria
Tel: 963 21 213 477
Fax: 963 21 213490/225105
Telex: 331208/331263

Tom Nordblom
ICARDA
PO Box 5466
Aleppo, Syria
Tel: 963 21 213 477
Fax: 963 21 213490/225105
Telex: 331208/331263

Ahmed Osman
ICARDA
PO Box 5466
Aleppo, Syria
Tel: 963 21 213 477
Fax: 963 21 213490/225105
Telex: 331208/331263

Euan Thomson
ICARDA
PO Box 5466
Aleppo, Syria
Tel: 963 21 213 477
Fax: 963 21 213490/225105
Telex: 331208/331263

Tunisia

Youssef Ammari
Institut National de Recherche en
Genie Rural, Eau et Forets
BP 10.2080
Ariana, Tunisia
Fax: 216 1753098/717 951

Mohamed Ben Diaf
NGO/UTAP
34 Route du Kef-Cité de la Police
Den-Den 2011
Tunis, Tunisia
Fax: 216 1 751 666

Mouldi Ben Said
Direction Generale des Forets
30, rue Alain Savary
PO Box 1002
Tunis-Belvedere, Tunisia
Tel: 216 1 790 431
Fax: 216 1 793 603

Hichem Ben Salem
INRAT
rue Hédi Karray
PO Box 2049
Ariana, Tunisia
Tel: 216 1 230239
Fax: 216 1 752 897

Wassila Bencheikh
ICARDA Tunis Office
8 Rue Ibn Khaldoun
PO Box 2049
1004 Tunis, Tunisia
Tel: 216 1 232207
Fax: 216 1 751 666

Salah Chouki
Office de l'Elevage et des Paturages
30, rue Alain Savary
PO Box 1002
Tunis-Belvedere, Tunisia
Tel: 216 1 790 431
Fax: 216 1 793 603/772159

A. Hajlaoui
GTZ-CRDA/DASPI Project
CRDA BP 175
PO Box 9100
Sidi-Bouزيد, Tunisia
Fax: 216 6 633 236

Hanen Jellouli
INRAT/ICARDA Tunis Office
Tunis, Tunisia
Fax: 216 1 751 666

Mondher Lahmar
INRAT
Tunis, Tunisia
Fax: 216 1 751 666

Mohamed Neffati
Institut des Régions Arides
BP 610
Route de Djoff Km 22-El Fjé
Medenine, Tunisia
Tel: 05 640 661
Fax: 216 5 640 435

Ali Nefzaoui
INRAT
rue Hédi Karray
PO Box 2049
Ariana, Tunisia
Tel: 216 1 230107
Fax: 216 1 711 741

Abdelhamid Zammouri
ONG/Association des Jeunes de
Zammour
Beni Khedache
AJZ BP 353
Medenine, Tunisia
Fax: 216 5 640935

Fatine El-Euch
Direction Generale des Forets
30, rue Alain Savary
PO Box 1002
Tunis-Belvedere, Tunisia
Tel: 216 1 790 431
Fax: 216 1 793 603

Youssef Hajji
Office de l'Elevage et des Pâturages
30, rue Alain Savary
PO Box 1002
Tunis-Belvedere, Tunisia
Tel: 216 1 790 431
Fax: 216 1 793 603

Lamia Ben Salem
Office de l'Elevage et des Pâturages
30, rue Alain Savary
PO Box 1002
Tunis-Belvedere, Tunisia
Tel: 216 1 790 431
Fax: 216 1 793 603

Hachmi Ben Rhouma
Office de l'Elevage et des Pâturages
30, rue Alain Savary
PO Box 1002
Tunis-Belvedere, Tunisia
Tel: 216 1 790 431
Fax: 216 1 793 603

Mohsen Chebbi
Office de l'Elevage et des Pâturages
30, rue Alain Savary
PO Box 1002
Tunis-Belvedere, Tunisia
Tel: 216 1 790 431
Fax: 216 1 793 603

Mohamed Cherni
Office de l'Elevage et des Pâturages
30, rue Alain Savary
PO Box 1002
Tunis-Belvedere, Tunisia
Tel: 216 1 790 431
Fax: 216 1 793 603

Lazhar Jemmali
Office de l'Elevage et des Pâturages
30, rue Alain Savary
PO Box 1002
Tunis-Belvedere, Tunisia
Tel: 216 1 790 431
Fax: 216 1 793 603

Riadh Kerrit
Office de l'Elevage et des Pâturages
30, rue Alain Savary
PO Box 1002
Tunis-Belvedere, Tunisia
Tel: 216 1 790 431
Fax: 216 1 793 603

Mohamed Souissi
Office de l'Elevage et des Pâturages
30, rue Alain Savary
PO Box 1002
Tunis-Belvedere, Tunisia
Tel: 216 1 790 431
Fax: 216 1 793 603

Ludwig Mayer
GTZ-CRDA/DASPI Project
BP 175
PO Box 9100
Sidi-Bouزيد, Tunisia
Fax: 216 6 633 236

Mondher Lahmar
INRAT
Laboratoire de Production Animale
rue Hédi Karray
PO Box 2049
Ariana, Tunisia
Tel: 216 1 230 239
Fax: 216 1 711 741

Turkey

Lutfu Tahtacioglu
c/o ICARDA/East Anatolia Agric.
Res. Inst.
Gezkoy, Erzurum, Turkey
Tel: 90 4 287 35 95
Fax: 90 442 327 2274
Telex: 42994

Uzbekistan

Uktam Kho Zhimuratovich Aripov
Karakul Sheep Institute
M. Ulugbek Kuchasi 47 ui
PO Box 700000
Samarkand, Uzbekistan
Tel: 33 32 79
Fax: 90 312 287 8955
Telex: 35 78 05

Mukhtar Nasirov
Karakul Sheep Institute
M. Ulugbek Kuchasi 47 UI
PO Box 700000
Samarkand, Uzbekistan
Tel: 33 32 79
Fax: 90 312 287 8955
Telex: 35 78 05

REGIONAL TRAINING WORKSHOP ON NATIVE AND EXOTIC FOREST SHRUBS
IN ARID AND SEMI-ARID ZONES
TUNISIA MINISTRY OF AGRICULTURE
AND ICARDA-CIHEAM-FAD RNE-SOC-IPGRI-CROI

