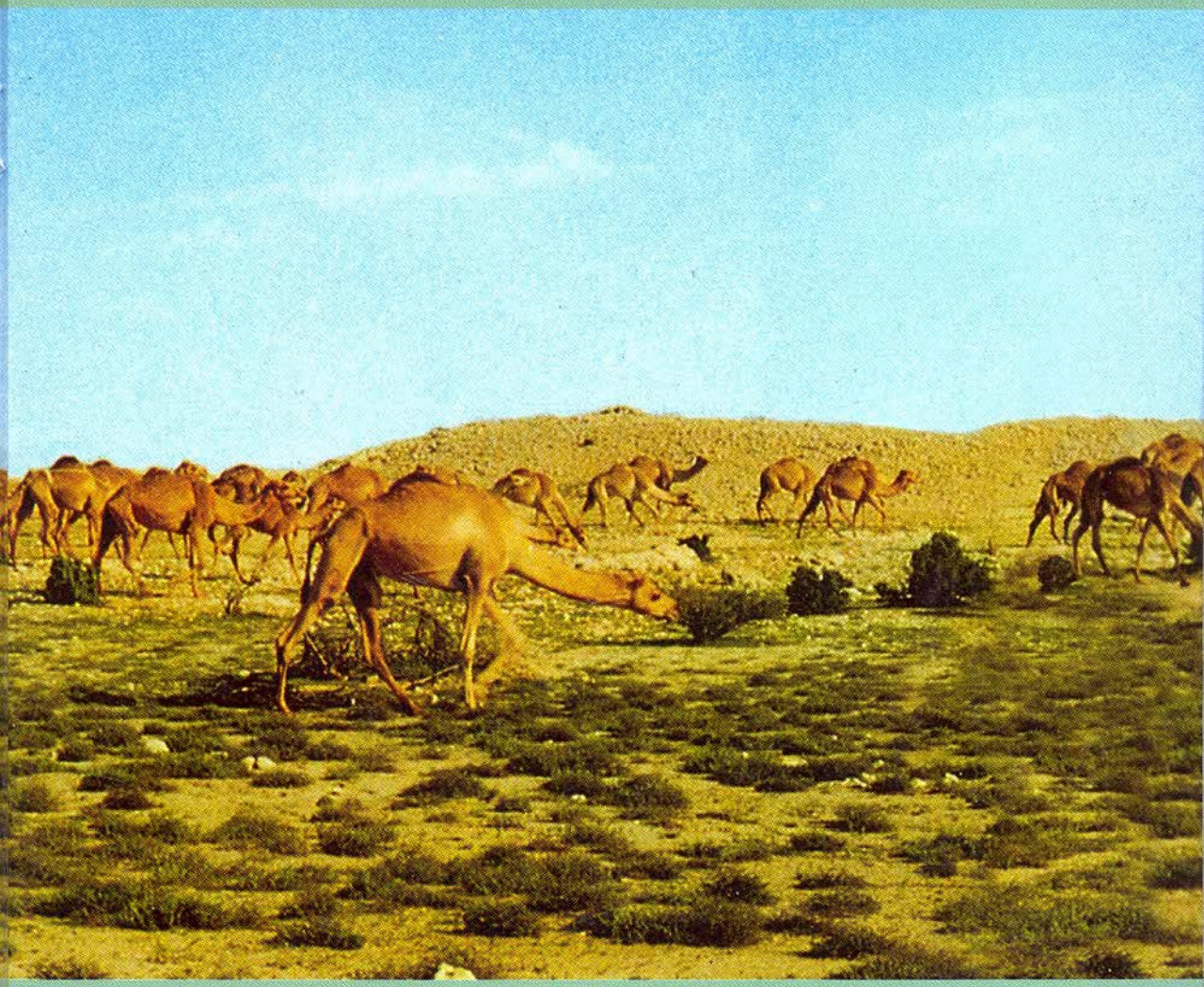
CHEMICAL CONSTITUENTS AND NUTRITIVE VALUES OF RANGE PLANTS IN QATAR



H.S. Al-Easa, A.M. Rizk and E.M. Abdel-Bari
Scientific and Applied Research Centre
University of Qatar

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PREFACE

When the book "Phytochemistry of the Flora of Qatar" was first published in 1986, many young researchers in the field of Phytochemistry in the Arab World were grateful for a long waited text with a comprehensive bibliography relevant to their local plants. The book incorporated a wealth of literature surveyed up to 1985 covering the topic in general and specifically the flowering plants of the region.

In 1989, a second book "Phytochemistry of the Horticultural Plants of Qatar" was published. The book upgraded the bibliography and gave information on the known active ingredients, medicinal and economical uses of horticultural plants grown in Qatar. In the book a total of 2300 references were included.

A third book entitled "Medicinal and Poisonous Plants of Qatar" was published in 1995. The book was directed towards the study of medicinal plants. These had been the center of attraction with many developing countries in search of important compounds in its wild plants that would hopefully change their future. The book with its wealth of literature survey was a welcomed source of relevant knowledge.

The fourth book in these series was published in 2000, titled "Phytochemistry of the Macro and Blue-green Algae of the Arabian Gulf" focused on a completely new world of organisms, the algae. Once belonging to the Plant Kingdom, the algae are new placed in the Kingdom Protista. The algae are different from previous taxa studied in being (a) filamentous-thalloidal and (b) living in an aquatic habitat. The latter meant that these organisms might incorporate in their tissues elements initially absorbed from their aquatic media. With Qatar having no fresh water sources or bodies above ground except for seasonal rains, their macro algae are all marine. As such, they stand as excellent monitors of environmental change in the Arabian Gulf with its ever increasing expansion in petro-chemical industries.

Advances in the knowledge in the field of chemistry and the interest of various scientists studying different organisms of the living world have promoted much research in recent years in both plant and animal taxa. This rapid increase in Phytochemical knowledge has necessitated the updating of the bibliography to include the latest published material. The approach chosen was a multidisciplinary study of an important group of plants: the range plants.

Range plants of the State of Qatar might seem trivial to an outsider but to animal herders grazing wild range plants is a must for the health and well being of their animals.

The boom in the Oil Industry in the Gulf States in general means fear of an adverse effect on natural habitats. Destruction of natural habitats might result to the permanent loss of important range plants. In this book the focus on range plants is an effort to illustrate their value and importance as a nutritive source of feed. This might help policy makers to preserve and conserve as much as possible of the natural ecosystems that support growth of range plants.

The range plants chosen for this study are either well known locally as range species or are potentially range species because of their taxonomic position e.g. grasses and legumes.

One of the main aims underlying the writing of this book was the desire to emphasize the importance of interdisciplinary studies. The purpose of such studies is to bring together a collection of information pertaining to a selected group of organisms.

Such an approach would promote interest of researchers to collaborate and to draw attention to specific taxa within their own sphere. A study on range plants would draw attention to

their value. It is also desired that plant breeders would take keen interest in promoting the status of potential range species to species of economical importance in range. Perhaps the efforts would culminate in the production of variants suitable and tolerant of the local conditions.

The multidisciplinary approach presented in this book is also expected to stimulate enquiry and to broaden the scope of young researchers who no doubt will benefit from the updated bibliography. The book will also enrich knowledge with its in-depth information on chemical structures of the compounds mentioned in the text.

The investigation necessitated that the general chemistry of the genera of the studied species is first presented prior to the information gained on the local species. In total the book comprises detailed information on 1666 species.

The material presented in this book has been organized into the 3 covered aspects: the chemistry, the nutritive value and the taxonomy of the range plants of Qatar. The sequence followed is an alphabetical order of the families including the gymnosperms, the dicotyledons and the monocotyledons. Each aspect of the study is designed to be as comprehensive as possible with accuracy of details and updated information. For this a thorough search in all relevant journals and books has been undertaken to throw light on the chemistry and nutritive values of range plants. All factual material has been carefully selected. In all the bibliography in this book includes 4386 published literature.

The chemical survey informs on the proximate, amino acids, carbohydrates, fatty acids, minerals and other constituents. The chemical structures of some selected compounds are included. Of the 1619 chemical compounds covered in the book, the chemical structures of 1373 compounds have been drawn and included with the text.

The surveys of the nutritive values cover the proteins, carbohydrates, fatty acids and other elements.

The book covers all the information concerning the chemical and nutritive constituents of these plants until 2003 with references exceeding 3400 titles.

The taxonomical study of the selected taxa, the symonomy has been limited to those known in earlier studies. Species were selected from a wide range of habitats. The morphological descriptions of the species are followed by information on their habitat and distribution. Where relevant, information on local use is included. Coloured plates are included to facilitate field recognition. Arabic and English vernacular names are included when known. In total 162 species belonging to 99 genera and belonging to 34 families are covered in this book. All material for analysis was collected from the wild.

One outstanding feature of this book is the detailed information summarized in the 178 tables included in the text. Of particular interest and value are tables 173-178 (inclusive) where for the first time all values of the studied taxa are given.

The book is appendixed by a number of lists to show what has been presented. This includes a glossary of technical terms to accommodate the extra information e.g. medical terms, included in the book. The glossary has a total of 158 terms.

ABOUT THE AUTHORS

Hala Sultan Saif Al-Easa, Chair person of the Chemistry Department since March 2001 is an Associate Professor of Organic Chemistry, College of Science, University of Qatar. She graduated from the University of Qatar in 1982, and received her M.Sc. from the State University College of New York, Buffalo (U.S.A.) in 1985. She joined the Scientific and Applied Research Center, the University of Qatar in May 1985 as a research assistant, and upon receiving her Ph.D. in 1990 from Reading University, U.K., was appointed a lecturer. In 1993, she joined the Chemistry Department, College of Science and in 1997 she became an Associate Professor in Organic Chemistry. She received the Alexander von-Humboldt Stiftung, grant and spent January 1994 - March 1995 at Ludwig Maximillian Universität, Munich. She published more than 20 papers mainly on the chemistry of medicinal plants and algae, and two reviews. She is a co-author of a book published by the College of Science at the University of Qatar on the Phytochemistry of Algae.

Abdel-Fattah M. Rizk has worked as a Professor of Organic Chemistry in the Chemistry Department, College of Science, University of Qatar since 1980 and previously in the National Research Centre of Egypt. He graduated from Cairo University with B.Sc. (Hons.) in 1956. He obtained his M.Sc. (1959) and Ph.D. from Cairo University in the field of Organic Chemistry (Natural Products). He received post-doctoral fellowships from the British Council (one year at Bradford University, 1965-1966) and the Alexander von-Humboldt Stiftung, Germany (two years at Frie Universität, W. Berlin, 1966-1976, 1972-1973) and has worked as a visiting scientist at the U.S. Food and Drug Administration, Washington D.C. (one year, 1975-1976). He was appointed Professor of Organic Chemistry (Natural Products) in 1974 and has published about 140 papers mainly on the Chemistry of Medicinal plants. He supervised 38 M.Sc. and Ph.D. candidates in the same field. He is the author (and/or editor) of eight books published by SARC (University of Qatar) and CRC Press (U.S.A.). He is a member of the editorial board of Phytotherapy Research (U.K.). He received the State Prize in Chemistry, Egypt (1974) and was awarded the first class Decoration of Science and Arts.

Ekhlas M. M. Abdel Bari is a Professor of Plant Systematics in the Department of Biological Sciences, the University of Qatar since 1994 and previously in the Department of Botany, the University of Khartoum, Sudan. She graduated with an B.Sc. (Hons.) in 1963 from the University of Khartoum. She obtained her M.Sc. in 1965 from the University of Khartoum and her Ph.D. in Nov. 1969 from the University of Cambridge, U.K. She has supervised a number of M.Sc. and Ph.D. degrees and her published 5 books and more than 30 papers and scientifc reports which focus on floristic studies and environmental issues. She teaches Plant Systematics, Plant Diversity, Biodiversity, Conservation and Management and is in charge of the Herbarium of the College of Sciences. She is involved in a number of projects of environmental nature sponsored by SARC (Scientific and Applied Research Centre, University of Qatar).

A Note On The Natural Rangelands Of The State Of Qatar

The State of Qatar is a small semi-arid country with a total area (including its islands) of 11,437 sq km and a coastline of 563 km and over 80% of its land is classified as stony.

It is difficult to envisage the importance of the Country's limited natural habitats, as grasslands or rangeland supporting a great animal wealth in particular of camels, sheep and goat herds.

Camels are kept for sport (camel racing, a much favoured sport in all Arabian Gulf countries), for milk production (for owners' use only) and for meat production (on a small scale where only young camels "hewars" are slaughtered). Cattle are usually kept in pens and rarely graze outside.

Animal numbers have been on the increase with more of the locals being able to afford this luxury as a result of the oil boom. The increase in animal wealth has left its toll on the natural vegetation. There are various reports by the eldery that some species important for herding have since disappeared (Plates, 1, 2, 3).

In a study on the vegetation of the State of Qatar, Abulfatih *et al.* (2000) established that the vegetation is linked to geomormophology and soils and the amount of seasonal precipitation. Soil is an important determinative element with salinity and texture being the two most important chemical and physical properties respectively.

A glaucous green greyish appearance is the dominant feature in Qatar's grasslands as is well demonstrated by: the grass communities of sabkhas (*Sporobolus ioclados* and *Aeluropus lagopoides*; Plate 4), on stabilized wind blown sands over rocky grounds (*Panicum turgidum*; Plates 5, 6), on sand dunes (*Lasiurus scindicus* and *Chrysopogom*, and on compact sands in depressions (*Cymbopogon proximus*, Plate 7).

There is a considerable difference in the productivity and general health of the wild plants between 'good' and 'bad' years of rains. The determinitive factor of years of 'good' range or otherwide, is dependent on the duration and amount of precipitation of the rainy season and specificly the vegetated depressions known as rodats. Rodats are distributed all over the Country but the majority (including the best) are located in the north-eastern and central zones of the State of Qatar. Many of the deep rodats have since been transformed into agricultural fields. These in turn are becoming extensive and too demanding on the very limited natural resource: the underground water. Some of the rodats, in particular the less productive, were distributed (on temporary basis), to animal herders, as animal pens [isbaa(s)] and natural grazing ground.

The basic composition of the plant communities in the Country is of a few trees, few shrubby species which produce new growth with the onset of the rainy season and predominantey of ephemerals, annuals and few biennials. These are totally dependent on the amount of annual precipitation for their numbers and density. Although there is no sharp line of demarcation between 'excellent' and 'poor' rodats, their species composition reflects on the standard of the individual rodats as rangeland.

Plant communities are important as natural grazing lands. The main species of importance inlude: *Acacia ehrenbergiana, A. tortilis, Ziziphus numularia, Leptadenia pyrotechnica, Cocculus pendulus* (a liane), *Ephedra ciliata* (a gymnosperm), *Lycium shawii* (the most

common shrub) *Capparis decidua* and a wealth of ground vegetation of grasses, sedges and herbs which flourish during the season of growth (Plates 8,9).

Many plant communities with dense growth of halophytes exist in Qatar, in particular along the north-eastern coastline (Plate 10). These do not form grazing grounds.

Depending on the depth of the rodat and its location, its floristic composition varies. Shallow rodats and depressions (Plate 11, 12) with poorer soils will support only *A. tortilis* and *Lycium shawii* and annual growth. In contrast, rodats and wadis that are deeper depressions and with sandy loamy soils, will retain rain water longer and will support *Ziziphus* and an array of the above mentioned woody taxa.

Herds in Qatar are all dependent on supplement feed. Bales of *Chloris*, grown in neighbouring Saudi Arabia, are imported to Qatar in the form of hay. Dates, imported and locally grown, are a basic feed for camels. Leucerne, (available throughout the year), *Pennisetum, Zea* and *Sorghum* are locally grown fodder available in season, as well as, some legumes (Plate 13). However, oats (locally grown and imported) is the main grain feed for all herds and chicken.

Equally important are by products of agriculture in the form of: weeds in neglected or abondoned fields for one reason or another, twigs from regular pruning of hedges and avenue trees and mawned grass. In certain areas where sewage water is disposed, green growth particularly of *Phargmitis* is encouraged. Herds of camels were seen to graze such vegetation.

Grazing on natural vegetation is vital for the overall health of the herds and their productivity. Wild plants are the source of a number of elements necessary for the well-being of the herds. If the rainy season fails or is extremely short, the animals are kept on the supplement feed inspite of the fact that all herders stress that natural vegetation is vital for their animals.

There is no denial that the natural vegetation in Qatar is stressed by over-grazing. There is no statistics on the effect of grazing pressure on the natural plant cover in Qatar. Continuous grazing, particularly of new growth, often results in the reduction of stature and canopy of the woody species. Sunted *Acacia tortilts* and *Lycium* are a common sight all over Qatar. Bare ground throughout the year is indicative that not much is over-looked by the continually searching herds for a blade of grass. The long periods of drought and poor rains have also led to the expansion of xerophytic taxa such as *Zygophyllum qatarense*, the most dominant succulent xerophyte in Qatar, which is not preferentialy grazed.

In recent years focus has been on the importance of natural range to both wild animals (kept in captivity) and domestic animals. Some of these wild animals are being released on natural habitats to restore them to nature. Many 'isbaas' have since been demolished to reduce animal numbers and the rising pressure on natural vegetation. Natural forests of *Avicennia marina* are now semi-conserved and an active programme of preservation of the coastline is being persued by the local government.

Unfortunately Qatar remains a small country with limited natural rangeland and if these are not well controlled, they will be lost forever.

Initially, agricultural advancement in Qatar's by open irrigation using underground water was the only factor causing loss of natural rangeland, but promoting the availability of localy grown fodder. Three main factors crop from agricultural pratices affecting natural range:

1- loss of land to fields means a continous shrinakage of natural rangeland.
2- use of underground water, lowers the water table and could cause death of deep-rooted tree species.

3- while many of these farms grow leucerne and fodder grasses, which are the main source of 'green' feed to domestic and wild animals in captivity, agriculture introduces weed species and weeds are always competitive. Weeds also harbour many pests.

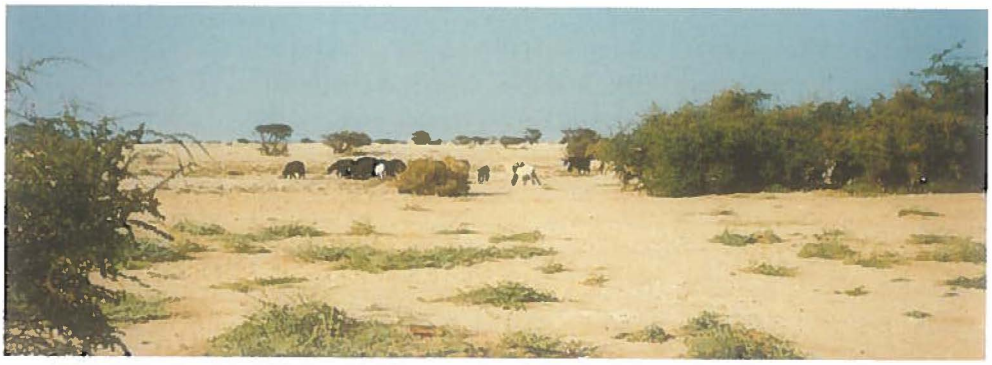
Unaccounted for but detrimental to the natural vegetation are the effects of the advancement in petrochemical industries. The exact extent of the influence of the oil industry on the natural vegetation in the State of Qatar has so far not been assessed. There is evidence of stunted deformed growth of certain species and the disappearance of sensitive taxa in the vicinity of petrochemical sites. The effect of the release of noxious gasses on animal health has not been studied but most herds are kept far away from the source of air pollutants.

The impact of industrial development and agricultural advancement on natural vegetation has been the theme of many studies, seminars, discussions, etc. in all countries with conditions similar to the State of Qatar. Worry and fear is when the negative impacts of both preceed any positive gains.

The increase in Doha's population and the large amount of water from sewage and domestic use has resulted in the release and disposal of these waters in sites in the outskirts of Doha, Dukhan and other major towns. These waters encourage plant growth and green growth draws the attention of grazing animals. What danger this poses to animal health remains to be seen. According to a recent study Abulfatih *et al.* (2002), danger lurks.

It is high time that more effort is concentrated on the treatment of effluents. The advantages will be many in particular if clean water is released to restore healthy growth of some of the larger rodats such as Al-Majda and Rodat Rashid. This should never be attempted without long term field experimentation.

The present work is the outcome of a long term of study which focuses on the nutritional value of natural range species in the flora of the State of Qatar. It also provides extensive details on their chemical constituents. The information provided should warrant more attention to the management of range in the State of Qatar.



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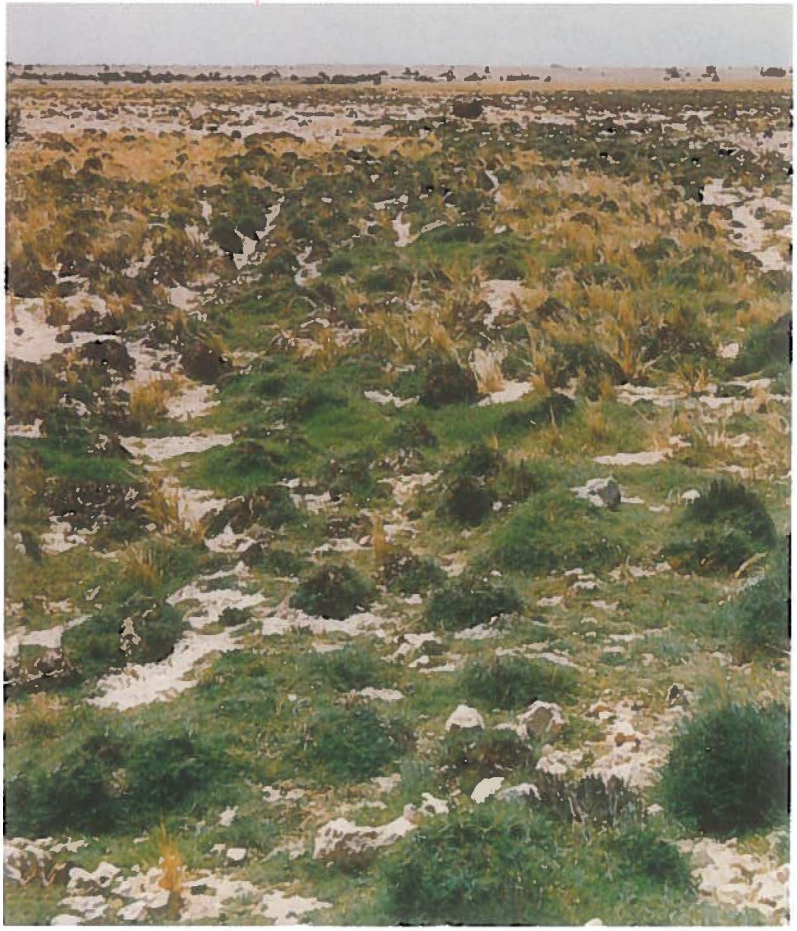
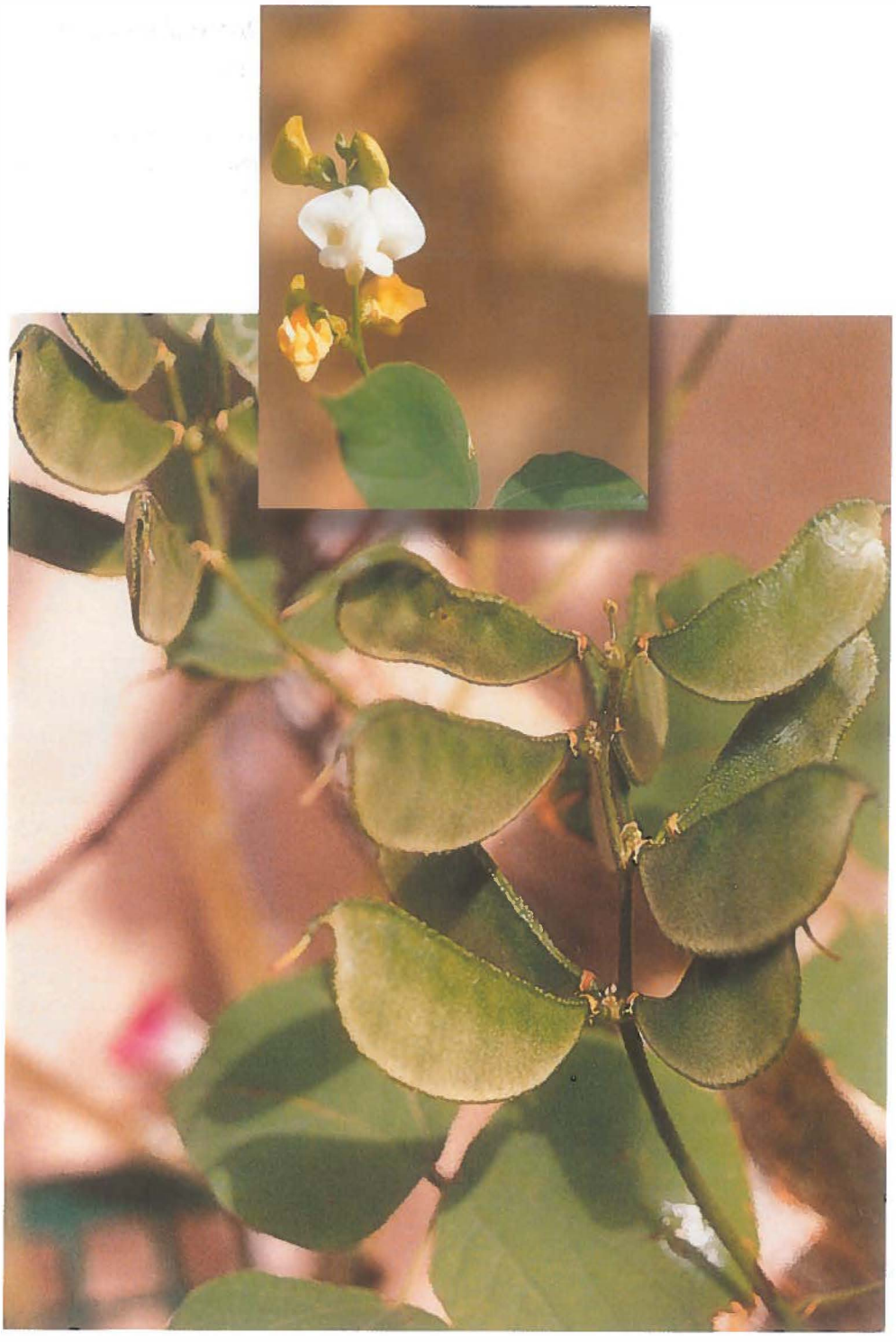
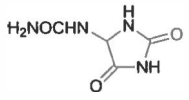




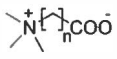
I. ACANTHACEAE Durande

1. BLEPHARIS A. Juss.

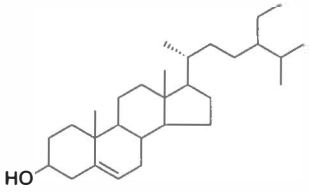
The constituents of few *Blepharis* species have been studied. 9-Hydroxydodecanoic acid has been isolated from the seed oil of *B. sindica* (Ahmad *et al.*, 1983). The seeds of *B. sindica* contained allantoin **(1)**, betaine **(2)**, β-sitosterol **(3)**, oleanolic acid **(4)**, apigenin **(5)**, terniflorin **(6)**, purine-6"-*O*-coumarate **(7)** and blepharin **(8)** (Ahmad *et al.*, 1984). Allantoin was also identified in *B. sindica* stalks (Khatri *et al.*, 1989).



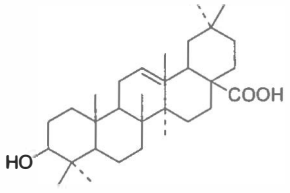
1 Allantoin



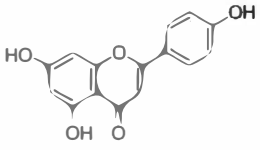
2 Betaine



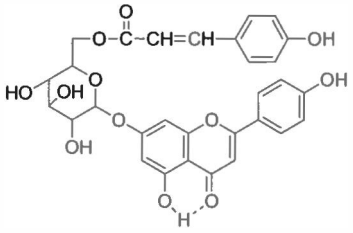
3 β-Sitosterol



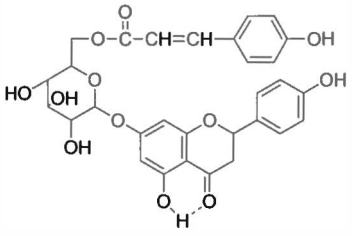
4 Oleanolic acid



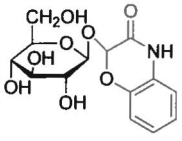
5 Apigenin



6 Terniflorin



7 Purine-6"-*O*-coumarate



8 Blepharin

1.1. ***Blepharis ciliaris*** (L.) B. L. Burtt., Notes Roy. Bot. Gard. Edinb., 22:94 (1956).
syn. *Blepharis persica* (Burm. f.) Kuntze (1891); *B. edulis* (Forsskal) Pers., Syn. 2:180 (1806).

Shouk El Dhab (Ar.)

Low compact semi-perennial spiny herb producing new foliage with the onset of the rains. Leaves sessile with spiny margins, long and narrow canaliculate. Inflorescences spicate of

blue zygomorphic flowers with spiny bracts. Fruit a bi-locular capsule enclosed by the spiny bracts. Seeds sometimes germinate on the mother plant inside the persistent bracts.

Habitat and Distribution

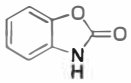
Common on compact soils in depressions and shallow rain pools in central Qatar.
Reported as grazed by camels and not by sheep or goats.

Constituents

The minerals of *B. ciltaris*, growing in Qatar, are shown in Table 178 (Al-Easa, 2002d).

The seeds of *B. ciliaris*, growing in Pakistan, contained 20 % oil. Fractionation of the oil showed that it consisted of wax esters (3.21 %), triglycerides (56.42 %), free fatty acids (10.36 %), 1:3 diglycerides (3.8 %), 1:2 diglycerides (5.06 %), 2-monoglycerides (2.98 %), 1-monoglycerides (5.42 %) and polar lipids (9.77 %). The fatty acids of the lipids ranged from C_{10} to C_{22}. The total lipids as well as its fractions, including wax esters, triglycerides, free fatty acids, 1:3 diglycerides and 2-monoglycerides showed a high percentage of unsaturated fatty acids except that of 1-monoglycerides and polar lipids, which showed a high percentage of saturated fatty acids (Tables 1 and 2) (Waheed *et al.*, 1992).

Benzoxazolone (**9**, m.p.140°C) and blepharin (m.p.226-227°C, a benzoxazine glucoside) have been isolated from the seeds (Chatterjee *et al.*, 1990).



9 Benzoxazolone

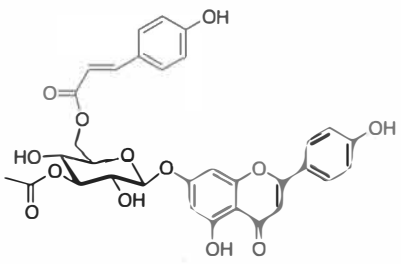
Table 1. Fatty acids percentage of various lipid classes and oil of *Blepharis persica* seeds

Lipids	$C_{10:0}$	$C_{12:0}$	$C_{14:0}$	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	$C_{20:0}$	$C_{22:0}$
Whole oil	0.04	0.26	0.09	8.88	3.47	35.07	34.91	10.39	0.67	6.22
Wax esters	1.35	3.75	1.02	15.69	4.54	36.91	18.19	12.47	0.32	5.76
Triglycerides	0.37	1.26	0.79	8.46	2.56	50.16	26.81	6.42	0.21	2.96
Free Fatty Acids	0.67	7.83	3.08	13.48	5.06	19.14	30.69	10.93	0.19	8.93
1:3-Diglycerides	3.15	8.29	5.15	15.49	2.18	14.18	20.16	16.54	0.25	14.61
1:2-Diglycerides	0.85	6.88	5.44	15.81	1.23	14.76	21.44	17.13	0.16	16.30
2-Monoglycerides	1.06	8.33	4.84	11.23	4.46	61.85	4.43	2.54	0.28	0.98
1-Monoglycerides	0.89	12.87	11.72	20.13	5.00	25.10	10.84	7.96	0.26	5.23
Polar lipids	1.01	13.19	11.35	23.95	3.09	22.39	12.99	7.55	-	4.48

Table 2. Percentage of saturated and unsaturated fatty acids of *Blepharis persica* seeds oil and its fractions

Lipid fractions	% of saturated fatty acids	% of unsaturated fatty acids
Whole oil	19.63	80.37
Wax esters	32.43	67.57
Triglycerides	16.61	83.39
Free Fatty Acids	39.24	60.76
1:3-diglycerides	49.12	50.88
1:2-diglycerides	46.67	53.33
2-monoglycerides	31.18	68.82
1-monoglycerides	56.10	43.90
Polar lipids	57.07	42.93

From the aerial parts of *B. ciliaris*, collected from the Qassim province, Saudi Arabia, two acylated flavonoids have been isolated, a flavone (**10**, apigenin-7-(3"-acetyl-6"-*E*-*p*-coumaroyl-glucoside)) and a flavanone (**11**, naringenin-7-(3"-acetyl-6"-*E*-*p*-coumaroylglucoside)) (Harraz *et al.*, 1996a).



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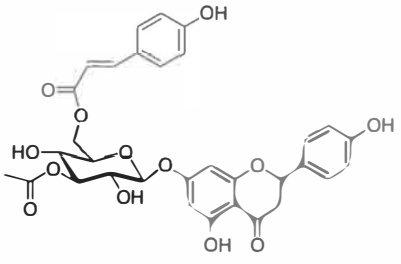


11

The plant extract and also the crushed roasted seed exhibited significant antibacterial activity (Harraz *et al.*, 1996b), and were reported to have several applications (Rizk and El-Ghazaly, 1995).

II. AIZOACEAE Martynov

1. AIZOON L.

The genus is represented by one species only in Qatar.

1.1 ***Aizoon canariense*** L. Sp. Pl., ed. 1, 488 (1755).
syn. *Glinus crystallinus* Forssk., Fl. Aegypt.-Arab. 95 (1775).

Chafna, Jafna, Gafnah (Ar.)

Prostrate suffrutescent annual herb, star-shaped with few radiating very leafy branches. Leaves on abaxial surface only, clustered, fleshy, subsessile, spathulate-obovate. Inflorescences of minute yellow flowers maturing to strong more or less woody fruits inset in the branches. Flowers and fruits Jan.-May and plant would continue to grow if moisture is available.

Habitat and Distribution

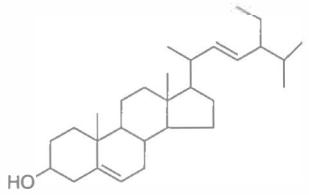
Widespread throughout Qatar, more common in rodats and moist areas, appearing soon after the rains in most habitats. It is common for seedlings to appear on dead mother plants (germinating in capsules). Leaves of new plants edible as a salad.

Constituents

The proximate analysis, amino acids, and minerals of *A. canariense*, growing in Qatar, are shown in Tables 175, 176 and 178 (Al-Easa, 2002a,b,d).

The unsaponifiable matter of the lipids consisted of sterols (10.67 %), hydrocarbons (66.01 %), aliphatic alcohols (19.76 %) and triterpene alcohols (3.5 %). Analysis of the hydrocarbon fraction revealed the presence of $C_{23:0}$, 7.78; $C_{24:0}$, 10.78; $C_{25:0}$, 13.17; $C_{26:0}$, 15.57, $C_{27:0}$, 17.96; $C_{29:0}$, 17.96; $C_{31:0}$, 5.99 and others 10.78 %. The aliphatic alcohol fraction consisted of $C_{21:0}$, 4.00, $C_{22:0}$, 20.00; $C_{24:0}$, 20.00; $C_{26:0}$, 16.00 and $C_{28:0}$, 40 %. The sterol fraction contained β-sitosterol (66.67 %) and stigmasterol **(12)** (33.33 %) (Al-Easa *et al.*, 2002).

The plant contains coumarins and saponins (Rizk *et al.*, 1986a).

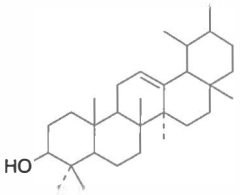


12 Stigmasterol

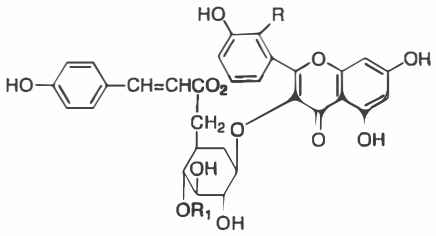
III. AMARANTHACEAE Adans.

1. AERVA Forssk.

Aerva lanata has been reported to contain β-sitosterol, β-sitosterol palmitate, α-amyrin **(13)** (Aiyar *et al.*, 1973) and four flavonoid glycosides **(14-17)** (Zadorozhnii *et al.*, 1986).

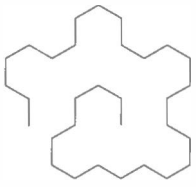


13 α-Amyrin

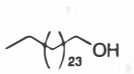


14 R = R_1 = H
15 R = OMe; R_1 = H
16 R = H; R_1 = COCH=CHC_6H_4OH-4
17 R = OMe; R_1 = COCH=CHC_6H_4OH-4

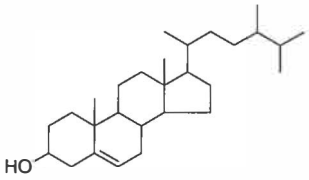
Hentriacontane **(18)**, ceryl alcohol **(19)**, β-sitosterol and its D-glucoside, campesterol **(20)**, stigmasterol, stigmasterol acetate, α-amyrin, betulin **(21)**, lupeol **(22)** and chrysin **(23)** were identified as constituents of *A. lanata* (Wassel and Ammar, 1987; Chandra and Sastry, 1990; Abdel-Wahab *et al.*, 1997).



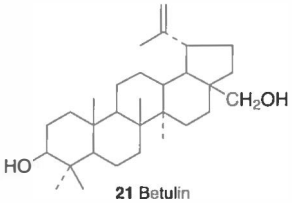
18 Hentriacontane



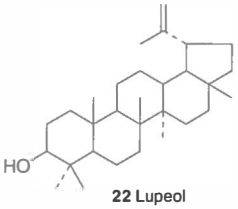
19 Ceryl alcohol



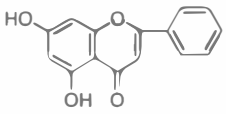
20 Campesterol



21 Betulin

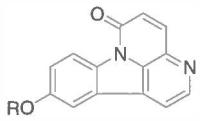


22 Lupeol



23 Chrysin

Two alkaloids were isolated from *A. lanata viz.* 10-methoxycanthin-6-one (methyl aervin) (**24**) and 10-hydroxycanthin-6-one (aervin, **25**) (Ammar *et al.*, 1996).



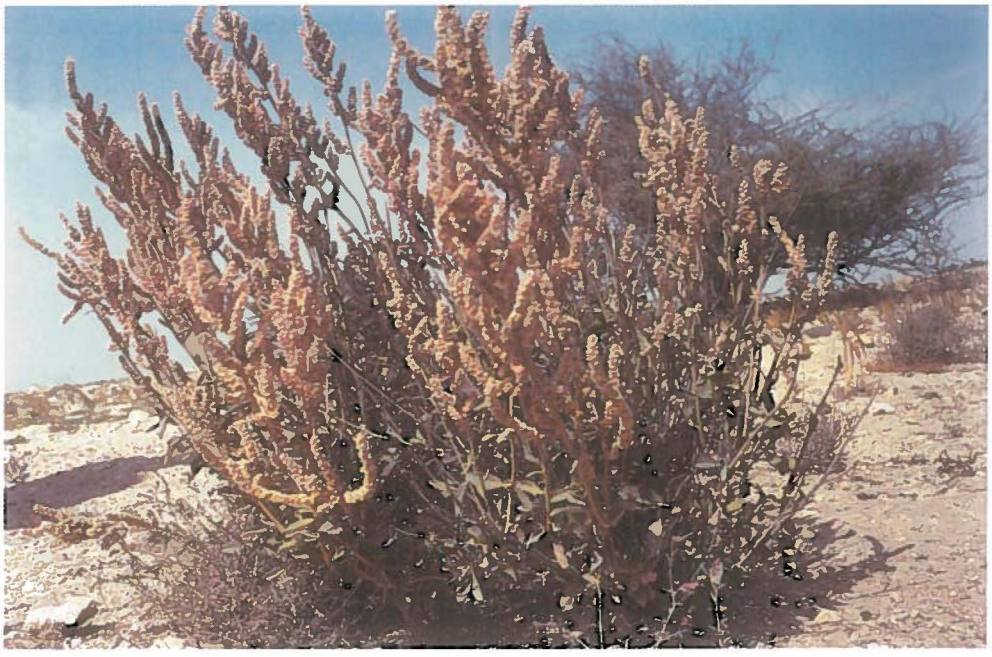
24 Methyl aervin; R = Me
25 Aervin. R = H

The plants of the genus *Aerva* are used in folk medicine to cure lithiasis, dropsical affections, eye affections, diuresis, toothache and in disorders of the abdomen and inflammations of the internal organs (Usmanghani *et al.*, 1982a,b; Rizk and El-Ghazaly, 1995).

1.1 ***Aerva javanica*** (Burm. f.) Juss. ex Schult. in Roem & Schult. Sys. Veg., ed. 15, 5:565 (1819).

syn. *Aerva persica* (Burm. f.) Merrill in Philipp. Journ. Sci. 19:348 (1921); *Aerva tomentosa* Forssk., Fl. Aegypt.-Arab.:cxxii, 170 (1775); *Celosia lanata* L., Sp. Pl., ed. 1:205 (1753).

Arwa, Tuwaim, Tirf (Ar.)



Densely hairy undershrub with alternate, ovate-lanceolate ash green leaves clustered at the lower part of the plant and topped by numerous long peduncles with white inflorescences giving the whole plant an appearance of a whitish woolly bush. Inflorescences terminal and

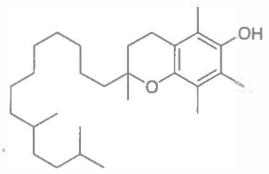
Table 5. Amino acid composition of LPC prepared from *Amaranthus hypochondriacus* (g amino acid /16g N) compared to that of soybean meal and alfalfa LP*

Amino acids	g Amino acid/16 g N		
	A. hypochondriacus LPC	Alfalfa LPC†	Soybean meal‡
Lysine (**43**)	6.6	5.9	6.5
Threonine	5.0	5.1	1.3
Proline	4.6	4.9	6.3
Cysteine	1.2	1.2	1.5
Methionine (**44**)	2.4	2.3	1.3
Valine	6.9	6.3	5.3
Isolecucine	5.8	5.6	5.3
Leucine	9.3	9.3	8.2
Phenylalanine	6.0	5.9	5.3
Tyrosine	4.2	4.8	3.3
Histidine	2.4	2.3	2.7
Arginine	5.8	6.5	7.3
Aspartic acid	9.9	10.0	14.0
Serine	5.3	4.3	5.6
Glutamic acid	10.6	11.4	20.0
Glycine	5.4	5.5	5.2
Alanine	6.0	6.3	5.3

† Kuzmicky and Kohler (1977).
‡ International feed reference number 5 04 604.
* Cheeke *et al.* (1981).

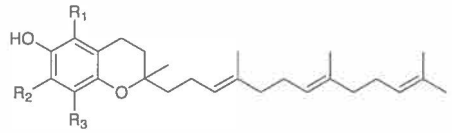
Amaranthus obtained by cryogenic processes contained 13.2 % protein, 63.5 % carbohydrates, 6.7 % fat, 3.3 % mineral elements, 17.7 mg % vitamin C, 0.29 mg % vitamin B_1 (**46**) and 0.12 mg % vitamin B_2 (**47**) (Simakhina *et al.*, 1995). The dried leaves of *A. caudatus* contained 21.51 % protein (Oshodi, 1993).

Bird and Lane (1947) reported that total ascorbic acid was highest in green leaves of *A. retroflexus* and decreased after flowering (780 and 450 mg/100 g dry weight respectively). On the other hand, Aliotta and Pollio (1981) stated that the same species contained 145.73-195.78 mg/100 g vitamin C. According to Lawanson *et al.* (1991), the highest amounts of total free sugars and vitamin C occurred in the different organs (leaves, stem, or shoots) of the mature leafy vegetable *A. dubius* at later stages. Maximum levels of inorganic phosphate were observed at early stages of maturity of the plant in both leaves and stems. Tocopherol (vitamin E) (**48**) content of leaves of *Amaranthus* species was 2.6 mg/100 g (Engel and de Vries, 1946).

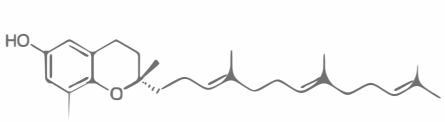


48 Tocopherol (Vitamin E)

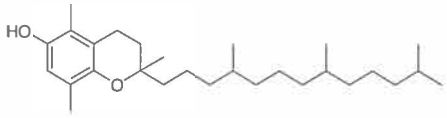
Seeds of thirteen amaranth (*A. cruentus*, *A. hypochondriacus*) accessions were surveyed for their composition of tocols (Lehmann *et al.*, 1994). The most common tocols found were α-tocopherol (2.97 to 15.65 mg/kg seed), β-tocotrienol **(49)** (5.92 to 11.47 mg/kg seed) and γ-tocotrienol **(50)** (0.95 to 8.69 mg/kg seed), while some *A. cruentus* accessions contained δ-tocotrienol **(51)** (0.01 to 0.42 mg/kg seed). Unlike many cereal grains, *Amaranthus* species have significant amounts of both β-and γ-tocotrienols, however, β-tocopherol **(52)** was not detected in any of the amaranths (Lehmann *et al.*, 1994).



49 β-Tocotrienol $R_1=R_3=Me$; $R_2=H$
50 γ-Tocotrienol $R_1=H$; $R_2=R_3=Me$



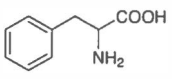
51 δ-Tocotrienol



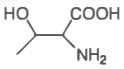
52 β-Tocopherol

The major protein fractions of amaranth seeds according to the Osborne classification were: albumin, globulin and glutelin (Martinez *et al.*, 1997). The protein of *A. hypochondriacus* (yellow seeds) and *A. anclancalius* (black seeds) were fractionated into albumin, globulin, prolamin and glutelin. The average proportions of these soluble proteins were 65:17:11:7 respectively. Albumin had the highest lysine content (7.3-8.2 %), and globulin had highest methionine (4.1-5.3 %) and phenylalanine **(53)** (6.0-6.1 %) content. Prolamin had the highest threonine **(54)** (4.6-5.4 %) and leucine **(55)** (6.8-6.9 %) content, and glutelin had a very low methionine content (0.6-1.0 %) (Correa *et al.*, 1986b). Several studies were reported on the isolation, characterization and composition of *A. hypochondriacus* albumin (Raina and Datta, 1992; Marcone *et al.*, 1994a; Datta *et al.*, 1997; Martinez *et al.*, 1997) and globulin (e.g. Romero-Zapeda and Paredes-López, 1996). The amino acid composition of *A. hypochondriacus* albumin-1 showed a high proportion of essential amino acids like lysine, leucine, threonine, phenylalanine, valine **(56)** and cystine **(57)** that are otherwise deficient in the major seed proteins of legumes and cereals (Datta *et al.*, 1997). Even though there is no agreement, most research papers state that the albumin is shown to be present in the largest amount, followed by glutelins, with globulins appearing in the third place (Segura Nieto *et al.*, 1994). Since seed storage proteins are found in the largest amounts (Fukuyima, 1991), it is striking that the albumin fraction, which usually accounts for the biologically proteins, is found in that highest amount in amaranth seeds, although albumins have been also described as reserve proteins in some plants (Higgins, 1984; Martinez *et al.*, 1997). In amaranth, however, two types of albumin have been described (Konishi *et al.*, 1991): albumin 1, removed with water and /or solutions; and albumin 2, extracted with water after the flour has been treated with saline solutions to remove albumin 1 and globulins. Because albumin 2 resists treatment with pronase, which

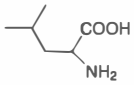
digests albumin 1, it has been suggested that the albumin 2 fraction is located in more protected sites, perhaps associated with protein bodies, which would account for its role as a storage protein. Because of its unique solubility characteristics, the reported differences of the main fractions (Segura-Nieto *et al.*, 1994) could result from the sequence in which the solvent had been used; therefore, the albumin 2 fraction would appear as included in either the globulin or the glutelin fraction (Konishi *et al.*, 1992).



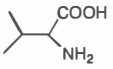
53 Phenylalanine



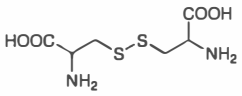
54 Threonine



55 Leucine



56 Valine



57 Cystine

Albumin 1 and 2 have been investigated by several researchers (Mora-Escobedo *et al.*, 1990; Segura-Nieto *et al.*, 1992; Marcone *et al.*, 1994a; Martinez *et al.*, 1997). On the other hand, the globulin fraction has been thoroughly studied (Segura-Nieto *et al.*, 1994) and a major globulin of the 11S type, amarantin (Konishi *et al.*, 1985a; Marcone and Yada 1991,1992; Barba de la Rosa *et al.*, 1992; Romero-Zapeda and Paredes-López, 1996) has been described, together with a minor fraction of the 7S leguminous type (Barba de la Rosa *et al.*, 1992; Segura-Nieto *et al.*, 1992). The major globulin, with a dodecameric quaternary structure-similar to that ascribed to soy 11S globulin (Marcone *et al.*, 1994b) was made up, similarly to these globulins, by acid subunits (A) of molecular masses in the range of 30-40 kDa and basic subunits (B) of about 20 kDa (Segura-Nieto *et al.*, 1994). Furthermore, other monomeric peptides, which were not included in this category because of their higher or lower molecular weights, have been reported (Segura- Nieto *et al.*, 1994).

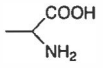
Alcohol soluble proteins from *Amaranthus* seeds differed from prolamin fractions of cereals and plants (Gorinstein, 1993). A novel α-amylase inhibitor (which belongs to a group of small proteins called "knottins") (Chagolla *et al.*, 1995; Lu *et al.*, 1999) was isolated from *A. hypochondriacus* seeds.

Zheleznov *et al.* (1997) reported a 13-21 % variation in seed protein content in wild and cultivated forms of amaranth. The latter authors also stated that seed proteins of amaranth were highly nutritive and composed presumably of easily digestible albumins and globulins (over 50 % of total protein), of 20.8 % alkali-soluble proteins-glutelins with similar nutritive valuc; and of 12 % alcohol-soluble protein-prolamins, which were lacking in essential amino acids.

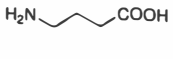
Amino acid analysis demonstrated that albumins are a good source of lysine but are deficient in leucine and threonine. Lysine content was lower in globulins, but globulins were richer in leucine. Most essential amino acids of both proteins were acceptable compared to the FAO/ WHO/UNU reference pattern (Mora-Escobedo *et al.*, 1990). Cheeke *et al.* (1980) reported

that the amino acid content of *Amaranthus* leaf protein was comparable to that of soybean meal. L-Leucine was the limiting amino acid in 10 amaranth (*A. cruentus*) seed samples (Becker *et al*., 1981). Correa *et al.* (1986b) found that the protein content of several *Amaranthus* seeds had a high lysine (5.3-6.3 %) and S amino acids content (3.4-4.0 %) and leucine could be limiting. According to Imeri *et al.* (1987) the average values for methionine, threonine, cystine, leucine, and lysine were 168, 276, 74, 381 and 370 mg/g N respectively in 25 varieties of amaranth (*A. caudatus*). Lysine ranged from 5.2-6.0 g/16g N-in the seeds of *A. caudatus*, and the limiting amino acids were leucine, followed by valine or threonine (Pedersen *et al*., 1987a). In comparison with fine wheat flour, the flour from *A. hypochondriacus* had high lysine content (5.95 g/16 g N in comparison with 2.90 g/16 g N) (Dodok *et al*., 1997).

Consistent changes in the free amino concentrations in response to Na nutrition were observed in mature leaves of *A. tricolor*. Alanine **(58)**, γ-aminobutyric acid **(59)**, and glycine **(60)** were present in greater and aspartate and arginine in lower concentrations in mature leaves of Na-deficient that in normal plants (Grof *et al*., 1986).



58 Alanine



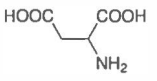
59 γ-Aminobutyric acid (β-Alanine)

60 Glycine

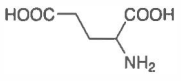
Two small (29 and 30 residues) basic proteins named Ac-AMP1 and Ac-AMP2, with strong antifungal and antimicrobial properties were isolated from the seeds of *A. caudatus* (Broekaert *et al*., 1992). They are probably involved in the protection of seeds or seedlings against fungi and microorganisms. Investigation of the protein-carbohydrate interaction by ^{1}H-NMR titration studies of Ac-AMP2 with *N*,*N*',*N*''-triacetylchitotriose showed a specific binding with an association constant at 315 K of200 l mol^{-1} pH 2 and of 1000 l mol^{-1} at pH 7 (Verheyden *et al*., 1995). The conformation in water of the antimicrobial protein Ac-AMP2 was determined using ^{1}HNMR, DIANA and restrained molecular modeling (Martins *et al*., 1996). El Bouyoussfi *et al.* (1997) determined the disulphide bridge pairing of Ac-AMP2, using a fast method involving enzymic fragmentation followed by identification of the fragments with FAB mass spectrometry. The results confirmed the location of the three-disulphide bridges as previously established by Martins *et al.* (1996). The purification and characterization of the antiviral protein (AAP29) from the leaves of *A. mangostanus* have been also reported (Cho *et al*., 1995)

Singh *et al.* (1993) purified two *Amaranthus* lectins, namely *A. caudatus* (ACL) and *A. spinosus* (ASL). Both lectins showed similarities in biological and physico-chemical properties. These are dimeric proteins composed of subunits having molecular weights of 35,800 and 37,000 Da respectively, which are not held together by disulphide linkages. The two lectins were found to be non-specific and reacted with human and various animal erythrocytes. These are glycoprtoeins having no metal ion requirement for their activity. A lectin of molecular weight ~ 45,000 per subunit from *A. leucocarpus* seeds was also isolated (Zenteno and Ochoa, 1988). It was found to be a glycoprotein (10 % cut weight /wt. carbohydrate) containing six *N*-acetyl-D-glucosamines, four D-galactose, one D-glucose and traces of xylose residues for

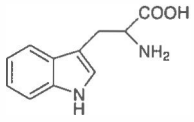
each three D-mannose residues per mol. Its amino acid composition revealed predominance of acidic residues (aspartic **(61)** and glutamic **(62)**) and of glycine and alanine. In addition, the lectin contains an unusual amount of essential amino acids such as methionine, tryptophan **(63)** and lysine. In contrast to *A. caudatus* hemagglutinin, *A. leucocarpus* lectin is inhibited by serum glycoproteins such as fetuin, it is mitogenic, and is not toxic (Zenteno and Ochoa, 1988). A *N*-acetyl-α-D-galactosamine-specific lectin from the seeds of *A. paniculatus* was isolated and found to be a homo dimer and a glycoprotein (10.5 % carbohydrate) with molecular weight of a subunit of 27,000. Its amino acid composition revealed high content of valine, leucine, and acidic amino acid residues. This lectin also had high contents of methionine, tryptophan and lysine. A lectin (AHML) with no carbohydrate moiety was isolated from seeds of *A. hypochondriacus* var. *mexico*. AHML was specific for *N*-acetyl-D-glucosamine as were the other *Amaranthus* lectins. AHML has a native molecular weight of 45.0 kDa and was composed of identical subunits with a molecular weight of 3.6 kDa (Ozeki *et al.*, 1996). *A. paniculatus* lectin agglutinated normal and papain-treated rabbit and human A, B, and O erythrocytes (Sawhney and Bhide, 1992). The seeds of *A. leucocarpus* meal had a protein efficiency ratio of 2.15 when the lectins had been removed compared to 1.95 for the control meal (Calderon de la Barca *et al.*, 1985). Seeds of several *Amaranthus* species were reported as lectin-rich taxa (Pelia and Sandhu, 1990).



61 Aspartic acid



62 Glutamic acid



63 Tryptophan

A. caudatus agglutinin (ACA or amaranthin) is a lectin purified from seeds of the amaranth grain. ACA is a tightly associated homodimer of 66,000 molecular weight and contains two identical carbohydrate-binding sites. Unlike most lectins, ACA is not glycosylated and does not require metal cations for sugar binding. *A. caudatus* agglutinin contains a novel arrangement of four β-trefoil domains. The sugar-binding site provides specificity for the carcinoma-associated T-antigen disaccharide even when 'masked' by other sugars (Transue *et al.*, 1997).

Amaranthus starch has been studied and some interesting findings have been reported, e.g. a wide range of viscosity, resistance to shear thinning, stable paste properties, and small starch granule size (Kazutoshi and Sakaguchi, 1981; Stone and Lorenz, 1984; Yanez *et al.*, 1986; Paredes-López *et al.*, 1988,1994; Paredes-López and Hernandez-López, 1991; Bahnassey and Breene, 1994; Myers and Fox, 1994; Zhao and Whistler, 1994; Bhattacharyya *et al.*, 1995; Sudhakar *et al.*, 1996). A wide range of variation was found in the various properties tested both among *Amaranthus* species and among genotypes of the same species (Corke *et al.*, 1997; Wu and Corke, 1999). Physical and functional properties of starches from 93 non-cultivated genotypes of nine *Amaranthus* species from a world germ plasma collection and an additional 31 cultivated *Amaranthus* genotypes were tested by Wu and Corke (1999). When comparing starches from cultivated and non-cultivated genotypes, it was generally found that amylose was lower; starch pasting profiles were more consistent with higher peak viscosity,

lower breakdown, and lower setback; the gelatinization temperature was lower and energy of enthalpy was higher. Under cool storage, the hardness of cultivated starch pastes was lower and the adhesiveness was higher. Amylose content was a primary factor affecting the physical and functional properties of *Amaranthus* starch. The average amylose content of all genotypes tested was 19.2 % with means of 10.7 and 23.2 % for cultivated and non-cultivated species, respectively (Table 6).

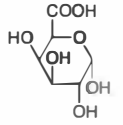
Amylose content was about 14 % and 0 % of normal and waxy starches of *A. hypochondriacus* respectively (Sugimoto *et al.*, 1981). Glutinous and non-glutinious starches were detected in seeds of *A. hypochondriacus* (Okuno and Sakaguchi, 1981). The characteristics of starch isolated from *A. hypochondriacus* have been extensively studied (e.g. Lorenz and Collins, 1981; Konishi *et al.*, 1985b; Perez *et al.*, 1993a,b; Bello-Pérez *et al.*, 1996; Perez and Emaldi, 1998).

The wild species, *A. retroflexus*, considered to be an agricultural weed, had the highest mean amylose content, 34.3 % as compared with 7.8 % for A. *hypochondriacus*, which was the lowest value. *A. tricolor* also had a high mean amylose content of 29.0 % (Wu and Corke,1999).

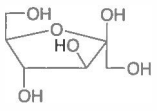
Singhal and Kulkarni (1988) reported that *A. polygamus* and *A. gracilis* had low amylose starches (111.7 and 97.1 g/kg respectively), and *A. spinosus* and *A. tenuifolius* had appreciable proportions of amylose (166.7 and 245.0 g/kg respectively).

Many *Amaranthus* starches were reported to be good thickeners and stabilizers in food processing (Singhal and Kulkarni, 1991; Corke *et al.*, 1997; Bello-Pérez *et al.*, 1998; Wu and Corke, 1999). Suitability of *A. paniculatus* starch to substitute conventional thickness (e.g. maize starch) in textiles printing of indigosol (solubilized Vat) was reported (Teli *et al.*, 1996). The potential value of *A. hypochondriacus* starch as a major component of corrugated-board glues was also reported (Wolkowski *et al.*, 1997).

Pectic substances were isolated and characterized from the aerial parts of purple amaranth (*A. cruentus*). Galacturonic acid **(64)**, galactose, rhamnose, xylose, arabinose, fructose **(65)** and glucose were the constituents of the pectic fraction (Sosmina *et al.*, 1996). Pectic substances have been also characterized from the seeds of *A. caudatus* (Chernenko *et al.*, 1997). Experiments with isolated rat heart showed that pectin isolated from *A. cruentus* caused coronary spasm without changing contractile tone (Desalen *et al.*, 1997).



64 Galacturonic acid



65 Fructose

Sucrose was the major sugar of *A. cruentus* seeds followed by raffinose **(66)**. Inositol **(67)**, stachyose **(68)** and maltose **(69)** were also found in small amounts (Becker *et al.*, 1981).

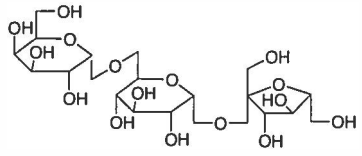
There have been a number of investigations into the composition of the seed lipids of both vegetable amaranths [*A. caudatus* (*A. edulis*), *A. cruentus*, *A. dubius*, *A. tricolor* (*A. gangeticus*)] and the weed species (*A. hybridus*, *A. retroflexus*, *A. spinosus*) (e.g. Stoller and Weber, 1970;

Table 6. Genetic variation in starch content, amylose content and pasting of *Amaranthus* and reference starches[a]

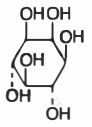
Species	Growth Location	No. of Genotypes	Starch (%)	Amylose (%)	PV (RVU)	HPV (RVU)	P_{time} (min)	CPV (RVU)	BD. (RVU)	SB (RVU)
1. *A. cruentus*	Beijing	14	22.0±18.5	19.2±14.2	248±83	173±70	7.7±0.3	210±111	75	38
	Wuhan	34	19.5 ±15.1	25.0±15.7	288±109	202±80	7.9±0.4	288±1 25	86	106
2. *A. dubius*	Wuhan	3	3.4±1.8	24.6±10.5	...	...	...	...	...	...
3. *A. hybridus*	Beijing	8	7.9±2.2	19.8±4.8	210±78	182±66	8.9±1.2	241±93	27	40
	Wuhan	6	5.3±2.1	22.3±6.6	213±70	174±36	8.6±0.9	244±80	39	117
4. *A. hypochondriacus*	Wuhan	6	37.6±16.6	7.8±12.7	172±56	127±56	8.3±0.4	151±79	45	49
5. *A. pumilus*	Beijing	3	5.1±0.4	19.7±6.9	104±20	102±25	9.0±1.4	121±28	2	121
6. *A. retroflexus*	Wuhan	3	6.1±0.6	34.3±3.5	222±9	223±5	7.9±1.0	289±38	-1	65
7. *A. spinosus*	Wuhan	4	3.2±1.3	18.1±11.6	20 7±82	217±86	9.2±0.6	253±109	-10	37
8. *A. tricolor*	Wuhan	8	4.0±1.0	29.0±9.9	162±104	176±87	9.9±1.1	190±84	-14	14
9. *A. viridis*	Wuhan	3	2.0±0.3	12.9±8.0	172±0	96±1	10.9±0.3	90±0	76	-6
Cultivated species		31	36.4±11.6	10.7±12.4	296±227	151±48	7.9±0.4	185.3±71	144	59
Non-cultivated species		93	14.5±15.1	23.2±13.2	229±99	176±72	8.4±1.0	233.3±112	52	57
Total		124	20.1±17.3	19.2±13.9	253±155	166±67	8.2±0.9	225.4±155	86	57
Maize starch			na	24.3	353	117	7.4	287	236	170
Rice starch			na	15.7	296	156	7.4	280	140	124
Wheat starch			na	28.1	312	187	8.2	362	125	175

[a]PV = peak viscosity; HPV= holding viscosity; P_{time} = time to peak viscosity; CPV = cool paste or final viscosity. Values ±standard deviation. BD= breakdown (PV-HPV); SB=setback (CPV-HPV). RVU = Rapid Visco Analyzer units; na = not available; ... = *A. dubius* not tested for pasting properties.

Dixit and Varma, 1971; Opute, 1979; Becker *et al.*, 1981; Fernando and Bean, 1984; Lorenz and Hwang, 1985; Bressani *et al.*, 1987; Prakash and Pal, 1992; Yanez *et al.*, 1994; Karaseva *et al.*, 2000). The lipid content of the grain of four *Amaranthus* species, studied by Opute (1979) ranged from 16.95 % for the common weed *A. spinosus* to 9.75 % for the garden omamental, *A. arthropurpureus* (Table 7). Fifty-nine percent of the fatty acids present in *A. muricatus* were unsaturated with linoleic acid amounting to 40 % of the total fatty acid content (Escudero *et al.*, 1999a).



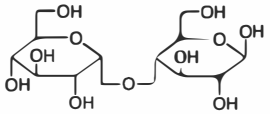
66 Raffinose



67 Inositol

gal-(α1→6)-gal-(α1→6)-glu-(α1→2β)-fru

68 Stachyose



69 Maltose

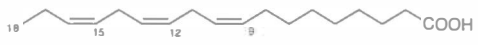
Table 7. Total lipid and fatty acid composition of four *Amaranthus* species

Species	Total lipids	Fatty acid						
		14:0	16:0	18:0	18:1	18:2	18:3	20:0
1. *A. arthropurpureus*	9.75	0.3	22.5	2.5	29.1	44.2	0.8	0.6
2. *A. hybridus*	10.99	0.2	21.1	5.4	21.3	50.4	0.7	0.8
3. *A. spinosus*	16.95	0.2	19.3	4.3	24.0	48.7	0.5	0.9
4. *A. tricolor*	9.92	0.3	19.8	4.4	20.2	53.7	0.4	1.1

Free lipids of 8 varied *Amaranthus* varieties, studied by Lorenz and Hwang (1985) ranged from 5.69-7.23 % and bound lipids from 0.42-0.91 %. Crude fat content of grains of 21 *Amaranthus* accessions (eight species) ranged from 5.2-7.7 % (Budin *et al.*, 1996).

Study of the fatty acids revealed that the major fatty acids of the seeds were linoleic, oleic, stearic and palmitic acids. The unsaturated acids constituted about 70 % of the total acids. Trace amounts of the following acids were found in some studies: myristic, palmitoleic, linolenic **(70)**, arachidic **(71)** and lignoceric **(72)** (Opute, 1979; Bertoni *et al.*, 1984; Fernando and Bean, 1984,1985; Lorenz and Hwang, 1985; De Arellano *et al.*, 1996; Dailey *et al.*, 1997; Dodok *et al.*, 1997). Docosenoic acid ($C_{22:1}$) was present in *A. cruentus* at the level of 9 % (Yanez *et al.*, 1994). In some of these studies (Stoller and Weber, 1970; Opute, 1979; Lorenz and Hwang, 1985), the nonpolar lipids were further characterized as triglycerides (major component), sterols, sterol esters, diglycerides, monoglycerides, free fatty acids and hydrocarbons. *A. gangeticus* leaves yielded on extraction with chloroform-methanol, 10.6 %

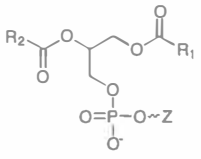
lipids (dry weight), which was separated into nonpolar lipids (53.6 %), glycolipids (33.8 %), and phospholipids (12.6 %) (Lakshminarayana *et al.*, 1984). The nonpolar lipids were made up (weight %) of pigments (8.1), hydrocarbons (4.9), ester waxes (1.8), fatty acid methyl esters (2.7), triacylglycerols (6.4), fatty acids (5.6), diacylglycerols (5.6), sterols (9.3), monoacylglycerols (4.7) and unidentified components (4.5). The glycolipids comprised (weight %) monogalactosyl diglycerides (15.6), steryl glycosides (4.1), cerebrosides (6.8) and digalactosyl diglycerides (7.3). The phospholipids consisted (weight %) of cardiolipin (2.0), phosphatidylglycerol **(73)** (3.1), phosphatidylethanolamine **(74)** (3.2), phophatidylinositol **(75)** (1.7), and phosphatidylcholine **(76)** (2.6). The usual fatty acids were found in varying concentrations in different lipid classes. *trans*-3-Hexadecenoic acid amounted to 12.3 % in phosphatidylglycerol fatty acids (Lakshminarayana *et al*., 1984). Phosphatidylserine **(77)** was also reported in the polar lipids by Lorenz and Hwang (1985).

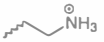


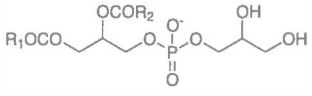
70 Linolenic acid

71 Arachidic acid

72 Lignoceric acid

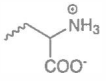


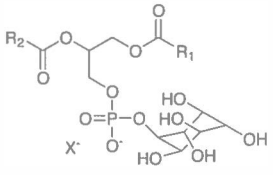
74 Phosphatidylethanolamine; Z= 



73 Phosphatidylglycerol; $R_1 = R_2$ = fatty acid residue

76 Phosphatidylcholine; Z= 

77 Phosphatidylserine; Z= 

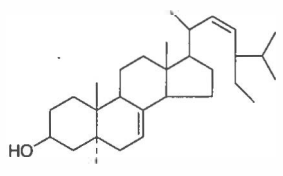


75 Phosphatidylinositol

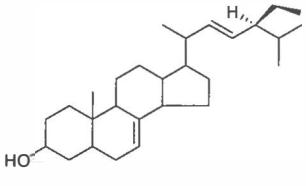
Acyl lipids and their constituent fatty acids were studied in leaves, chloroplasts, and bundle-sheath strands of *A. paniculatus*, grown under normal and 4 % oxygen-containing atmosphere (Knacker and Schaub, 1984). In all fractions, the major lipids were monogalactosyldiacylglycerol, digalactosyldiacylglycerol, sulfoquinousyldiacylglycerol and phosphatidylglycerol. Significant quantities of phosphatidylcholine and phosphatidylethanolamine were restricted to leaves and bundle- sheath strands. All lipids, except phosphatidylglycerol, where 3-*trans*-hexadecenoic acid was also present, contained palmitic, stearic, oleic, linoleic and linolenic acids.

The nonpolar lipids of *A. palmeri* (leaves and flowering parts), were studied by Dailey *et al.* (1989,1997). The wax ester consisted of a series of C_{36}-C_{56} homologues, with the C_{40}, C_{42}, C_{44}, C_{46} and C_{48} homologues being predominate. The major wax ester fatty acids were C_{16}, C_{18}, C_{20}, C_{22} and C_{24}. Similar trends in carbon number distribution were found between free and bound fatty alcohols, with the C_{22}, C_{24}, C_{26}, C_{28}, C_{30} and C_{32} homologues predominating (Dailey *et al.*, 1989).

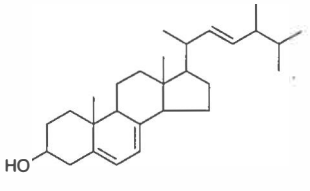
Fernando and Bean (1985) studied the sterols of seeds of weedy and vegetable species of *Amaranthus*. The major sterol was spinasterol **(78)**, which ranged from 46 to 54 % of the total sterol mixture. Δ^7-Stigmasterol **(79)** occurred in the next higher amount, with lesser amounts of ergosterol **(80)**, stigmasterol and 24-methylenecycloartenol **(81)**. The desmethyl sterol content, of nineteen species and varieties of Amaranthaceae (*Amaranthus* and *Celosia*) varied from 0.0084 % to 0.034 % of the total dry weight (Xu *et al.*, 1986). In these species spinasterol and 7-stigmastenol were the dominant sterols, although low levels of five unsaturated sterols were detected. Minor sterols identified in ≥1 species included cholesterol **(82)**, campesterol, stigmasterol and sitosterol as well as 7,22-stigmastadienol,7,24(8)-ergostadienol,7-ergostenol, 7,25-stigmastadienol, and 7,24(8)-stigmastadienol. Stigmastanol and 24-methylcycloartenol were also present (Xu *et al.*, 1986). On the other hand, Endo *et al.* (1995) reported that the major sterol of the seeds from varieties of *A. caudatus*, *A. cruentus* and *A. hypochondriacus* was sitosterol. Chondrialasterol was the major sterol of leaves and flowering parts of *A. palmeri*. The sterols campesterol, stigmasterol, ergost-7-en-3β-ol, chondrillast-7-enol and 24-ethylidenecholest-7-en-3β-ol were present in lesser quantities (Dailey *et al.*, 1997). α-Spinasterol glucoside and β-sitosterol glucoside were identified from *A. chlorostachys* (Sarg *et al.*, 1993).



78 α-Spinasterol



79 Δ^7-Stigmasterol

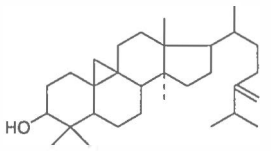


80 Ergosterol

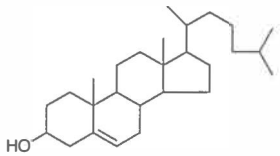
Three ecdysteroids, amasterol **(83)**, ecdysterone, pterosterone and a sesquiterpene lactone iresin, were isolated from *A. indica* (Bratoeff *et al.*, 1996).

Several triterpenes were isolated from *Amaranthus* species. 24-Methylenecycloartanol was identified in *A. tricolor* (Fernando and Bean, 1984), *A. palmeri* (Daily *et al.*, 1997) and others (Fernando and Bean, 1985; Xu *et al.*, 1986). Lupeol and lupeol acetate were detected in *A.*

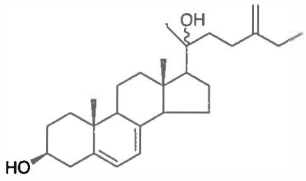
chlorostachys (Sarg *et al.*, 1993). Dailey *et al.* (1997) identified α-amyrin and β-amyrin (**84**), lupeol and cycloartenol in *A. palmeri*.



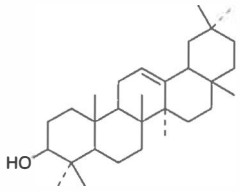
81 24-Methylenecycloartenol



82 Cholesterol



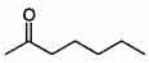
83 Amasterol



84 β-Amyrin

Investigation of the root of *A. spinosus* revealed the presence of two saponins: β-D-glucospyranosyl-(1→2)-β-D-glucopyranosyl-(1→2)-β-D-glucopyranosyl-(1→3)-α-spinasterol and β-glucopyranosyl-(1→4)-β-D-glucopyranosyl-(1→3)-α-spinasterol (Banerji, 1980). Several triterpenoid saponins were isolated from the leaves of *A. caudatus* (Rastrelli *et al.*, 1998) and from seeds of *A. cruentus* (Junkuszew *et al.*, 1998). Ionol-derived glycosides were also isolated from *A. caudatus* (Rastrelli *et al.*, 1998). *A. chlorostachys* and *A. tricolor* contained 2.19 % and 2.89 % saponins (Ateya, 1992).

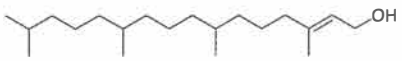
Seed heads of *A. palmeri* were rich in 2-heptanone (**85**), which was consistently found, together with 2-heptanol, in all tissues (Connick *et al.*, 1987). Nine volatile methyl ketones (2-heptanone, 2-octanone, 2-nonanone, 2-undecanone, 2-hexanone, 3-methyl-2-butanone, 2-pentanone, 3-hydroxy-2-butanone and 2-butanone) (Bradow and Connick, 1998a) and eight low molecular weight aliphatic alcohols and aldehydes (2-heptanol, 3-methyl-1-butanol, 1-hexanol, hexanal, 1-pentanol, acetaldehyde, ethanol and 2-methyl-1-propanol) (Bradow and Connick, 1988b) were identified in the mixture of volatiles released by *A. palmeri*. These volatile compounds significantly inhibited the germination of carrot, tomato, onion and *A. palmeri* seeds (Bradow, 1985; Bradow and Connick, 1988a,b).



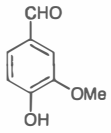
85 2-Heptanone

Fischer and Quijano (1985) isolated phytol (**86**), vanillin (**87**), 3-methoxy-4-hydroxynitrobenzene (**88**) and 2,6-dimethoxybenzoquinone (**89**) from *A. palmeri*. Hydroxycinnamic acid esters, e.g. (*E*)-caffeoylisocitric acid (major) and *p*-coumaroyl-and feruloylisocitric acids (minor) were isolated from the cotyledons of *A. cruentus* (Strack *et al.*, 1987a). Sixteen phenolic acids (ellagic (**90**), gallic (**91**), chlorogenic (**92**), protocatechuic (**93**),

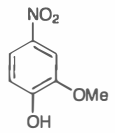
homoprotocatechuic **(94)**, caffeic **(95)**, gentisic **(96)**, *p*-coumaric **(97)**, ferulic **(98)**, syringic **(99)**, vanillic **(100)**, salicylic **(101)**, *p*-hydroxyhenzoic **(102)**, *p*-hydroxyphenylacetic **(103)**, 3,4-dimethoxycinnamic acid **(104)** and γ-resorcylic acids) were identified in *Amaranthus* spp.



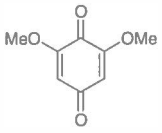
86 Phytol



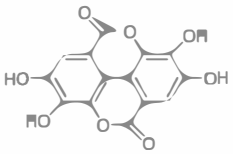
87 Vanillin



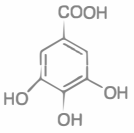
88 3-Methoxy-4-hyroxynitrobenzene



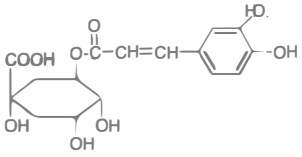
89 2,6-Dimethoxybenzoquinone



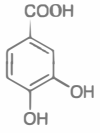
90 Ellagic acid



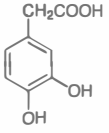
91 Gallic acid



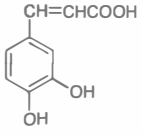
92 Chlorogenic acid



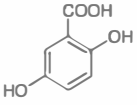
93 Protocatechuic acid



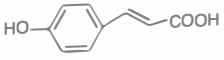
94 Homoprotocatechuic acid



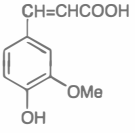
95 Caffeic acid



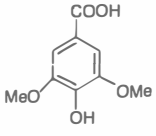
96 Gentisic acid



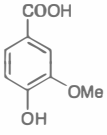
97 *p*-Coumaric acid



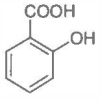
98 Ferulic acid



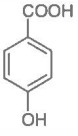
99 Syringic acid



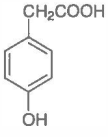
100 Vanillic acid



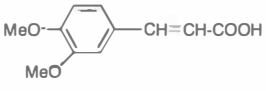
101 Salicylic acid



102 *p*-Hydroxybenzoic acid



103 *p*-Hydroxyphenylacetic acid



104 3,4-Dimethoxycinnamic acid

Table 11. Genetic variation in thermal properties of *Amaranthus* and reference starches[a]

Species	Growth Location	No. of Genotypes	T_r (°C)	T_p(°C)	T_c(°C)	ΔH(J/g)	T_r (T_c-T_o)
1. *A. cruentus*	Beijing	14	68.8±2.5	77.8±1.8	89.1±1.3	13.1±2.7	20.3
	Wuhan	34	62.3±2.0	78.0±1.7	89.6±1.8	13.3±1.8	27.3
2. *A. dubius*	Wuhan	3	72.4±1.1	82.0±1.0	91.4±1.2	8.4±1.7	19.1
3. *A. hybridus*	Beijing	8	66.8±2.8	75.3±3.2	86.8±3.0	8.7±1.5	20.0
	Wuhan	6	68.0±2.7	78.8±2.6	89.1±1.3	10.8±2.3	21.1
4. *A. hypochondriacus*	Wuhan	6	66.1±2.0	73.9±2.0	88.8±1.0	14.5±1.0	22.6
5. *A. pumilus*	Beijing	3	69.6±0.7	76.1±0.5	86.5±1.5	7.3±0.8	17.0
6. *A. retroflexus*	Wuhan	3	68.9±2.0	78.1±1.4	89.2±1.1	11.2±0.6	20.4
7. *A. spinosus*	Wuhan	4	67.6±1.3	79.6±0.7	90.6±2.6	8.6±3.3	23.0
8. *A. tricolor*	Wuhan	8	73.0±2.5	82.0±1.3	91.5±1.2	10.0±2.3	18.5
9. *A. viridis*	Wuhan	3	71.9±0.7	80.2±0.9	87.9±3.3	6.7±1.4	16.0
Cultivated species		31	67.0±6.7	75.6±7.2	86.7±8.3	13.4±2.3	19.7
Non-cultivated species		93	68.8±2.7	77.9±2.8	89.2±2.1	11.5±2.9	20.4
Total		123	68.2±4.1	77.2±4.3	88.5±4.4	12.0±2.9	20.3
Maize starch			62.8	71.9	82.8	11.1	20.0
Rice starch			61.4	78.7	88.6	11.8	27.2
Wheat starch			56.6	63.9	75.1	9.2	18.5

[a] T_o= onset temperature; T_p =peak temperature; T_c =completion temperature: DH= energy of enthalpy (J/g). Values±standard deviation.
Tr= gelatinization temperature range (T_c-T_o).

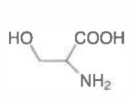
Table 12. Genetic variation in textural properties of *Amaranthus* and reference starch pastes after 24 hrs and 7 days at 4°C[a]

Species	Growth Location	No. of Genotypes	After 24 hr		After 7 days		Change from 24 hr to 7 days	
			Hardness	adhesiveness	Hardness	adhesiveness	Hardness	adhesiveness
1. *A. cruentus*	Beijing	14	118±97	1.2±1.8	224±190	1.4±2.1	90	11
	Wuhan	34	172±135	1.5±2.0	284±247	1.4±2.5	65	-7
2. *A. dubius*	Wuhan	3	136±97	3.0±5.2	257±201	1.0±1.7	89	-67
3. *A. hybridus*	Beijing	8	139±64	11.8±10.5	149±73	9.71±6.1	7	-17
	Wuhan	6	129±65	9.8+13.4	159±71	9.0±6.6	23	-8
4. *A. hypochondriacus*	Wuhan	6	55±95	7.8±10.9	67±119	2.3±2.3	23	-68
5. *A. pumilus*	Beijing	3	114±112	1.7±2.9	198±181	1.3±0.6	73	-20
6. *A. retroflexus*	Wuhan	3	289±36	3.3±0.6	375±178	2.0±3.5	30	-39
7. *A. spinosus*	Wuhan	4	240±55	7.5±10.6	531±162	7.5±6.4	121	0
8. *A. tricolor*	Wuhan	8	194±86	7.8±8.8	327±201	3.5±4.4	69	-55
9. *A. viridis*	Wuhan	3	70±11	7.0±8.5	63±13	4.0±2.8	-10	-43
Cultivated species		31	58±62	3.8±4.2	84±106	3.7±4.5	45	-2
Non-cultivated species		93	152±113	6.4±9.6	237±207	3.1±4.5	56	-52
Total		124	134±120	6.3±9.6	200±198	3.6±5.1	49	-44
Maize starch			560	36	764	0	36	-100
Rice starch			88	13	174	16	98	23
Wheat starch			481	40	447	21	7	-48

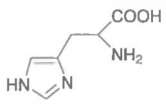
[a]Values±standard deviation.

In quantitative and qualitative terms, *A. viridis* was found to be an excellent source of protein. Its amino acid composition compared favourably to that of a World Health Organization (WHO) for protein standard (Sena *et al.*, 1998).

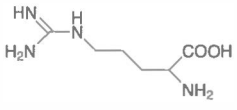
The leaves of *A. viridis*, growing in Niger contained 18.4 % protein; the amino acid composition of which was as follows: aspartate, 13.3; glutamate, 23.7; serine **(118)**, 9.12; glycine 9.65; histidine **(119)**, 3.75; arginine **(120)**, 13.7; threonine, 9.16; alanine, 10.6; proline **(121)**, 10.7; tyrosine **(122)**, 8.94; valine, 11.9; methionine, 2.11; isoleucine **(123)**, 8.78; leucine, 16.1; phenylalanine, 10.5; lysine, 9.94; cysteine **(124)**, 3.96 and tryptophan, 8.11 mg/g dry weight (Freiberger *et al.*, 1998).



118 Serine

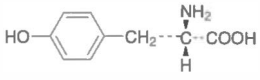


119 Histdine

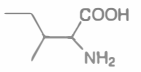


120 Arginine

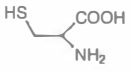
121 Proline



122 Tyrosine



123 Isoleucine



124 Cysteine

The seeds of *A. viridis* had a very low starch yield (2.0 %) as compared with other *Amaranthus* species (Table 6). The thermal and textural properties of the starch are shown in Tables 11 and 12 (Wu and Corke, 1999).

An antiviral protein (amaranthin with a molecular mass of 30 kDa) was purified from the leaves of *A. viridis*. Cytotoxicity of the amaranthin was similar to that of pokeweed antiviral protein (PAP) (Kwon *et al.*, 1997).

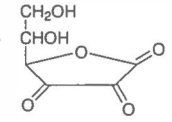
The total lipid of *A. viridis*, growing in Spain, amounted to 0.29 % of the fresh weight of which the fatty acids represented 85.93 %. The fatty acids, identified in the same sample were: $C_{14:0}$, 0.78; $C_{16:0}$, 21.08; $C_{16:3\omega6}$, 0.401; $C_{6:2\omega6}$, 0.35; $C_{16:1\omega7}$, 1.59; $C_{18:0}$, 3.30; $C_{18:3\omega3}$, 24.34; $C_{18:2\omega6}$, 20.24; $C_{18:3\omega6}$, 0.25; $C_{18:1\omega7}$, 0.33; $C_{18:1\omega9}$, 8.60; $C_{20:0}$, 0.57; $C_{20:5\omega6}$, 0.24; $C_{22:0}$, 1.75; $C_{24:0}$, 1.18 (Guil *et al.*, 1996a). The fatty acids identified by Freiberger *et al.* (1998) from the leaves of *A. viridis*, growing in Niger, were: $C_{16:0}$, 5.26; $C_{18:0}$, 0.72; $C_{18:1n9}$, 0.72; $C_{18:2n6}$, 0.70; $C_{18:3n3}$, 3.83 and $C_{20:0}$, 15.2 mg/g. The leaves of the plant, growing in Pakistan, contained palmitic acid as the major fatty acid (77.8 % of total fatty acids) (Khan and Khan, 1989). *A. viridis* has been reported as a rich source of essential fatty acids ($C_{18:2\omega6}$ and $C_{18:3\omega3}$) and carotenes (Guil-Guerrero and Rodriguez-Garcia, 1999).

24-Ethyl-22-dehydrolathosterol (24-ethyl-5α-cholesta-7, *trans*-22-dien-3β-ol, spinasterol) was the predominant component of the 4-demethylsterol fraction separated from *A. viridis*. The other identified sterols were three Δ^7-sterols (24-methyllathosterol, 24-methyl-22-dehydrolathosterol and 24-ethyllathosterol) and two Δ^5-sterols (24-ethylcholesterol and 24-ethyl-22-dehydrocholesterol) (Behari *et al.*, 1986). The fatty acid, sterol and hydrocarbon content of the lipid extract of *A. viridis*, growing in Egypt were reported by El-Hossary *et al.* (2000a).

Amasterol, an ecdysone precursor and a growth inhibitor, was isolated from the roots of *A. viridis* (Roy *et al.*, 1982).

From *A. viridis*, growing in Egypt, three flavonoids were isolated and identified as quercetin, isoquercetin and rutin. Also, a triterpene saponin glycoside was isolated and its saponin content amounted to 0.4 %. The aqueous, alcoholic and butanolic extracts possessed variable degrees of anti-inflammatory, antipyretic and antihepatoxic effects. Moreover, the aqueous extract showed an anthelmintic effect (El-Hossary *et al.*, 2000b).

Ascorbic and dehydroascorbic acid **(125)** of *A. viridis*, growing in Spain, were reported as very high (15.4 mg/100 g). The nitrate content of the same sample was 597 mg/100 g (Guil *et al.*, 1997).



125 Dehydroascorbic acid

The vitamins and antinutrients of the leaves of *A. viridis*, growing in Spain, were as follows: moisture 81.17±3.12 g; ascorbic acid, 103±35; dehydroascorbic acid 36±9; carotenoids, 15.4±4.1; oxalic acid 960±220 and nitrate, 597±67 mg/100 g plant (Guil *et al.*, 1997). Carotenoids of *A. viridis*, growing in Brazil, were 4.0 g/100 g (Mercadante and Rodríguez-Amaya, 1990) and 11.5 mg/g for the plants growing in India. *A. viridis*, from India contained 1,100 oxalic acid and 680 nitrate mg/100 g plant (Prakash and Pal, 1991). Vitamin C was also earlier found to be 35.1 mg % in the leaves of *A. viridis* growing in Brazil (Wasicky and Ferreira, 1951). The mean provitamin content per 100 g of edible portion was 640 retinol/ equivalent for *A. viridis*, growing in Netherlands (Hulshof *et al.*, 1997).

The mineral content of *A. viridis* leaves, growing in Niger, was as follows: Ca, 27,400; Cr, 9.30; Cu, 8.50; Fe, 687; K, 65,000; Mg, 14,700; Mn, 39.4; Mo, 7.50; Na, 1,160; Ni, 6.10; P, 3,910; Se, 19.3 and Zn <5.0 µg/g dry weight. High concentrations of P were also reported in *A. viridis* leaves. The plant also contained significant amounts of selenium (Ezeala, 1985; Freiberger *et al.*, 1998).

The trypsin-inhibitor content of *A. viridis* leaves amounted to 1.43 µg/mg dry weight of plant and its heat resistance was 100 % (Vanderjagt *et al.*, 2000).

IV. ASCLEPIADACEAE Borkh.

1. GLOSSONEMA Decne.

1.1. ***Glossonema edule*** N.E.Br. Kew Bull. 183 (1895).

Atter, Jarawa, Yarawa (Ar.)

Short-lived perennial herb dying back and re-appearing with the onset of the rainy season. Roots deep, whitish and fleshy. Stem whitish, very leafy with dark green-greyish leaves. Leaves petiolate, broadly ovate with undulate margins and distinct mid-ribs. Inflorescences cymose; flowers deep yellow. Fruit a pair of ovoid follicles with soft scattered prickles, pale green when young becoming darker and mottled at maturity. Flowers and fruits with the onset of the rainy season.

Habitat and distribution

Widespread along depressions, watercourses, sandy stony soils throughout Qatar.
Fruits collected in season; edible.

Constituents

The minerals of *G. edule* growing in Qatar are shown in Table 178 (Al-Easa 2002d).

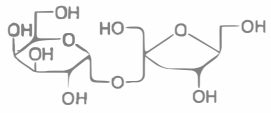
The nutritive constituents of both the pericarp and the unripe seeds of the fruit have been reported (Table 14). The pericarp constituted 59.52 % of the fruit, while the unripe seeds constituted 40.48 %. (Rizk *et al*., 1983a). Investigations of the amino acids in both parts revealed slight quantitative difference with chemical scores of 40 for each of methionine and tryptophan and 65 for lysine. The ratio of essential:total amino acids averaged 34.5 as compared with a corresponding value of 47.4 for the reference egg proteins (Table 15).

Table 14. Chemical constituents of *Glossonema edule*

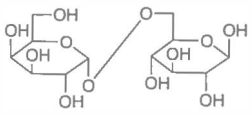
Constituents		Whole fruit	Pericarp	Unripe seeds
Moisture %		87.4[a]±3.6	88.05[a]±2.8	86.35[a]±4.3
g % in dry matter				
Protein		14.70±3.1	11.05±2.8	19.45±3.7
Lipids (ether extract)		2.69±1.9	3.69±3.0	1.44±4.0
Crude fibre		11.22±6.0	16.60±4.9	4.29±5.5
Soluble-carbohydrates		63.29±5.8	59.70±5.6	67.92±8.0
Ash		7.19±1.1	7.80±3.2	6.40±2.3
mg/100g dry matter				
Iron	(10)[b]	3.67	3.72	3.60
Zinc	(15)[b]	1.83	1.15	2.70
Copper	(2.0-3.0)[b]	0.76	0.40	1.23
Manganese	(2.5-5.0)[b]	2.26	2.16	2.38

[a] Mean values of three determinations ± standard error of the mean.
[b] mg/day, Recommended Dietary Allowances (1980) for the adult male.

As regards the soluble carbohydrates, they amounted to a level which is in agreement with the levels found in most of the vegetables and fruits. Glucose, galactose, arabinose and sucrose **(126)** were detected in both parts. However, the unripe seeds were found to contain, in addition to the previous sugars, the oligosaccharides melibiose (**127**) and raffinose. The fiber content in the dry matter of the pericarp was quite high and made it suitable for feeding children, whose stomach capacity is limited. Yet this high fiber content could prove to be useful in the control of obesity (Rizk *et al*., 1983a).



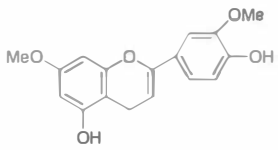
126 Sucrose



127 Melibiose

The study of the fatty acids of both parts revealed slight qualitative and quantitative differences (Table 17). The fat was characterized by a high content of palmitic acid (60 % of the total fatty acids "TFA") and total saturated fatty acids (80 % TFA). These fatty acids have

Velutin **(161)** (4,5'-dihydroxy-7,3' dimethyoxyflavone) was identified from the leaves of *A. officinalis* (Majumdar *et al.*, 1981).



161 Velutin

A study by Sassen (1977a,b) on mangroves involving an analysis of monobasic acids only, suggested a major input of mangrove lipids to the sediment and presented evidence of selective degradation of short-chain fatty acids.

1.1. ***Avicennia marina*** (Forssk.) Vierh. in Denkschr. Akad. Wien, Math.-Nat. 71:435 (1907).
syn. *Sceura marina* Forssk. Fl. Aegpt.-Arab. cv, 85; Cent. II 18 (1775).

Girm, Schura (Ar.)

Evergreen dark green mangrove trees or shrubs not exceeding 4 m high producing a cable network of breathing roots (pneumatophores), each root 40-60 cm long, corky and covered with lenticels. Leaves opposite, shiny green, glabrous above, grey and hairy beneath, ovate to ovate-lanceolate. Inflorescences terminal and axillary clusters of small yellow flowers. Fruit 1-1.5 cm across; seeds vivaporous germinating in the fruit on the mother plant and exposing 2 very large fleshy cotyledons. Seedlings drop and are dispersed by the gentle water current. Many are lost but some set in sheltered bays and form dense natural forests.

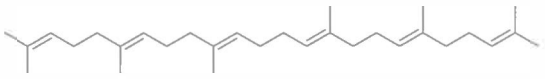
Habitat and Distribution

Mangrove forests are common on the muddy shorelines of the eastern coast of Qatar (widespread from Al Reweis to Al-Wakra) where many experimental plots and plantations are on trial since the eighties. They seem to be more successful on the north-central parts of the eastern coastline on the tidal zones and the lagoons than elsewhere.

Mangrove forests were the main source of wood and camel fodder in the past. Extensive camel grazing destroys the forests. However at present, they are semi- protected.

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *A. marina,* growing in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d). The unsaponifiable matter of the lipids of the same sample contained sterols (29.44 %), hydrocarbons (20.04 %), aliphatic alcohols (11.35 %), 4-methylsterols (1.82 %) and triterpene alcohols (37.35 %). The following hydrocarbons were identified: $C_{23:0}$, 2.59; $C_{24:0}$, 3.24; $C_{25:0}$, 6.15; $C_{26:0}$, 5.50; $C_{27:0}$, 11.33; $C_{29:0}$, 19.42; $C_{31:0}$, 19.42; squalene (**162**), 22.65 and a 9.71 % unidentified others. Eight aliphatic alcohols were identified: $C_{18:0}$, 5.7; $C_{20:0}$, 0.57; $C_{21:0}$, 0.57; $C_{22:0}$, 5.71; $C_{23:0}$, 1.14; $C_{24:0}$, 6.68; $C_{26:0}$, 9.14 and $C_{28:0}$, 70.29 %. The sterol fraction consisted of β-sitosterol (85.02 %) and stigmasterol (14.98) (Al-Easa *et al.*, 2002).

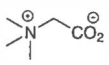


162 Squalene

A marina, growing in Hainan Island (China), contained 1.02 % fat of which the unsaponifiable constituted 0.23 % of it. The fatty acids of lipid of this sample were: $C_{8:0}$, 59:91; $C_{10:0}$, 1.62; $C_{12:0}$, traces; $C_{14:0}$, traces; $C_{16:0}$, 1.61; $C_{18:0}$, 1.63, $C_{18:1}$, 1.50; $C_{18:2}$, 2.65; $C_{18:3}$, traces; $C_{20:0}$, 1.93; $C_{20:1}$, traces, $C_{20:2}$; 6.67; $C_{22:0}$, 0.83 and $C_{24:0}$, 16:08 % (Xu *et al.*,1997a).

A. marina (hypocotyls, baccae and capsules) have been reported to be a promising source for sugars and pectin. It contained reducing sugars (6.09 %), total sugars (11.7 %) and pectin (1.3 %). The percentage sugar constituents were rhamnose (0.12), arabinose (0.71), xylose (0.21), mannose (0.35), glucose (2.16) and galactose (1.12). The pectin is soluble in water; with ester methoxyl and galacturonic acid content was 3.74 and 60.05 % respectively (Xu *et al.*, 1997a).

Glycinebetaine **(163)** was detected in *A. marina*, growing in Umm al Qawain, United Arab Emirates (Adrian-Romero *et al.*, 1998). Nitrogen content of the leaves of *A. marina* was reported higher than other mangrove species studied by Kawamitsu *et al.* (1997).



163 Glycinebetaine

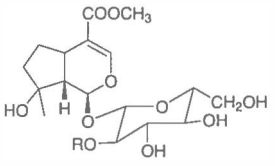
The absorption, accumulation and distribution of several heavy metals in the *A. marina* community at Futian Nature Reserve in Shenzhen, China, have been studied (Peng *et al.*, 1997). There were significant differences in the content of the heavy metals in different fractions of *A. marina* and the content ranges were: 1.8-13.8 for Cu, 0.4-3.15 for Pb; 3.4-69.5 for Zn,

0.013-0.295 for Cd, 0.28-0.73 for Cr, 0.43-7.65 for Ni and 25-1552 mg/g for Mn. Thomas and Fernandez (1997) found Cu, Zn and Pb in higher concentration in *A. officinalis*, growing in Kerala on the south-west of India.

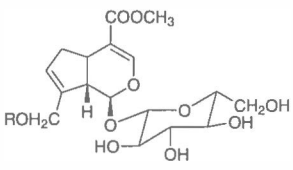
Biochemical analysis of *A. marina* foliage, from Pakistan, showed that carbohydrates were the major organic metabolite (57.5 g % dry weight). *A. marina*, in India, has also more carbohydrates, in addition to chlorophylls, indicating that inspite of more salts in the metabolic environment it was better adopted and was therefore found in a more saline environment than *A. officinalis* (Kotmire and Bhosale, 1980). The C:N ratio of 18.9:1 showed that leaves were deficient in protein. Seventeen amino acids were detected. Cystine and aspartic acid were the two dominant amino acids. Organic constituents represented 13.46 g % dry weight. The leaves had a high calorific content (5.68 k cal/g) (Qasim *et al.*, 1986).

The component hydrocarbons, sterols, alcohols, monobasic, α-ω-dibasic, and ω-hydroxy acids of the fresh and decayed leaves and the pneumatophores of *A. marina*, in Australia, were reported in detail by Wannigama *et al.* (1981). During leaf decay, the total absolute concentrations of monobasic acids was reduced largely due to a decrease in the concentration of C_{18} polyunsaturated fatty acids, whereas the concentrations of the long chain monobasic acids, ω-hydroxy acids, and α-ω-dibasic acids were enhanced. Resistance to degradation shown by the cutin-derived acids relative to the cellular and wax derived lipids may allow the use of these cutin compounds as quantitative markers of *A. marina* in mangrove associated sediments (Wannigama *et al.*, 1981).

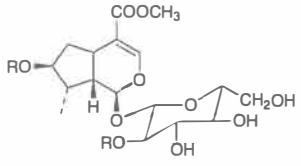
Phytochemical screening of *A. marina*, from Qatar, revealed the presence of alkaloids, flavonoids, saponins and tannins (Rizk, 1982). Terpenes, sterols, coumarins, carotenes and xanthophylls were determined in the different parts of *A. marina*, growing in the Saudi Arabian Red Sea coast (Zahran *et al.*, 1983). The following iridoid glucosides were isolated from the leaves of *A. marina*: mussaenoside (**164**), iridoid glucosides (2'-cinnamoylmussaenoside (**165**), geniposide (**166**), 5-phenyl-2,4-pentadionylgeniposide (**167**), 7-*O*-(5-phenyl-2,4-pentadienoyl)-8-epiloganin (**168**) (Koenig and Rimpler, 1985). The bark of *A. marina* was found to contain betulic acid, taraxerol, taraxerone and traces of a hydrocarbon probably triacontane (Bell and Duewell, 1961).



164 Mussaenoside; R = H
165 2'-Cinnamoyl-mussaenoside; R = cinnamoyl



166 Geniposide; R = H
167 R = 5-phenyl-2,4-pentadienoyl

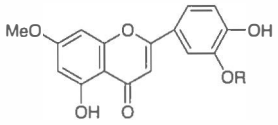


168 R = 5-phenyl-2,4-pentadienyl

A. marina found on the seaward fringe of the vegetation (India), has been shown to have in their leaves more Na and Cl than in the leaves of *A. officinalis*. It was suggested that the level of K, was maintained and that helped in increasing salt tolerance (Kotmire and Bhosale, 1980). The salinity tolerance of *A. marina* has been reported (e.g. Ball and Anderson, 1986; Ball, 1988; Kawamitsu *et al.*, 1997).

The ash content of the foliage and branch wood of *A. marina*, growing in Australia, was found to be 16.11 and 6.67 % respectively. The concentration of the elements in the mature foliage and branch wood were respectively as follows: N, (1.76, 0.40 %); Ca, (0.33, 0.67 %); K, (1.37, 0.63 %); Na (3.11, 0.73 %); Cl (6.07, 1.57 %); S (0.32, 0.03 %); P (0.16, 0.08 %); Mg (0.57, 0.16 %); Si (0.08, 0.05 %); Al (0.01, 0.01 %); Ti (10.1, 5.8μg/g); Mn (72.0, 7.9 μg/g); Cu (20.1, 9.4 Mg/g) and Zn (19.35, 5.6μg/g) dry matter (Spain and Holt, 1980).

The aerial parts of *A. marina*, growing in Egypt, contained the following flavonoids: luteolin-7-*O*-methylether, chrysoeriol-7-*O*-glucoside, isorhamnetin-3-*O*-rutinoside, luteolin-7-*O*-methylether-3'-*O*-β-D-glucoside **(169)** and its galactoside analogue **(170)** (Sharaf *et al.*, 2000).



169 R = β-D-glucosyl
170 R = β-D-galactosyl

VI. BRASSICACEAE Burnett. (CRUCIFERAE Adans.)

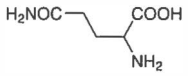
1. BRASSICA L.

A great number of *Brassica* species are used as food and feed. Several species are used in many parts of the world as pasture, forage or silage for livestock (Morrison, 1959). Dwarf Essex (*B. napus*) and marrow-stem kale (*B. oleracea*) are grown for these purposes. Rapeseed, derived from *B. napus* and *B. campestris*, is one of the major oil seed in commerce. The seed meal remaining after oil extraction could be fed to livestock, but in limited amounts since it contained toxic substances (sulphur compounds) (Rizk, 1986).

Lipids, proteins, and mineral elements constituted ~ 70 % of the intact *B. juncea* seed, the remainder representing primarily carbohydrates and fibers. The kernel, accounting for ~ 80 % of the seed, included most of the lipids and a large proportion of the proteins and soluble sugars, with the sum of these three constituents approaching 90 % of the kernel. Integuments, hygroscopic due to their mucilage content, contained 2-3 times more water than the kernel. They contained > 50 % fibers, (~ 30 % cellulose and 20 % lignin), hemicelluloses, and mucilages (Vangheesdaele and Fournier, 1980). The contents in the edible parts of *Brassica* vegetables (9 cultivars) were reported by Morimoto *et al.* (1983) as follows: water (91.7-96.2 %), protein (1.0-2.5 %), lipid (0.1-0.4 %), soluble pectin (0.32-0.63 %), ash (0.7-1.4 %), Ca (0.059-

0.150 %), P (0.029-0.057 %), Fe (0.0005-0.0014 %), Na (0.011-0.040 %), vitamin C (0.025-0.116 %), oxalic acid (0.17-0.64 %) and β-carotene (570-4900 μg/100 g). Chemical analysis of *Brassica* seed and meal indicated a high content of protein, fat and crude fiber as well as glucosinolates; and an adequate amount of methionine. The presence of both low and high molecular weight proteins was indicated by Sharma and Garg (1994). The protein quality evaluation of rapeseed meal has also been reported by Goh *et al.* (1980). Ilami *et al.* (1997) reported the characterization of BnD22, a drought-induced protein, in *Brassica napus* leaves. The oil and protein content in the eleven *Brassica* species, studied by Dhindsa *et al.* (1975) ranged from 32.70-42.45 % and 24.06-31.87 % respectively.

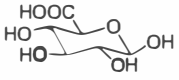
The major free amino acids in *B. campestris* var. *chinensis*, *B. campestris* var. *narinosa*, *B. juncea* and *B. oleracea* var. *alboglabra* were glutamine (**171**) and alanine. Glucose was the major free sugar in these species (Matsuoka *et al.*, 1987).



171 Glutamine

An arabinan has been isolated from the water-soluble pectin substances of cabbage cell wall material. The polysaccharide was highly branched and of the same structural type as other arabinans associated with seed pectins (Stevens and Selvendran, 1980). Kido *et al.* (1996) reported the isolation and characterization of arabinogalactan proteins (AGPs, 5 fractions) released by cellulase digestion of cabbage leaves. The content of AGPs in head leaves of cabbage was 2.5-folde higher than that of green leaves. One of the five AGPs fractions was a typical arabinogalactan protein, which was rich in hydroxyproline (28.3 %) and consisted of protein (15.4 %), neutral sugars (78.8 %) with an arabinose/galactose ratio of 1.6:1 and uronic acid (5.8 %). The other four AGPs were complexed with rhamnogalacturonan having wide spectra in protein and pectin content.

Rape stems (*B. napus*) were found to contain a glucuronoxylan containing D-glucuronic acid (**172**) and 4-*O*-methyl-D-glucuronic acid (Rizk, 1986).



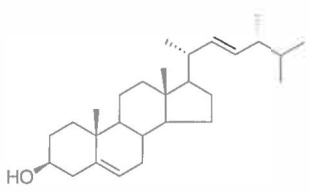
172 D-Gulcuronic acid

Brassica seed fat contained about 14-16 types of fatty acids. The major types were palmitic, oleic, linoleic, linolenic, eicosanoic and erucic (**173**) acids. The percentages of the latter four acids were: 10.9-25.97, 10.30-17.10, 10.80-20.37 and 32.72-60.42 % respectively, in the eleven species studied by Dhindsa *et al.* (1975). In none of the Indian domesticated species of *Brassica* did erucic acid range lower than 50 % (Anand and Mali, 1979). Erucic and eicosanoic acids were reported to be genetically controlled by the same 2-gene pair system (Kondra and Stefanson, 1965) or 1-gene-pair system (Krzymanski and Downey, 1969). This has been stated as an evidence of the positive relationship between erucic and eicosanoic acids and a negative association of both with oleic acid. This was later proved by the study carried out on the relationships between various pairs of major fatty acids in *B. carinata*, *B. campestris*, *B. juncea*

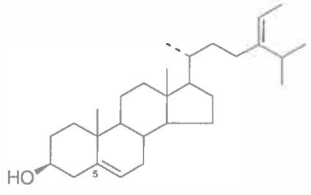
and *B. napus* (Rahman, 1978). The majority of > 300 *B. oleracea* accessions screened, by Mackenzie *et al.* (1997), had < 10 % erucic acid in the sn-2 position of triglycerides, but 7 genotypes contained > 30 % sn-2 erucic acid and two had > 50 %.

173 Erucic acid

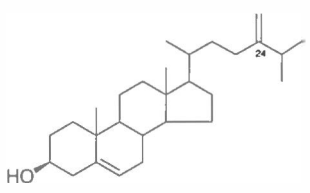
The occurrence of 24-methylenelanost-8,24-dien-3β-ol and 4α,14α,24-trimethyl-9β,19-cyclocholest-24-en-3β-ol has been reported. Twelve more sterols were isolated from the 4-monomethyl-sterol fraction of the seeds of the species. The following sterols were identified in *B. napus* seeds oil: sitosterol, campesterol, brassicasterol **(174)**, 28-isofucosterol **(175)**, stigmasterol, 24-methylenecholesterol **(176)**, *trans*-22-dehydrochotesterol **(177)**, stigmasta-5,25-dienol **(178)**, fucosterol **(179)**, cholestanol **(180)**, campestanol **(181)** and stigmastanol **(182)**. Δ^5-Avenasterol and Δ^7-stigmasterol were also detected in *Brassica* oils (Rizk, 1986). Daucosterol, in addition to β-sitosterol were identified in the pollen of *B. campestris* (Peng and Yang, 1998).



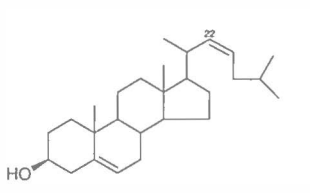
174 Brassicasterol



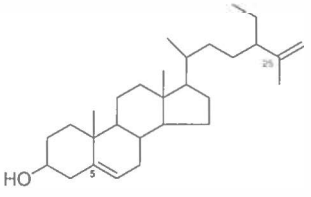
175 28-Isofucosterol
(Δ^5-Avenasterol)



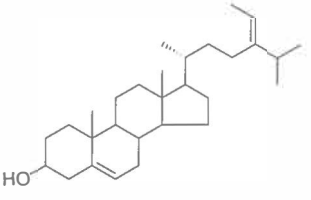
176 24-Methylenecholesterol



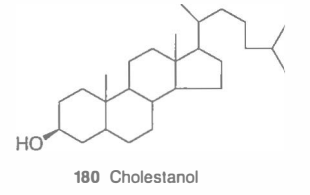
177 *trans*-22-Dehydrocholesterol



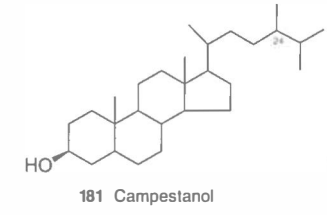
178 Stigmasta-5,25-dienol



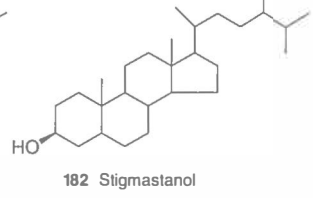
179 Fucosterol



180 Cholestanol



181 Campestanol

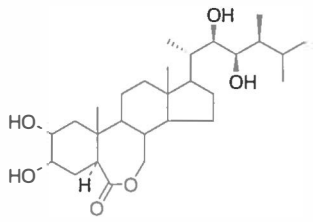


182 Stigmastanol

The major constituents of the epicuticular wax from *Brassica* species were nonacosane, nonacosan-15-one and 15-ol (and 14-ol), which together comprised at least 60 % of the wax.

Other identified compounds in the wax were ketols, primary alcohols, aldehydes and fatty acids (Baker and Holloway, 1975). *B. juncea* contained abundant nutrient elements Zn, Cu, Fe, Ca, Mg, K, Na and Mn and many types of essential amino acids, but no lysine (Chen and Guan, 1999). Rosa (1996) studied the seasonal variation of mineral and crude protein levels in leaves, stems and heads of two Portuguese cabbages (*B. costata*, *B. oleracea* var. *tronchuda*) and one Portuguese kale (*B. oleracea* var. *acephala*) which are commonly used for fodder in Portugal and Spain. Average concentration of Ca was 34.4 g kg^{-1} dry matter (DM) in the leaves with a minimum of 7.8 in heads. S was also higher in the leaves than in stems and heads (8.8 *vs.* 6.1 and 7.0 g kg^{-1} DM). The highest Mn concentration was 86.6 mg kg^{-1} in the leaves with 25.1 in stems and 32.7 in heads. Levels of K and Zn were highest in stems with 41.8 g kg^{-1} and 137.3 mg kg^{-1}, respectively, whereas P tended to be higher in the heads with 5.2 g kg^{-1}. In leaves and heads, concentrations of P, K, S, Fe, Mn and Zn were higher in the summer/winter (SW) season than in spring/summer (SS) and in stems, P and K were higher in SW. In the heads the highest crude protein level was 200 g kg^{-1} (DM) in Troncha (cabbage variety), while in the leaves it was 267 g kg^{-1} in Galega (kale variety). Summer/winter conditions induced higher amounts of crude protein than SS conditions, in leaves (257), stems (169) and heads (217 g kg^{-1}). Glucosinolate levels were higher in the heads (1919 moles 1000 g^{-1} DM for Troncha and 1991 for Penca, a cabbage variety) than in the leaves with levels in SS seasons 35 % higher in the heads and 36 % higher in the leaves than in SW seasons.

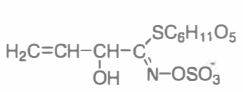
Brassinolide **(183)** (22*R*,23*R*,24*S*)-2α,3α,22,23-tetrahydroxy-24-methyl-6,7-*S*-5-α-cholestano-6,7-lactone), a plant-growth promoting steroid was isolated from *B. napus* pollen (Grove *et al.*, 1979).



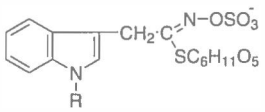
183 Brassinolide

Several glucosinolates have been identified from *Brassica* species. Indolylglucosinolates are widespread in these species. Examples of the glucosinolates detected in some *Brassica* species (e.g. *B. campestris*, *B. carinata*, *B. esculenta*, *B. gemmifera*, *B. hirta*, *B. juncea*, *B. kaper*, *B. napus*, *B. nigra*, *B. nitra*, *B. oler*, *B. oleracea*, *B. persica*, *B. pseudojunca* and *B. rapa*) were progoitrin **(184)**, glucobrassicin **(185)**, neoglucobrassicin **(186)**, gluconastrutin **(187)**, gluconapin **(188)**, sinigrin **(189)**, glucoiberin **(190)**, glucoibervirin, glucoraphanin, sinalbin **(191)**, glucoalysin, 4-hydroxy-3-idolyl and 4-methoxy-3-indolymethyl glucosinolates (e.g. Bradshaw, 1984; Rizk, 1986; Velisek *et al.*, 1995; Jongen,1996; Getinet *et al.*,1997). Glucosinolates have been identified in the different parts of *Brassica* species (*viz.* seeds, leaves, flower buds and roots), but their percentages in the seeds are usually higher. In the green flower buds of *B. oleracea* types, the major glucosinolates were 2-propenyl-3-methylsulphinylpropyl- and indol-3-ylmethyl-, which accounted for an average of 35, 25 and 29 % respectively of the total glucosinolate content, while in *B. rapa*, but-3-enyl represented 86 % of the total with pent-4-enyl and 2-phenylethyl being the other major glucosinolates. (Rosa,

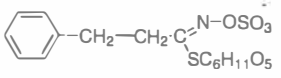
1997). The average total glucosinolate content of the flower buds was between 2518 mmol 100 g^{-1} dry weight in Troncha and 4979 mmol 100 g^{-1} dry weight in Nabo (*B. rapa*), which is much higher than the highest reported amounts for broccoli (*B. oleracea* var. *italica*) (Rosa, 1997). The concentration of 3-indolylmethylglucosinolate **(193)** was reported as relatively high in cabbage heads (6.39 mmol/kg dry weight) and kale leaves (3.25) but not in turnip and rape (Bradshaw *et al.*, 1984). The glucosinolates in the roots of turnip (*B. rapa*) generally increased with increasing the number of days to maturity. In the roots of rutabaga (*B. napobrassica*), the mean content of thiocyanate ion was lower in early-seeded (May) than in late-seeded (June) crops (Chong *et al.*, 1982).



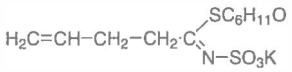
184 Progoitrin



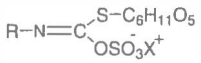
185 Glucobrassicin; R = H
186 Neoglucobrassicin; R = OMe



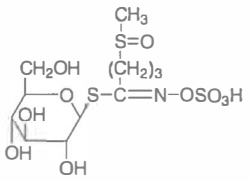
187 Gluconastrutin



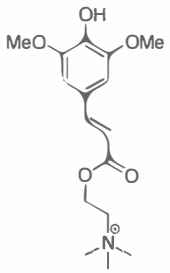
188 Gluconapin



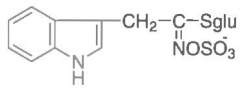
189 Sinigrin R = CH_2=CH-CH_2; X = K
191 Sinalbin R = *p*-$HOC_6H_4CH_2$; X=sinapin



190 Glucoiberin



192 Sinapin

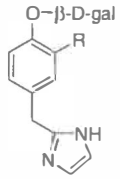


193 3-Indolylmethylglucosinolate

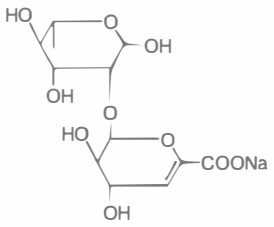
Organic isothiocyanates are the main biologically active catabolites from glucosinolates. They contribute to the desirable characteristic flavours of *Brassica* species. They also possessed goitrogenic activity and some products inhibited the neoplastic effects of carcinogens (El-Sayed and El-Sakhawy, 1995). Glucosinolates have also been reported as cancer modulating agents (Jongen, 1996).

Virtanen *et al.* (1963) reported that rat-feeding experiments of 350 days failed to show goitrogenic properties in milk from cows fed marrowstem kale (*B. oleracea* var. *moelleria*). Later, Pyska and Bobek (1975) stated that *Brassica* fodder increased the serum SCN^- level in cows by ~ 500 % and milk SCN^- level by ~ 300 %, and the milk-to-serum iodine ratio dropped by 38 %.

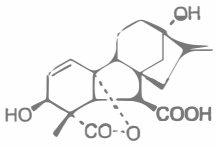
> 100 μM. The growth-promoting activity in hypocotyls was 20 or 30 times as much as that of gibberellic acid (**221**) (Hasegawa *et al.*, 1992).



218 Semilepidinoside A R = H
219 Semilepidinoside B R = OMe



220 Lepidimoide



221 Gibberellic acid

2.1. ***Lepidium aucheri*** Boiss., Ann. Sci. Nat. Bot.,sér. 2,17:195 (1842).

Rashad barri (Ar.)

Very low annual herb hardly reaching 15 cm high. Branches rather stiff and horizontal; branches and whole plant with purple tinge and very few leaves. Fruit small siliculas with two seeds (one per loculus). Flowers and fruits with the onset of the rains.

Habitat and Distribution

A localized stiff herb at the Rodat Al-Majda, N.E. Qatar on sandy clayey soils.

Nothing has been reported on the constituents of this species.

3. SAVIGNYA DC.

3.1. ***Savignya parviflora*** (Delile) Webb, Giorn. Bot. Ital. 2(2):215 (1847).
syn. *Lunaria parviflora* Delile, Descr. Egypte, Hist. Nat. 248 (1814).

Gargees, Gelglat (Ar.)

Small annual erect herb hardly exceeding 30 cm high with limited basal branching and an indumentum of branched hairs. Leaves initially a rosette of spathulate leaves with sinuate margins. Inflorescences racemes with minute whitish flowers. Fruit oblong siliculas up to1.5 cm long and 1 cm broad, deflexed, on slim pedicels. At maturity, the false septum is distinct and membranous. Seeds winged. Flowers and fruits February to April.

Habitat and distribution

Frequent in pockests of sandy soils on sandy stony terrain throughout central and southern Qatar. The plant is eaten at the seedling stage as a salad. The taste is similar to *Eruca sativa*.

Constituents

The seeds of *S. parviflora* were reported to contain 25.2 % protein and 19.0 % fat (Duke and Atchley, 1986).

Phytochemical screening of the plant, growing in Qatar, revealed the presence of alkaloids, saponins, sterols and tannins (Rizk *et al*., 1986a).

4. ZILLA Forssk.

El-Menshawi *et al*. (1980) reported the presence of (*S*) and (*R*)-2-hydroxy-3-butenyl glucosinolates in extracts of siliquas containing seeds of *Z. biparmata*, *Z. spinosa* and *Z. spinosa* var. *microcarpa*.

1. ***Zilla spinosa*** (L.) Prantl in Engl. & Prantl, Natürl. Planzenfam. 111(2):175 (1891).
   syn. *Bunias spinosa* L., Mant. 96 (1769); *Zilla microcarpa* (DC.) Vis.in Spongia, Comment. Med. 2:209 (1836).

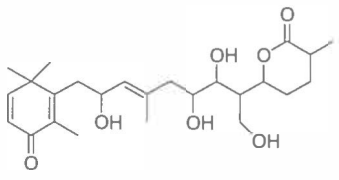
   Silla, Shaga, Sillah (Ar.)

Low much branched undershrub with many radiating almost leafless, green branches with an indumentum of branched hairs. Branches spine-tipped. Leaves simple falling off early.

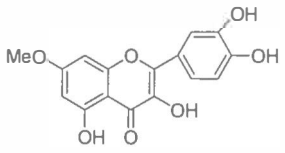
Other studies on the characterization of mabinlins were reported (Din *et al.*, 1986; Liu *et al.*, 1993).

Palmitoleic acid (9.8 %) was detected in *C. divaricata* seed oil (Kittur *et al.*, 1993). Seeds of *C. decidua* contained 18 % fat (Raj, 1987a). Surface wax in flowers, buds and young fruits of *C. decidua* was around 14 %. The wax was a mixture of 9 neutral products associated with N- and S- containing oils. Of these, two were unsymmetrical and straight chain ketones; one was an unidentified isomer of β-sitosterol and the other was a glycoside. Hydrocarbons (C_{29} and C_{31}) were also detected (Raj, 1987b).

Six oxygenated heterocyclic constituents, named capparisesterpenoids and deciduaterpenolides A **(227)**, B, C, D and E were isolated from the root bark of *C. decidua* (Gupta and Ali, 1997). *C. decidua* root bark also yielded two sterols (24β-methylcholest-7-ene-22-one-3β-ol and 24-β-methycholest-9(11)-ene-22-one-3α-ol), one diterpene alcohol (3-methyl-7-hydroxymethylene-10-(12,16,16-trimethylcyclohex-11-ene-yl)-dec-9-ene-5-one-8-ol), two aliphatic constituents (butyl-3-oxo-eicosanoate and 25-oxo-octacosan-1,20-diol) and one diterpene ester (9-(11,15,15-trimethylcyclohex-11-ene-13-one-yl)-one-6-hydroxy-methylene-7-one-yl,4'-methylheptanoate) (Gupta and Ali, 1998).



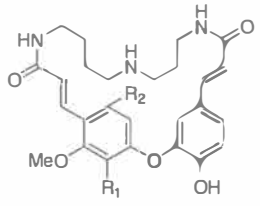
227 Deciduaterpenolide A



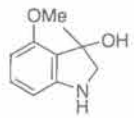
228 Rhamnetin

Several flavonoid glycosides of kaempferol, quercetin and isorhamnetin have been detected in three *Capparis* species (Sharaf *et al.*, 1997). Flavonoid aglycons of seven *Capparis* species were identified as kaempferol, quercetin, isorhamnetin, and their 7-*O*-methyl derivatives: rhamnocitrin, rhamnetin **(228)** (quercetin 7-methyl ether) and rhamnazin, respectively (Pelotto and Del Perez Martinez, 1998).

The root bark of *C. decidua* contained the following spermidine alkaloids: capparidisine **(229)** (Ahmad *et al.*, 1985) capparisine **(230)** (Ahmad *et al.*, 1986b) and capparisinine **(231)** (Ahmad *et al.*, 1987c). Capparidisine, showed a dose-dependent depressant effect on heart rate and coronary flow in an isolated rabbit's heart (Rashid *et al.*, 1989).



229 Capparidisine R_1 = OMe; R_2 = H
230 Capparisine R_1 = H; R_2 = H
231 Capparisinine R_1 = H; R_2 = OMe

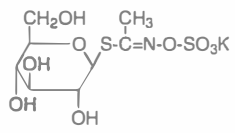


232 3-Hydroxy-3-methyl-4-methoxyindole

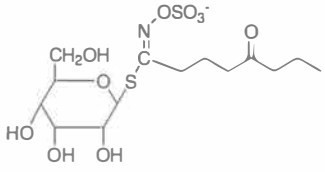
The seeds of *C. masaiki* yielded oxazolidine-2-thione (Hu *et al.*, 1987). 3-Hydroxy-3-methyl-4-methoxyindole **(232)** was isolated from the roots of *C. tomentosa* (Dekker *et al.*, 1987).

Leaves of *C. baducca*, *C. hastata* and *C. odoratissima* contained methylglucosinolate. Benzylglucosinolate was detected in leaves of *C. flexuosa* (Gmelin and Kajaer, 1970).

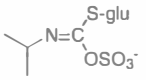
Glucosinolates have been identified in several *Capparis* species e.g. *C. angulata*, *C. baducca*, *C. cartilagena*, *C. flexuosa*, *C. geleata*, *C. hastata*, *C. inermis*, *C. linearis*, *C. nobilis*, *C. ovalifolia*, *C. ovata* var. *palestina*, *C. rupestris*, *C. salicifolia*, *C. spinosa* and *C. tuereckheimii*. Examples of the glucosinolates identified were: glucocapparin **(233)**, glucocapangulin **(234)**, glucoputranjivin **(235)**, glucocochlearin **(236)**, glucocappasalin **(237)**, glucobrassicin **(185)**, glucoiberin **(190)**, neoglucobrassicin **(186)**, gluconorcappasalin, 3-methyl-3-butenylglucosinolate **(238)** and sinigrin **(189)** (Ahmed *et al.*, 1972a).



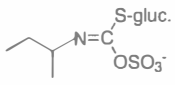
233 Glucocapparin



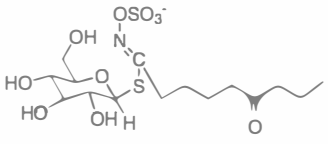
234 Glucocapangulin



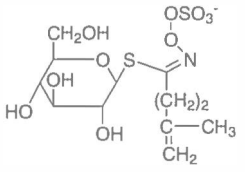
235 Glucoputranjivin



236 Glucocochlearin



237 Glucocappasalin



238 3-Methyl-3-butenylglucosinoate

The dietary fiber of teent (*C. decidua*) varied from 38.5 to 55.7 %, with hemicellulose as the predominant constituent. Teent had pronounced hypocholesterolemic effect (Agarwal and Chauhan, 1988).

The toxicity of *C. tomentosa* in sheep and calves has been reported (Ahmed *et al.*, 1981).

1.1. ***Capparis spinosa*** L.var. ***aegyptia*** (Lam.) Boiss., Fl. Orient. 1:420 (1865).
syn. *Capparis aegyptia* Lam., Encycl. 1 = 605 (1785).

Dabayee, Shefallah, Shafallah, Lasaf (Ar.)

Trailing-scandent spiny shrub forming circular mats up to 2-2.5 m across of rambling branches radiating from a central base. Spines at leaf bases, recurved. Leaves simple, entire, oval-orbicular 3-5 cm long and 3-4.5 cm across, leathery. Inflorescences axillary, usually solitary. Flowers large, white to pale rose, of 4 sepals and petals and numerous stamens surrounding an elongated ovary on a distinct gynophore. Fruit ellipsoid pear-shaped and gourd-like, fleshy, splitting into 4, exposing grey pepper-like seeds on red pulp. Mature pericarp of fruit never dries completely. Flowers and fruits in summer (May-August).

Habitat and Distribution

Common in central and north-eastern Qatar, rare elsewhere. In depressions with fine sandy loams along roadsides (Al-Dhakhira, Ras Laffan and along the sides of Al-Shamal road from Al-Khor and beyond. A favoured camel browsing plant. Flower buds and immature fruits are locally pickled (caper).

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *C. spinosa*, growing in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d).

Leaves and fruits of *C. spinosa*, growing in Azerbaidzhan, contained reducing sugars (calculated as glucose) 1.68 and 32.9 %, fats 0.71 and 3.75 % and ascorbic acid 70.8 and 135.5 mg % (Rakhimova *et al.*, 1978).

The average composition of capers (*C. spinosa*), as influenced by cultivars, size and harvest date was as follows: moisture 79 %, ash 1.6 %, protein 5.8 %, fat 1.6 %, Ca 871 ppm, Mg 636 ppm, K 542 mg/100mL, Na 226 ppm, Fe 13 ppm, P 21 mg/100 g and crude fiber 5.4 % (Rodrigo *et al.*, 1992). Water, crude fiber, crude oil, total carotenoids and starch values increased in *C. spinosa* flower buds harvested in both June and August. Both materials contained high amounts of Na, K, P, Ca, Mg and Mn with Mn decreased in August. Small buds harvested in June were more suitable for processing (Ozcan and Akgul, 1998). The seeds of *C. spinosa* var. *spinosa* were rich in protein, oil and fiber and showed high content of unsaturated fatty acids, suggesting that they may be valuable for food uses (Akgul and Ozcan, 1999).

The lipid content of *C. spinosa* var. *aegyptia*, collected from two localities in Egypt and *C. spinosa* var. *deserti* (growing in El-Sallum, Egypt) were 1.10, 1.70 and 2.5 % respectively. The fatty acids of the different species are shown in Table 18 (Ahmed *et al.*, 1972b)

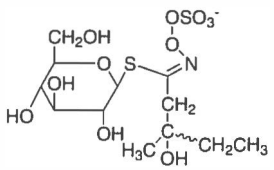
Table 18. The fatty acids percentage in the Egyptian *Capparis* species

Species	12:0	14:0	16:0	18:0	18:1	18:2	18:3
1. *C. ovata* var. *palestina* (New Valley)	1.32	1.42	33.74	16.23	18.60	22.44	6.15
2. *C. spinosa* var. *aegyptia* (Wadi El-Rashrash)	3.17	3.05	6.26	5.69	5.24	4.69	71.92
3. *C. spinosa* var. *aegyptia* (Wadi-Hof)	1.71	1.86	5.40	6.49	6.61	6.82	71.03
4. *C. spinosa* var. *deserti* (El-Sallum)	4.85	5.27	17.80	20.29	16.57	19.03	16.15

The major fatty acids of *C. spinosa* var. *spinosa* were linoleic, oleic, linolenic and palmitic (Ozcan, 1999). The study of the lipids (including neutral lipids, glycerides, phospholipids) and fatty acids in the aerial parts of caper bush (*C. spinosa*), growing in Uzbekistan, has been reported (Tolibaev and Glushenkova, 1995).

Sucrose was identified in *C. spinosa* var. *aegyptia* and var. *deserti* (Ahmed *et al.*, 1972b). The mucilage prepared from *C. spinosa* consisted of glucose, arabinose, xylose and glucuronic acid (Hammouda *et al.*, 1975).

C. spinosa var. *aegyptia* and var. *deserti* were found to contain the following glucosinolates: glucocapparin, glucocleomin **(239)**, glucoiberin, glucocapangulin and sinigrin (Ahmed *et al.*,1972c). In addition to sulphides, isothiocyanates and other flavour molecules, elemental sulphur (S_8) was identified in *C. spinosa* (Brevard *et al.*, 1992). The oils of the ripe fruits and roots of *C. spinosa* var. *mucronifolia* contained methyl-, isopropyl- and *sec.* butyl-isothiocyanates (Afsharypuor *et al.*, 1998). The unripe fruits of *C. spinosa* var. *mucronifolia* were composed mainly of methyl isothiocyanate (39.2 %), isopropyl isothiocyanate (21.4 %) and *sec*-butylisothiocyanate (6.4 %) (Afsharypour and Jazy, 1999).

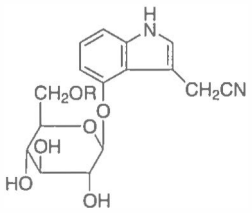


239 Glucocleomin

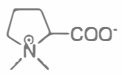
β-Sitosterol, β-sitosterol-β-D-glucoside, 1-triacontanol (Ahmed *et al.*, 1972; Hammouda *et al.*, 1975), *n*-alkanes, 2-hexenal and thymol were identified in *C. spinosa* (Afsharypour *et al.*, 1998).

Capparilosides A **(240)** and B **(241)** (two glucose-containing 1H-indole-3-acetonitrile compounds) were isolated from the mature fruits of *C. spinosa* (Calis *et al.*, 1999).

L-stachydrine **(242)** and choline were isolated from *C. spinosa* var. *aegyptia* (Hammouda *et al.*, 1975). The alkaloidal content of the plant amounted to 0.02 and 0.074 % in the leaves and fruits respectively (Rakhimova *et al.*, 1978).



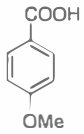
240 Capparilloside A R = H
241 Capparilloside B R = β-D-glucopyranosyl



242 Stachydrine

Several flavonoids were isolated from the different parts of *C. spinosa*. The aerial parts contained rutin (quercertin-3-*O*-rhamnoglucoside) (Ahmed *et al.*, 1972b; Hasler *et al.*, 1992; Rodrigo *et al.*, 1992; Tuerkoez *et al.*, 1995), quercetin 7-*O*-β-D-glucopyranoside-β-L-rhamnopyranoside (Artem'eva *et al.*, 1981), kaempferol-3-glucoside, kaempferol-3-rutinoside, kaempferol-3-rhamnorutinoside (Rodrigo *et al.*, 1992), kaempferol, quercetin, kaempferol-3-*O*-(2"-*O*-β-D-rhamnopyranosyl)-α-L-glucopyranoside , quercetin-3-*O*-β-D-glucopyranosyl and quercetin 3-*O*-(2"-*O*-β-D-rhamnopyranosyl)-α-L-glucopyranoside (Benkinouar *et al.*, 1996). The flowers of *C. spinosa* were reported to contain kaempferol, quercetin and flavonoid glycosides (Tomas and Ferreres, 1976). Rutin amounted to 3.90 % of *C. spinosa* leaves (Tuerkoez *et al.*, 1995).

C. spinosa contained citric, tartaric and oxalic acids (Hammouda *et al.*, 1975), *p*-methoxybenzoic acid **(243)** (Gadgoli and Mishra, 1999) and riboflavin (Benjkinouar *et al.*, 1996).



243 *p*-Methoxybenzoic acid

The flowers were reported to be used as an expectorant, diuretic and stimulant .The juice and volatile fraction of *C. spinosa* had anticystic, fungicidal and bactericidal activities (Rakhimova *et al.*, 1978). The antimicrobial activity of *C. spinosa* extracts has been reported by Mahasneh *et al.* (1996). The antihepatoxic acitivity of *p*-methoxybenzoic acid from the plant was also reported (Gadgoli and Mishra, 1999).

VIII. CHENOPODIACEAE Vent.

1. ATRIPLEX L.

Atriplex is a large widely distributed and cosmopolitan genus of the Chenopodiaceae. *Atriplex* species are herbs or shrubs ranging in size from herbaceous annuals of a few centimeters high to woody perennials of up to 5 meters (Osmond *et al.*, 1980). Some estimates, both on harvest and non-destructive methods, have been made of the net primary productivity of *Atriplex*

species in natural habitats. These estimates showed that a reasonable yield of biomass could be obtained from wastelands (Aslam, 1999). In one long-term study, the average above ground production of an *A. confertifolia* community in Utah over a twelve years span was 195 g dry weight m^{-2} yr^{-1} (Hutchings and Stewart, 1953). Similarly, Goodin (1979) has estimated that sustained yield of 100 g dry weight m^{-2} yr^{-1} were possible in some *Atriplex* communities. The edible biomass of *Atriplex* spp. is a very important feed resource of cattle in arid and semi-arid regions of the world. Protein content was significantly higher in leaves than in the stems of *A. cordobensis* throughout the year. This high protein content adequately met the nutritional requirements of cattle in dry marginal areas (Aiazzi *et al*., 1999). The chemical characteristics of *A. lampa* leaves were: protein, 26.93; ash, 21.80; ether extract 4.65; dry matter, 37.30; Na, 6.05 and Ca, 0.41 (g/100 g) (Fernandez *et al*., 1999).

The results of a two-year study on *Atriplex* survival in Jordan indicated that *A. canascens*, *A. halimus*, *A. lentiformis*, *A. nummularia* and *A. polycarpa* had survived the dry conditions of Al-Muwaqar (Jordan) whereas two other species *viz. A. amincola* and *A. undulata* were not able to withstand these conditions. *A. halimus* and *A. polycarpa* were found to be the most productive after two years of establishment in a low-flood land with deep soil; they produced 1,088 and 577g dry matter/bush, respectively. The productivity of *Atriplex* species (taking into account of percentage average survival) could amount to about 0.5 t/ha of dry matter for both *A. halimus* and *A. polycarpa* (Abu-Irmaileh, 1994). The total consumable dry matter of *A. halimus*, produced in the semi-arid lands of Sicily was 1.66 t/ha, with a crude protein content ranging from 11.6 to 23.3 % and a high NaCl content (Stringi *et al*., 1991).

Atriplex species are considered highly salt-tolerant as evidenced by their natural occurrence on salty land in dry environments. In aerated culture solutions, they were reported to grow at high electrolyte concentrations and several of them had a growth optimum at 50 to 200 m^{-3} external NaCl (Flowers *et al*., 1977; Greenway and Munns, 1980; Munns *et al*., 1983; Aslam, 1999). Habitats occupied by *Atriplex* species are often characterized by moderate to high aridity, high temperature, salinity, alkalinity, and low nutrient availability. Such salt-affected soils for which reclamation was inappropriate could potentially be used to obtain forage from *Atriplex* species (O'Leary, 1983; Malcolm, 1986; Aslam, 1999). Salt tolerance of several *Atriplex* species have been reported e.g. *A. amnicola* (Aslam *et al*., 1986), *A. canescens*, *A. cuneata* (Richardson and Mckell, 1980; Glenn *et al*., 1994), *A. halimus* (Zid and Boukharis, 1977), *A. littoralis* (Bigot and Binet, 1979), *A. nummularia* (Uchiyama, 1985, 1986), *A. nitens* (Priebe and Jaeger, 1978) *A. rhagodioides* (Mahmood and Malik, 1987) and *A. spongiosa* (Storey and Jones., 1979). Richardson and Mckell (1980) reported that because of the high salt tolerance of *A. canescens* and *A. cuneata*, these saltbush species may be very important in the rehabilitation of processed oil shale disposal sites. The effects of external sodium chloride on the growth of *A. amnicola* and the ion relations and carbohydrate status of the leaves were studied by Aslam *et al.* (1986). The results obtained showed that the Na^+ content in moles per leaf, excluding the bladders, increased linearly with the age of the leaves and a concurrent increase in succulence was closely correlated with the Na^+ concentration. There was a pronounced diurnal fluctuation in concentrations of carbohydrates. During the night, most plant parts showed large decrease in starch and sugar. However, concentrations of carbohydrates in most plant organs were similar in plants grown at 25 and 400 mol m^{-3} NaCl (Aslam *et al*., 1986). According to Osmond *et al.* (1980), *Atriplex* spp., though do not require other than trace amounts of Na^+ for normal growth, yet they frequently grow better in the presence of

Two hydroxycinnamic acid esters have been isolated from cell suspension cultures of *C. rubrum* and identified as 1-*O*-(*E*)-*p*-coumaroyl- and 1-*O*-(*E*)-ferruloyl-(β-[1→2]-glucuronosyl)-β-glucose (Bokern *et al.*, 1987).

Trace-element concentration (Cu, Pb, Zn, Ag, Co, Ni, Cr, Mo, Sn, Sb, Mn, V, Bi, Cd, Ge, W, As, and B) was determined in *C. glaucum* (Rainau *et al.*, 1985). The elements detected in *C. acuminatum* were: Mg, Ca, Zn, K, Mn, Fe, Co, Pb, Na and Cu (Kim and Lee, 1986). *C. rubrum* was among the plants classified by Radman and Fedec (1987) as chloride halophytes with ion composition dominated by Na and Cl; while *C. salinum* was classified as an alkali halophyte with relatively high K, Mg, and Ca and low Cl contents.

More than twenty *Chenopodium* species have been for various reasons considered toxic or potentially toxic. However, the anthelmintic properties of these species were also reported (Rizk, 1986). *C. ambrosioides* has been used as nervine, antirheumatic, anthelmintic and emmenagogue agent. The methanol extract of *C. ambrosioides* showed a hypothermic effect as well as inhibition of acetic acid-induced writhing in mice (Okuyama *et al.*, 1993). Aqueous and ethanolic extracts of *C. ugandae* prossessed molluscicidal potency, exhibiting high mortality rate (100 %) against *Biomphalaria pfeifferi* and *Lymnaea natalensis* (Chifundera *et al.*, 1993).

2.1. *Chenopodium album* L., Sp. Pl., ed. 1, 218 (1753).

Samghat reeh (Ar.)

Erect annual herb with a tap root. Stem with many ribbed leafy branches. Leaves alternate, variable in shape usually ovate-rhomboid with entire to slightly toothed margins. Inflorescences terminal and axillary compound spikes of minute greenish flowers. Fruit a 1-seeded utricle; seeds black.

Habitat and distribution

A cosmopolitan weed of gardens, fields, roadsides and arable land.

The plant is a common weed and has been used in Europe, India and U.S.A. as a pot-herb and as spinach (Watt and Breyer-Brandwijk, 1962). Formerly, the leaves were consumed as a vegetable until replaced by spinach. Seeds were ground to flour and fruits were eaten by poultry (Mabberley, 1993). The young leaves are used as a salad for human consumption (Lavaud *et al.*, 2000).

Constituents

The nutrient composition of the seeds (growing in India both as a pot herb and as a crop) showed that they were a good source of protein (14 %), fat (7.3 %), niacin (3.5 mg/100 g), and Ca (300 mg/100 g). Being rich in lysine content (4.1 g/16 g N), this pseudocereal has been reported as a good protein supplementary value in diets based on common cereals and millets (Deosthale, 1981). The analysis of *C. album*, growing in Pakistan, showed that it contained a sufficient amount of carbohydrate 4.33 %, fiber 9.032, protein 1.024 %, fat 0.216 %, ash 3.138 % and water 82.26 %. (Dahot and Soomro, 1997). The protein content of *C. album*, growing in Argentina, amounted to 25 % dry matter (Escudero *et. al.*, 1999b). *C. album* has been reported to contain relatively high amounts of vitamin C and carotenoids (Guerrero and

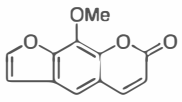
lsasa, 1997; Guil *et al.*, 1997). Ascorbic acid (vitamin C) + dehydroascorbic acid content amounted to 155 mg/100 g (Guil *et al.*, 1997). Folic acid, thiamine, niacine and ribone were detected in the plant (Dahot and Soomro, 1997). The nutritional and antinutritional compostition of *C. album* leaves are shown in Table 20 (Prakash and Sharma, 1995). Vitamin A content of *C. album* was 13,000-15,000 IU/100 mg fresh weight (Aliotta and Pollio, 1981). The presence of antinutritional and toxic principles e.g. oxalic acid and nitrates, has been reported as amounting to 1100 ±610 and 350±47 mg/100g in edible leaves respectively (Guil *et al.*, 1997). A high content of oxalic acid in goosefoot (*C. album*) with a range values from 360 to 2000 mg/100 g of fresh weight was also reported (Guil *et al.*, 1996b). The seeds of *C. album* contained 11.2 % protein (Prakash and Pal, 1998), the amino acid composition of which is shown in Table 21. The accumulation of nitrate occurred mostly in the stem (Vetter, 1996).

C. album seeds contained 7 % oil, which consisted primarily (99.3 %) of neutral lipids (mainly triglycerides) but including hydrocarbons, wax esters, sterols, free fatty acids, mono and diglycerides and only 0.7 % of polar lipids. The oil consisted mainly of unsaturated fatty acids (82.4 %) having a higher percentage of oleic acid (42.3 %) as compared to linoleic acid (35.8 %) (Riaz *et al.*, 1993). The lipids amounting to 0.59 % in the aerial parts (dry weight) contained the following fatty acids: $C_{14:0}$, 0.66; $C_{16:0}$, 15.68; $C_{16:3}\omega_3$, 0.31; $C_{16:2}\omega_6$, 0.31; $C_{18:0}$, 1.69; $C_{18:3\omega3}$, 44.82; $C_{18:4\omega3}$, 0.17; $C_{18:2\omega6}$, 15.86; $C_{18:1\omega9}$, 2.90; $C_{20:0}$, 0.23; $C_{20:5\omega3}$, 0.36; $C_{20:3\omega6}$, 0.17; $C_{20:4\omega6}$, 1.30; $C_{22:0}$, 1.00 and $C_{24:0}$, 0.61 % (Guil *et al*, 1996b).

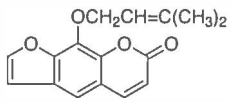
Daun and Tkachuk (1976) reported the fatty acid composition of the seed oil (9.1 %) as follows: $C_{14:0}$, 0.3; $C_{16:0}$, 8.4; $C_{16\,1}$, 0.3; $C_{18:0}$, 0.9; $C_{18:1}$, 20.7; $C_{18:2}$, 56.3; $C_{18:3}$, 6.5; $C_{20:1}$, 2.3; $C_{20:2}$, 0.5; $C_{22:0}$, 0.3; $C_{22\,1}$, 3.6 and $C_{24:0}$, 0.3 %.

The 4-demethylsterols from leaves, roots and cell cultures of *C. album* were a mixture of Δ^7-sterols (> 61 %) and Δ^5-sterols (> 36 %). The Δ^7-sterols were 24-ethylcholesta-7,22-dien-3-β-ol and 24-ethylcholest-7-en-3-β-ol. The isolated Δ^5-sterols were sitosterol and stigmasterol. Traces of cholesterol and $\Delta^{5,7}$-sterols were also detected (Corio-Costet *et al.*, 1993). Sitosterol and 22-dehydrospinasterol also occurred in *C. album* (Salt and Alder, 1985).

Mukherjee *et al.* (1985) detected two cytotypes, one diploid (2n = 18) and one hexaploid (2n = 54) in *C. album* from West Bengal, India. Chemical differences existed in the seeds of the 2-cytotypes. The diploid contained β-sitosterol, campesterol and xanthotoxin (**259**), whereas the polyploid contained stigmasterol, *n*-triacontanol, scopoletin, and imperatorin (**260**) along with a hydrocarbon. Chemical investigation of seeds of the broad leaf diploid cytotype *C. album* showed the presence of cryptomeridiol and 8-acetoxycryptomeridiol (Bera *et al.*, 1991). Octatetracontane, ($C_{48}H_{98}$), tetracos-1-ene ($C_{24}H_{48}$), octadec-1-ene ($C_{18}H_{36}$), pentatriacontane ($C_{35}H_{72}$), pentatriacont-1-ene ($C_{35}H_{70}$) and lupeol were isolated from the seeds of the diploid cytotype. The growth-retarding activity of tetracos-1-ene, octadec-1-ene, pentatriacontane and pentatriacont-1-ene were reported (Bera *et al.*, 1992). Existence of germination inhibitors in the mature seeds of *C. album* was earlier reported (Watanabe, 1970a,b). The hydrocarbon fraction of the cuticular leaf wax contained C_{22} to C_{31} *n*-alkanes with *n*-nonacosane as the principal component. Thirteen aldehydes, *n*-C_{18} to *n*-C_{32} alcohols with *n*-octacosanol as the major component and six alcohol acetates, free and esterified acids have been also detected (Rizk, 1986).

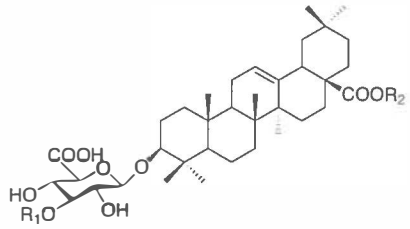


259 Xanthotoxin

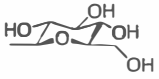


260 Imperatorin

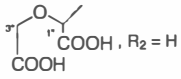
Lavaud *et al.* (2000) isolated three saponins from the roots of *C. album*. One of them was a *seco*-glycoside analogous to compounds that were previously found in species belonging to the order Caryophyllales. The saponins were identified as calenduloside E (3-*O*-β-D-glucuronopyranosyl oleanolic acid, **261**), chikusetsusaponin IVa (**262**) and 3-*O*-[3'-*O*-(2"-*O*-glycolyl)-glyoxylyl-β-D-glycopyranosyl] oleanolic acid (**263**).



261 Calenduloside E; $R_1 = R_2 = H$
262 Chikusetsusaponin; $R_1 = H$, $R_2 =$

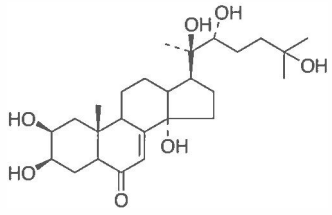


263 $R_1 =$



, $R_2 = H$

β-Ecdysone (**264**) and polypodine B were isolated from *C. album* roots (Toth *et al.*, 1981). The presence of these ecdysteroids in *C. album* suggested that its use as a refreshing vegetable might have a sound basis (Toth *et al.*, 1981).



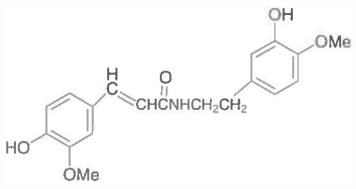
264 β-Ecdysone

The issue of Zn, Cu, Pd, Cd, Ni and Cr accumulation in *C. album* in the context of its possible use for treatment of sludge and waste substrates was discussed by Porebska and Ostrowska (1999). Roots of *C. album* have been reported to accumulate more Zn than above ground parts (Koehl *et al.*, 1995).

Choline (Bernard *et al.*, 1983) and glycinebetaine (Weigel and Larher, 1985; Adrian-Romero *et al.*, 1998) were detected in white pigweed *C. album* herb.

Several flavonoids have been found in *C. album viz.* kaempferol-3-*O*-β-diglucoside, kaempferol-3-*O*-arabinoglucoside, quercetin, quercetin-3-*O*-xylosylglucoside and quercetin-3-rhamnoglucoside (Bahrman *et al.*, 1985; Bylka and Kowalewski, 1997; Gallardo and De Israilev, 1998).

A phytotoxin, chlorogenic acid (a growth inhibitory compound) was isolated from the air-dried lambsquarters (*C. album*) (Mallik *et al.*, 1994). A phenolic amide (*N-trans*-feruloyl-4-*O*-methyldopamine, **265**) was isolated from the roots. It showed attracting activity toward the zoospores of *Aphanomyces cochlioides*, a pathogenic fungus against some plants of the Chenopodiaceae (Horio and Yoshida, 1993).



265 *N-trans*-Feruloyl-4-*O*-methyldopamine

C. album has been shown to contain traces of ascaridole, sitosterol, oleanolic acid and an antifungal substance (Rizk, 1986). Mucondialdehyde (*trans*-2-*trans*-4-hexadiendial) was identified as a stress metabolite from the leaves induced by cupric chloride (Tahara *et al.*, 1994).

Cyanogensis has been reported in some plants of *C. album* (Aikman *et al.*, 1996). The most active fraction of the allergenic component(s) from the respiratory allergen of *C. album* pollen has been separated as a protein with a molecular weight of 24,000 (Jamil *et al.*, 1977).

2.2. ***Chenopodium murale*** L., Sp. Pl., ed.1, 219 (1753).

Khaisa, Zurbaich (Ar.)

Erect leafy weed with herbaceous furrowed stem. Branches varying in height according to growth condition from 10 to 80 cm, soft. Leaves soft, large, distinctly toothed with varying petiole lengths and shapes commonly ovate-romboid. Inflorescences much branched spikes of small green flowers with fleshy perianth. Fruit a 1-seeded utricle; seeds black.

Habitat and distribution

Much more widespread than *C. album* and equally cosmopolitan. In Qatar under avenue trees, in gardens, parking areas, roadsides and a notrorious weed of vegetable plots.

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *C. murale*, growing in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d).

Crude protein amounted to 22.42 % in *C. murale*, growing in Egypt. Rhamnose, xylose, arabinose, glucose, fructose, galactose, sucrose and raffinose as well as traces of cellobiose and galacturonic acid were identified in the plant (Hifanawy *et al.*, 1999a).

A study of the various fractions of the plant, a favourite forage plant for cattle and sheep, showed that it contained 21.3 and 4 % protein, dry and wet weights respectively, of which 84.3 % was digestible. The following values were found (%) dry and wet weights: ash, 16.2, 3.0; Ca, 1.0, 0.37; P, 0.54, 0.1. The values for crude protein, ash, Ca and P in the leaves were ~ 2.5 times those for stems. The values for crude cellulose and crude fiber in the stems were ~ 3 times those for the leaves. The digestibility of the crude cellulose was greater than that for the crude fiber, but less than that for the non-N extract. The calculated nutritive value of *C. murale* was said to be comparable with that of good forage plants (Proto, 1961-1962).

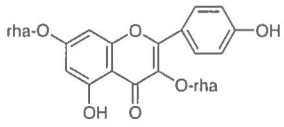
The nutritional and antinutritional composition of *C. murale* leaves, growing in Pakistan are shown in Table 20 (Prakash and Sharma, 1995) and the amino acid composition of the seeds is shown in Table 21 (Prakash and Pal, 1998). The plant contained 11.2±2.1 carotenoids, ascorbic acid 112±16 and dehydroascorbic acid 21±6 mg/100 g edible leaves (Guil *et al.*, 1997).

The lipids of the aerial parts, amounting to 0.43 % (dry weight), contained the following fatty acids: $C_{14:0}$, 0.48; $C_{16:0}$, 16.82; $C_{16:2\omega6}$, 0.43; $C_{16:1\omega7}$, 1.46; $C_{18:0}$, 16.6; $C_{18:3\omega3}$, 30.04; $C_{18:4\omega3}$, 0.14; $C_{18:2\omega6}$, 17.86; $C_{18:1\omega7}$, 0.55; $C_{18:1\omega9}$, 6.96; $C_{20:0}$, 0.72; $C_{20:5\omega3}$, 0.41; $C_{20:4\omega6}$, 1.01; $C_{22:0}$, 1.37 and $C_{24:0}$, 2.22 % (Guil *et al.*, 1996b).

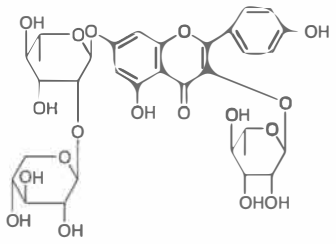
The presence of antinutritional and toxic principle *viz.* oxalic acid and nitrates, has been reported to amount to 1010±520 and 341±76 mg/100g edible leaves, respectively (Guil *et al.*, 1997).

Several flavoniods have been isolated from *C. murale viz.* quercetin, kaempferol (Bahrman *et al.*, 1985; El-Sayed *et al.*, 1999), kaempforel-3,7-dirhamnoside (kaempferitrin (**266**) or hespedin) (Gohar and Elmazar, 1997), kaempferol-3-rhamnoside-7-xylosyl(1→2)-rhamnoside (**267**), kaempferol-7-rhamnoside, kaempferol-3-rhamnoside-7-glucoside, herbacetin and quercetin (El-Sayed *et al.*, 1999). The coumarin scopolotin was also isolated from the plant (El-Sayed *et al.*, 1999).

Kaempferitrin, as well as the total flavonoid mixture on the rabbit cardiovascular system showed related hypotension and bradycardia. It also produced a dose-related hypotension in genetically prone hypertensive rats (Gohar and Elmazar, 1997).

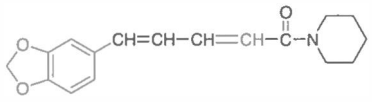


266 Kaempferitrin



267

Piperine (**268**) was isolated from *C. murale* (Hifnawy *et al.*, 1999b). The presence of alkaloids in the plant was reported by several investigators (Rizk, 1986). *p*-Cymene, ascaridole and aritazone (terpenes) were found in leaves and infloresences of *C. ambrosioides* and *C. murale* (Datta and Ghosh, 1987).



268 Piperine

3. *CORNULACA* Delile

3.1. ***Cornulaca monacantha*** Delile, Descr. Eygypt, Hist. Nat. 20b, t 22 f 3 (1814).
syn. *Cornulaca aucheri* Moq., Chenop. Monogr. Enum 163 (1840).

Thallej, Hadh (Ar.)

Low spiny undershrub with stunted, spiny deflexed leaves up to 30 cm high. Flowers clustered, minute, surrounded by spiny spikes. Fruit spiny. Plant drying to brown spiky bushes during dry season and with pale green growth during wet season. Flowers September.

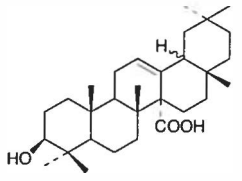
Habitat and Distribution

Sandy saline soils near coastal areas. Common in Salwa, Um Bab and Dukhan areas.

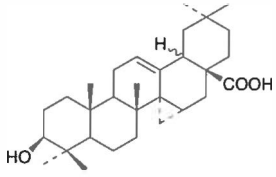
Constituents

The proximate analysis and minerals of *C. monacantha*, growing in Qatar, are shown in Tables 175 and 178 (Al-Easa, 2002a,d). The unsaponifiable matter of the lipid of the plant growing in Qatar contained sterols (17.48 %), hydrocarbons (45.0.2 %), aliphatic alcohols (27.70 %), 4-methylsterols (2.14 %) and triterpene alcohols (7.66 %). The following hydrocarbons were identified: $C_{21:0}$, 1.25; $C_{23:0}$, 1.60; $C_{24:0}$, 1.22; $C_{25:0}$, 5.80; $C_{26:0}$, 2.43; $C_{27:0}$, 12.75; $C_{29:0}$, 29.01; $C_{30:0}$, 9.01; $C_{31:0}$, 18.31; squalene, 9.72 and unidentified others (8.88 %). The following fatty alcohols were also identified: $C_{20:0}$, 11.08; $C_{22:0}$, 21.61; $C_{24:0}$, 30.80; $C_{26:0}$, 19.37; $C_{27:0}$, 3.44; $C_{28:0}$, 10.68 and unidentified others, 3.03 %. The sterol fraction consisted of stigmasterol (48.92 %), β-sitosterol (38.94 %), cholesterol (12.14 %) and traces of campesterol (Al-Easa *et al.*, 2002).

The plant contained three sterols (including fucosterol) (Dawidar and Amer, 1974). Several pentacyclic triterpenoids (e.g. cornulacic (**269**), monacanthic (**270**) and epiketonic acids) were isolated from *C. monacantha*, growing in Egypt and Saudi Arabia (Amer *et al.*, 1974; Dawidar *et al.*, 1980; Al-Jaber *et al.*, 1991). Recently, Kamel *et al.* (2000) isolated from the aerial parts of *C. monocantha* three new triterpenoidal saponins identified as 3-*O*-[β-xylopyranosyl(1→3)-β-glucopyranosyl)]-30-methylphytolaccagenate, 3-*O*-[β-xylopyranosyl-(1→3)-β-glucopyranosyl)]-30-methylphytolaccagenate-28-*O*-β-glucopyranoside and 3-*O*-[β-xylopyranosyl-(1→3)-β-glucopyranosyl)]-30-methylserjanate 28-*O*-β-glucopyranoside, together with nine known saponins of oleanolic acid, hederagenin and 30-methylphytolaccagenate.



269 Cornulacic acid



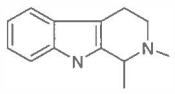
270 Monacanthic acid

Phytochemical screening of *C. monacantha*, growing in Qatar, revealed the presence of alkaloids, coumarins, saponins and sterols (Rizk *et al.*, 1986a).

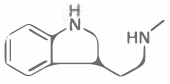
4. HALOXYLON Bunge (*HAMMADA* Iljin.)

A number of alkaloids have been isolated and identified in some *Haloxylon* species: leptocladine (**271**), dipterine (**272**) and eleagnine (**273**) from *Hammada leptoclada* (Orzakuliev *et al.*, 1964).

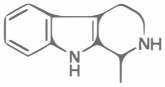
Several alkaoids were isolated from *Hammada articulata* subsp. *scoparia viz. N*-methylisosalsoline (**274**), carnegine (**275**) (Carling and Sandberg, 1970) isosalsoline (**276**), salsolidine (**277**), dehydrosalsolidine (**278**), isosalsolidine (**279**), *N*-methylcorydaldine (**280**), tryptamine (**281**), *N*-ω-methyltryptamine (**282**) and tetrahydroharman (**283**) (Benkrief *et al.*, 1990). Alkaloids were also identified in *Hammada varkhanica* (Sadykov, 1987). A flavonoid (isorhamnetin-3-*O*-β-D-robinobioside) (**284**) was isolated from *Hammada articulate* subsp. *scorparia* (Benkrief *et al.*, 1990). Alkaloids, cardiac glycosides, flavonoids, sterols, volatile oil and bases, tannins, coumarins and saponins were detected in *Hammada salicornica.* The latter species possessed antidiabetic activity (Ajabnoor *et al.*, 1984). Glycinebetaine of *Haloxylon recurvum* was reported to increase with increasing salinity (Khan *et al.*, 1998).



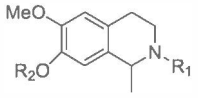
271 Leptocladine



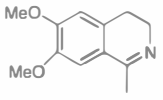
272 Dipterine



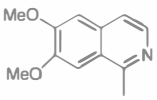
273 Eleagnine



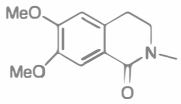
274 *N*-Methylisosalsoline; R_1= Me, R_2=H
275 Carnegine; R_1= R_2=Me
276 Isosalsoline; R_1=R_2=H
277 Salsolidine; R_1= H, R_2=Me



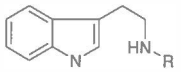
278 Dehydrosalsolidine



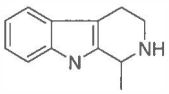
279 Isosalsolidine



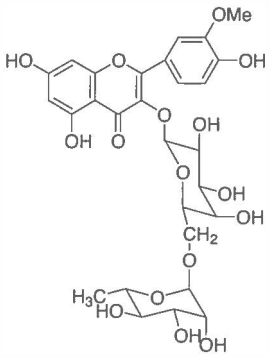
280 *N*-Methylcorydaldine



281 Tryptamine; R=H
282 *N*-ω-Methyltryptamine; R=Me

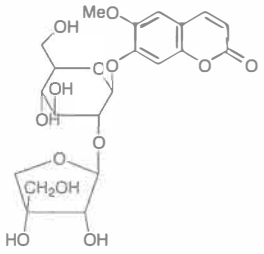


283 Tetrahydroharman

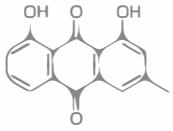


284 Isorhamnetin-3-*O*-β-D-robinobioside

Twenty-six volatile compounds were identified in *Haloxylon schmittiana.* Hydrocarbons, constituting 53.08 % of the oil, consisted of aliphatic as well as monoterpenes and sesquiterpenes; α-pinene **(285)** (9.4 %) and camphene **(286)** (9.3 %) were the major hydrocarbons, while the major sesquiterpenes were caryophyllene **(287)** (2.8 %), longifolene **(288)** (2.52 %), germacrene-D **(289)** (2.4 %) and β-farnesene **(290)**. The volatile oil exhibited

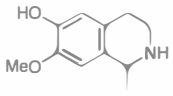


300 Lariside

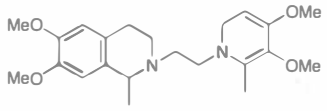


301 Chrysophanol

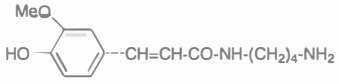
The isoquinoline alkaloids, salsoline (**302**) and salsolidine represented the most common alkaloids in the studied species *viz. S. collina*, *S. kali*, *S. pestifera*, *S. richteri*, *S. ruthenica*, and *S. subaphylla* (e.g. Ryabinin and Il'ina, 1949; Proskurnina, 1958; Borkowski *et al.*, 1959; Mushinskaya *et al.*, 1975; Dauletmuratov and Komarova, 1980; Sadykov and Khodzhimatov, 1985; Rizk, 1986). Leaves and fruits of *S. richteri* contained 0.17-0.8 and 0.32-1.25 % dry weight alkaloids respectively. Salsoline was the main alkaloid (62.5-72.1 % of total alkaloids) (Dauletmuratov and Komarova, 1980). Pakanaev *et al.* (1980) reported that substantial alkaloids amounting to 0.5-3.1 % were found in leaves, flowers and especially seeds of *S. richteri.* During fruiting the leaves, stems, seeds, and roots of *S. pestifera* contained 0.32, 0.24, 0.51 and 0.01 air-dry weight % total alkaloids respectively. Salsoline and salsolidine made up 78.67-83.08 and 10.63-14.52 % of the total alkaloids respectively (Sadykov and Khodzhimatov, 1985). Other alkaloids have been isolated e.g. salsamine (**303**) from *S. richteri* (Rizk, 1986), subaphylline (**304**) from *S. subaphylla* (Ryabinin and Il'ina, 1949) and triacetonamine from *S. kali*, *S. longifolia*, *S. rigida* and *S. tetrandra* (Karawya *et al.*, 1971b). Methyl carbamate (**305**) (a volatile nitrogenous base) was identified in the last four species (Karawya *et al.*, 1972c).



302 Salsoline



303 Salsamine



304 Subaphylline

CH_3COONH_2

305 Methyl carbamate

Pollen of *S. kali* is one of the most allergenic and widely distributed pollens in Tehran (Shaffii, 1977). Two allergen proteins were isolated and characterized from *S. pestifer* pollen grains (Shafiee *et al.*, 1981). The hypotensive effect of salsoline and salsolidine has been reported (Shvarev, 1958; Borkowski and Wrocinski, 1959; Allaberdin, 1971). Preparations of *S. paletzkiana* have a pronounced vasoconstrictor, hypertensive and cardiac-stimulant activities (Gavrilyuk, 1940). The antispasmodic and anthelmintic activities of *S. tetrandra* have been reported (Zahran and Negm, 1974). The flavonoids from *S. rosmarinus* possessed antimicrobial activity (Mahmoud *et al.*, 1989). Hepato-protective effect of *S. collina* extract was reported by Vengerovskii *et al.* (1995).

Basson *et al.* (1969) reported that grootlamsiekte, a specific syndrome of prolonged gestation in sheep was caused by *S. tuberculata* var. *tomentosa*.

5.1. ***Salsola cyclophylla*** Baker, Bull. Misc.Inf. Kew 1894:340 (1894).

Hamd (Ar.)

Low woody undershrub with intricate stiff branches, up to 25 cm high usually less due to extensive grazing. Branches sharp-pointed, whitish, with minute sessile dwarf and scale-like leaves. Inflorescences axillary fascicles of minute greenish flowers. Calyces persistent in fruit developing into membranous wings encircling the fruit.

Habitat and Distribution

Frequent on stony ground in southern Qatar and coastal areas near Ras Ushairij where it forms a mixed community with *Zygophyllum qatarense* and *Limonium axillare* and sporadic elsewhere in particular the land between Al-Rayan and Al-Shahaneya.

Nothing has been reported on the constituents of this species.

5.2. ***Salsola imbricata*** Forssk., Fl. Aegypt.-Arab. CVII, CVIII, 57 (1775).

syn. *Salsola baryosma* (Roem. et Schult.) Dandy in Andrews, Fl. Pl. Anglo-Egypt. Sudan 1:111 (1950); *Chenopodium baryosmom* Schult ex Roem. et Schult., Syst. Veg., ed. 15, 6:269 (1820); *Salsola foetida* Delile ex Spreng., Sept. Veg. 1:925 (1824).

Hamd Zefer (Ar.)

Evergreen low much-branched woody undershrub up to 60 cm high and forming mats spreading up to 1.5 cm across with succulent young shoots and whole plant with distinct sardine/fishy odor. Leaves with rudimentary laminas and bases clasping and encircling branches. Mature branches bare. Inflorescences spicate, of minute green flowers with distinct calyces that enlarge and turn pappery and persistent in fruit (appearing as white flowers).

Habitat and Distribution

Widespread and is the most common succulent undershrub on saline coastal soils beyond the tidal zone. Plants can respond to extreme heat stress by partial physiological death of older branches. As a salt-tolerant plant, it is widespread in sabkhas (saline depressions and salt flats) and may be encountered in moist habitats, sewage disposal areas, edge of agricultural fields and as a roadside weed in residential areas throughout with lush pale green growth. It is the most common plant in Doha.

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *S. baryosma*, growing in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d). The seeds of *S. baryosma*, collected from Pakistan, contained Cl, 0.98; Na, 3.09; Mg, 0.40; K, 0.62 and Ca, 0.285 mmol g^{-1} dry weight (Khan and Ungar, 1996). Seasonal variation in chloride ion percentage of *S. baryosma*, growing in India, in relation to the salt basin, was studied (Rajpurohit and Sen, 1979). The highest value of all minerals observed was at the depth of 75 cm (2.56 and 2.60 % in April and May respectively), whereas the minimum value was in June and July (0.07 and 0.03 % respectively) at the surface.

Phytochemical screening of *S. baryosma*, growing in Qatar, revealed the presence of alkaloids, coumarins, saponins and sterols (Rizk *et al.*, 1986a).

5.3. ***Salsola schweinfurthii*** Solms, Bot. Zeitung (Berlin) 59:173 (1901).
syn. *Darniella schweinfurthii* (Solms) Brullo, Webbia 38:313 (1984).

Hamd (Ar.)

Unramed shrub reaching up to 50 cm high with whitish young branches and fissured older branches. Leaves sessile, alternate. Inflorescences of few flowers on axillary spikes. Fruit winged.

Habitat and Distribution

Reported by Batanouny (1981) as occasional on saline soil of southern Qatar and by Boulos (2000) as a plant reported in Saudi Arabia and Oman of the Gulf Countries.

Constituents

The protein and neutral sugar content of *S. schweinfurthii*, growing in Egypt, amounted to 83.6 and 15.3 mg/g dry weight (Turki, 1998).

5.4. ***Salsola soda*** L., Sp. Pl., ed. 1, (1753).

Hamd (Ar.)

Rare small annual herb up to 15 cm high. Plant succulent, ash-green usually with purple tinge. Leaves sessile, fleshy.

Habitat and Distribution

Occurs in association with *Avicennia marina* on muddy coastlines in N.E. Qatar at Al-Khor, Al-Dhakhira and Ras Al-Madbakh.

Constituents

Rovesti (1940) recommended the use of *S. soda* and others, as vegetable substitutes for fats in the manufacture of soap. *S. soda*, growing in Poland, contained salsoline (Borkowski *et al.*, 1959).

Phytochemical screening of *S. soda*, growing in Qatar, revealed the presence of alkaloids, coumarins, flavonoids and sterols (Rizk *et al.*, 1986a).

5.5. ***Salsola vermiculata*** L., Sp. Pl., ed. 1, (1753).

Hamd (Ar.)

An annual suffruticose succulent herb growing up to 30 cm high. Much related to *Salsola imbricata* but rather hairy and with non-rudementary succulent leaves. Similar to other *Salsola* species in flowering and fuiting.

Habitat and Distribution

A roadside species and also at the edges of cultivated ground and large parks. Common in Doha, rare in the wild.

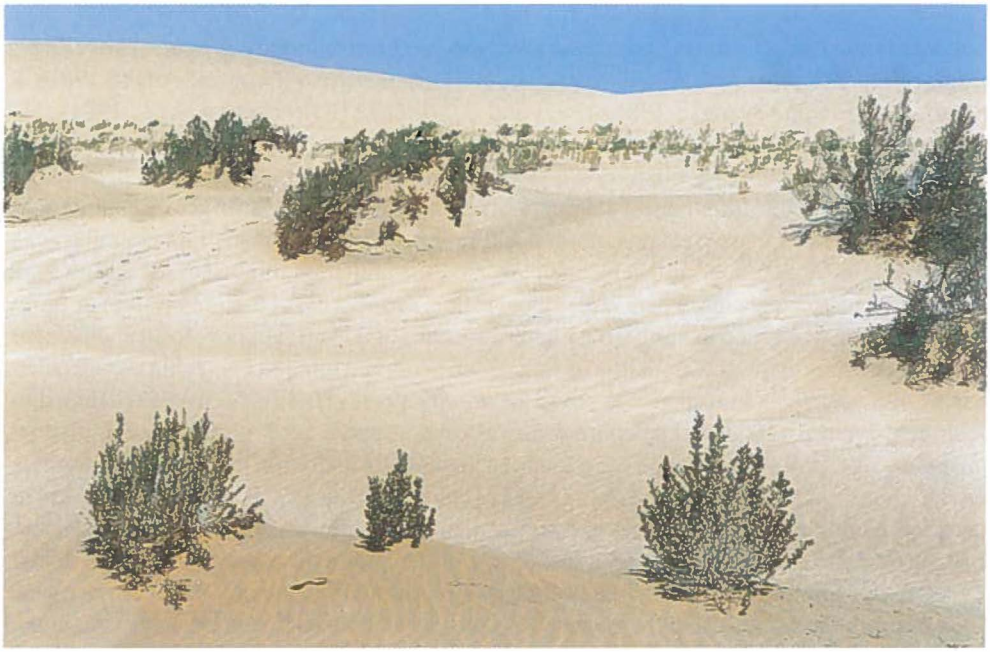
Constituents

S. vermiculata, growing in Iraq, was reported as a good indicator of sodium carbonate formation and indicated low salinity in sandy soils and low to high salinity in heavier soils. It is an excellent indicator of deep ground waters (at depth greater than 2 m) (Habib *et al.*, 1971).

6. *SEIDLITZIA* Bunge ex Boiss.

6.1. ***Seidlitiza rosmarinus*** Bunge ex Boiss., Fl. Orient. 4:951 (1879).
syn. *Suaeda rosmarinus* Ehrenb. ex Boiss., pro syn. *Salsola rosmarinus* (Bunge ex Boiss.) Solms, Bot. Zeitung (Berlin) 59:171 (1901).

Shenan (Ar.)



Low woody perennial halophytic shrub with succulent young shoots and leaves. Stem basal with many whitish branches. Leaves sessile succulent, opposite, terete [in poor growth it resembles *Anabasis setifera*]. Inflorescences axillary, of small flowers. Fruit winged.

Habitat and Distribution

Seidlitiza is an excellent sand stabilizer with its low growth trapping moving sand and debris. It is common south of Sealine (Masaeed) the area of Bargan sand dunes and the sandy shores N. Doha (Thaileb). It has been reported in a number of locations along Qatar's coastline throughout on saline sandy soils. In the past *Seidlitiza* was used as a soap substitute and a tenderizer of beans.

Table 30. Chemical composition of *S. aegyptiaca*

Constituents	%
Moisture	84.75
g/100 g dry material	
Protein	10.50
Lipids (ether ext.)	1.64
Crude fibre	5.93
Soluble carbohydrates	22.33
Mucliage	2.10
Ash	39.82
Carbohydrates (by difference)	
mg/100 g dry material	17.68
Iron (10)*	10.08
Zinc (15)*	4.54
Copper (2.0-3.0)*	0.70
Manganese (2.5-5.0)*	6.98

* mg/day Recommended Dietary Allowance (1980).

The protein level of *Schanginia aegyptiaca* approached that found in cereals, especially rice and corn. The amino acids pattern (Table 31) of the protein clearly demonstrated that both lysine and methionine were limiting in the protein.

Table 31. Amino acid composition of *S. aegyptiaca* with reference to the FAO pattern (mg/g N)

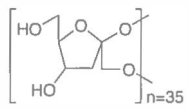
Amino Acids	FAO Ref. Pattern	Egg protein	*S. agyptiaca*	Chemical score
Essential Amino Acids				
Lysine	344	487	216	63
Methionine		200	61	
Cystine		131		
(*Total sulphur*)	(*219*)	(*331*)	(*61*)	
Phenylalanine		344	182	
Tyrosine		237	135	
(*Total aromatic*)	(*375*)	(*581*)	(*217*)	
Leucine	437	550	296	68
Isoleucine	250	369	156	62
Valine	312	444	134	43
Threonine	250	306	177	71
Tryptophan	62	87		
Total-cystine-tryptophan		2937	1357	
Non-essential Amino Acids				
Aspartic acid	626	359		
Glutamic acid	816	406		
Alanine	382	220		
Proline	203	159		
Serine	450	205		
Glycine	199	234		
Arginine	454	184		
Histidine	196	88		
Total	3326	1855		
E/T* %	46.9	42.2		

* Total = Essential A. A. + Non-Essential A. A. -cystine – tryptophan; Rizk *et al.* (1984).

The free sugars of *Schanginia aegyptiaca* were identified as glucose, galactose and sucrose, and the components of the mucliage (2.1 %) as glucuronic acid, galacturonic acid, galactose, arabinose, rhamnose and an unidentified sugar (Rizk *et al.*, 1984).

The sterol fraction of *Schanginia aegyptiaca* consisted of stigmasterol (56.31 %), β-sitosterol (38.14 %), campesterol (5.55 %) and traces of cholesterol. The fatty acids pattern of this plant was reported as characteristic with low chain saturated fatty acids absent and palmitic acid representing the major constituent (52.85 %). The saturated myristic (0.46 %) and stearic (6.04 %) acids were also present. Palmitoleic and linolenic acids were detected as traces, and a high content of the essential fatty acids (59.35 %) was reported. The very high ash content (39.82 %) reflected the particular origin of this plant, which grows on saline soils. The iron content, as compared with the recommended allowances may help in alleviating the iron deficiency anaemia. The plant may be considered as a nutritional supplement (Rizk *et al.*, 1984).

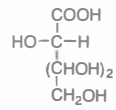
storage (Ernst *et al.*, 1996). The levels of sucrose and fructose in chicory (*C. intybus* var. *foliosum*) roots remain about the same over the growing season, while the levels of total non-structural carbohydrates (TNC) and fructans increased. At the onset of cooler fall temperatures and especially during storage, sucrose and fructose contents increased. Concurrently, the second fructan series that contained no glucose (inulo-*n*-ose, n = 2-18) accumulated, while at the same time, fructans (inulin) with a high degree of polymerization (DP) and TNC decreased. Chicory leaves contained low concentrations of fructans. Only trace amounts were found in the leaf lamina but leaf petioles, especially in the basal region, the amount was higher. The inulo-*n*-ose series up to DP 4 (inulotetraose) was also detected in the leaves (Ernst *et al.*, 1995).



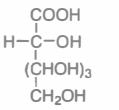
312 Inulin

The major fatty acid (FA) present in the lipid of *C. intybus* var. *foliosum* during the post-harvest period was linoleic (33-62 %), followed by palmitic (24-36 %). Changes in the FA composition were observed after harvest in both leaves and flowering stalks. The most pronounced changes occurred in the younger leaves within the first four post-harvest days. Older leaves showed the greater amounts of FA. Younger leaves had higher saturated to unsaturated FA ratios. Floral stalks and leaves showed a decrease in total FA and saturated to unsaturated ones with time (Krebsky *et al.*, 1996).

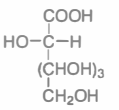
Roasted chicory (*C. intybus*) root is used as a coffee substitute and is usually sold as a constituent of mixtures with roasted barley malt and related products in Germany. Bitterness and acidity tastes are characteristics of chicory. Aldonic acids (e.g. arabonic **(313)**, gluconic **(314)**, mannonic **(315)**, ribonic **(316)**, etc.), deoxyaldonic acids (e.g. 3-deoxypentonic, isosaccharinic, lactic **(317)**, etc.), furanoic acids (e.g. 2-furanoic), oxo acids (e.g. 2-oxovaleric, pyruvic **(318)**), volatile acids (formic, acetic, propanoic, butanoic), several other aliphatic acids (e.g. citric, fumaric, malic, succinic, quinic) and aromatic acids (e.g. benzoic, 2,4- 2,5- 3,4-dihydroxybenzoic, 3-hydroxycinamic, vanillic, etc.) have been detected in roasted chicory (Barlianto and Maier, 1994, 1995a,b; Wohrmann *et al.*, 1997).



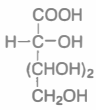
313 Arabonic acid



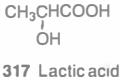
314 Gluconic acid



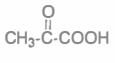
315 Mannonic acid



316 Ribonic acid



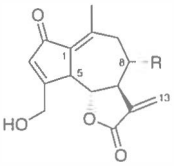
317 Lactic acid



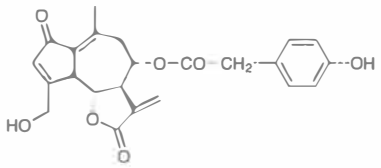
318 Pyruvic acid

Sesquiterpene lactones (e.g. lactucin **(319)**, 8-deoxylactucin **(320)** and lactuopicrin **(321)**) were isolated from *C. intybus* (St. Pyrek, 1985; Rizk, 1986). Four sesquiterpene lactones,

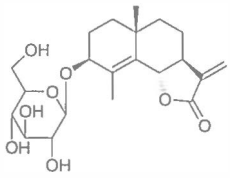
cichoriolide A (**322**), and cichoriosides A, B (**323**), and C were isolated from *C. endivia* and *C. intybus* together with other nine sesquiterpene lactones (Seto *et al.*, 1988). α-Amyrin, taraxerone, β-sitosterol and baurneyl acetate were isolated from the roots of *C. intybus* (Du *et al.*, 1998). The sesquiterpenoid phytoalexin cichoralexin (**324**) was identified from *C. intybus* inoculated with *Pseusdomanas cichorii* (Monde *et al.*, 1990).



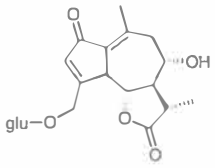
319 Lactucin; R = OH
320 8-Deoxylactucin; R = H



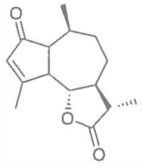
321 Lactuopicrin



322 Cichoriolide A



323 Cichorioside B



324 Cichoralexin

Kaempferol glycosides were isolated from *C. endivia* (Rizk, 1986). The major anthocyanin of red leaves of *C. intybus* was identified as cyanidin-3-*O*-β-(6-*O*-malonyl)-D-glucopyranoside (Bridle *et al.*, 1984).

C. intybus was demonstrated to be a potential indicator for heavy metal contaminated sites (Simon *et al.*, 1996). A high concentration of heavy metals was also observed in the edible green parts of endive (*C. endivia*) (Zupan *et al.*, 1997).

The water-soluble extract of chicory was found to reduce glucose uptake from the perfused jejunum in rats (Kim and Shin, 1996).

1.1. ***Cichorium endivia*** L. subsp. ***pumilum*** (Jacq.) Cout., Fl. Porl. 622 (1913).

syn. *Cichorium pumilum* Jacq., Obs. Bot. 4:3 (1771); *C. intybus* L. subsp. *pumilum* (Jacq.) Ball., J. Linn. Soc. 16:534 (1828).

Chiboria (Ar.)

Erect much branched seasonal herb with rather stiff grooved branches. Leaves lobed; tips of lobes pointed. Inflorescences composite heads of blue florets. Fruit cypselas with short pappus.

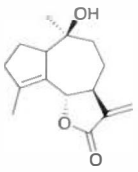
Habitat and Distribution

Very rare in Qatar and recorded only as a weed in leucerne fields and house gardens in Doha. Possibly an introduced weed preferring good rich (fertilized) soils.

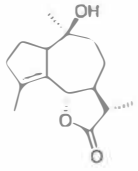
Constituents

The leaves of *C. pumilum*, a weed growing in alfalfa fields, are eaten by villagers in Egypt as a green salad. The roots contained inulin (Rizk, 1986).

A flavonoidal glycoside, identified as isoquercitrin, has been isolated from the plant. The roots contained 2 guaianolides, 10β-hydroxycichopumilide **((325)**, 10β-hydroxyguaia-4,13-dien-6,12-olide) and 10β-hydroxy-11β,13-dihydrocichopumilide **(326)** (Rizk, 1986).



325 10β-Hydroxycichopumilide



326 10β-Hydroxy-11β,13-dihydrocichopumilide

2. IFLOGA Cass.

2.1. ***Ifloga spicata*** (Forssk.) Sch.-Bip. in Webb. and Birth. Phyt. Canar. 2:3 (1845).
syn. *Chrysocoma spicata* Forrsk., Fl. Aegypt.-Arab. LXXIII (1775).

Alk ghazal (Ar.)

Minute ephemeral herb 6-8 cm high, erect with usually one stem composed of an elongated dense spicate inflorescence on a very short leafy stem. Inflorescences dense with rough involucral bracts enclosing minute flowers. Friut cypselas with pappus.

Habitat and Distribution

Widespread in Qatar on sandy soils. Common in central Qatar appearing after the seasonal rains. If the rainy season is good it will produce further growth of flowering branches. On the other hand, if the rains are poor only small (about 4 cm) individuals grow with a single shoot terminating in one inflorescence.

Constituents

The proximate analysis and amino acids of *I. spicata*, growing in Qatar are shown in Tables 175 and 176 (Al-Easa, 2002a,b)

Phytochemical screening of *I. spicata*, growing in Qatar, revealed the presence of coumarins, flavonoids, sterols, and probably alkaloids (Rizk *et al.*, 1986a).

3. LACTUCA L.

The fatty acids of seed oil of *L. sativa* var. *longifolia* were identified as oleic (61.5 %), stearic (20.4 %), palmitic (9.7 %), myristic (2.8 %), *cis*-palmitoleic (1.2 %), behenic (0.5 %) and lignoceric (0.3 %) acids (Said *et al.*, 1996).

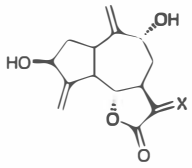
Sesquiterpene lactones have been isolated from several *Lactuca* species. Examples of these compounds are shown in Table 32.

Table 32. Sesquiterpenes of some *Lactuca* species

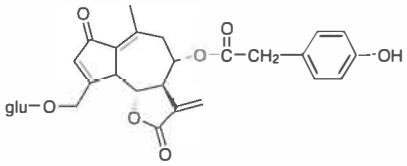
Species	Sesquiterpenes	References
1. *L. floridana*	Lactucin and lactuopricrin	Bohlman *et al.* (1981)
2. *L. laciniata* (roots)	9α-Hydroxyzaluzanin C **(327)**, 9α-hydroxy-11,13α-dihydrozaluzanin C **(328)**, lactucopicriside **(329)**, lactulide A **(330)**, lactuside B **(331)**, 11β,13-dihydrolactucin acetate and 11,13α-dihydroglucozaluzanin C	Nishimura *et al.* (1986); Bi *et al.* (1996)
3. *L. sativa* (aerial parts)	Lactucin, 11β,13-dihydrolactucin, lactupicrin, 3-β-hydroxy-11β,13-dihydroacanthospermolide **(332)**, and 3β,14-dihydroxy-11β,13-dihydro-costunolide	Mahmoud *et al.* (1986)
4. *L. serriola*	Jacquinelin **(333)** and 8-deoxylactucin	St. Pyrek (1977)
5. *L. tatarica* (roots)	11βH,13-Dihydrolactucin-8-*O*-*p*-methoxyphenyl -acetate **(334)**, three guaianolide glycosides, tataroside(3β,11β,14-trihydroxy-11,13-dihydrocostunolide-3β-glucopyranoside **(335)**)	Kisiel *et al.* (1997); Kisiel and Barscz (1998)
6. *L. virosa*	Lactucin, jacquinelin, lactucopicrin, 8-desoxylactucin, lactuside A **(336)**, 11β,13-dihydrolactucin	Gromek (1989,1991); Gromek *et al.* (1992); Kisiel and Barszcz (1997)

The study of the surface lipids (waxes) of four leaf lettuce (*L. sativa* var. *crispa*) varieties revealed the presence of fatty acids, primary and secondary alcohols, aldehydes, esters and

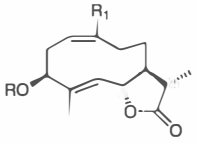
alkanes. Primary alcohols were the major fraction and alkanes occurred in small amounts. The alkanes were C_{19-33}, with pentacosane and hentriacontane were the major components. Mean content of these two compounds was 41.8-55.7 % in the varieties. Branched-chain alkanes were also present. C_{20-32} alkanols were found with docosanol, tetracosanol, and hexacosanol as the major components. Branched-chain alcohols were present in small amounts (Breier and Buchloh, 1987). Octadecanoic acid, hexacosanol, β-sitosterol, muxicaosu 7-*O*-β-D-glucoside and yanguqiangsu 7-*O*-β-D-glucoside were isolated from *Ixeris chinensis* (*L. chinensis*) (Zhou and Yuan, 1996). Thirty-nine triterpenoids including 17-epilupenyl acetate and ixerenyl acetate were isolated from the aerial parts and the roots of *I. chinensis* (Shiojima *et al.*, 1996). β-Sitosterol and β-amyrin were identified in the seeds of *L. sativa* var. *longifolia* (Said *et al.*, 1996).



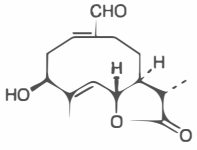
327 9α-Hydroxyzaluzanin C; X = CH_2
328 9α-Hydroxy-11,13α-dihydrozaluzanin C; X = H, αMe



329 Lactupicriside



330 Lactulide A; R = H, R_1 = CHO
331 Lactuside B; R = glu, R_1 = CH2OH
336 Lactuside A; R = glu, R_1 = CHO



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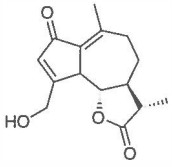
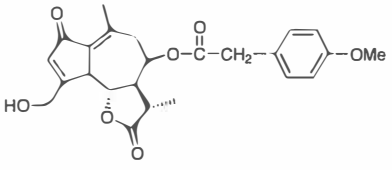


333 Jacquinelin



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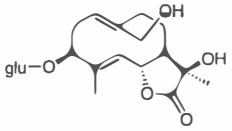
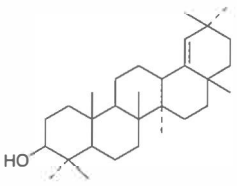


335 Tataroside

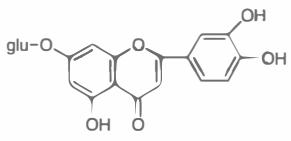
Ixeris chinensis had good quality of vitamin C and unharmful amount of nitrate and nitrite (Qiu, 1998). The Fe content in *L. scariola* was 0.0160-0.42 mg % (Chang, 1985). Lettuce and endive were reported as cadmium accumulative species (Garate *et al.*, 1993).

Early works on the latex of *L. sativa* and *L. virosa* revealed the presence of the two isomeric alcohols, α and β-lactucerol, which were later shown to be mixtures, the former being impure taraxasterol, which was present, together with amyrin and germanicol **(337)** in the latex of *L. virosa*. Five closely related triterpene acetates (α-amyrenyl, β-amyrenyl, germanicyl, taraxasteryl and lupenyl acetates), together with β-amyrin, taraxasterol and sterols have been isolated from *L. denticulata* and *L. indica* (Rizk, 1986).

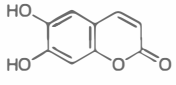


337 Germanicol

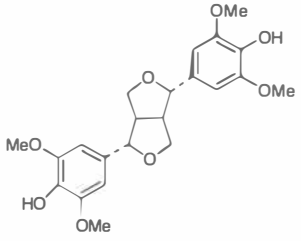
Several flavonoids were isolated from *Lactuca* species. Luteolin-7-glucoside and rutin were identified in some species (Rizk, 1986). Six flavonoids were isolated from aerial parts of *L. quercina* and *L. tatarica*. Of these, three compounds, apigenin, luteolin and quercetin-3-*O*-β-glucopyranoside were found in both species, two compounds, apigenin-7-*O*-β-glycopyranoside and kaempferol-3-*O*-β-glucopyranoside occurred in the latter species and one luteolin-7-*O*-β-glucopyranoside **(338)** from the former one (Kisiel, 1998). "Round" lettuce contained 11 mg of quercetin g^{-1} fresh weight compared to 911 mg g^{-1} in the outer leaves and 450 mg g^{-1} in the inner leaves of "Lollo Rosso" a lettuce variety (Corzier *et al.*, 1997). Seven phenolic compounds: esculetin **(339)**, luteolin, luteolin-7-*O*-glucopyranosiduronic acid-6"-methyl ester, (*E*)-2,5-hydroxycinnamic acid and ethy-4-hydroxybenzoate were isolated from *Ixeris denticulate* var. *pinnatipartita* (*L. denticulata*) (Ma *et al.*, 1998a). Scopoletin, luteolin, apigenin, (*E*)-2,5-dihydroxycinnamic acid, *bis*-(2-ethylhexyl) phthalate, (+)-syringaresinol **(340)**, *p*-hydroxybenzaldehyde **(341)**, 1,4-benzenedimethanol were isolated from the herb of *Ixeris sonchifolia* (*L. sonchifolia*) (Ma *et al.*, 1998b). A pigment isolated from *L. sativa* leaves was identified as cyanidin 3-*O*-(6"-malonylglucoside) (Yamaguchi *et al.*, 1996).



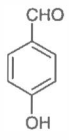
338 Luteolin-7-*O*-glucoside



339 Esculetin



340 (+) Syringaresinol



341 *p*-Hydroxybenzaldehyde

6.2. ***Sonchus oleraceus*** L., Sp. Pl. ed.1,:794 (1753).

Jeidaid (Ar.)

Erect annual herb with milky sap and basal leaves reaching up to 80 cm high but usually 25-40 cm high. Cauline leaves amplexicaul with ± triangular auricles; margins pinnati-lobed. Inflorescences numerous capitula on leafy panicles, rather congested; florets ligulated, bisexual. Fruit cypselas (achenes) with 10 or more slightly tubercled, and striae with a tuft of soft hair not exceeding 1 cm length.

Habitat and Distribution

Avery common weed of agricultural fields, lawns, parks, house gardens, etc. throughout Qatar. The leaves are edible as lettuce.

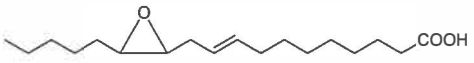
Constituents

S. oleraceus in one of the major widespread weeds which contaminates winter vegetables such as *Trifolium* and *Trigonella* species. It is commonly eaten fresh by farmers in Egypt as a major diet. Leaves and stems are often eaten as a salad (Rizk, 1986). According to Guil-Guerrero *et al.* (1998), a minimum diet of 77 g of the leaves per day would provide a sufficient amount of vitamin C to meet the recommended daily allowance of 60 mg per person.

The proximate composition, amino acids, fatty acids and minerals of *S. oleraceus,* growing in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d).

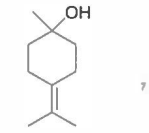
The proximate composition as well as the content of mineral elements, fatty acids, vitamin C, carotenoids and oxalic acid of *S. oleraceus*, growing in Spain, are shown in Tables 36-40 (Guil, Gerrero *et al.*, 1998). The vitamin C content (45 mg/100 g edible leaves) of *S. oleraceus*, reported by Guil *et al.* (1997) was consistent with those reported by Saleh *et al.* (1977), and

higher than other results from Bruno *et al.* (1980). The vitamins and antinutrients of edible leaves reported by Guil *et al.* (1997) were as follows: ascorbic acid (45±21), dehydroascorbic acid (9±4), carotenoids (15.3±3.1), oxalic acid (98±39) and nitrate (148±46) mg/100 g, edible leaves. Other data on the vitamin C and provitamin A in the leaves of *S. oleraceus* have been reported (Bruno *et al.*, 1980; De Alemaida-Muradian *et al.*, 1998). In addition to the fatty acids detected by Guil-Gerrero *et al.* (1998) (Table 38), Guil *et al.* (1996a) reported the presence of $C_{20:5\omega3}$ (0.35 %), $C_{22:5\omega3}$ (0.25 %) and $C_{22:4\omega6}$ (0.27 %) in the plant, which is also growing in Spain. Seed oil of *S. oleraceus*, growing in India, contained 13.7 % vernolic acid **(373)** (Ahmad *et al.*, 1986a).

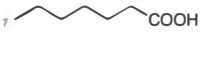


373 Vernolic acid

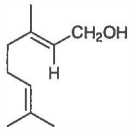
The study of the triterpenoid constituents of *S. oleraceus* revealed the presence of α-amyrin (El-Khrisy *et al.*, 1992), taraxasterol (Khan and Varshney, 1970), and 3β,25-epoxy-3-hydroxyolean-18-en-28-oic acid (Ahmed, 1992). Several terpenoids were isolated from the roots (Shiojima *et al.*, 1997). The volatile oil from *S. oleraceus* contained γ-terpineol **(374)**, heptanoic acid **(375)**, geraniol **(376)**, bornyl acetate, geranial **(377)**, anethole **(378)**, hexanoic acid **(379)**, butanol and other unidentified components (Ahmed, 1992). Ceryl alcohol and β-sitosterol were also isolated from the plant (El-Khrisy *et al.*, 1992).



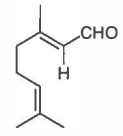
374 γ-Terpineol



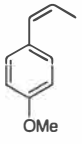
375 Heptanoic Acid



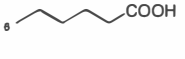
376 Geraniol



377 Geranial

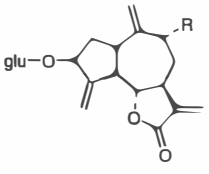


378 Anethole

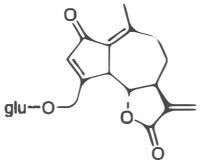


379 Hexanoic Acid

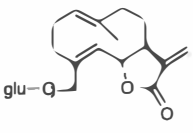
Nine sesquiterpene glycosides were isolated from *S. oleraceus*: glucozaluzanin C **(380)**, macrocliniside A **(381)**, crepidiaside A **(382)**, picriside B **(383)**, picriside C **(384)** and sonchusides A **(385)**, B **(386)**, C **(387)** and D (Miyase and Fukushima, 1987).



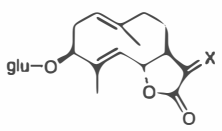
380 Glucozaluzanin C; R = H
381 Macroliniside A; R = OH



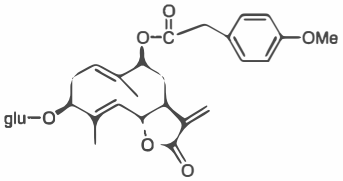
382 Crepidiaside A



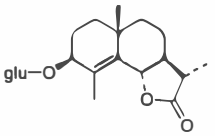
383 Picriside B



384 Picriside C; X = CH_2
385 Sonchuside A; X = H, α Me

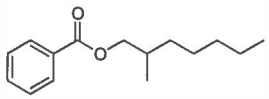


386 Sonchuside B



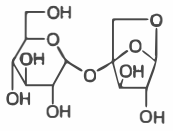
387 Sonchuside C

Mousa and Al-Hazimi (1990b) isolated 2-methylheptylbenzoate **(388)** from *S. oleraceus* together with an acetate ester.



388 2-Methylheptyl benzoate

A disaccharide **(389)** (Mousa and Al-Hazimi 1990a) and sucrose (Mousa and Al-Hazimi 1990b) were identified in the plant.



389

The following flavonoids were identified in *S. oleraceus*: apigenin-7-glucuronide, luteolin-7-glucoside, luteolin-7-glucuronide, and luteolin-7-glucosylglucuronide (Mausour *et al.*, 1983a). Two coumarins *viz.* esculetin and scopoletin were isolated from the leaves (Mansour *et al.*, 1983a; El-Khrisy *et al.*, 1992).

The leaves and stems have shown a higher ascorbic acid oxidase activity and the stems were reported to contain 0.144 % rubber (Rizk, 1986). *S. oleraceus*, growing in Qatar, gave positive tests for alkaloids and saponins , in addition to flavonoids and coumarins (Rizk *et al.*, 1986a).

Several uses of *S. oleraceus* in folk medicine have been reported (Rizk and El-Ghazaly, 1995).

6.3. ***Sonchus tenerrimus*** L., Sp. Pl. ed.1, 794 (1753).

Jeidaid (Ar.)

Mostly annual herbs with tap-root system. Similar to *S. oleraceus* but differs in the structure of the achenes. Leaves mostly petiolate, glabrous. Inflorescences with bisexual ligulate florets. Fruit cypselas, narrow, laterally compressed with many straie.

Habitat and Distribution

Weed if cultivated and arable lands favouring areas where moisture is high.

Constituents

The proximate composition as well as the contents of mineral elements, fatty acids, vitamin C, carotenoids and oxalic acid of *S. tenerrimus*, growing in Spain are shown in Tables 36-40 (Guil-Gerrero *et al.*, 1998). In addition to the fatty acids detected (Table 38), Guil *et al.* (1996a) also reported the presence of $C_{16:1\omega9}$ (4.08 %), $C_{22:5\omega3}$ (0.38 %) and $C_{22:4\omega6}$ (1.83 %) in the plant, growing in Spain. Of the twenty edible wild plants in S.E. Spain, studied by Giul *et al.* (1996a), sow-thistle (*S. oleraceus*) and sow-thistle of the wall (*S. tenerrimus*) showed higher lipid content than in more common vegetables.

Mineral content, especially K (Table 37) was high in comparison with the range of other examined edible-vegetables (Guil-Guerrero *et al.*, 1998). The vitamins and antinutrients of the edible leaves were reported by Guil *et al.* (1997), as follows: ascorbic acid (38±14), dehydroascorbic acid (10±4), carotenoids (5.7±1.1), oxalic acid (64±32) and nitrate (89±17) (mg/100 g leaves). Investigation of the plant revealed that the stems contained 0.04 % sterols, and the stalks and roots contained 0.112 % and 0.237 % rubber, respectively (Rizk, 1986). The flavonoids of the plant were identified as apigenin-7-glucuronide, luteolin-7-glucoside, luteolin-7-glucuronide and luteolin-7-glucosylglucuronide (Mansour *et al.*, 1983a).

XI. CONVOLVULACEAE Durande.

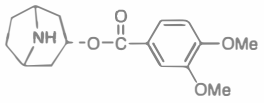
1. CONVOLVULUS (Tourn. f.) L.

Several *Convolvulus* species have been reported to contain tropane alkaloids, which were mainly localized in the roots. Atripova (1996) isolated 18 tropane alkaloids from two *Convolvulus* species. Examples of these alkaloids are shown in Table 41.

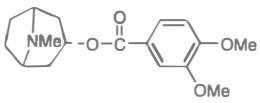
Table 41. Alkaloids of some *Convolvulus* species

Species	Alkaloids	References
1. *C. krauseanus* (aerial parts)	Convolvine **(390)**, convolamine **(391)**, convolidine **(392)**, phyllabine and convolicine **(393)**	Atripova (1985); Rizk (1986)
2. *C. lineatus*	Convolvine and convolvamine	Rizk (1986)
3. *C. sabatius* ssp. *mauritanicus* (roots)	consiculine **(394)** and consabatine **(395)**	Jenett-Siems *et al.* (1998)
4. *C. siculus* (roots)	consiculine and consabatine	Jenett-Siems *et al.* (1998)
5. *C. subhirsutus* (roots)	convolvine, phyllabine, convolidine and confoline (*N*-formylconvoline) **(396)**	Sharova *et al.* (1980)
6. *C. subhirsutum* (roots)	convolvine, convolvamine, convolvidine and convosine **(397)**	Atripova and Yunusov (1986 a,b)

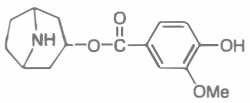
The isolation of the alkaloid cuscohygrine **(398)** from several *Convolvulus* species was also reported (Rizk, 1986).



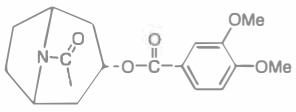
390 Convolvine



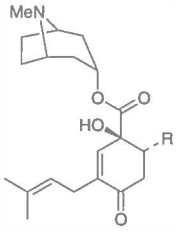
391 Convolvamine



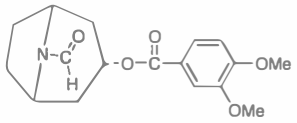
392 Convolidine



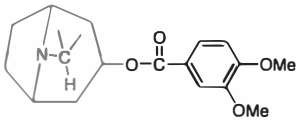
393 Convolicine



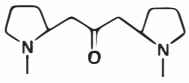
394 Consiculine; R = OH
395 Consabatine; R = H



396 Confoline



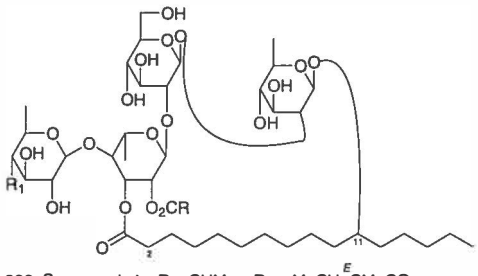
397 Convosine



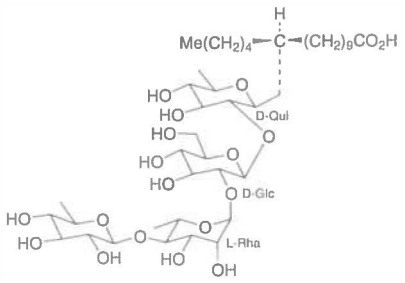
398 Cuscohygrine

The fatty acids of *C. lanatus* were identified as palmitic (37.33 %), stearic (4.14 %), oleic (34.37 %), linoleic (14.81 %) and linolenic (9.33 %). *C. lanatus*, contained α-amyrin, β-amyrin, β-sitosterol, campesterol, stigmasterol, hexadecanol, octadecanol, nonadecanol, tetracosanol, hexacosanol (Seif El-Nasr *et al.*, 1984), and oleanolic acid (Dawidar *et al.*, 2000).

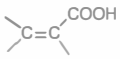
Several resin glycosides named scammonins (I-VIII) were isolated from scammony roots (*C. scammonia*) (Noda *et al.*, 1990, 1992; Kogetsu *et al.*, 1991). Scammonins I-VI **(399-404)** have a common glycosidic acid, scammonic acid A **(405)** and an intramoleculr macrocyclic ester structure. Scammonins VII and VIII are composed in addition of (2*S*)-2-methylbutyric acid and tiglic acid **(406)**, of orizabic acid A, and a glycosdic acid named scammonic acid B, with similar macrocyclic ester structures to those of scammonic A-based scammonins I-VI (Noda *et al.*, 1992).



399 Scammonin I; R = $CHMe_2$, R_1 = MeCH=CMeCO$_2$
400 Scammonin II; R = CMe=CHMeCO$_2$, R_1 = MeCH=CMeCO$_2$
401 Scammonin III; R = $CHMe_2$, R_1 = OH
402 Scammonin IV; R = CMeC=CHMeCO$_2$, R_1 = OH
403 Scammonin V; R = $CHMe_2$, R_1 = H
404 Scammonin VI; R = MeCH=CMeCO$_2$, R_1 = H

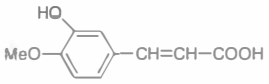


405 Scammonic acid A



406 Tiglic acid

Three coumarins; namely scopoletin, umbelliferone and aesculetin as well as caffeic acid and quercitrin were isolated from *C. lanatus* (El-Fiky *et al*., 1996). The presence of coumarins (e.g. scopolotin, isoscopoletin, herniarin and umbelliferone) in other species *viz. C. aeyranisis*, *C. hystrix*, *C. microphyllus* and *C. sepium* has been reported (Khalil *et al*., 1981; Seif El-Nsar, 1982; Rizk, 1986). Vanillin, vanillic acid, syringic acid, ferulic acid, isolferulic acid **(407)** and a stilbene carboxylic acid were isolated from *C. hystrix* (Dawidar *et al*., 2000).



407 Isoferulic Acid

1.1. ***Convolvulus arvensis*** L., Sp. Pl., ed. 1, (1753).
syn. *Convolvulus auriculatus* Desr. in Lam., Encycl. 3:540 (1792). *Convolvulus longipedicellatus* Sa'ad, Meded. Bot. Mus. Herb. Rijks Univ. Utrecht 281:233 (1967).

Fatgha, Hazmi, Ollaeik, Oleiq (Ar.); Bind weed (En.)

Prostrate, trailing/twining annual or short-lived perennial herb. Leaves alternate, simple, sessile variable, mostly repand and cordate-hastate at base. Inflorescences axillary, solitary or few-flowered cymes (2-3); flowers showy, faintly scented, funnel-shaped white or pale rose 1.5 - 2.5cm across. Fruit a capsule with 1-4 seeds. Flowers and fruits: April-August.

Habitat and Distribution

Grown as an ornamental plant and has since spread and became a noxious weed very common in agricultural plots difficult to eradicate. Frequent with palm trees grown in avenues and main roads throughout Qatar. Rare in rodats. Planted in Doha as seasonal flowers and this is possibly the origin of its invasion of agricultural land.

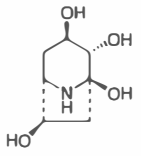
Constituents

The proximate analysis, amino acids and fatty acids of *C. arvensis*, growing in Qatar, are shown in Tables 175-177 (Al-Easa, 2002a-c).

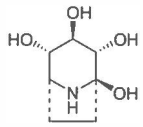
C. arvensis is one of the most widely distributed bindweeds in the Mediterranean basin, Europe and Asia (Karawya *et al*., 1972a). Singh (1962) reported its utilization as cattle feed during its flowering stage on the basis of its high content of protein, Ca and P. The plant is one of the weeds, which, under certain conditions, are rendered toxic by absorption, and storage of potassium nitrate (Karawya *et al*., 1972a).

α-Amyrin, β-sitosterol, campesterol, stigmasterol and several *n*-alkanes and *n*-alkanols were identified in the aerial parts of *C. arvensis* (Sowemino and Farnsworth, 1973).

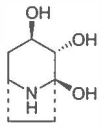
Evans and Somanabandhu (1974) identified the alkaloid cuscohygrine in the plant. Calystegins **(408-410)**, polyhydroxy-*nor*-tropane alkaloids, alkaloid glycosidase inhibitors have been isolated from the roots of *C. arvensis* (Molyneux *et al*., 1993).



408 Calystegin B_1



409 Calystegin B_2



410 Calystegin A_3

Glycinebetaine (0.72 % dry weight) was detected in *C. arvensis* (Adrian-Romero *et al*., 1998).

Isoscopoletin, scopoletin, umbelliferone and isoferulic acid were identified in the aerial parts of the plant (Khalil *et al*., 1981; Seif El-Nasr, 1982). The presence of β-methylesculetin was also reported by Constantinescu and Palade (1967). Two flavonoids, quercetin and kaempferol have been identified in the plant (Rizk, 1986).

The presence of other compounds in *C. arvensis* have been also reported *viz*. caffeic acid, δ-aminovaleric acid, saponins (Rizk, 1986), and purgative resins (Provosta, 1959-1960). Analysis of the lipids has been reported by Stoller and Webber (1970).

The aqueous extract of *C. arvensis* possessed muscarinic and nicotinic activities (Tariq *et al*., 1977). Meng *et al*. (2000) reported that high molecular weight extracts of *C. arvensis* (field bindweed) (after removing toxic low molecular weight components) inhibited the growth of tumour cells, and the growth of blood vessels, and enhanced the immune function.

1.2. ***Convolvulus deserti*** Hochst. & Steud., Unio Itin. no. 783 (1837).

Hazmi, Khatmi (Ar.)

Prostrate perennial herb with many basal long branches. Branches covered with hairs. Leaves alternate, linear, sub-sessile. Inflorescences axillary. Flower white to pale rose, about 1 cm across. Fruit a capsule.

Habitat and Distribution

The plant produces new shoots with the onset of the rainy season and its more common on wadis and water courses in central Qatar.
Reported as grazed by animals.

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *C. deserti*, growing in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d).

Phytochemical screening of *C. deserti*, growing in Qatar, revealed the presence of alkaloids coumarins, flavonoids and sterols (Rizk *et al.*, 1986a).

1.3. ***Convolvulus fatmensis*** Kunze, Flora (Regensburg) 23:172 (1840).

Oleiq (Ar.)

Prostrate annual herb with many basal long trailing branches. Leaves slightly pinnately lobed with cordate base and inset veins. Inflorescences axillary with small flowers, less than 1 cm across. Flowers pale rose. Fruit a capsule.

Habitat and Distribution

Less common in the wild occurring in few shady rodats. Occasional as a weed in cultivated fields and collected as fodder in a mixture of other field weeds.

Constituents

Phytochemical screening of the plant, growing in Qatar, revealed the presence of alkaloid coumarins, flavonoids and sterols (Rizk, 1982).

1.4. ***Convolvulus glomeratus*** Choisy in A.DC., Prodr. 9:401 (1845).

Oleiq, Fatgha (Ar.)

Twining perennial greyish green hairy herb entangled on the neighboring growth. Branches may exceed 1 m in length and whole plant up to 50 cm high. Leaves variable in size, ovate-lanceolate or ovate, up to 3.5 cm long; margins entire; bases cordate-hastate. Inflorescences globular heads of small-congested white flowers enclosed by a pair of hairy bracts and carried on peduncles 5 cm long; flowers 1-0.5 cm across.

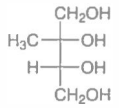
Habitat and Distribution

Occasional as a twiner and scandant herb in rodats with dense growth in central Qatar; sometimes as bushy growth in neighbouring open gardens in Doha.

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *C. glomeratus*, growing in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d).

A branched alditol, identified as 2-*C*-methyl-D-erythritol **(411)** was isolated from the plant (Anthonsen *et al.*, 1976; Shah *et al.*, 1977). The plant gave positive tests for alkaloids, coumarins, flavonoids, saponins and sterols (Rizk *et al.*, 1986a).



411 2-*C*-Methyl-D-erythritol

1.5. ***Convolvulus pilosellifolius*** Desr. in Lam., Encycl. 3:551 (1792).

Rukheima, Hathmi, Khatmi, Melbo (Ar.)

Perennial prostrate soft herb with numerous trailing radiating branches covered with silvery hairs. Branches may exceed 30 cm in length. Leaves alternate, linear lanceolate, sessile, up to 3 cm long. Inflorescences axillary cymes, 1-5-flowered; flowers funnel-shaped, rose-coloured. Fruit a capsule with 4 seeds. The plant flowers and fruits February-April.

Habitat and Distribution

Widespread on rocky sandy soils and in depressions of sandy or sandy-gravelly soils. Common during the rains at Al-Shahaneya race ground. Because the plant is well-grazed, only stunted portions remain which produce a regrowth of new shoots after the rains. It is reputed as a good camel fodder.

Constituents

The proximate analysis and amino acids of *C. pilosellifolius*, growing in Qatar, are shown in Tables 175 and 176 (Al-Easa, 2002a,b).

Phytochemical screening of the plant, growing in Qatar, revealed the presence of alkaloids coumarins, flavonoids, saponins and sterols (Rizk, 1982).

1.6. ***Convolvulus prostratus*** Forssk., F. Aegypt.-Arab. 203 (1775).
syn. *C. microphyllus* Spreng., Syst. Veg. 1:611 (1824).

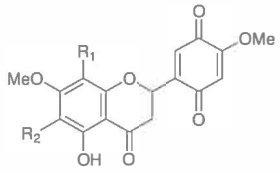
Rukreima, Rakhama (Ar.)

Sub-woody perennial herb with many basal decembent-prostrate branches. Branches reddish, very villous glandular. Leaves linear 2-2.5 cm long, hairy. Inflorescences with pale rose-pink flowers over 3 cm across on peduncles about 4 cm long.

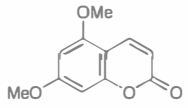
Habitat and Distribution

Appearing with new sbouts after the rainy season in moist areas such as wadis, runnels, water-catch ment depressions in central Qatar on gravely soil.
Reported as grazed by animals.

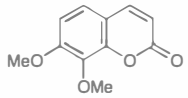
coumarin, 7-methoxy-8-(γ,γ-methylallyloxy) and 7-(γ,γ-dimethylalloxy)-8-methoxycoumarin (Dini *et al.*,1993). A coumaran remirol (**476)** was isolated from the basal stems of *C. distans* and *C. nipponicus* (Morimoto *et al.*, 1999).



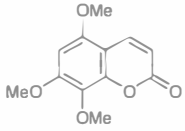
471 Breverin; R_1 or R_2 = Me, R_1 or R_2 = H
472 Scaberin; $R_1 = R_2$ = Me



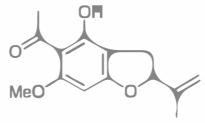
473 5,7-Dimethoxycoumarin



474 7,8-Dimethoxycoumarin



475 5,7,8-Trimethoxycoumarin



476 Remirol

Aerial and underground parts of *C. longus* contained 0.095 and 0.044 air-dried weight % alkaloids respectively, from which bervicolline and bervicarine were identified (Sadykov and Begovatov, 1990). *C. stoloniferus* contained alkaloids (0.13 %), glycosides (0.77 %), saponins (0.5 %) , flavonoids (0.78 %) and tannins (1.78 %) (Vu and Pho, 1993).

C. scariosus possessed antifungal activity (Dikshit and Husain, 1984). *C. stoloniferus* exhibited a dilation action on isolated uterus muscle of white rat (Nguyen and Vu, 1993; Vu and Pho, 1993). Unprocessed cyperi (*Cyperus*) rhizomes has a significant peroxidative effect and hepatoprotective activity (Kim and Park, 1997).

1.1. ***Cyperus conglomeratus*** Rottb., Desr. Pl. Rar. Progr. 16 (1772).
syn. *Cyperus jeminicus* Rottb., Descr. Pl. Rar. Progr. 24 (1775).

Rasha (Ar.)

Perennial sedge with numerous rather swollen adventitious roots, rarely developing a very long underground thin rhizomatous stems giving upright tufts of shoots. Whole plant tough with rigid culms and terminating in compound digitate spikes. Spikes initially green soon becoming brown at maturity. Fruit elongated slim brown indehiscent nuts.

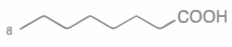
Habitat and Distribution

A very variable common and widespread sedge on coastal sand dunes forming pure stands. Widespread on N. E. Qatar.

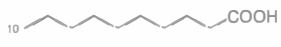
Constituents

The proximate analysis, amino acids and minerals of *C. conglomeratus*, growing in Qatar, are shown in tables 175, 176 and 178 (Al-Easa, 2002a,b,d).

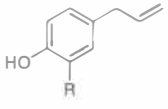
Investigation of the underground tubers of *C. conglomerates,* growing in Saudi Arabia, gave five fatty acids, three terpenoids, two sterols, five aromatic shikimates and two flavones. The fatty acids were: *n*-caprilic (**477**, octanoic), capric (**478**, decanoic), myristic, palmitic and linoleic. The terpenoids were: β-clemene, phytol and (4*R*,8*R*,12*R*)-4-hydroxy-4,8,12,16-tetramethylhepta-decanoic acid lactone. The sterols were: β-sitosterol and stigmasterol. The shikimates were phenol, 1-phenylethanol, chavicol **(479)**, 3-ethoxy-4-hydroxyallylbenzene **(480)**, the ethyl ester of allylcatechol and isoferulic acid. The flavans were 5-hydroxy-7,3',5'-trimethoxyflavan (**481**) and 5,7-dihydroxy-3'5'-dimethoxy-6-prenylflavan **(482)** (Abdel-Mogib *et al.*, 2000).



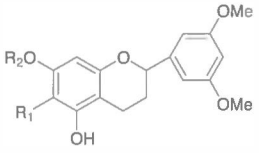
477 Caprilic acid



478 Capric acid



479 Chavicol; R = H
480 R = OEt



481 R_1 = H, R_2 = Me
482 R_1 = $CH_2CH=C(CH_3)_2$, R_2 = H

Phytochemical screening of the plant, growing in Qatar, revealed the presence of flavonoids, coumarins and steroids (Rizk, 1982).

The study of Boer and Srageant (1998) on the terrestrial perennial *C. conglomeratus,* in Abu Dhabi, showed that it is an indicator for salinity levels.

1.2. *Cyperus laevigatus* L., Sp. Mont. Alt. 179 (1771).

syn.. *Cyperus lateralis* Forssk., Fl. Aegypt.-Arab., 13 (1775); *Juncellus laevigatus* (L.) C.B. Clarke in Hook. f., Fl. Brit. Ind. 6:590 (1893).

Rasha, Saad (Ar.)

Perennial sedge with numerous rather swollen adventitious roots, rarely developing a very long underground thin rhizomatous stems giving upright tufts of shoots. Whole plant tough with rigid culms terminating in compound digitate spikes. Spikes initially green soon becoming brown at maturity. Fruit elongated, slim, brown indehiscent nuts.

Habitat and Distribution

A very variable common arid widespread sedge on coastal sand dunes forming pure stands. Widespread on N.E. Qatar coastlines.

Constituents

C. laevigatus, growing in Egypt, contained phytol, 1-octadecene, β-sitosterol, stigmasterol and apigenin (Nassar *et al.*, 2000).

1.3. *Cyperus rotundus* L., Sp. Pl., ed. 1, 45 (1753).

syn. *Chlorocyperus rotundus* (L.) Pallu, Allg. Bot. Zeitschr. 6:61 (1900).

Saad, Seida (Ar.); Nut grass, Nut sedge, Sedge (En.)

Perennial sedge with stolons spreading from base terminating in deep burried corymbs. Culms triangular, glabrous, mid zone leafless. Leaves along 3-sided culms, rosette-like, sessile, at the base clasping the culms, glossy, dark green. Inflorescences terminal on end of culms, umbellate, raceme-like spikes, subtended by 3-5 smaller leaves; spikelets overlapping. Fruit a nutlet, small in size. Flowers and fruits throughout the year.

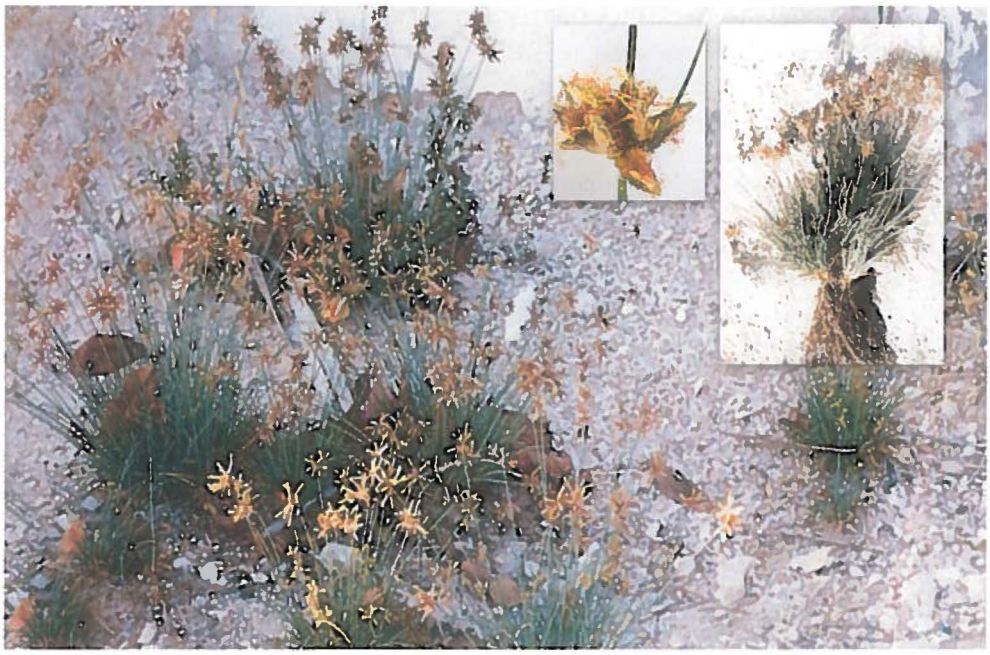
Habitat and Distribution:

More common on rich soils where water is available: lawns, gardens, cultivated fields, rodats and water catchment areas. Plant spreads by vegetative means, the corymbs separate when the plant is pulled off the ground which makes it a noxious weed difficult to rid of cultivated fields.

Constituents

Wild onion nut grass *C. rotundus,* growing in Australia, contained 54.4 % water and 0.7 % fat (James, 1983).

The bulbous ends of the root resemble small nuts and have a camphoraceous odour, It is rich in oil and has a somewhat butter taste (Rizk, 1986).



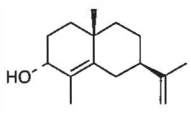
The study of organic nitrogen reserves and their mobilizing during sprouting of purple nut sedge (*C. rotundus*) tubers, revealed that some net protein degradation occurred after 2-4 weeks sprouting in the presence or absence of exogenous nitrogen. Amino acids decreased much faster, especially during the first two weeks. The major amino acids were arginine and asparagine, which together accounted for 70 % of the total amino acids at day 0, and which had almost disappeared after 4 weeks of sprouting (Fischer *et al.*, 1995). The effect of some factors *viz.* plant growth stages, dehydration and pH of leaf extract on the yield of the leaf protein concentrations from *C. rotundus*, *C. squarrosus*, *C. compressus* and *C. pumilus* were studied by Pandey *et al.* (1996a). Freshly harvested leaf samples, at the pre-flowering phase of the plant growth and its natural pH, the leaf extract during heat coagulation of protein were found to produce the best yield of leaf protein. Drying of the leaf protein, obtained from the above four *Cyperus* species reduced the pepsin-trypsin and pepsin-pancreatin digestibility as compared to fresh leaf protein (Pandey *et al.*, 1996b).

The essential oil from the rhizomes of *C. rotundus*, growing in different countries, has been thoroughly studied, and the isolation of many components was reported. Like the other essential oils, the composition of the oil of *C. rotundus* varied according to the area in which it was cultivated or grew (Rizk, 1986).

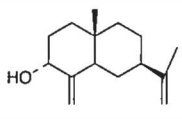
Gas-liquid chromatography of the essential oil of Indian origin revealed the presence of more than twenty-seven components, comprising sesquiterpene hydrocarbons (25 %, ten components), sesquiterpene epoxides (12 %, two components), sesquiterpene ketones (20 %, four components), monoterpenes and aliphatic alcohols (25 %, four components) and unidentified (18 %) (Kapadia *et al.*, 1967). Four major chemotypes of *C. rotundus* (purple nutsedge) have been reported based on the composition of the essential oils in mature tubers (Komai *et al.*, 1991). These were: (1) H-type, α-cyperene and β-selinene, (2) M-type, α-

cyperone, β-selinene, cyperene and cyperotundone, (3) O-type, α-cyperene and cyperotundone, (4) K-type, cyperene, cyperotundone, patachoulenyl acetate and surgeonyl aceteate (Komai, 1994). Seasonal variation study of *C. rotundus* tubers, growing in Chad, showed a relatively constant composition of the essential oil during the vegetative cycle (Mahmout *et al.*, 1997).

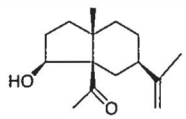
The sesquiterperoids identified in *C. rotundus* were: copaene, cyperene, cyperenone, cyperol **(483)**, isocyperol **(484)**, cyperolone **(485)**, α-cyperone, β-cyperone, cyperotundone, epoxyguaiene **(486)**, kobusone **(487)**, isokobusone **(488)**, muskatone **(489)**, 4α,5α-oxidoeudesm-11-en-3α-ol **(490)**, patchoulenone **(491)**, rotundene, rotundenol **(492)**, rotundone **(493)**, α-rotunol **(494)**, β-rotunol **(495)**, selinatriene, β-selinene, sugetriol **(496)** (Rizk, 1986), α-copaene, copadiene **(497)**, β-elemene, β-caryophyllene, α-humulene, δ-cadinene, calamenene, caryophyllene oxide, humulene oxide, cyperotundone, patchoulenyl acetate, sugeonyl acetate, sugetriol triacetate (Komai *et al.*, 1994), 2α-(5-oxopentyl)-2β-methyl-5β-isopropenylcyclohexanone **(498)**, 2β-(5-oxopentyl)-2β-methyl-5β-isopropenylcyclohexanone **(499)**, a tetracyclic acetal with cyperolone skeleton **(500)**, four eudesman-type sesquiterpenoids **(501-504)** (Ohira *et al.*,1998) and 8 others of the eudesmane type (Nozaki *et al.*,1995).



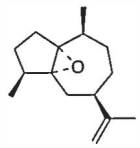
483 Cyperol



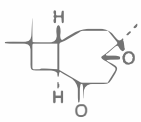
484 Isocyperol



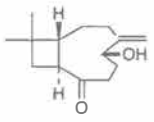
485 Cyperolone



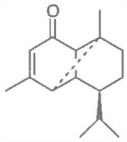
486 Epoxyguaiene



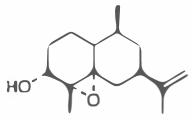
487 Kobusone



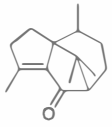
488 Isokobusone



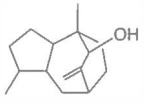
489 Mustakone



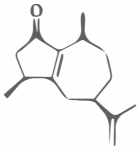
490 4α,5α-Oxidoeudesm-11-en-3α-ol



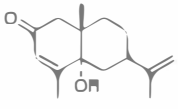
491 Patchoulenone



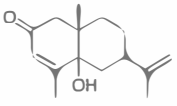
492 Rotundenol



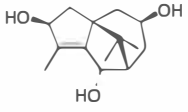
493 Rotundone



494 α-Rotunol

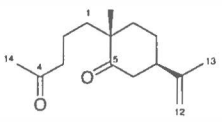


495 β-Rotunol



496 Sugetnol

497 Copadiene



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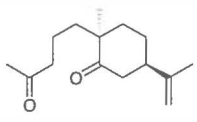

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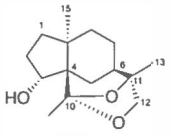

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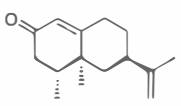

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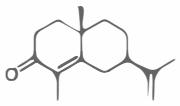

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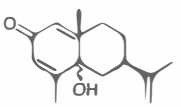
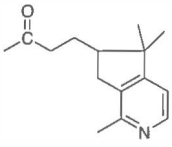
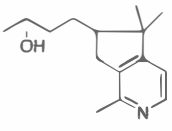


503 β-OH
504 α-OH

Rotundines A **(505)**, B **(506)** and C (**506**-6-epimer), three sesquiterpene alkaloids, have been recently isolated from the rhizomes of *C. rotundus* (Jeong *et al.*, 2000).



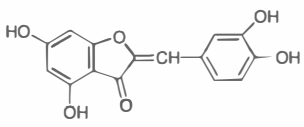
505 Rotundine A



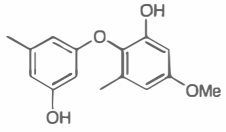
506 Rotundine B

β-Sitosterol (Gupta *et al.*, 1980a; Kim *et al.*, 2000a), oleanolic acid and a saponin identified as 3-*O*-(2-rhamnosylglucosyl)-oleanolic acid (Singh and Singh, 1980) have been isolated from the tubers of *C. rotundus*.

Aureusidin **(507)** (Rizk, 1986) and rhamnetin 3-*O*-rhamnosyl-(1→4)-rhamnopyranoside (Singh and Singh, 1986) were isolated from the tubers. Investigation of the phytotoxic metabolites of *Ascochyta cypericola*, a fungal pathogen of *C. rotundus*, have yielded cyperine **(508)**, an extremely active biphenyl ether (Stierle *et al.*, 1991).



507 Aureusuidin

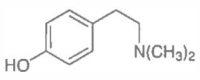


508 Cyperine

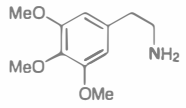
The tubers were also found to contain glucose, fructose, starch, cardiac glycosides, tannins, vitamin C, acids, bitter substances and polyphenolic substances (Rizk, 1986).

C. rotundus has been used as an analgesic, anti-inflammatory agent, diuretic and emmenagogue in folk remedies. The diuretic effect of *C. rotundus* was significantly increased in renal failure rats, the significant inhibition of blood urea nitrogen was revealed (Kim *et al.*, 1998c). It also induced stretching of the uterus muscle isolated from white rat (Vu and Pham, 1993) and had analgesic effects in the acetic acid writhing test (Vu and Mai, 1994). An agonistic activity to the benzodiazepine receptor by *C. rotundus* has been reported (Ha *et al.*, 1999). Pharmaceutical compositions containing extracts of *C. rotundus* are used for skin or hair pigmentation (Meybeck *et al.*, 1992). α-Cyperone isolated from the tubers possessed insecticidal acticvity against the diamond back moth larvae (Dadang *et al.*, 1996).

(e.g. 24-alkylsterols and avenasterols) (Rizk, 1986), flavonoids (Khaitbaev *et al.*, 1987, 1993; Yang *et al.*, 1996), and proanthocyanidins (catechin, gallocatechin, epigallocatechin and leucodelphinidin) (Islambekov *et al.*, 1982) were identified from *A. pseudoalhagi*.



531 Hordenine



532 Mescaline

A. maurorum, growing in Pakistan, contained K_2O, 1.92; Na_2O, 0.54 and CaO, 1.86 % in its ash (Sarwar et *al.*, 1989).

The use of the different parts of the plant (whole plant, root, manna "sweet exudate of leaves, branches" and stems) in folk medicine was reported (Al-Yahya *et al.*, 1987; Rizk and El-Ghazaly, 1995).

The proanthocyanidin isolated from *A. pseudoalhagi* possessed hypolipidemic properties (Glozman *et al.*, 1989), antioxidant properties effective in heart infaraction (Bashirova *et al.*, 1987,1989; Khushbaktova *et al.*, 1992), and artoprotecter effects (work capacity enhancement during work) (Khushbaktova *et al.*, 1988). Alhagin, from *A. pseudoalhagi*, possessed antiatherosclerotic and hypolipedemic effects (Aizikov *et al.*, 1986).

2. *ASTRAGALUS* L.

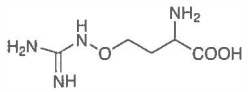
Astragalus is a very large genus of the Tribe Galegeae represented in Qatar by six species, mostly seasonal herb or low growing herbaceous perennials. *Astragalus* is subdivided into a number of sections represented by one or more species in the flora: *Astragalus corrugatus* Bertol (Harpilobus), *A. eremophilus* Boiss. (Facinellus), *A. hamosus* L. (Buceras), *A. sieberi* DC. (Chronopus) and *A. tribuloides* Del. (Oxyglottis).

The most common use of *Astragalus* in Asia is as forage for livestock and wildlife. Uphof (1968) listed thirty-two species known to have been used by man for food, medicine, cosmetics, substitutes for tea or coffee or as sources of vegetable gums.

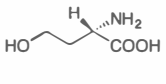
The study of the nutritive constituents of *Astragalus* species indicated that their forage quality is highly variable among species and accessions within species (Rizk, 1986). *Astragalus* spp. have a high content of protein amino acids. Savos'kin *et al.* (1971) analysed thirteen *Astragalus* species for total and protein nitrogen as well as other constituents. The highest total and protein nitrogen was found in *A. propingus* (6.9 and 4.5 %) and the highest vitamin C content (500 mg %) in *A. melilotoides*. Later, Savos'kin and Kadyrova (1974) analysed sixteen *Astragalus* species (growing in Novosibrisk, USSR) and reported that the amino acid and protein content correlated with the taxonomic placement of the species in various sections where the content of dry matter depended on the xerophtic characteristics of plants rather than on their systematic grouping. The subgenera *Phaca* (*A. propinquus* and *A. puberulus*), *Ercidothrix* (*A. ceratoides*, *A. austrosibimicus*, *A. onobrychis*, *A. sulcatus* and *A. testiculatus*), and *Calycocystis* (*A. folicularis*) contained 0.68-0.79, 0.45-0.64, and 0.51-0.5 % phosphorous in leaves. Xerophytes contained less potassium than xeromesophytes. The nitrogen and phosphorous levels were 49.9 % and 46.6 % respectively. In dry years, the dry matter was higher than in wet years (Savos'kin *et al.*, 1978). Specklepod loco (*A. lentiginosus*) contained

protein, 19.3; oil, 1.1; polyphenol, 7.4 and hydrocarbon < 0.1 % (dry, ash-free plant weight) (Carr *et al.*, 1985).

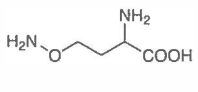
Brown and Fowden (1966) showed that some *Astragalus* species contained δ-acetylornithine. The distribution of certain non-protein amino acids and other ninhydrin-reacting compounds in seed extracts of 120 *Astragalus* species was determined by Dunnill and Fowden (1967). The latter study showed that all selenium-accumulating species tested were rich in *S*-methylcysteine, its δ-glutamyl derivative, and their sulphoxides. The majority of other species contained canavanine **(533)** as the major soluble-nitrogen component. Other amino acids generally present were δ-acetylorinithine, homoserine **(534)**, γ-hydroxynorvaline, δ-hydroxynorvaline, γ-glutamylphenylalanine and γ-glutamyltyrosine. Other non-protein amino acids and peptides, such as canavanine, γ-glutamylphenylalanine and γ-glutamyltyrosine were also reported in the seeds of *Astragalus* species (Rizk, 1986). Canaline **(535)**, a hydrolysable product of canavanine, as well as *erythro*-hydroxy-L-aspartic acid, have been also found in *Astragalus* species (Rizk, 1986). The root extracts from *A. membranaceus* and *A. chrysopterus* contained 25 and 21 amino acids respectively, amounting to 1.26 and 0.56 % of the total extract content (Xiao *et al.*, 1984).



533 Canavanine



534 Homoserine

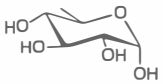


535 Canaline

The content and variation of trace elements in several *Astragalus* species have been studied e.g. *A. tibetanus* (Sudnitsyna, 1973) and *A. huangheensis* (Su *et al.*, 1985). *Astragalus* species, in general, were high in Ca, Mg, S, K and Cl (Beath *et al.*, 1934a,b, 1935; Beath, 1943; Cannon, 1964; Hamilton and Gilbert, 1971). Extensive work has been carried out on the selenium containing amino acids of *Astragalus* species (Rizk, 1986; Parker *et al.*, 1991; Cowgill and Lindenberger, 1991,1992; Neuhierl and Böck, 1996). In these plants Se was accumulated mainly in the form of Se-methylcysteine, whereas selenium-incorporation into proteins was reduced by approximately 90 % in comparison with non-accumulating *Astragalus* species (Shrift and Virupaksha, 1981). Biochemical analysis of several selenium-accumulating *Astragalus* species showed that, as in non-accumulating plants, seleno-amino acids probably were synthesized along pathways normally associated with sulphur metabolism (Brown and Shrift, 1982). A specific feature of selenium-accumulating species within the genus *Astragalus* is the accumulation of Se-methyl-selenocysteine accompanied by the synthesis of the respective sulphur derivative, *S*-methyl-cysteine (Dunnill and Fowden, 1967). Using cultured cells of *A. bisulcatus*, Neuhierl and Böck (1996) have characterised a specific selenocysteine methyltransferase with properties suited for diverging selenium from intrusion into sulphur pathways in this selenium-accumulating species.

Cowgill and Landenberger (1992) described how non-seleniferous *Astragalus* species coexist with seleniferous ones and what chemical changes occurred in non-seleniferous species that allowed the toleration of large quantities of volatilised Se-bearing compounds. These compounds are known for their phytotoxicity as well as for their toxicity to mammals and insects. *A. bisulcatus* and *A. racemosus*, two Se-accumulators were capable of tolerating several thousand milligrams Se per kilogram leaf tissue (Brown and shrift, 1982; Ihnat, 1989). The two latter species have been reported as good candidates for remediation of Se-enriched soils and sediments (Parker *et al.* 1991).

Astragalus species are used as a source of gum tragacanth. Within the exudates from *Astragalus* species, more than one structural type were represented, among which there was evidence of the occurrence as a minor component of neutral arabinogalactan. The bulk of the polysaccharide, however, was of quite different structure, based upon a chain of 1,4-linked D-galactopyranuronic acid units, most of which were substituted at C-3 by D-xylopyranosyl groups (Rizk, 1986). The chemical characterisations of several *Astragalus* gum exudates have been reported (Rizk, 1986; Anderson and Grant, 1988,1989; Anderson, 1989). The data obtained confirmed that the gums from different *Astragalus* species varied widely in their chemical composition e.g. galactomannans, glucans, other polysaccharides (with or without hexauronic acids), physico-chemical parameters, solubility and amino acid composition (Rizk, 1986; Anderson and Grant, 1989). Purified *A. lehmannianus* galactomannan (4.8 %) contained 55 % D-mannose and 45 % D-galactose (Mestechkina *et al.*, 2000). Evidence for the safety of gum tragacanth as a food additive has been proven (Anderson, 1989). Among the sugars identified from *Astragalus* polysaccharides were glucose, galactose, mannose, xylose, fucose (**536)** and arabinose. The polysaccharides from *A. echidnaeformis* were found to be very potent agents, protecting mice from mortality (Smee and Verbiscar, 1995).



536 D-Fucose

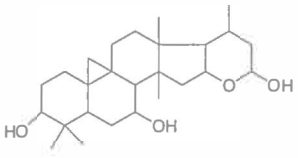
Acidic polysaccharides with activity on the reticuloendothelial system have been isolated from the roots of *A. membranaceus* (Tomoda *et al.*, 1992) and *A. mongholicus* (Rizk, 1986; Shimizu *et al.*, 1991). Astragalans (neutral polysaccharides) were isolated from the roots of *A. mongholicus* (Rizk, 1986). Two polysaccharides active in the enhancement of the IgM antibody production in the aged mice were isolated from *Astragalus* (Astragali Radix). The major components of the polysaccharides were neutral carbohydrates (89.3 and 95.5 %), followed by uronic acid and protein; glucose was the major predominant sugar component (Kajimura *et al.*, 1997). The mucilage content of 15 *Astragalus* species (from Iran) varied from 3.44 to 23.56 % dry weight. The mucilages of the different species showed the presence of glucose, galactose, arabinose, xylose, fucose and rhamnose but in different amounts. The uronic acids were detected in 12 of the 15 species (Ebrahimzadeh *et al.*, 2000).

The isolation and identification of many triterpenoid sapogenins and saponins from several *Astragalus* species have been reported (e.g. Rizk, 1986; He and Findlay, 1991; Hirotani *et al.*, 1994, 1995; Zhou *et al.*, 1995; Nikolov and Benbasst, 1997).

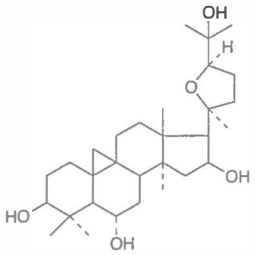
Stigmast-4-en-3-one and a mixture of 2'-angeloyloxy-1',2'-dihydroxyanthyletin and 2'-senecioyloxy-1',2'-dihydroxyxanthletin were isolated from the roots of *A. membranaceus* (Kim and Kim, 2000). β-Sitosterol was identified from *A. pycnanthus* (Isaev and Agzamova, 1999). Four major 3-β-hyroxysterols (cholesterol, campesterol, stigmasterol and β-sitosterol) were identified in the roots of 18 species and the seeds of five species of *Astragalus* growing in Iran (Ebrahimzadeh *et al.*, 2001).

Cycloastragenol was a common genuine aglycone in ten of the eleven astragalosides detected (Rizk, 1986; Kuang *et al.*, 1997; Sun *et al.*, 1997). A number of other triterpenoid sapogenins were identified e.g dasyanthogenin (**537)** from *A. dasyanthus*, cyclosiversigenin (**538)** from *A. sieversianus* and cycloasgenin from *A. taschkendicus* (Rizk, 1986). Several cycloartane glycosides were isolated from *A. boeticus* (Asaad, 2000), *A. dissectus* (Sukhina *et*

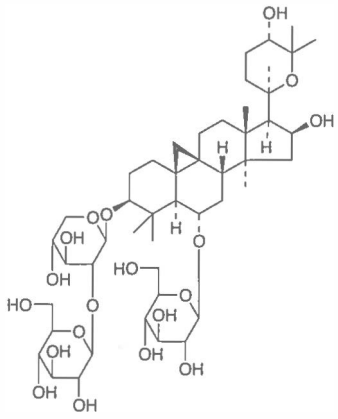
al., 1999), *A. globiceps* (Uteniyazov *et al.*, 1999), *A. oleifiolius* (Bedir *et al.*, 2000), *A. microcephalus* (Bedir *et al.*, 1998), *A. orbiculatus* (Agzamova and Isaev, 1997), *A. peregrinus* (Verotta *et al.*, 2001), *A. trojanus* (Bedir *et al.*, 1999), *A. trigonus* (Verotta *et al.*, 1998b) and *A. pycanthus* (Agzamova and Isaev, 2000; Isaev and Agzamova, 1999). Other triterpene glycosides e.g. soyasaponin I, sophoraflavoside II and robinioside E were isolated from *A. shikokianus* (Yahara *et al.*, 2000). Examples of the isolated triterpene glycosides are compounds (**539-550**) (Agazamova and Isaev, 1999, 2000; Sukhina *et al.*, 1999; Bedir *et al.*, 1999; Mamedova *et al.*, 2001).



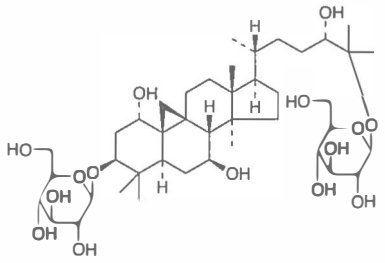
537 Dasyanthogenin



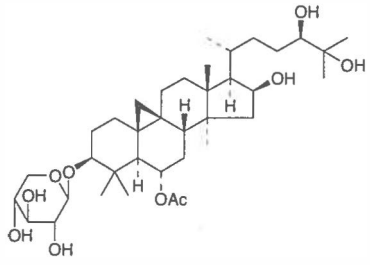
538 Cyclosiversigenin



539 Cyclocanthoside F



540 Macrophyllasaponin E



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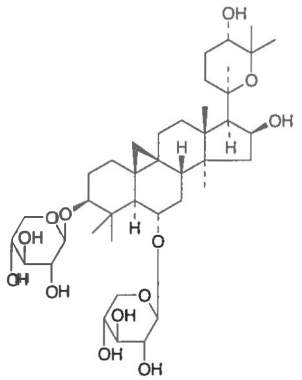
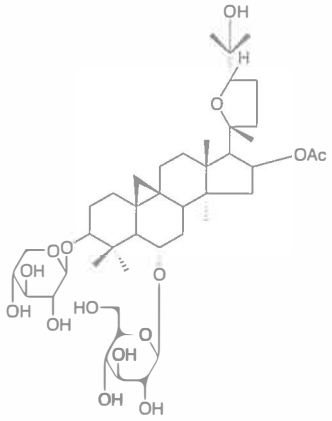
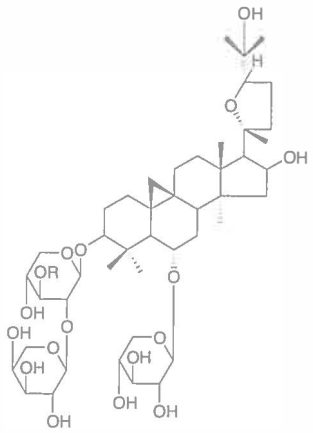


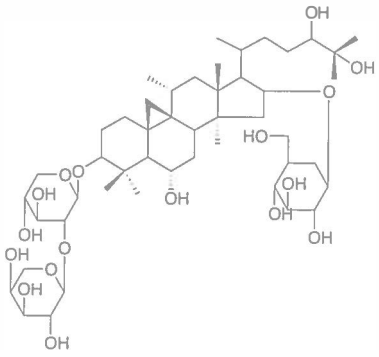
542 Cyclosieversioside



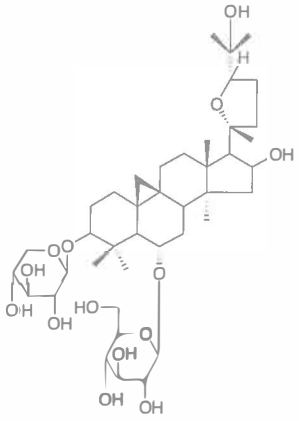
543 Trojanoside



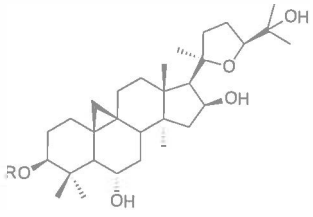
544 Askendoside B; R = Ac
545 Askendoside D; R = H



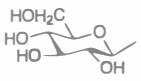
546 Askendoside G



547 Cyclosiversioside F



548 R =



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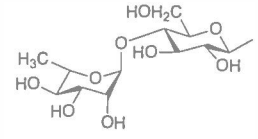

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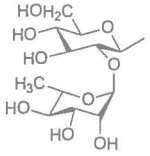
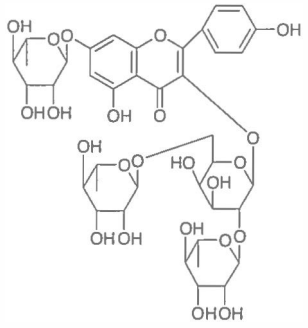
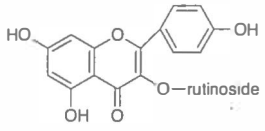


Several flavonoids have been identified from *A. ammodendron*, *A. caucasicus*, *A. dahuicus*, *A. dancicus*, *A. falcatus*, *A. fragidus*, *A. glycophyllos*, (Rizk, 1986), *A. complanatus* (Cui *et al.*, 1991,1992; Yamaki *et al.*, 1991), *A. cicer* (Lenssen *et al.*, 1994), *A. mongholicus* (Subarnas *et al.*, 1991) and *A. onobrychis* (Benbassat and Nikolov, 1995). Examples of the flavonoids isolated from *Astragalus* species included apigenin, quercetin, isorhamnetin, kaempferol and their glycosides (Rizk, 1986). Astragalin (kaempferol-3-*O*-glucoside) was detected in several species e.g. *A. ammodendron* (Rizk, 1986), *A. brachycarpus* (Kazakov *et al.*, 1981b), *A. lasioglettis* (Kazakov *et al.*, 1981a), *A. membranaceus* var. *mongholicus* (Yan *et al.*, 1998) and *A. polygala* (Kazakov *et al.*, 1981b). Astrasikokioside I **(551)** (kaempferol-3-*O*-α-L-rhamnopyranosyl-(1→6)-[α-L-rhamnopyranosyl-(1→2)]-β-D-galactopyranosyl-7-*O*-α-L-rhamnopyranoside), kaempferol-3-*O*-α-L-rhamnopyronosyl(1→2)-β-D-galactopyranosyl-7-*O*-α-L-rhamnopyranoside and robinin were isolated from *A. shikokianus* (Yahara *et al.*, 2000). Two antimicrobial isoflavans (Song *et al.*, 1997a) and six isoflavones (Song *et al.*, 1997b) were isolated from *A. membranaceus*. The isolation of isoflavones and a peterocarpan from *A. mongholicus* has been reported (Subarnas *et al.*, 1991). The isoflavones afrormosin, calycosin and odoratin, isolated from the roots of *A. membranaceus* possessed antioxidative activities superior or similar to those of butylhydroxytoluene and α-tocopherol (Shirataki *et al.*, 1997). The aerial parts of *A. tana* contained the following flavonoids: astragalin (kaempferol-3-glucoside), kaempferol, kaempferol-3-*O*-β-D-robinobioside, nicotiflorin (kaempferol-3-rutinoside **(552)**) and ascaside (kaempferol-3-*O*-β-D-galactopyranosyl-(3",4")-di-*O*-α-L-rhamnopyranoside) (Alaniya and Chkadua, 2000).

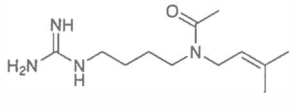


551 Astrasikokioside I

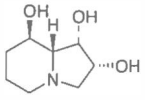


552 Nicotiflorin

Astragalus species have been found to produce alkaloids e.g. smirnovine **(553)** and swainsonine **(554)** from *A. tibetanus* and *A. lentiginosus* respectively and melanins from *A. cicer* (Rizk, 1986).

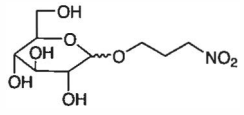


553 Smirnovine



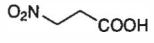
554 Swainsonine

Many *Astragalus* species are useful as forage plants, or to control erosion or as ornamentals. On the other hand, some *Astragalus* species are known as poisonous plants. The three general syndromes of poisoning in livestock caused by the consumption of certain *Astragalus* species are: (1) selenium poisoning associated with the genus *Astragalus* (approx. 21 species) that are known to accumulate selenium (Beath and Lehnert, 1917), (2) locoweed poisoning (about 13 species), and (3) intoxication associated with the consumption of the nitro-containing species (209 species) (Williams and Barneby, 1977a,b; Williams, 1980). Their various effects on livestock include: habituation, emaciation, neurologic damage and reproductive alterations. Problems related to reproduction include birth defects, abortions and depressed sexual activity, including attenuated spermatogenesis and oogenesis. Locoweeds (*Astragalus* species) are potent abortifients, and of all the clinical signs of locoweed intoxication, abortions appear to have the most serious economic effect on livestock. Death and resorption of the fetus or abortion may occur anytime during gestation after the animal has ingested an excessive amount of the plant. In addition, lambs born to ewes consuming locoweed may be small and weak at birth (James *et al.*, 1967,1981; Ellis *et al.*, 1985). Feeding 300 g or 400 g of dried spotted locoweed, *A. lentiginosus* per day to 11 pregnant Columbia ewes from the 20th to the 50th days resulted in dead and endematous fetuses. It was found that aspartate aminotrasferase values were increased, whereas serum progesterone values were significantly diminished. It was also reported that alterations in cotyledonary prostaglandin values might be a mechanism for altering the corpus lutem function and inducing fetal death, which would ultimately result in abortion (Ellis *et al.*, 1985). Ultrasonographic imaging was used to monitor fetal and placental developments in ewes fed locoweed (Panter *et al.*, 1987). More than half of the 558 species and varieties of North American *Astragalus* synthesise toxic aliphatic nitro compounds and another 5 % accumulate toxic levels of selenium from the soil or synthesise compounds associated with locoweed poisoning (Kingsbury, 1964; Williams and Barneby, 1977a,b). Range cattle and sheep are chronically or acutely poisoned by *Astragalus* species that accumulate the glycoside miserotoxin **(555)**, 3-nitro-1-propyl-β-D-glucopyranoside (Stermitz and Yost, 1978; Williams and James, 1978). The chronic form of intoxication was prevalent and related to the rate of consumption of the plant, the species of plant, and the stage of growth (James *et al.*, 1980). The nitro compounds catabolized in the digestive tract of ruminants were the highly toxic 3-nitro-1-propanol **(556)** and the less toxic 3-nitropropionic acid **(557)** (Wiliams and James, 1978; James *et al.*, 1980). Species of *Astragalus* that synthesise 3-nitropropanol at any level are prisonous to livestock. Concentrations of 5 to 9 mg NO_2/g of plant as 3-nitroperopanol in Emory milkvetch (*A. emoryanus* var. *emoryanus* (Rydb.) Corl) caused severe losses of cattle and sheep on range in New Mexico (Williams *et al.*, 1979).



555 Miserotoxin

556 3-Nitro-1-propanol



557 3-Nitropropionic acid

Panter *et al.* (1995) reported that selenium fed to open cycling ewes in the form of sodium selenate or *A. bisulcatus* at 24 or 29 ppm selenium, respectively, in alfalfa hay pellets did not

alter the estrus cycle length, estrus behaviour, progesterone or estrogen profiles, pregnancy rate or the outcome of parturition.

Species within the genus are chemotaxonomically related so that those that synthesise aliphatic nitro compounds (nitro-bearing species); tend to occur within certain taxonomic sections (Williams and Barneby 1977a,b). The nitro compounds are stable and can be detected in leaves of herbarium specimens that are over 100 years old (Williams, 1981). Miserotoxin, has been reported as the highly poisonous constituent of *A. miser* (Stermitz *et al.*, 1969, 1972). Ruminal microorganisms rapidly hydrolyse miserotoxin releasing the toxic aglycone 3-nitropropanol (Williams *et al.*, 1970; Majak and Clark, 1980). Clinical signs of intoxication observed under field conditions were similar to those produced by intra-ruminal injection or intervenous infusion of 3-nitropropanol (James *et al.*, 1980; Williams and James, 1976). Acute poisoning in cattle or sheep was associated with severe respiratory distress, pelvic limb weakness, recumbency and death. Knuckled metatarso-phalangeal joints and incoordination were manifested in chronic cases (Alston *et al.*, 1977). Low levels of metahemoglobin were produced when ruminants were poisoned by 3-nitropropanol or 3-nitropropanoic acid and its formation has been used as an indicator of the relative concentration of the nitrotoxin in the circulatory system (Williams and James, 1975). *In vitro* and *in vivo* metabolic studies were carried out with bovine blood to determine decay rates for 3-nitropropanol (Majak *et al.*, 1981). Enhanced degradation of 3-nitropropanol (NPOH) by ruminal microorganisms has been studied (Majk *et al.*, 1986). Ruminal fluid from cattle on fresh pasture diets enhanced the *in vitro* metabolism of NO^{-}_{2}, but rates of NPOH disappearance were not affected. Enhancement of NPOH degradation was achieved with supplements of nitroethane given intra-ruminally at 6.5 or 10mg/kg. The salt of nitroethane, given intra-ruminally at 20 mg/kg, resulted in the highest rate of NPOH degradation; this was similar to that reported for 3-nitropropionic acid which was much less toxic to ruminants than NPOH.

3-Nitropropanol is more toxic than 3-nitropropanoic acid. The difference in toxicity was apparently related to the rate of its absorption from the gastro-intestinal tract of the animal. As the plant matured, the concentration of the toxin decreased so that the plant was virtually non-toxic at senescence (James *et al.*, 1980). The disease in cattle associated with chronic poisoning by the nitro-bearing group of *Astragalus* has been called roaring disease, cracker heels, or knocking disease. The first signs of chronic intoxication in cattle are labored and rapid respiration (Williams and James, 1978). As the poisoning became more severe, the animal's respiration was eventually characterised by a wheezing or roaring sound. Other signs of intoxication include general body weakness, beginning in the pelvic limbs, knuckling of the fetlocks, goose stepping, and knocking together of the hind feet when walking. As the disease progresses, there may be drooping of the pelvic limbs or even loss of control of this part of the body; the limbs may be dragged when the animal moves. Some indication of temporary blindness has been observed. The animal may also drool saliva, the coat may become rough, and constipation or diarrhea may be observed. Less severely affected cattle may recover slowly. Lactating cows were commonly more affected than non-lactating cows (Bruce, 1927; Beath *et al.*, 1932; Williams, 1981).

3-Nitropropionic acid, obtained from *Astragalus* species had vasodilator and antihypertensive properties (Castillo *et al.*, 1993). 3-Nitro-1-propyl-β-D-laminaribioside has been isolated from the aerial parts of *A. miser* var. *serotinus* (Benn and Majak, 1989). Two new esters of glucose with 3-nitropropanoic acid and 5-oxotetrahydrofuran-3-acetic acid, together

Constituents

From the petroleum ether extract of *A. eremophilus*, collected from Egypt, β-sitosterol and ceryl alcohol were isolated. Several flavonoids were identified from the plant *viz*. kaempferol, quercetin, luteolin, luteolin-7-*O*-glucoside, astragalin, apigenin 7-*O*-glucoside, quercetrin and rutin (Makboul *et al.*, 1984).

2.3. *Astragalus hamosus* L., Sp. Pl., ed. 1, 758 (1753).
syn. *Astragalus brachyceras* Ledeb., Index Sem, Hort. Dorpat. 1822:3 (1822).

Halaq (Ar.)

Annual low spreading–decumbent herb with few branches reaching up to 10 cm long. Leaves compound of 6-12 pairs widely-spaced (7-8 mm apart); leaflets obovate, about 7 mm long, with white appressed hairs on the lower surfaces. Inflorescences few-flowered, clustered on a long peduncle, 6-8 cm long. Flowers papilonaceous with hairy calyces. Fruit 3-4, light brown, glabrous, upward curved legumes.

Habitat and Distribution

Widespread on shallow sandy soils throughout Qatar after the seasonal rains.

Constituents

The analysis of crude protein, crude fibre, tannin and oxalic acid concentrations of twenty-one accessions of *A. hamosus*, collected from different origins (Spain, Iran, Italy and Algeria)

showed high variation in content: protein 10.7 to 14.2 %; crude fibre 11.9-21.0 %; tannin 3.5-7.2 mg/g and oxalic acid 0.15-1.10 % (Davis, 1982).

A. hamosus, assayed 10.11 mg of NO_2/g in compounds that yielded 3-nitropropionic acid upon hydrolysis (Williams, 1980). The presence of nitro compounds in herbarium specimen (from Italy, Algeria and Iraq) showed an approximate concentration of 2 to 4 mg NO_2/g of dry weight (Williams, 1981a).

A. hamosus has been reported as an excellent sheep forage. The nitro content of the plant was so low that the plant would be only marginally toxic to livestock under range conditions. The effects on the livestock that graze *Astragalus* with low levels of 3-nitropropionic acid over long periods are unknown (Williams and Davis, 1982). However, water extracts of the leaves were toxic to chicks at the equivalence of 3 g of dried plant per chick and lethal at 6-8 g (Williams, 1980).

2.4. ***Astragalus siebieri*** DC., Prodr., 2:295 (1825).

Low woody silvery grey woolly sub-shrublet becoming stout and often spiny towards the end of its growth season. Leaves compound, imparipinnate, 6-8 cm long, of 12-22 pairs of leaflets and a terminal spiny tip. Inflorescences axillary, few-flowered racemes with yellow comparatively large papilinaceous flowers. Fruit broad sessile ± tough woody legumes.

Habitat and Distribution

Occasional in water catchment areas in central Qatar.
The plant is always heavily grazed.

Habitat and Distribution

Widespread but never forming pure stands or large communities. Common on sandy soils in south and south west Qatar, in Dukhan, Ras Ushairij and old Emirates route.

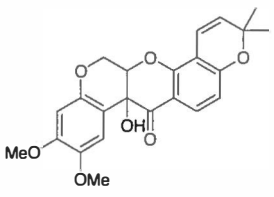
Constituents

The proximate analysis, amino acids and minerals of *I. articulata*, growing in Qatar, are shown in Tables 175, 176 and 178 (Al-Easa, 2002a,b,d).

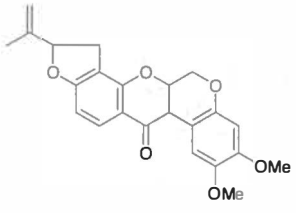
Small amounts of nitro compounds (4-8 mg NO_2/g of plant) were detected in herbarium specimen of *I. argentea* (collected from Haiti in 1926). *I. tinctoria* contains 2.8 mg NO_2/g plant (Williams *et al.*, 1981b).

A purified galactomannan from *I. tinctoria* grown in India, contained D-galactose (38.5 %) and D-mannose (58.5 %) in a molar ratio of 1:1.52 (Sen *et al.*, 1986). Khan and Kapoor (1999) reported that *I. articulata* seeds, could be utilized as suspending, dispersing and water holding agent in pharmaceutical and food industries.

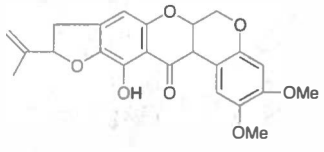
Coumarins and flavonoids were the major active compounds in the organs, especially leaves, in *I. tinctoria*. They were accompanied by cardiac glycosides, saponins and tannins (Dzhuraev *et al.*, 1986). The rotenoid content of various tissues of *I. tinctoria* were studied as an alternative source of these compounds. Total rotenoid content was highest (0.6 %) in the leaves, followed by the roots (0.51 %), seeds (0.4 %), pods (0.34 %) and stems (0.32 %). The rotenoids identified were tephrosin (**567**), dequelin, dehydrodequelin, rotenone (**568**) and sumatrol (**569**). Control of the cyclops *Mesocyclops leuckarti* with rotenoids was reported and discussed (Kamal and Mangla, 1987).



567 Tephrosin



568 Rotenone



569 Sumatrol

The purple urine observed from rats fed *I. tinctoria* was most probably due to the pigment indigo (Aylward *et al.*, 1987). The alcoholic extract of the aerial part of *I. tinctoria* exhibited antihepatotoxic effect (Anand *et al.*, 1979).

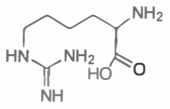
I. articulata forage from Indonesia contained 0.3 mg/g^{-1} 3-nitropropanoic acid (Alyward *et al.*, 1987).

4. *LOTUS* L.

The chemical composition, feeding value and digestibility of several *Lotus* species, and their evaluation as fodder plants, have been discussed by several authors (Rizk, 1986). *L. tenuis* showed high levels of crude protein [average 21.1 % dry matter (DM) basis] that did not change significantly with maturity. Digestibility of (DM) and organic matter reached mean

values of 72.0 and 66.5 % respectively, with a decline following a quadratic tendency (lowest value at approximately 120 days of growth), thereafter showing an increase toward the end of the growth cycle, in which the participation of regrowth acquired importance. Total cell wall content ranged 28-42 % with no significant change in time, inspite of the increase found for the fraction that included leaves, flowers and fruits. Lignin content increased from 8 to 12 % through the growth cycle, in the plant as a whole and leaves, but not in the stems, where it did not change. *L. tenuis* appeared to be a highly nutritive forage legume, characterized by a lower increase in fiber content and a lower decrease in digestibility with the advance of maturity, in comparison with other forage legumes (Echeverria *et al.*, 1986). A 3-year study on the stages of growth birdsfoot trefoil (*L. corniculatus*) at harvest showed that the dry matter yield increased significantly, in the spring growth, with advance in maturity up to the midbloom stage. However, the highest annual yield was obtained, when the birdsfoot trefoil was harvested at the full bloom stage both in the spring and the summer growth. Maximum protein yield per unit of land was also obtained at the full bloom stage. In the spring forage, the percentages of crude protein, cell content, cell well, lignocellulose, lignin, cellulose, ash and P and in the summer forage, the percentages of crude protein, lignocellulose, cellulose, ash, and P decreased significantly with maturity (Gervais, 1988).

Seventeen amino acids were identified in *Lotus* seeds. The total content of amino acids in *Lotus* seeds were 24.1 % (Zhao and Zhong, 1996). The study of free amino acids in the seeds of different *Lotus* species showed a high concentration of canavanine (2-amino-4-(guanidinooxy) butyric acid), γ-glutamyltyrosine and γ-glutamylphenylalanine. In some species (*L. helleri* and *L. purshianus*), homoarginine **(570)** (N^6-amidinolysine) was found (Rizk, 1986).

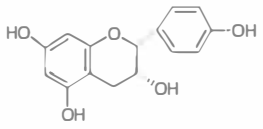


570 Homoarginine

Lotus species have been found to contain relatively high concentrations of condensed tannins. The role of condensed tannins (CT) in the nutrional value of *Lotus* species (e.g *L. corniculatus* and *L. pedunculatus*) for ruminants has been extensively studied (e.g Barry *et al.*, 1986a,b; Barry and Manley, 1986; Waghorn *et al.*, 1987; Lee *et al.*, 1995a; Wang *et al.*, 1996; Broderick and Albrecht, 1997). The tannins have been reported apparently to reduce the level of soluble proteins in ingested legume leaves below that required to induce bloat (Miltimore *et al.*, 1970). Studies have established that legumes that do not cause bloat, bird's-foot trefoil (*L. corniculatus*) produced protein pricipitants, principally condensed tannins, in their leaves (Ross and Jones, 1974). High concentrations of condensed tannins (CT) in *L. pedunculatus* depressed the mean matabolizing energy intake in sheep due to depressions in both the voluntary intake and the digestion of organic matter (Barry and Duncan, 1984). Relative to non-containing fresh forage, condensed tannins in *L. pedunculatus* increased duodenal N flow and calculated absorption of amino acids from the small intestine, but depressed ruminal digestion of soluble carbohydrate and hemicellulose (Barry, 1984). McNabb *et al.* (1993) reported that CT reduced the proteolysis of forage protein and the degradation of S amino acids to inorganic sulfide in the rumen, resulting in increased net absorption of methionine

and increased utilization of cystine for dry body synthetic reaction in sheep with a high capacity for wool growth. According to Tanner *et al.* (1994), the inhibitory effect of CT may have been due to CT binding to the dietary protein or to the rumen proteases, interfering with the action of proteases on susceptible sites within the substrate. The principle effect of CT in growing lambs grazing *L. corniculatus* was reported to increase wool growth without affecting voluntary feed intake (Wang *et al.*, 1996). High temperature (30° C) stress induced the formation of additional condensed tannin in the leaves of big trefoil (*L. uliginosus*) (Lees *et al.*, 1994).

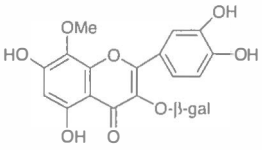
The study of the chemical structure of the proanthocyanidin polymers of *L. corniculatus* showed that the polymer was partially glycosidated with a number average in the range of 1800-2100 (six to seven flavoniod units). The products from phloroglucinol scission reaction indicated the extender flavan units to consist mostly of epicatechin (67 %) and epigallocatechin (30 %), with minor amount of catechin and epiafzelechin (**571**) units, which were linked together predominantly by C-4/C-8 interflavonoid bonds. The polymer chains were terminated mostly by catechin (83 %) and to a lesser extent, by epicatechin (16 %) (Foo *et al.*, 1996). The polymers of the proanthocyanidins were shown to be highly heterogenous with catechin, epicatechin, gallocatechin and epigallocatechin, all being constituent components of both the extenders as well as the terminating units (Foo *et al.*, 1997). *p*-Coumaric, vanillic and *p*-hydroxybenzoic acids were identified from *L. creticus* (Saenz Rodriguez *et al.*, 1990). The structures of the condensed tannins of three fodder *Lotus* species *viz. L. corniculatus*, *L. peducnculatus* and *L. tenuifolius* were described by Foo *et al.* (1982).



571 Epifzelechin

L. corniculatus yielded several flavonoids identified as: gossypetin-3-galactoside, gossypetin-7-methylether-3-galactoside (previously identified as quecetagetin-3-galactoside and its 7-methylether), 5,7,3',4'-tetrahydroxy-8-methoxylflavonol (corniculatusin-3-*O*-β-D-galactoside, **572**) quercetin, kaempferol, isorhamnetin, fisetin (5-deoxyquercetin, **573**), 5-deoxyisorhamnetin, (**474**), 5-deoxykaempferol (**575**), saxangularetin, (8-methoxykaempferol, **576**), limocitrin (8-methoxyisorhamnetin, **577**) (Rizk, 1986), kaempferol-3-glucosyl-7-rhamnoside, kaempferol-3,7-dihramnoside, kaempferol-7-glucoside, quercetin-7-rhamnoside, quercetin-3-glucosyl-7-rhamnoside and quercetin-3,7-dihrhamnoside (Walewska and Strzlecka, 1984). The herb, foliage, flowers, and seeds of *L. corniculatus* contained 0.99, 1.90, 1.93 and 0.42 % flavonoids, respectively (Walewska and Strzelecka, 1984). Four flavonoids were isolated from *L. glinoides*: kaempferol, quercetin, quercetin-3-*O*-galactoside and apigenin-7-*O*-glucoside (Radwan, 2000). The flavonoid compounds of *L. tenuis* were identified by Strittmatter *et al.* (1992) as kaempferol, kaempferol-3-*O*-glucoside and kaempferol-3-*O*-glucosyl-7-O-rhamnoside. The study of the flavonoids in the pasture legume *L. tenuis* (birdsfoot trefoil) in connection with different developmental stages revealed the presence of kaempferol and kaempferol-3-*O*-glucosyl-7-*O*-rhamnoside during the whole life cycle of the plant and in the different organs, whereas kaempferol-3-*O*-glucoside could only be detected during the reproductive stage. The seeds of *L. tenuis* had a high concentration of free quercetin and its

glycosides. No flavonoids were found in the roots (Wagner *et al.*, 1996). Naringenin, kaempferol, quercetin, three quercetin glycosides asnd catechin were detected in the seed exudate of *L. peduncularis*. Root exudates contained catechin, naringenin and quercetin in addition to apigenin, kaempferol and other flavones and flavonones (Steele *et al.*, 1999). Flavonoids accumulated faster than carotenoids prior to anthesis in *L. corniculatus*. The flavonoid content exceeded that of carotenoids by 5-fold in fully opened flowers. During floral development kaempferol decreased, wheras its 8-*O*-methyl derivative remained unchanged; the 8-OH derivative, was not found. In contrast, quercetin, 8-methoxyquercetin, and 8-hydroxquercetin increased during most of the development cycle (Jay, 1986).



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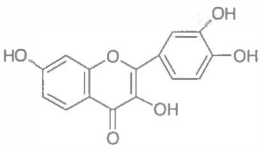
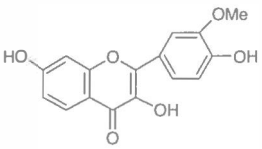


573 Fisetin



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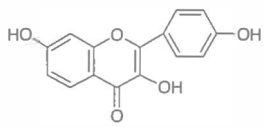

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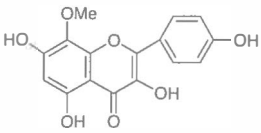

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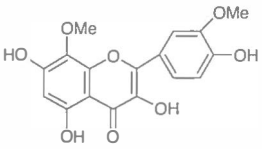
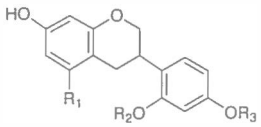
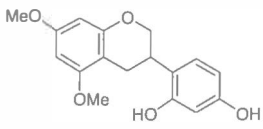


577 Limocitrin

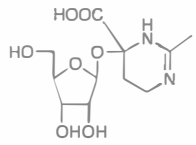
The anthocyanin awobanin (delphinidin-3-(*O*-*p*-coumaroylglucoside)-5-glucoside was isolated from *L. corniculatus*. Several isoflavan phytoalexins have been identified from *Lotus* species inoculated with fungi e.g. sativan (sativin, **578**), demethylvestitol (**579**), vestitol (**580**), 5-methoxyvestitotol (**581**) and lotisoflavan (**582**) from *L. angustissumus*, *L. carbonum*, *L. corniculatus*, *L. hispidus* and *L. uliginosus* (Rizk, 1986). Rhizolotine (**583**), an opine-like metabolite was isolated from root nodules of *L. tenuis* isnoculted with *Rhizobium loti* (Shaw *et al.*, 1986).



578 Sativan (= Sativin); R_1 = H, R_2 = R_3 = Me
579 Demethylvestitol; R_1 = R_2 = R_3 = H
580 Vestitol; R_1 = R_2 = H, R_3 = Me
581 5-Methoxyvestitol; R_1 = OMe, R_2 = H, R_3 = Me



582 Lotisoflavan



583 Rhizolotine

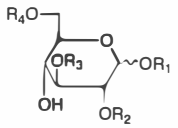
L. corniculatus contained prolinebetaine, glycinebetaine, pipecolatebetaine and hydroxyprolinebetaine (Wood *et al.*, 1991).

Several studies have been reported on the fucose binding proteins of *L. tetragonalobus* (e.g. Leu *et al.*, 1985; Kamada *et al.*, 1987; Sehested and Skovsgaard, 1988). These are glycoproteins, whose major components had apparent relative molecular masses of > 100,000.

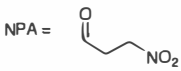
Cyanogenesis has been recorded in many *Lotus* pecies (e.g. *L. australis*, *L. corniculatus*, *L. krylorii* and *L. ornithopodioides*) (Ramani and Jones, 1984; Ramani *et al.*, 1986; Rizk, 1986; Aikman *et al.*, 1996).

Oleanolic acid and a saponin, which upon hydrolysis, yielded soyasapogenol B, were isolated from *L. corniculatus* (Rizk, 1986).

Four aliphatic nitro esters were isolated from foliage and roots of *L. pedunculatus*: hiptagin [1,2,4,6-tetra-(3-nitropropanoyl)-β-D-glucopyranose], karakin (**584**) [1,4,6-tri-(3-nitropropanoyl)-β-D-glucopyranose], coronarian (**585**) [2,6-di-(3-nitropraponoyl)-β-D-glucopyranose] and cibarian (**586**) [1,6-di-(3-nitropropanoyl)-β-D-glucopyranose] (Gnanasunderam and Sutherland, 1986).



584 Karakin; R_1 = β-$CH_3CH_2CH_2CH_2NO_2$, $R_2 = R_3 = R_4$ = H
585 Coronarian, R_1 = αH, $R_2 = R_4$ = NPA, R_3 = H
586 Cibarian, R_1 = β-NPA, R_4 = NPA, $R_2 = R_3$ =H



The presence of alkaloids in certain *Lotus* species has been reported. Lupanine was identified as the main alkaloid of *L. aegeus* (Rizk, 1986).

4.1. *Lotus garcinii* DC., Prodr. 2:212 (1825).

Garn al Ghazal (Ar.)

Woody perennial undershrub. Inflorescences solitary with sessile mauve flowers.

Habitat and Distribution

A rare plant in Qatar reported by Batanouny (1981) as growing on maritime calcareous sand at Ras Ushairij.

Constituents

The proximate analysis, fatty acids and minerals of *L. garcinii*, growing in Qatar, are shown in tables 175, 177 and 178 (Al-Easa, 2002a,c,d).

L. garcinii, growing in Pakistan, contained garcintin [3-*O*-(3"-*O*-α-L-rhamnopyranosyl)-α-L-rhamnopyranosyl kaempferol], isophytol, hexadecanoic acid, cholesterol, oleanolic acid, betulinic acid and lupeol (Ali *et al.*, 2000).

Phytochemical screening of *L. garcinii*, growing in Qatar, revealed the presence of alkaloids, coumarins, flavonoids, sterols (and/or terpenes) and tannins (Rizk *et al.*, 1986a).

4.2. ***Lotus halophilus*** Boiss. and Spruner in Boiss., Diagn. Pl. Orient., ser. 1,2:37 (1843).
syn. *L. villosus* Forssk. Fl. Aegypt.-Arab. LXXI (1775), non Burm. Fag.Fl. Cap. Prodr. 23 (1768).
L. pusillus Viv.; Fl. Libyc. Spec. 47 (1824), non Medicus, Bot. Beob. 1783:226 (1784).

Garn al Ghazal (Ar.)

Prostrate annual herb with numerous slender radiating branches. Leaves alternate imparipinnate of 5 leaflets, the terminal leaflet larger, whole leaf about 1 cm long. Inflorescences axillary of few flowers. Flowers about 0.5 cm long, yellow; calyx persistent in fruit. Fruit linear, slightly falcate brown pods, about 2 cm long.

Habitat and Distribution

Widespread on sandy soils after the first rains all over Qatar.

Constistuents

The fatty acids analysis and minerals of *L. halophilus*, growing in Qatar, are shown in tables 177 and 178 (Al-Easa, 2002a,d).

Phytochemical screening of *L. halophilus*, growing in Qatar, revealed the presence of alkaloids, coumarins, flavonoids, sterols (and/or terpenes) and tannins (Rizk *et al.*, 1986a).

5. *MEDICAGO* L.

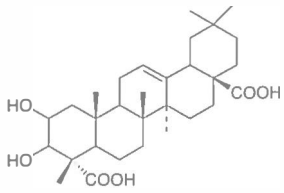
Medicago species, and in particular *M. sativa* (alfalfa), are well-known forage plants. Other than *M. sativa* (discussed later in detail), the nutritive value of some other species has been reported e.g. *M. arborea* (Martin *et al.*, 2000), *M. dendiculata*, *M. falcata* (yellow alfalfa), *M. facinata*, (Rizk, 1986), *M. luplina* (Vitkus *et al.*, 1985), *M. suaeveolens* (Zheng and Huang, 1994) and several others. The crude protein content of the pods of several *Medicago* species ranged from 13.11 to 24.75 % and that of the seeds from 27.65 % to 49.96 %. The seeds of *Medicago* species were reported poor in CaO and rich in P_2O_5. A guanidinooxy compound, similar in its colour reactions to canvanine, has been detected in *M. arborea* (Rizk, 1986).

Betaines were characterized in *Medicago* species. Salt resistance of apical meristems in wild and cultured leucerne species decreased in the order of *M. maina*, *M. varia*, *M. coerulea*, *M. littoralis*, *M. difalcata*, *M. trautvetteri*. Maximum accumulation of betaines in the salt-resistant wild *M. marina* was observed at 0.8 % NaCl in the medium, whereas that in moderately resistant *M. varia* was at 0.5 % and that in non-resistant *M. trauvetteri* was at 0.3 % NaCl (Baburina and Shevyakova, 1987).

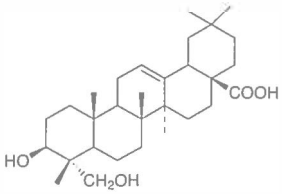
The seeds of *M. luplina* contained a galactomannan, the structure features of which did not deviate from the commonly accepted galactomannan structure (Rizk, 1986).

The occurrence of saponins in several *Medicago* species and their aglycons were surveyed in the seeds of 33 species of *Medicago*. The aglycons identified in these species were medicagenic acid **(587)**, zahnic acid, oleanolic acid, hederagenin **(588)** and soyasapogenols B **(589)**, E **(590)**, X and Y (Jurzysta *et al.*, 1992). Medicagenic acid glycosides were also detected in the leaf tissue of several *Medicago* species (Jurzysta *et al.*, 1988). Of the 14 investigated species by Ilieva (1995); the lowest saponins content was found in *M. coerulea* and *M. sativa*

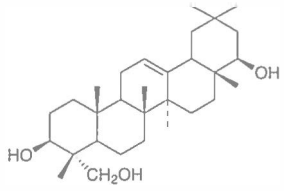
and the highest in *M. quasifalcata* and *M. falcata*. The saponins isolated from tops, blossoms and roots of *M. luplina* (black medic terfoil) gave on hydrolysis the following aglycons: soyasapogenols B, C (**591**), D (**592**), E, N (**593**) and An (**594**), medicagenic acid and hederagenin (Gorski *et al.*, 1984a,b; Jurzysta *et al.*, 1987; Oleszek *et al.*, 1987). Among 500 individually analysed plants of *M. luplina*, the saponin contents ranged from 0.07-0.5 % in the leaf sap (Gorski *et al.*, 1984c).



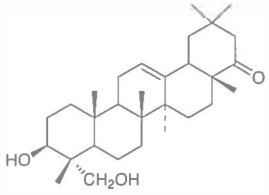
587 Medicagenic acid



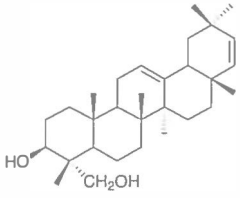
588 Hedragenin



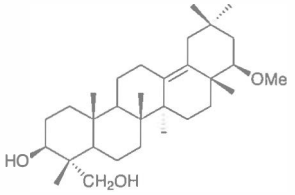
589 Soyasapogenol B



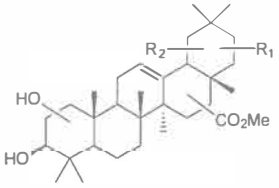
590 Soyasapogenol E



591 Soyasapogenol C

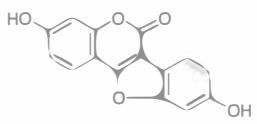


592 Soyasapogenol D

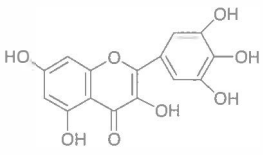


593 Soyasapogenol N; R_1R_2 = O
594 Soyasapogenol An; R_1 = H, R_2 = OH

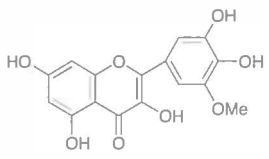
Coumestrol (**595**), an estrogenic compound which occurs in alfalfa, was also detected in other species e.g. *M. littoralis*. Several flavonoids and other phenolic compounds were identified from *Medicago* species. Twenty-two flavonoids were isolated from the seeds of *M. varia*, including the 5-methoxy flavonoids: luteolin-5-methylether, luteolin-5,3'-dimethylether, azaleatin-3-galactoside and quercitin-5,3'-dimethylether-3-glucoside (Rizk, 1986). Compounds, tentatively identified as kaempferol, quercetin, myricetin (**596**) and laricitrin (**596**) were present in the hydrolyzates of *M. arborea*, *M. cretacea*, *M. hybrida*, *M. luplina* and *M. rodiata* (Jurzysta *et al.*, 1988). Seven main flavonoids (luteolin, luteolin-7-glucoside, 7,3',4'-trihydroxylavone, 7,3',4'-trihydroxyflavone-7-glucoside, 7,4'-dihydroxyflavone, quercetin-3-glucoside, and kaempferol-3-glucoside) were identified in the seed coats of *M. arborea* and *M. strassevi* (Perez-Garcia *et al.*, 1992). The major flavoniods of *M. humulus* were quercetin and rutin (Prostodusheva *et al.*, 1998).



595 Coumestrol



596 Myricetin



597 Laricitrin

Bauchrowitz *et al.* (1992) described the cloning and characterization of 2 lectin genes from *M. trancatula.*

The study of the carotenoids in petals of 22 *Medicago* species, revealed that no major carotenoid was species or group- specific; a few minor pigments, however, were group or species-specific. The amount of carotenoids ranged from 7 µg/g dry matter in violet-flowered *M. sativa* to 2,120 µg/g in brownish-yellow *M. platycarpos.* Xanthophylls constituted 76-99 % of the total with lutein as the major component. β-Carotene, lutein and flavoxanthin were ubiquitous in petals (Rizk, 1986).

Screening of more than sixty species of annual and perennial *Medicago* species in Canada, as well as of thirty-five species in Australia, revealed that none of the tested species produced tannins in the leaves. On the other hand, all the tested species produced high levels of condensed tannins in the seed coat (Rizk, 1986).

5.1. ***Medicago laciniata*** (L.) Mill. Gard. Dict., ed. 8, no.5 (1768).

syn. *Medicago polymorpha* L. var. *laciniata* L., Sp. Pl., ed. 1, 781 (1753); *M. laciniata* (L.) All., Pl. Pedem. 1:316 (1785).

Jat Barri, Nafal (Ar.)

Annual herb up to 6 cm high with spreading branches 5.5 cm across. Leaves trifoliate, minute. Leaflets never exceeding 0.5 cm length. Inflorescences few-flowered racemes of yellow flowers. Fruit a coiled legume, 5-seeded, 1.5 cm across; valves of pod with hooked spines.

Two varieties were recorded for Qatar: var. *laciniata* and var. *brachyacantha* Boiss. [syn. *Medicago aschersoniana* Urb., Verh. Bot. Vereins. Prov. Brademb. 15:77 (1873)].

Habitat and Distribution

Widespread on sandy soils all over Qatar usually in shallow depressions and on sandy mounds appearing after the initial seasonal rains.

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *M. laciniata*, growing in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d).

M. laciniata was early reported to contain water 27.5 %; lipids, 1.75 %; albuminoids 6.6 %; fiber 5.97 %; carbohydrates 55.28 % and ash 2.94 % (Rizk, 1986).

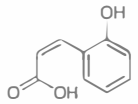
Soyasopogenols B and E were identified in the saponin hydrolysate of *M. laciniata* (Jurzysta *et al.*, 1992).

Luteolin 7-glucuronide, and di- and possibly triglycosides were detected in *M. laciniata* (Saleh *et al.*, 1982). Moreover, the phytochemical screening of the plant, growing in Qatar, revealed the presence of alkaloids, saponins, and sterols (and/or terpenes) (Rizk, 1986).

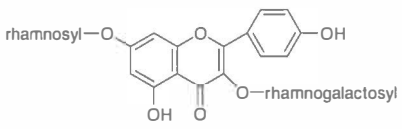
at 100 g/kg prevented heating and dicoumarol formation in hay rewetted to 400 g/kg moisture, but HT at 3 and 10 g/kg did not have any effect (Sanderson *et al.*, 1986). Anhydrous NH_3, at 10 or 30 g/kg prevented dicoumarol formation in sweet clover. Accordingly, Sanderson *et al.* (1985) reported that the anhydrous NH_3 appeared to be a promising preservative for preventing the occurrence of dicoumarol in sweet clover hay and thereby prevented the sweet clover bleeding disease in livestock.

o-Coumaric and coumarinic acids (the *trans*- and *cis*-isomers, respectivily of *o*-hydroxycinnamic acid (**642**)) were closely present in the glycosidic form in sweet clover tissue. *M. siculus* was found to contain coumarin, fraxiden, herniarin, scopoletin, umbelliferone and two fraxidin glycosides (Rizk, 1986).

A number of flavonoids have been identified in *Melilotus* species *viz.* robinin (**643**) from the flowers of *M. altissumus*, *M. arvensis* and *M. leucanthus*, quercetin, kaempferol and quercetin-3-galactoside from *M. siculus* (Rizk, 1986). The leaves and flowers of *M. officinalis* contained kaempferol (Kang *et al.*, 1987a), robinin and kaempferol-3-*O*-[galacto-3-gluco-3-arabino-3-rhamnoside] (Sutiashvili and Alaniya, 1999]. The phytoalexin medicarpin was isolated from the infected leaves of *Melilotus* species (Rizk, 1986).



642 o-Hydroxycinnamic acid



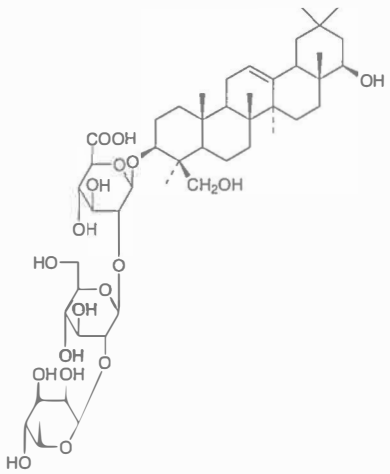
643 Robinin

M. officinalis contained the following phenolic acids: *o*-coumaric, *p*-coumaric, ferulic, melilotic, sinapic, salicylic, *p*-hydroxybenzoic, *p*-hydroxyphenylacetic, vanillic, gentisic, protocatechuic, syringic, gallic and caffeic acids (Dombrowicz *et al.*, 1991).

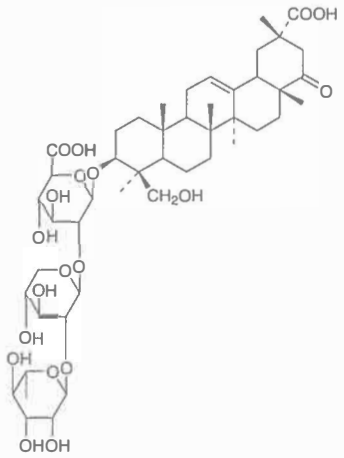
Monoterpenes (Woerner and Schreier, 1990), oleanic triterpenes (Nicollier and Thompson, 1983; Kang *et al.*, 1987a,b, 1988; Kang and Woo, 1988) and steroids (Bohannon *et al.*, 1974; Balbaa *et al.*, 1977; Khodakov *et al.*, 1994, 1996) were isolated from *Melilotus* species.

M. officinalis contained saponins e.g. azukisaponin V (**644**) (Kang *et al.*, 1987b), melilotus-saponin O_1 [3-*O*-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranosyl-(1→3)-β-D-galacto-pyranosyl-(1→2)-β-D-glucopyranosyl) soyasapogenol B] (Udeyama, 1998) and melilotus-saponin O_2 (**645**) [3-*O*-α-L-rhamnopyranosyl-(1→2)-β-D-xylopyranosyl-(1→2)-β-D-glucopyranosyl melilotigenin] (Hirakawa *et al.*, 2000). Soyasapogenols B and E were identified in the acid hydrolysis fraction of *M. officinalis* (Kang *et al.*, 1987a). The sapogenin melilotigenin (**646**) was isolated from the leaves and flowers of *M. officinalis* (Kang and Woo, 1988).

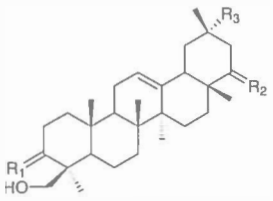
The aerial parts of *M. messanesis* (sweet clover) contained the following triterpenes: melilotigenin (**646**), melilotigenins B-D (**647-649**), soyasapogenols B, G and E, lupeol, betulin, betulinaldehyde (**650**), betulinic acid, betulonic acid (**652**), messagenin (**653**, a *nor*-lupane) gammacer-16-ene-3-one (**651**), messagenolide, messagenic acids A-I (**654-661**), platanic acid (**662**), 3β,28,30-lup-20(29)-enetriol (**663**), 3-oxoplatanic acid (**664**), and 3,29-dioxolup-20(30)-en-28-oic acid (**665**) (Macias *et al.*, 1994-1998).



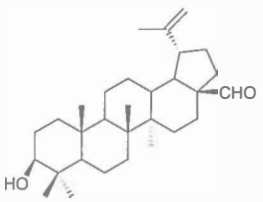
644 Azukisaponin V



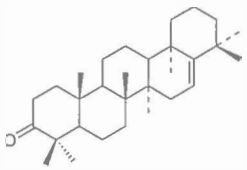
645 Melilotus-saponin O_2



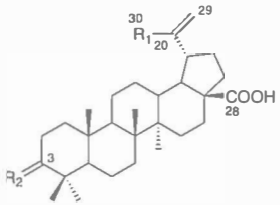
646 Melilotigenin; R_1 = OHβ, Hα, R_2 = O, R_3 = COOH
647 Melilotigenin B; $R_1 = R_2$ = O, R_3 = Me
648 Melilotigenin C; R_1 = O, R_2 = OHβ, Hα, R_3 = Me
649 Melilotigenin D; $R_1 = R_2$ = O, R_3 = COOH



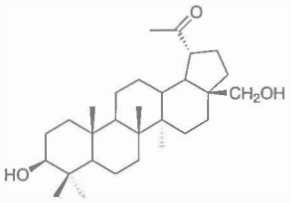
650 Betulinaldehyde



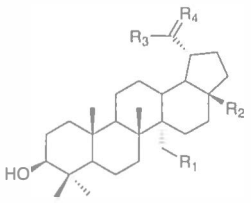
651 Gammacer-16-en-3-one

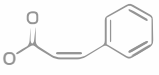


148 Betulic acid (=Betulinic Acid); $R_1 = CH_3$, R_2 = OHβ, Hα
652 Betulonic acid; $R_1 = CH_3$, R_2 = O
657 Messagenic acid D; $R_1 = CH_2OH$, R_2 = OHβ, Hα
658 Messagenic acid F; R_1 = CHO, R_2 = OHβ, Hα
659 Messagenic acid G; $R_1 = CH_2OH$, R_2 = O
665 3,29-Dioxolup-20(30)-en-28-oic acid; R_1 = CHO, R_2 = O

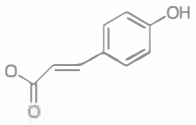


653 Messagenin



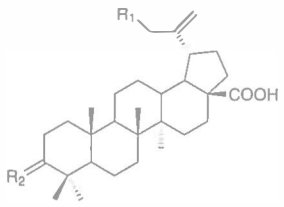


654 Messagenic acid A; R_1 = ; R_2 = COOH, R_3 = H, R_4 = CH_2



655 Messagenic acid B; R_1 = ; R_2 = COOH, R_3 = H, R_4 = CH_2

656 Messagenic acid C; R_1 = H, R_2 = COOH, R_3 = H, R_4 = CHO, H
662 Platanic acid; R_1 = H, R_2 = COOH, R_3 = H, R_4 = O
663 3β,28,30-Lup-20(29)-enetriol; R_1 = H, R_2 = CH_2OH, R_3 = OH, R_4 = CH_2

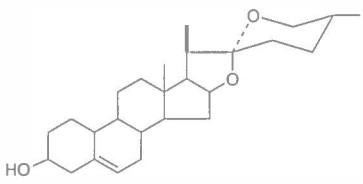


660 Messagenic acid H; R_1 = OH, R_2 = O
661 Messagenic acid I; R_1 = OH, R_2 = OHβ, Hα
664 3-Oxoplatanic acid ; R_1 = H, R_2 = O

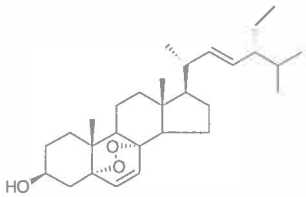
Diosgenin (**666**) and 25α-spirosta-3,5-diene were detected in the roots, stems, leaves and pericarp of *M. siculus* (Balbaa *et al.*, 1977). Diosgenin was also identified in *M. messanensis* (Bohannon *et al.*, 1974). Five steroids were isolated from *M. messanensis viz.* β-sitosterol, ergosterol peroxide (**667**), 7α-hydroxysitosterol (**668**), 7β-hydroxysitosterol (**669**) and 7-oxositosterol (**670**) (Macias *et al.*, 1997). Triterpenes and steroids isolated for *M. messanensis* possessed potential allelopathic activity (Macias *et al.*, 1994-1998).

Trillin, dioscin and four steroid saponins were isolated from the seeds of *M. tauricus* (Khodakov *et al.*, 1994,1996).

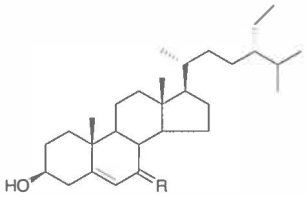
The effects of NaCl salinity and plant age on allocation of biomass and mineral elements in *M. segetalis* (annual sweet clover) were studied by Romero and Maranon (1996). Salt-stressed plants were smaller and invested proportionately more biomass in the leaves, N was accumulated in the roots of young plants and excluded from the leaves and the fruits, where K was depleted from the roots and accumulated in the leaves and the fruits. Immobile Ca accumulated in the leaves with age. Phloem-mobile P and N were translocated to the flowers and the fruits. Fe, Cu, and Zn were diluted in the leaves and not affected by salt, whereas Mn concentration increased with age and salinity. Salinity induced a re-allocation of the biomass and mineral elements in all the plant organs except the reproductive structures.



666 Diosgenin



667 Ergosterol peroxide



3 β-Sitosterol, R = H
668 7α-Hydroxysitosterol, R = OHα, H
669 7β-Hydroxysitosterol, R = OHβ, H
670 7-Oxositosterol, R = O

Beside the use of *Melilotus* species as a valuable fodder, certain species has been used in folk medicine. *M. officinalis* (common melilot) was employed as an analgesic in neuralgia, in bronchial disorders, as an antispamodic, stimulant, slight astringent and in cigarettes for asthma. It was also applied to wounds and glandular swellings in the form of plasters or poultices. In addition, its decoction was prescribed as a stomachic while its infusion was employed as an antiopthalmic (Abou-Donia, 1976).

Pediatric anti-inflammatory ointment and skin cosmetic moisturizer preparations contained *M. officinalis* extracts (Tanase *et al.*, 1986; Shinomiya, 1991). An extract of *M. officinalis* flowers and leaves (containing 0.2 % coumarin) decreased both spontaneous and bradykinin-induced contraction of the smooth muscle of isolated bovine mesentric lymphatics (Ohhashi *et al.*, 1986). The immunostimulant, antiacmicm and adaptogenic activities of the polysaccharides of *M. officinalis* were evaluated (Podkolzin *et al.*, 1996).

6.1. ***Melilotus albus*** Medik., Vorles, Churpfäls. Phys.-Öcon. Ges. 2:382 (1787).
syn. *Melilotus argutus* Rchb., Fl. Germ. Excurs. 499 (1832).

Handagog (Ar.)

Similar to *M. indicus* but with white flowers and paler green pods with very faint veins on the valves. The plant has also similar habitat and distribution as above.

Habitat and Distribution

Widespread as a garden and farm weed during the rainy season only. Common on rodats during the rains.
Less common than above though with similar habitat and distribution.

Constituents

M. alba, white sweet clover, is a widely distributed plant in the United States, and a source of feed for animals, a cover crop and a source of nectar for the honey bee (Nicollier and Thompson, 1983). *M. alba* was reported as rich in protein (Ripa and Geidans, 1964). Proteins, free amino acids and peptides in the vegetative organs of *M. alba* were reported as follows: non-protein compounds (extracted with ether and acetone) 8.17-14.29 %, albumin 4.08-6.69 %, globulins 1.78-2.45 %, total soluble N 14.70-22.76 %, glutelins extracted with 0.2 % NaOH 26.79-33.47 % and glutelins extracted with 2 % NaOH 42.68-44.08 % (based on total N) (Ripa, 1966). Inoculation of *M. albus* with nodule bacteria increased the total plant amino acids content by 1.5-2 fold, protein content 3 % and dry mass yield by 24.6-27.6 % (Makarenko and Deineko, 1986).

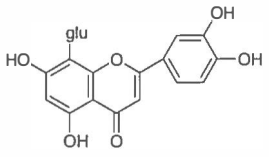
Coumarin, *o*-cumaric acid and melilotic acid were the major active componds in white sweet clover (*M. alba*) (Nicollier *et al.*, 1985). Other related compounds were detected *viz.* 7-hydroxycoumarin 6-glucoside, *o*-hydroxycinnamic acid, *trans* 2-hydroxycinnamic acid and 4-hydroxycinnamic acid. The changes occurring in the glucoside of *o*-hydroxycinnamic acid in *M. alba* leaves during ontogenesis of the plant was reported (Rizk 1986). The coumarin content of *M. alba* was equal to 0.34 % (Orlov, 1988).

Sweet clover (*M. alba*) allowed to cure under damp conditions often supported the growth of fungi. As these fungi undergo metabolic operations the plant material became spoiled and appeared mouldy and dark in colour. At the same time the fungi utilized a substrate from the sweet clover to produce dicoumarol, which is an anitcoagulant, and thus cattle feeding on spoiled sweet clover developed a hemorrhagic disease (Rizk, 1986). Poisoning in stock due to white sweet clover (*M. alba*) has been reported. Several affected animals may die from hemorrhage, precedent to which there may be swellings all over the body due to extravasation

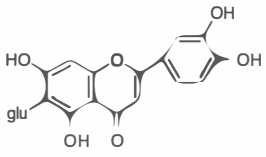
of the blood. The first indication of trouble may be bleeding from the nose. The affected animals may be recognized by the odour of dicoumarol emanating it. There was no evidence that green sweet clover is injurious to stock, or that bright, clean properly cured sweet clover was toxic (Watt and Breyer-Brandwijk, 1962; Abou-Youssef, 1979; Rizk, 1986).

M. alba contained the following flavonoids: robinoside, orientin **(671)**, isoorientin **(672)**, 6,8-Di-*C*-pentosylapigenin and probably quercetin 3-rhamnoglucoside (Rizk, 1986).

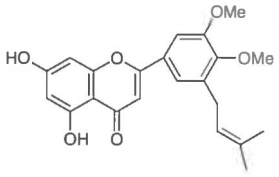
The leaves and flowers of *M. alba* contained a prenylated flavanone identified as 2,3-dihydro-5-dihydroxy-2-[3',4'-dimethoxy-5'-(3-methl-2-butenylphenyl]-4H-benzopyran-4-one **(673)** (Souleles, 1992).



671 Orientin



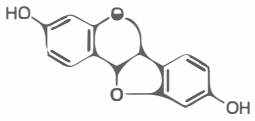
672 Isoorientin



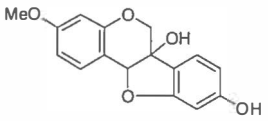
673

Al-Hazimi and Al-Andis (2000) isolated the following pterocarpans from the leaves of *M. alba*, growing in Saudi Arabia: 3-hydroxy-8,9-dimethoxypterocarpan, medicarpin and 3,8-dihydroxy-9-methoxypterocarpan.

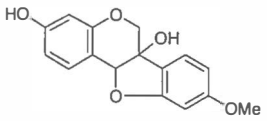
Inoculation of detached leaflets with *Botrytis cinerea* resulted in the production of the following phytoalexins: medicarpin, vestitol, demethylmedicarpin **(674)**, 6α-hydroxymedicarpin **(675)**, 6α-hydroxyisomedicarpin **(676)**, 4-hydroxydemethylmedicarpin **(677)**, 4-hydroxymedicarpin **(678)** and 4-hydroxyhomopterocarpin **(679)** (Rizk, 1986).



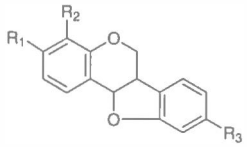
674 Demethylmedicarpin



675 6α-Hydroxyisomedicarpin



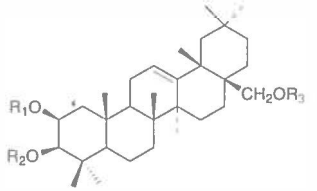
676 6α-Hydroxymedicarpin



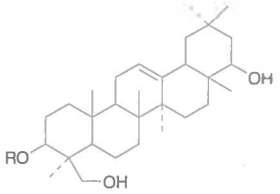
677 4-Hydroxydemethylmedicarpin; $R_1 = R_2 = R_3 = OH$
678 4-Hydroxymedicarpin; $R_1 = R_2 = OH$, $R_3 = OMe$
679 4-Hydroxyhomopterocarpin ; $R_1 = R_3 = OMe$, $R_2 = OH$

A triterpenoid saponin, melilotin **(680)**, 2β–[L-rhamnopyranosyl-(1→4)-β-D-glucopyransoyloxy-(1→2)]-3-β-L-rhamnopyranosyl-(1→4)-β-D-glucopyranosyloxy-(1→3)]-28-trihydroxyolean-12-ene, has been isolated from the flowers of *M. alba* (Nicollier and Thompson, 1983). Melilotoside D **(681)** (soyasapogenol B glycoside) was isolated from the

roots of *M. alba* (Shashkov *et al.*, 1994). Four more saponins of the oleanane series (glycosylated soyasapogenol B compounds) and nonglycosylated soyasapogenol B were also isolated from the roots of *M. alba* (Khodakov *et al.*, 1996).



680 Melilotin; R_3 = H, R_1,R_2 =rhamnose(1→4)glucose



681 Melilotoside D;R = {[α-L-rhamnopyranosyl-(1→2)]-[α-L-arabinopyranosyl-(→3)]-β-D-galactopyranosyl-(1→2))-α-Larabinopyranosyl}

M. alba has been early reported to contain a cyanogenic glycoside. A decoction of *M. alba* or *M. macrorhiza* was employed as a popular refreshing drink (Abou-Donia, 1976). The plant was also reported to contain alkaloids (Viladomat *et al.*, 1986).

6.2. ***Melilotus indicus*** (L.) All., Fl. Pedem. 1:308 (1785).

syn. *Trifolium indicum* L. Sp. Pl., ed. 1, 765 (1753). :765 (1753). *Melilotus parviflora* Desf., Fl. Atant. 2:192 (1799). *M. bonplandii* Ten., Index Sem. Hort Neapol. 1833:14 (1833). *M. tommasnii* Jord. Mém. Acad. Roy. Sci. Lyon, Sect. Sci., ser.2, 1:266 (1851).

Handagog, Handaquq (Ar.); Yellow mellilot (En.)

Erect slender annual herb. Leaves compound, trifoliolate, about 3 cm long, margin serrate. Inflorescences densely flowered racemes; flowers minute, yellow. Fruit an oblong-round pod with distinct veins on the valves.

Habitat and Distribution

Widespread as a garden and farm weed during the rainy season only. Common on rodats during the rains.

Constituents

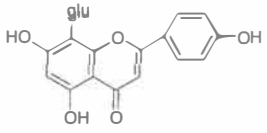
The proximate analysis, amino acids, fatty acids and minerals of *M. indicus*, growing in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d).

The plant is a valuable stock feed, both free and dry, although it has on occasion been considered by farmers to taint both flesh and milk. In Europe, the plant has been under suspicion of being poisonous (Watt and Breyer-Brandwijk, 1962).

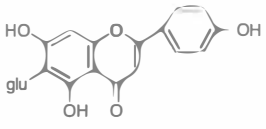
M. indicus contained coumarin, herniarin, umbelliferone, scopoletin, choline, β-sitosterol, a triterpene alchohol and an aromatic compound ($C_{18}H_{26}O_6$) (Rizk, 1986).

A D-galacto-D-mannan, with D-galactose to D-mannose ratio 1:1.14 was isolated from the seeds of *M. indica*. A highly branched structure having a mannan backbone composed of 36 % of (1→4) and 10 % of (1→2) linked β-D-mannopyranosyl units was proposed for the galacomannan (Gupta and Bose, 1986).

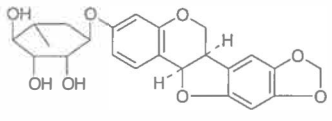
M. indica has been found to contain the following *C*-flavonoid glucosides: orientin, isoorientin, vitexin (**682**) and isovetxin (**683**) (El-Sayed *et al.*, 1997). The stems and seeds of *M. indica* yielded 8,9-methylenedioxypterocarpan 3-*O*-α-L-rhamnopyranoside (**684**) (Saxena and Nigam 1997a) and 1,9-dihydroxy-2-(3-methylbut-2-enyl)-3-methoxypterocarpan (**685**) (Saxena and Nigam, 1997b), respectively. The pterocarpanoids, isolated from the stems and seeds have been found to possess antifungal activity (Saxena and Nigam, 1996).



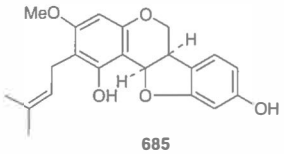
682 Vitexin



683 Isovitexin
(Saponaretin)



684

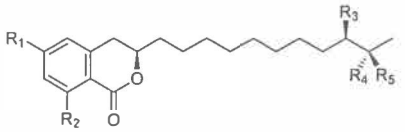


685

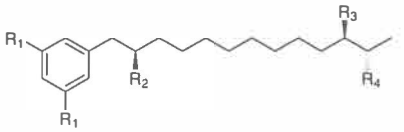
M. indica has been used as an emollient and as a fomentation, poultice or plaster on swelling. Its decoction was early advised by Arabs for urinary bladder pains and also as a diuretic, carminative, emmenagogue, for epilepsy and scorbion bite (Abou-Donia, 1976). In India, the plant is used for curing bronchitis, leprosy, "vata", vomiting and piles. The seeds are used as anthelmintic, antipyretic, for curing heart diseases and infantile diarrhoea (Chopra *et al.*, 1956).

7. *ONONIS* L.

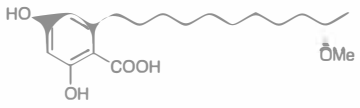
Several alkylisocoumarins (e.g. **686-689**), 5-alkylresorcinols (e.g. **690-697**) and alkylbenzoic acid derivatives (e.g. **698,699**) were isolated from *Ononis* species *viz. O. natrix* subsp. *hispanica* (Barrero *et al.*, 1990), *O. natrix* subsp. *natrix* (San Feliciano *et al.*, 1983), *O. natrix* subsp. *ramosissima* (Barrero *et al.*, 1997), *O. pubescens* (Barrero *et al.*, 1994b), *O. spinosa* (Barrero *et al.*, 1989) and and *O. viscosa* (Barrero *et al.*, 1991). Canedo *et al.* (1997) identified several 5-tridecylresorcinol derivatives (**700-710**) from *O. natrix*.



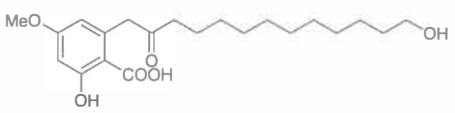
686 $R_1 = R_2 = OH, R_3 = H, R_4 R_5 = O$
687 $R_1 = R_2 = R_4 = OH, R_3 = R_5 = H$
688 $R_1 = R_2 = OH, R_3 = R_5 = H, R_4 = OMe$
689 $R_1 = R_2 = R_3 = OH, R_4 = R_5 = H$



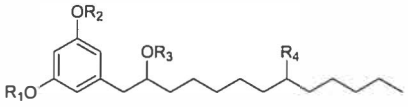
690 $R_1 = OH, R_2 = OAc, R_3 = R_4 = H$
691 $R_1 = R_2 = R_4 = OH, R_3 = H$
692 $R_1 = R_4 = OH, R_2 = OAc, R_3 = H$
693 $R_1 = R_2 = R_3 = OH, R_4 = H$
694 $R_1 = R_3 = OH, R_2 = OAc, R_4 = H$
695 $R_1 = R_4 = OH, R_2 = R_3 = H$
696 $R_1 = OH, R_2 = R_3 = H, R_4 = OMe$
697 $R_1 = R_3 = OMe, R_2 = R_4 = H$



698



699 2-Hydroxy-4-methoxy-6-(13-hydroxy-2-oxotridecyl) benzoic acid

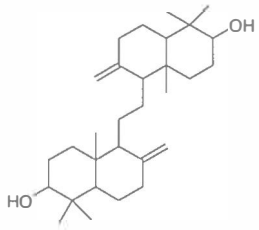


700 1-O-Methyl-5-(2-acetoxytridecyl)resorcinol; $R_1 = Me, R_2 = H, R_3 = Ac, R_4 = H$
701 1-O-Methyl-5-(2-acetoxy-8-oxotridecyl)resorcinol; $R_1 = Me, R_2 = H, R_3 = Ac, R_4 = O$
702 1-O-Methyl-5-(2-acetoxy-8-hydroxytridecyl)resorcinol; $R_1 = Me, R_2 = H, R_3 = Ac, R_4 = OH$
703 1-O-Methyl-5-(2-hydroxytridecyl)resorcinol; $R_1 = Me, R_2 = H, R_3 = H, R_4 = H$
704 1-O-Methyl-5-(2-hydroxy-8-oxotridecyl)resorcinol; $R_1 = Me, R_2 = H, R_3 = H, R_4 = O$
705 1-O-Methyl-5-(2,8-dihydroxytridecyl)resorcinol; $R_1 = Me, R_2 = H, R_3 = H, R_4 = OH$
706 5-(2-Acetoxytridecyl)resorcinol; $R_1 = H, R_2 = H, R_3 = Ac, R_4 = H$
707 5-(2-Acetoxy-8-oxotridecyl)resorcinol; $R_1 = H, R_2 = H, R_3 = Ac, R_4 = O$
708 5-(2-Acetoxy-8-hydroxytridecyl)resorcinol; $R_1 = H, R_2 = H, R_3 = Ac, R_4 = OH$
709 5-(2-Hydroxy-8-oxotridecyl)resorcinol; $R_1 = H, R_2 = H, R_3 = H, R_4 = O$
710 5-(2,8-Dihydroxytridecyl)resorcinol; $R_1 = H, R_2 = H, R_3 = H, R_4 = OH$

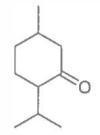
α-Onocerin (**711**), a triterpenoid of unusual structure has been isolated from several *Ononis* species (Rizk, 1986). Of the twelve *Ononis* species investigated by Rowan and Dean (1972), α-onocerin was found in all the examined species except in *O. pusilla*. Sitosterol was the major sterol in the twelve species. Stigmasterol, campesterol, cholesterol and the triterpenoids cycloartenol and 24-methylenecycloartenol also occurred. Some species contained an additional sterol, probably α-spinasterol, in the root.

The essential oil of *O. spinosa* roots contained menthone (**712**), isomenthone, camphor, linalool, menthol (**713**), astragole, carvone (**714**), *cis*-anethole and *trans*-anethole (Rizk, 1986).

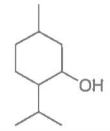
Several flavonoids were isolated from *Ononis* species (Table 46). Ononin (**715**), an isolflavone glucoside (formononetin-7-*O*-β-D-glucopyranoside) was detected in *Ononis* species (Rizk, 1986).



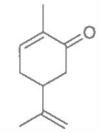
711 α-Onocerin



712 Menthone



713 Menthol



714 Carvone

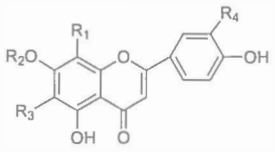
Table 46. Flavonoids of some *Ononis* species

Species	Flavonoids	Referrences
1. *O. arvensis*	Ononin (**715**), onogenin (**716**), formononetin, kaempferol and astragalin	Rizk (1986)
2. *O. spinosa* subsp. *leiosperma*	Ononin	Kyrmyzyguel *et al.* (1997)
3. *O. spinosus*	Apigenin, kaempferol, luteolin, quercetin, hyperoside (**717**), rutin, quercitrin (**718**), rhoifolin (**719**), cosmosiin and myricitrin (**720**)	Kartnig *et al.* (1985)
4. *O. vaginalis*	Apigenin, astragalin, chrysin, trifolin (**721**), luteolin-3',4'-dimethylether, cirsimatin, eupatilin, kaempferol-3-*O*-(2"-*O*-*p*-coumaroylglucoside)-7-*O*-glucoside, pseudobaptigenin-7-glucoside, isohemipholin, hispidulin, cirsimaritin, kaempferol-3-*O*-glucoside (**722**), kamepferol-3-*O*-galactoside (trifolin), quercetin-3-*O*-galactoside, quercetin-3-*O*-glucoside, naringenin 6-*C*-glucoside (hemipholin (**724**)) and ononin and its glucoside	Amer *et al.* (1989); Kassem *et al.* (1996); Abdel-Kader (1997); Bernhardt *et al.* (2000)

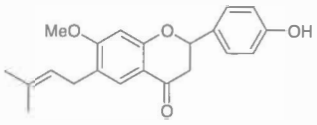
The study of the flavonoids of thirty species of *Psoralea* indicated a recurrent pattern of flavonoids, most of which were *C*-glycosylflavones characteristic of the genus. Patterns of various species were generally similar and characterized by large amounts of di-*C*-glycosides, lesser amounts of 8-*C*- and 6-*C*-monoglycosides and small quantities of mixed *C*- and *O*-glycosides. Examples of the flavonoids detected were orientin, isoorientin, vitexin, saponaretin, isosaponarin, vicenin (**735**), leucenin (**736**), apigenin 6,8-di-*C*-glycoside, luteolin 7-diglycoside and chrysoeriol-6,8-di-*C*-glycoside (Ockendon *et al.*, 1965). Rutin was detected in *P. repens* (Boardley *et al.*, 1986). Several isoflavones have been identified in *Psoralea* species and in particular in *P. corylifolia*. Daidzein was isolated from roots of *P. acaulis* (Zapesochnaya and Samylina, 1974). This isoflavonoid was also detected in *P. cinerea* (Neguyen *et al.*, 1997). The seeds of *P. corylifolia* contained several isoflavonoids e.g. bavachinin (**737**) (Bhalla *et al.*, 1968), neobavaisoflavone (3'-*C*-prenyldiadzein, (**738**)) (Bajwa *et al.*, 1974; Chen *et al.*, 1996), psoralenol (**739**) (Suri *et al.*, 1978), corylinal (**740**) (Gupta *et al.*, 1978) and corylifolin (**741**) (Zhu *et al.*, 1979), bavachin (**742**) and 6-hydroxy-6",6"-dimethylpyrano-(2",3":4'3')-isoflavone (Agarwal *et al.*, 2000).

Table 48. Furocoumarins of some *Psoralea* species

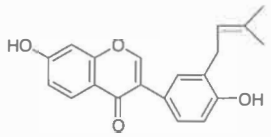
Species	Plant Part	Furocoumarins	Rreferences
1. *P. acaulis*	seeds	Psoralen	Samylina and Ladygina (1975)
2. *P. americana* (var. *polistachya*)	seeds	Psoralen, angelicin	Innocenti *et al.* (1977)
3. *P. bituminosa*	seeds	Psoralen, angelicin	Innocenti *et al.* (1997b,c)
4. *P. canescens*	all parts	Psoralen, angelicin	Innocenti *et al.* (1997a)
5. *P. cinerea*	fruits	Psoralen, angelicin	Innocenti *et al.* (1984); Nguyen *et al.* (1997)
6. *P. corylifolia*	fruits and seeds	Psoralen, angelicin, psoralidin, (isopsoralen) bakuchicin, neo-psoralen	Khastgir *et al.* (1959); Dattagupta *et al.* (1960); Cappelclletti *et al.* (1984); Kondo *et al.* (1990); Peng *et al.* (1996); Wei and Zhou (2000)
7. *P. dentata*	seeds	Psoralen, angelicin	Innocenti *et al.* (1977)
8. *P. drupacea*	fruits, seed and other parts	Psoralen, angelicin	Kartashkina *et al.* (1966); Akubakirov and Khalmurzaev (1967); Fedorin *et al.* (1975)
9. *P. glandulosa*	leaves seeds	Psoralen, angelicin Angelicin	Labbe *et al.* (1996) Innocenti *et al.* (1977)
10. *P. macrostachya*	leaves seeds	Psoralen Psoralen, angelicin	Kohlmuenzer (1965) Innocenti *et al.* (1977)
11. *P. psoralioides*	seeds	Psoralen	Baskin *et al.* (1967a)
12. *P. subacaulis*	seeds, leaves, flowers, roots	Psoralen	Baskin *et al.* (1967b, 1968)



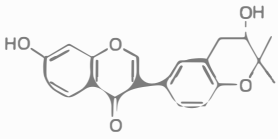
735 Vicenin-1; $R_1 = R_3 =$ *C*-glycosyl, $R_2 = R_4 = H$
736 Leucenin-1; $R_1 = R_3 =$ *C*-glycosyl, $R_2 = H$, $R_4 = OH$



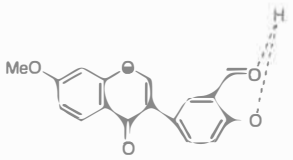
737 Bavachinin



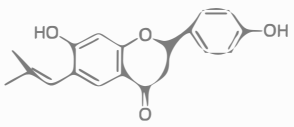
738 Neobavaisoflavone (3'-*C*-prenyldiazein)



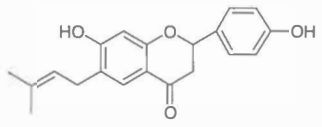
739 Psoralenol



740 Corylinal

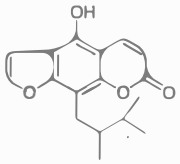


741 Corylifolin

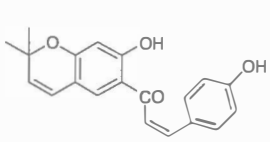


742 Bavachin

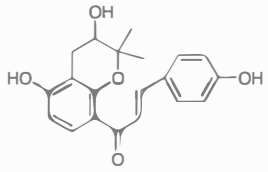
The seeds of *P. corylifolia*, were found to contain psoralidin **(743)**, a *C*-phenylcoumarin, bavachromene **(744)**, bavachromanol **(745)**, corylifonin **(746)** and several chalcones (e.g. **747-749**) (Bajwa *et al*., 1972; Zhu *et al*., 1979; Suri *et al*., 1980; Gupta *et al*., 1977b,1980a,1982b).



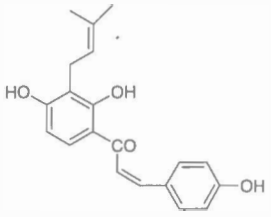
743 Psoralidin



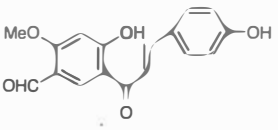
744 Bavachromene



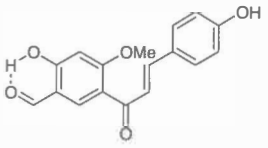
745 Bavachromanol



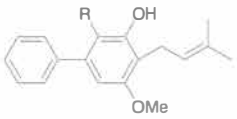
746 Corylifolinin



747 Neobavachalcone



748 Isoneobavachalcone



759 R = H
760 R = COOH

9.1. ***Rhynchosia minima*** (L.) DC., Prodr. 2:385 (1825).
syn. *Dolichos minimus* L., Sp. Pl., ed. 1, 726 (1753).

Adan al far (Ar.)

Prostrate perennial herb with hairy striate stems. Leaves trifoliolate with mid leaflet much larger than the opposite pair. Inflorescences axillary racemes; flowers yellow, streaked. Fruit flattened legumes, 2 cm long with few (2) mottled seeds.

Habitat and Distribution

A very rare plant in Qatar. Recorded at Al-Majda (rodat).
The plant is a common agricultural weed elsewhere.

Constituents

The seeds of *R. minima*, growing in India, contained 19.5 % protein. The amino acid composition of the seeds was as follows: aspartic, 9.0; threonine, 3.8; serine, 6.0; glutamic acid, 15.5; proline, 5.6; glycine, 8.4; alanine, 7.6; half cystine 0.4; valine, 6.3; methionine,

0.5; isoleucine, 4.5; leucine, 8.0; tyrosine, 1.1; phenylalanine, 5.1; histidine, 3.2; lysine, 4.4, and arginine, 4.8 (g/100 gm protein) (Prakash and Misra, 1988).

A steroidal glycoside, 3-*O*-β-D-galactopyranosyl-stigmasta-5,22-diene, along with ergosterol peroxide, stigmasterol and lupeol were isolated from the plant (Ahmed *et al.*, 1992).

The pericarp contained sitosterol, gallic acid, protocatechuic acid, hydroquinone diacetate and prodelphinidin. The leaves yielded four *C*-flavonoid glycosides (isovitexin, schaftoside, vicenin-2 and vicenin-3 (6-*C*-glucosyl-8-*C*-xylosylapigenin)) (Rizk, 1986).

The leaves of *R. minima* are used as abortifacient. The plant is used in the treatment of skin diseases and as a fish poison. In India, the plant has been reported to possess contraceptive properties (Rizk and El-Ghazaly, 1995).

10. SCORPIURUS L.

10.1. ***Scorpiurus muricatus*** L., Sp. Pl., ed. 1, 745 (1753).

Khuzaima (Ar.)

Annual small herb with lanceolate-spatulate long leaves up to 8 cm long. Inflorescences axillary, few-flowered, umbellate on long peduncles. Fruit coiled legumes, constricted between the seeds, bristly. Flowers and fruits in rainy season.

Habitat and Distribution

Rare in Qatar, in rodat with fine sandy soils in northern Qatar.

Trigonelline, the major alkaloid of *T. foenum-graecum* was detected in *T. corniculata* together with choline and betaine (Atal and Sood, 1964).

12.1. ***Trigonella anguina*** Delile, Descr. Egypte Hist. Nat. 254, t.38.2 (1814).

Nafal (Ar.)

Annual prostrate herb with many basal branches. Leaves trifoliolate. Inflorescences axillary racemose. Flowers few, congested and crowded, yellow. Fruit a wavy, torulose-folded legume.

Habitat and Distribution

Weed of cultivated and arable land and occurring on moist sites during the rainy season.

Constituents

The minerals of *T. anguina*, growing in Qatar, is shown in Table 178 (Al-Easa, 2002d).

Phytochemical screening of *T. anguina*, growing in Qatar, revealed the presence of alkaloids, coumarins, flavonoids, saponins and sterols (and /or terpenes) (Rizk *et al*., 1986a).

The plant gave negative reaction for flavolans (condensed tannins) (Goplen *et al*., 1980).

12.2. ***Trigonella hamosa*** L., Syst. Nat., ed. 10, 1180 (1759).
syn. Trigonella glabra Thumb., Prodr. Pl. Cap. 137 (1800).

Nafal (Ar.)

Annual erect-decumbent herb, Leaves trifoliolate. Inflorescences axillary, racemose, Flowers crowded on a distinct peduncle. Fruit falcate, slightly deflexed pods.

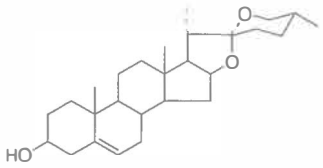
Habitat and Distribution

Common weed of cultivation, parks and gardens. Common in association with avenue trees.

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *T. hamosa*, collected from two different localities in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d).

The seeds of *T. hamosa* gave a negative lysis but a positive test for diosgenin/yamogenin (**788**) by the colour test (Hardman and Fazli, 1972a). The plant gave negative reaction for condensed tannins (Goplen *et al.*, 1980).



788 Yamogenin

12.3. ***Trigonella monantha*** C.A. Mey., Verz. Pfl. Cauc. 137 (1831).

Nafal (Ar.)

Prostrate annual herb. Branches many, basal. Inflorescences solitary or a pair of flowers in the leaf axils; flowers yellow, sessile or subsessile. Fruit a legume about 5 cm long.

Habitat and Distribution

Reported by Batanouny as rare in Qatar. Plant not seen and possibly a weed of vegetable plots.

Constituents

The seeds of *T. monantha* contained less than 0.2 % diosgenin (Bohannon *et al.*, 1974). The plant gave negative reaction of condensed tannins (Goplen *et al.*, 1984).

12.4. ***Trigonella stellata*** Forssk., Fl. Aegypt-Arab. 140 (1775).

Nafal (Ar.)

Annual prostrate herb with numerous basal branches. Leaves trifoliolate. Inflorescences axillary, racemose. Flower crowded on short peduncles; corolla yellow. Fruit crowded, spreading pods appearing as a bunch.

Habitat and Distribution

Weed of cultivated farms and gardens

Constituents

Phytochemical screening of *T. stellata*, growing in Qatar, revealed the presence of alkaloids, coumarins, flavonoids, saponins, and sterols (and/or terpenes) (Rizk *et al.*, 1986a).

Table 58. Groat nitrogen content, straw nitrogen content and groat oil content of six *A. sativa* cultivars and 10 *Avena* species grown in pot at three levels of nitrogen fertility (dry matter basis; means of three replicates)

	Leanda	Manod Oberon	Maris II	Sun	Froker	Hinoat	*A. steirilis*	*A. barbata*	*A. moroccana*	*A. murphyi*	*A. canariensis*	*A. eriantha*	*A. hirtula*	*A. longiglumis*	*A. prostrata*	*A. ventricosa*
Groat nitrogen content (%)																
N1	1.35	1.50	1.75	1.44	1.78	2.25	2.70	4.10	2.91	3.20	3.39	5.51	4.30	2.94	6.05	5.63
N2	1.37	1.57	1.66	1.53	1.81	2.47	2.87	4.07	3.36	3.39	3.77	5.00	4.31	3.10	5.80	5.77
N3	1.85	2.11	2.11	2.02	2.48	3.45	2.97	4.66	4.18	3.82	4.86	5.77	4.88	3.92	7.12	6.37
Straw nitrogen content (%)																
N1	0.19	0.20	0.16	0.22	0.23	0.26	0..30	0.34	0.24	0.24	0.27	0.68	0.29	0.28	0.56	0.47
N2	0.23	0.20	0.16	0.21	0.26	0.25	0.29	0.29	0.29	0.28	0.31	0.69	0.32	0.26	0.70	0.58
N3	0.31	0.28	0.23	0.26	0.32	0.35	0.32	0.33	0.38	0.34	0.65	0.68	0.35	0.31	0.70	0.78
Groat oil content (%)																
N1	8.29	7.63	7.88	8.06	6.69	7.14	10.77	9.26	9.34	8.59	9.85	13.67	8.00	8.47	8.92	12.20
N2	7.94	7.50	8.05	7.59	6.11	7.10	11.06	9.06	9.21	8.16	9.30	13.54	8.06	7.99	8.10	12.08
N3	7.26	6.82	6.93	6.91	5.61	6.73	10.52	8.11	8.33	7.45	8.54	12.89	7.21	6.93	8.05	12.02

N1; N2; N3, nitrogen fertility levelss, (Ammonium nitrate fertiliser N1 0.28 kg/m^3 N1: Basal mixture soil, peat and grit 7:2:2; Hydrated lime was added at 0.9 kg/m^3 and a compound. P/K fertiliser at 2.7 kg/m^3 .

N2: Basal mixture supplemented with ammonium nitrate fertiliser at 0.28 Kg/ m^3.

N3: Basal mixture supplemented with ammonium nitrate fertiliser at 0.42 Kg/ m^3.

Table 59. Total plant yields, groat yields and groat harvest indices of six *A. sativa* cultivars and 10 *Avena* species grown in pot at three levels of nitrogen fertility (dry matter basis; means of three replicates)

	Leanda	Manod	Maris Oberon	Sun II	Froker	Hinoat	*A. steirilis*	*A. barbata*	*A. moroccana*	*A. murphvi*	*A. canariensis*	*A. eriantha*	*A. hirtula*	*A. longiglumis*	*A. prostrata*	*A. ventricosa*
Total plant yield (g/plant)																
N1	6.82	6.98	6.69	6.89	6.15	4.82	6.05	5.48	6.04	6.05	4.87	2.72	5.06	5.28	2.63	2.51
N2	15.28	14.57	15.86	15.79	13.15	11.63	12.56	11.43	11.55	12.52	10.74	4.68	11.39	12.28	5.21	5.31
N3	25.13	25.22	27.15	28.28	23.36	20.00	27.53	22.63	19.71	24.35	15.28	10.47	21.86	24.00	8.06	6.82
Groat yield (g/plant)																
N1	2.30	2.34	2.06	2.19	2.05	1.43	0.87	0.49	0.93	0.86	0.90	0.13	0.56	0.87	0.19	0.15
N2	5.60	4.91	4.83	5.36	3.90	3.26	1.80	0.96	1.86	1.78	2.17	0.15	1.10	1.91	0.36	0.30
N3	9.57	9.87	9.94	10.75	9.04	5.67	4.10	2.27	3.42	3.78	2.96	0.22	2.35	4.25	0.48	0.21
Groat harvest index																
N1	0.336	0.335	0.308	0.314	0.333	0.297	0.144	0.088	0.153	0.143	0.185	0.040	0.108	0.166	0.073	0.070
N2	0.367	0.337	0.305	0.339	0.300	0.280	0.143	0.084	0.161	0.141	0.202	0.032	0.095	0.156	0.068	0.051
N3	0.382	0.393	0.366	0.379	0.388	0.285	0.150	0.100	0.174	0.155	0.194	0.022	0.107	0.177	0.060	0.024

N1; N2; N3, nitrogen fertility levels, see Table 58.

Table 60. Protein concentration in botanical parts of oat kernel

Variety	Groats	Hulls	Scutellum	Bran	Starchy endosperm
Orbit	13.8	1.7	32.4	18.8	9.6
Lodi	14.6	1.6	26.2	19.6	10.7
Garland	14.8	1.4	28.9	18.5	10.9
Froker	15.5	1.4	28.0	20.7	9.7
Portal	16.5	1.9	29.1	33.0	10.3
Dal	20.8	1.5	24.2	26.5	13.5
Goodland	22.5	1.9	32.4	32.5	17.0

Table 61. Amino acid composition of oats and groats (g amino acid/100 g amino acid recovered)

Amino acids	Oats			Groats	
	1	2	3	4	5
Lysine	4.14	4.2	5.2	4.5	3.9
Histidine	1.72	2.4	2.7	2.4	2.3
Arginine	6.95	0.4	6.3	6.8	6.2
Aspartic acid	8.06	9.2	11.1	8.7	9.0
Threonine	3.65	3.3	4.1	3.4	3.1
Serine	4.95	4.0	4.5	4.6	3.9
Glutamic acid	21.82	21.6	20.0	21.7	22.4
Proline	5.36	5.7	3.1	5.5	6.2
Cystine	1.83	1.7	6.4	2.1	2.0
Glycine	4.69	5.1	6.0	5.2	5.0
Alanine	4.72	5.1	5.5	5.0	5.0
Valine	5.44	5.8	6.2	5.5	5.7
Methionine	1.83	2.3	1.5	2.2	2.5
Isoleucine	4.09	4.2	4.5	3.9	4.3
Leucine	7.69	7.5	7.6	7.6	7.4
Tyrosine	3.76	2.6	2.4	3.0	2.5
Phenylalanine	5.56	5.4	5.3	5.2	5.5

Oat grain contained high amounts of nonstarch polysaccharides which are the main constituents of dietary fiber. Although this group of carbohydrates is a mixture of many polymers, the overwhelming quantity of these compounds may be classified as β-glucan, arabinoxylan, and cellulose (Lásztity, 1998). The β-glucan in oats contain about 70 % four-linked and 30 % three-linked β- glucopyranosyl units (Westerlund *et al.,* 1993; Lásztity, 1998). The β-glucan content of most dehulled grains of 243 samples of genetically variable oat lines, ranged from 4.5 to 5.5 %. Only 18 % of the samples had a β-glucan content higher that 5.5 % β (maximum 6.73 %) and only 15 % had a lower β-glucan content lower than 4.5 % (maximum 3.09 %) (Cho and White (1993). The β-glucan content in Swedish oat samples is 2.7 to 3.6 % (Lásztity, 1998). Oat bran contained 11.2 to 16 % β-glucan (Wood *et al*., 1989).

Table 62. Average amino acid composition of the different protein fractions isolated from oats grown in Hungary (g amino acid/100 g protein)

Amino acids	Albumins	Globulins	Prolamins	Glutelins
Lysine	8.3	4.9	3.1	5.2
Histidine	4.1	3.3	1.6	3.1
Arginine	5.3	8.5	5.0	9.1
Aspartic acid	12.5	9.8	4.2	10.8
Threonine	5.5	3.8	2.3	4.8
Serine	6.3	4.3	3.2	4.7
Glutamic acid	15.1	19.5	36.1	19.1
Proline	5.8	5.4	11.3	8.1
Cystine	6.5	5.8	3.0	4.0
Glycine	7.1	6.5	3.8	4.1
Alanine	1.7	1.8	3.1	1.4
Valine	7.3	5.1	5.5	4.4
Methionine	2.2	1.9	3.3	1.5
Isoleucine	4.1	4.7	3.8	4.3
Leucine	8.9	7.0	10.3	7.1
Tyrosine	2.6	2.4	2.1	4.8
Phenylalanine	7.8	6.1	7.5	7.1
Tryptophan	1.7	1.4	1.6	1.9

Table 63. Amino composition of some *A. fatua* and *A. sativa*

Amino acid composition	*A. fatua*	*A. sativa*	
g/total amino acids	Caryopses*	Caryopses*	Leaf**
Aspartic acid	9.1	9.0	12.5
Threonine	3.7	3.9	5.9
Serine	5.8	6.2	5.4
Glutamic acid	23.8	22.7	12.8
Proline	5.7	5.8	8.1
Glycine	4.9	5.4	5.7
Alanine	4.9	5.1	7.9
Cystine	2.6	2.2	1.0
Valine	4.1	4.5	4.5
Methionine	1.8	1.9	1.7
Isoleucine	3.2	3.4	3.2
Leucine	8.0	8.3	8.6
Tyrosine	4.7	4.6	4.4
Phenylalanine	5.8	5.6	5.7
Histidine	2.3	2.1	1.9
Lysine	4.6	5.0	6.8
Tryptophan	0.0	0.2	0.5
Arginine	5.1	3.8	3.4
Total amino acids (protein content) (g % fresh wt)	13.3	7.5	2.9

* Yeoh and Watson (1981).

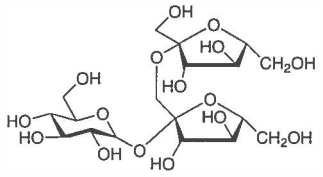
** Yeoh and Watson (1982).

Arabinoxylan in Swedish oats ranged from 4.1 to 15 %, calculated as a sum of arabinose, xylose and uronic acid polysaccharide residues. Arabinoxylan was found to be the main component (about 65 %) of nonstarch polysaccharides in dehulled oats. Cellulose content of oats ranges from 6.1 % to 13 % with an average of 9.1 %. The hull and bran contained higher amounts of cellulose-up to 40 %. Total dietary fiber of oat grain varied widely, ranging from 12.7 to 38 %. The dehulled grain had a lower dietary fiber content (5-12 %). About 30-50 % of the total dietary fiber was water soluble (Lásztity, 1998).

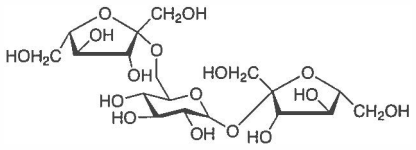
As in other cereal grains, oat contains small quantities of mono- and oligo-saccharides. Sucrose (0.7-0.9 %) and raffinose (0.1-0.2 %) are the main sugars found in oat kernel. Small quantities of maltose, glucose, fructose, stachyose and verbascose (a non-reducing pentasaccharide "*O*-α-D-galactopyranosyl-(1→6)-*O*-α-D-galactopyranosyl-(1→6)-*O*-α-D-galactopyranosyl-(1→6)-*O*-α-D-glucopyranosyl-(1→2)-β-D-fructofuranoside") were also detected particularly in bran (MacArthur and D' Appollnia, 1979; Lásztity, 1998).

In contrast with other winter cereals, cold hardened oat (*A. sativa*) has about 1/3 as much high degree of polymerization (DP > 6) fructans (Livingston, 1991). Fructans had been separated from oat stems and consisted exclusively of neokestose-based isomers with 2,6-linked and no branching. The structure and quantity of fructan oligomers in stems of 49 accessions from five *Avena* species *A. abyssinica, A. fatua, A. sativa, A. sterilis* and *A. strigosa,* have been studied by Livingston *et al.* (1993). The average DP of DP > 6 fructan from oat stems was 12.3. The results of linkage analysis of oligomers from oat stems were as follows (Livingston *et al.*, 1993):

DP3: raffinose, 6- ketose, 1-kestose **(813)** and neokestose **(814)**.

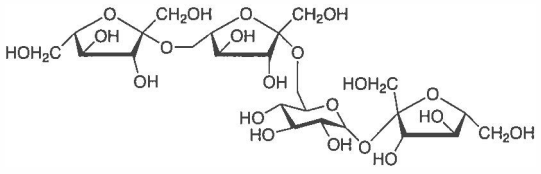


813 1-Kestose
(1-Kestotriose)

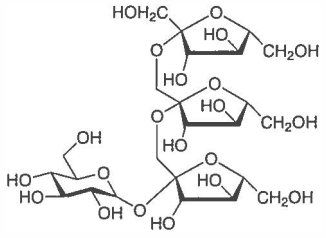


814 6^G-Kestotriose
(Neokestose)

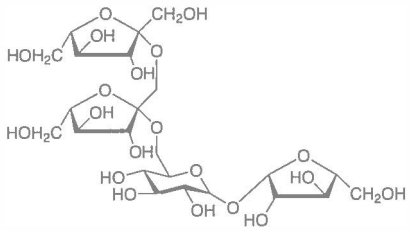
DP4: stachyose, 6^G6-kestotetraose **(815)**, 1,1-kestotetraose **(816)**, 6^G,1-kestotetraose **(817)** and 1& 6^G-kestotetraose **(818)**.



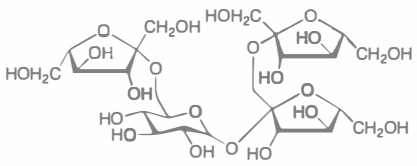
815 (6^G,6)-Kestotetraose



816 (1,1)-Kestotetraose

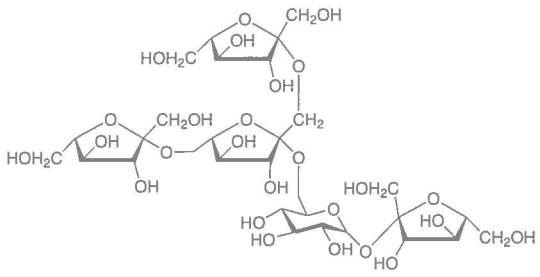


817 (6^{G},1)-Kestotetraose

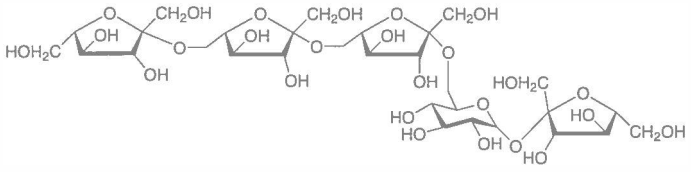


818 (1&6^{G})-Kestotetrose

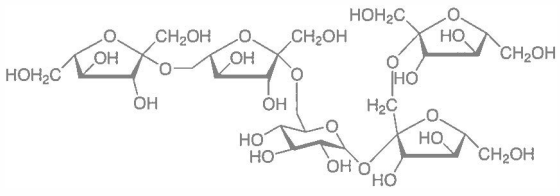
DP5: 6^{G} 1&6-kestopentaose **(819)**, **(820)**, 1&6^{G},6-kestopentaose **(821)**, 1&6^{G}, 1-kestopentaose **(822)**, 6^{G}1,1-kestopentaose **(823)** and 1,1&6^{G}-kestopentaose **(824)**.



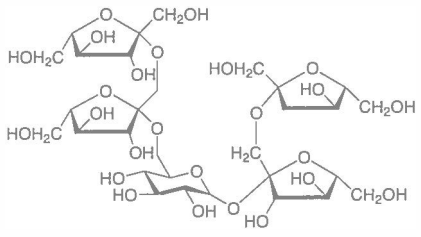
819 (6^{G},1&6)-Kestopentaose



820 (6^{G},6,6)-Kestopentaose



821 (1&6^{G},6)-Kestopentaose



822 (1&6^{G},1)-Kestopentaose

An appreciable amount of 1-kestose **(813)** was found and since **(815-817)**, **(821-824)**, all containing 2,1-linkage fructose were also found, enzymes for the synthesis of 2,1- linkages must be present. The data obtained by Sims *et al.* (1992) and Livingston *et al.* (1993) who reported fructans from excised leaves of *Lolium temulentum*, support the establishment of a

Gounaris *et al.* (1991) had undertaken a comparison of the protein components of stamens and pistils of *C. ciliaris*, at the stages of sporogenesis and of gametophyte enlargement. Four stamen-specific proteins were detected. One of them was specific to the microsporogenesis stage and one specific to the uninucleate microspore stage. The other two were found in both stages. The stamen-specific proteins might be involved in sexual differentiation in this species or they could be gametophyte-or meiosis-specific proteins.

The analysis of mineral elements at different days of growth of *C. ciliaris* (growing in India) revealed that with advancement of growth K, P and Fe showed a continuous decline whereas Ca, Zn, Cu and Mn remained more or less constant or increased slightly (Dutta and Dhir, 1980). In a study using K-Na and K-Mg nutrient replacement series in sand culture, Smith (1981) found that cation-anion values in the tops of *C. ciliaris* increased as the concentration of K in the nutrient solutions increased. The study of the chemical composition of *C. ciliaris*, collected from the Thal desert (Pakistan), did not show any outstanding relation between soil constituents and the chemical composition. The same plant sample contained 0.9-1.1 % lipids, 30.7-39.9 % fibres, 6.0-7.9 % proteins, 35.9-42.8 % carbohydrates and 8.0-10.4 % ash (Malik and Khan, 1971).

The growth of *C. ciliaris*, growing in India, was followed by determining shoot dry matter, root dry matter, total dry matter and pigments (chlorophylls and carotenoids). A linear relationship between shoot dry weight and total chlorophyll was found. Shoot and root weights and pigment contents varied according to harvest (plant age) date and self-shading (Kumar *et al.*, 1980).

Large grains (676 mg/1000 grains) of *C. ciliaris*, collected in India, contained markedly higher amounts of starch, protein, N, P and K than small grains (303 mg/100 grains), but they contained lesser amounts of reducing sugars and soluble carbohydrates. The high food reserve in large grains of *C. ciliaris* had a sustained effect on the maintenance of higher plant growth during the first year of seedling establishment. It has been tentatively concluded that the advantages provided by the large grains, such as higher germination, greater seedling vigour and large dry matter production in the first year establishment, provided ample scope for improving forage production in the arid areas (Kathju *et al.*, 1978).

Seasonal changes in dry weight and total available carbohydrates, *i.e.* nonstructural carbohydrates (TAC), were examined in *C. ciliaris*, growing (in Australia) under 2 defoliation regimes: cutting at a 5-cm height once, or cutting 8 times/year. TAC accumulated in the roots during autumn, winter and early summer, and were depleted in the spring. Frequent defoliation reduced amounts of TAC (Humphreys and Robinson, 1966). Earlier, Edwards (1936) reported no consistent differences in percentages of crude protein and ash between samples taken at periods of maximum yield (January-April) and those taken at the period of minimum yield (March).

C. ciliaris in West Australia when fed to sheep, had a higher nutritional value than several other subtropical grasses (Milford, 1960a), and it had been proved to be much preferred by cattle (Everitt *et al.*, 1981). A study on the palatability and nutritive value of anjan hay (*C. ciliaris*) as fodder for sheep showed that the body weights could be maintained (Singh, 1975). The influence of wilting on the quality of *C. ciliaris* silage in Cuba has been studied (Rodriguez *et al.*, 1989).

The effects of water stress on herbage quality have been studied by Wilson (1981). Field plots of *C. ciliaris* were subjected to periods of controlled drought, and herbage from these

plots was compared with those from well-watered plots. Leaf and stem dry-matter digestibility of water-stressed herbage was either similar to or higher than those of unstressed herbage. Sward digestibility in plots subjected to drought was higher than in the well-watered controls because, of a decreased proportion of stem and a higher digestibility of both leaf and stem. The higher rates of animal daily live-weight gain in the dry years supported the conclusion that herbage growth under low soil moisture had improved nutritive quality (Wilson, 1981). The effects of water stress of varying duration and intensity on the *in vitro* dry matter digestibility (DMD) and chemical composition of different plant fractions of *C. ciliaris*, grown in plots under semi-arid field conditions was reported (Wilson, 1983b). Other plots of this species were irrigated regularly for comparison. The DMD of herbage from water-stressed plants was either similar to or higher than that form plants of the wet treatment. Where DMD of leaves was higher for the dry treatment, this was usually due to a slower decline in their DMD as they aged. Most comparisons of dead leaf tissue indicated a higher DMD for the dry than the wet treatment. The most recently expanded leaves usually did not differ in DMD between wet and dry treatment. Water stress slowed stem development in the grass and particularly in early spring when this effect was most evident, the DMD of stem was higher in the dry than the wet treatment. Water stress applied to buffel grass stems after they had elongated and started flowering did not affect their DMD compared with the wet treatment. Cell-wall and lignin content of herbage from the dry treatment was similar to or lower than that from the wet treatment. The conclusion from these experiments is that the effects of short-term, moderate-to-severe, water stress on DMD were somewhat variable, but generally the digestibility of water-stressed buffel grass (stem, green leaf and even dead leaf) was similar to or as much as 4-13 units higher than that from well-matured plants. These results suggest that during droughts of short to medium length, provided the yield of leaf in particular is sufficient to satisfy the animal's intake requirement, the daily animal live weight gains on water-stressed herbage should be maintained or even employed when the stress is so severe that most plant tissue is killed (Wilson, 1983b). This contention supported the data from a grazing trial, which was reported by Wilson (1981). Of course, with continued drought the quantity of herbage available may eventually be insufficient to give good animal production despite its improved nutritive value (Wilson, 1983b). The DMD data (Table 69) indicate a variable effect of water stress between plant parts and the spring or summer cycle. Generally, DMD material from the dry treatment, including dead leaf, was either the same as or higher than that of the wet treatment.

The dry buffel grass was moderately stressed at the end of the drying season. The water stress had no effect on the DMD and the cell-wall content (CWC) and lignin content of the upper leaves or upper stem (Table 70), either during stress or in the period of rewatering. The data for the sward fractions in Table 71 indicate a generally higher DMD of green and dead leaf, and of stem, for the dry than the wet treatment. The water stress experienced by the dry plants was extreme, as indicated by leaf water potentials as low as -10.7 MPa (Table 72). The DMD of the last expanded leaf and whole tops of the dry treatment was either similar to or significantly higher than the corresponding value for the wet treatment (Table 72) (Wilson 1983b).

C. plectostachys contained a xylan (hemicellulose) consisting of a main chain of β-linked xylose residues to which were attached arabinose residues as side chains and an aldobiouronic acid containing residues of glucuronic acid, xylose and arabinose (McIlroy, 1963). Arabinose, xylose, mannose, galactose and glucose were identified in detergent residue of *C. nlemfuensis* (Pitman and Moore, 1985).

Tricin, flavone *C*-glycosides and apigenin were detected in *Cynodon* species (Harborne and Williams, 1976).

11.1. *Cynodon dactylon* (L.) Pers., Syn. Pl. 1:85 (1805).
syn. *Panicum dactylon* L., Sp. Pl., ed. 1,58 (1753).

Najil, Thayyal, Thaiyil, Najm (Ar.); Bermuda grass; Star grass, Couch grass (En.)

Perennial grass with long prostrate stolons (vegetative propagation) giving off adventitious roots at nodes and upright tufts of leafy shoots. Leaves linear with short ciliolate ligules. Inflorescences on 3- to 4-noded upright culms; Inflorescences digitate, of 3-5 spikes each 4-6 cm long; spikelets alternate on flat-backed rachis.

Habitat and Distribution

Lawn grass grown all over Qatari private and public gardens, frequently mowed and renewed. Also in shaded rodats and water catchment areas growing vegetatively during the rainy seasons and surviving on air moisture.

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *C. dactylon*, growing in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d).

Bermuda grass (*C. dactylon*) is one of the grasses cultivated for hay and pasture purposes and also as a lawn grass. The proximate chemical composition (crude protein, crude fiber, fat, carbohydrates, ash) and mineral content (Ca, N, K, Cl, Mg, Cu, Mn, Fe, P and Zn) of the plant growing in different parts of the world (e.g. Kenya, Nigeria, Uganda, Spain, U.S.A. Burma and S. Africa), has been reported (Toit *et al.*, 1934; Rhind, 1938-1939; Cantos, 1958; Bredon and Marshall, 1962; Dijkstra and Driven, 1962; Miller and Rains, 1963; Gomide *et al.*, 1969; Mao and Chang, 1971; Karue, 1974; Kappel *et al.*, 1985). *C. dactylon*, from lower and upper Bermuda, contained crude protein 4.25, 6.16; crude fiber 27.42, 30.51; fat 0.92, 0.77; carbohydrates 68.20, 53.75; ash 9.22, 8.80; P_2O_5 0.302, 0.515; CaO 0.321, 0.481; K_2O 1.444, 1.5666 and Fe_2O_3 0.070, 0.187 % respectively (Rhind, 1938-1939). *C. dactylon*, grown in Tanzania was found to be rich in protein coupled with low fiber value (Sreeramulu and Chande, 1983). Hay of Bermuda grass, grown in Venezuela, contained 4.7 % crude protein (Bustillos *et al.*, 1981). Howard-Williams and Junk (1977) reported the following nutritional value of *C. dactylon* in Brazil: dry matter (30.3 %), ash (10.2 %), protein (8.8 %), polyphenols (0.7 units g^{-1}), cell-wall (73.5 %) and caloric value (4.17 kcal g^{-1} dry mass). The mineral content of the shoots was as follows: Na 0.02, K 1.46, Mg 0.12, Ca 0.29, Si 2.88 and P 0.10.

The amino acid composition of *C. dactylon* cv. Coast cross 1 (grown in Cuba) (whole plant, and of 4 weeks of regrowth without fertilization in cutting areas and irrigated with 50 mm/h everyday) (Table 76) (Coto and Herrera, 1989), was similar to that reported by Fishman and Evans (1979). The total N of the plant and the buffer-soluble protein of *C. dactylon* (couch grass), grown in soil in glass house and in vermiculite in a growth chamber (27°C, 12h day, 400 μ E m^{-2} S^{-1}; 20° C, 12 h night), amounted to 3.4 ± 0.1 and 6.0 ± 0.4 % respectively (Pheloung and Brady, 1979). *C. dactylon*, grown in Kenya was reported as of high nutritive value in dry and wet seasons (Kraue, 1974).

Yeoh and Watson (1982) reported the following amino acids composition of the leaves of *C. dactylon*: aspartic acid, 12.9; threonine, 5.3; serine, 5.6; glutamic acid, 14.1; proline, 5.9; glycine, 5.4; alanine, 7.8; cystine, 1.0; valine, 4.6; methionine, 1.7; isoleucine, 3.6; leucine, 9.3; tyrosine, 4.5; phenylalanine, 5.6; histidine, 2.0; tryptophan, 0.1 and arginine, 3.9 (g % of total amino acids). The total amino acids (protein content) amounted to 4.1 (g % fresh weight).

The non-structural carbohydrates of *C. dactylon* were identified as glucose, fructose, sucrose and starch (Masaki and Ohyama, 1978). Xylose and glucose constituted the greatest proportion of monosaccharides hydrolysed (using trifluoroacetic acid) from Bermuda grass fiber residues (De Ruiter and Burns, 1987b). The plant contained enough carotene to meet the nutritional requirements of cattle (Pena *et al.*, 1977). Inorganic pyrophosphatase from *C. dactylon* leaves was quite similar to that of corn leaf (Mukherjee and Pal, 1981).

C. dactylon growing in India showed high content of K (6.16 %) and Na (0.23 %) of dry matter (More, 1982). Coastal Bermuda grass had nutritionally adequate amounts of Ca, Mg, and K, P levels were suboptimum for high producing ruminants and had Ca:P ratio, which could cause metabolic disorders in ruminants if used as a sole feed source (Bosworth *et al.*, 1980). The influence of stimulated rainfall on the retention of sludge heavy metals (Cd, Cu, Pb and Zn) by the leaves of *C. dactylon* was studied by Jones *et al.* (1979).

Table 76. Amino acid composition (TAA) of coast cross 1 Bermuda grass, protein component amino acids (CAA), peptide amino acids (PAA) and free amino acids (FAA) mmol/100 g DM

Amino Acids	TAA	CAA	PAA	FAA
Arginine	3.09	1.88	0.45	0.76
Histidine	0.68	0.36	0.33	+
Isoleucine	3.18	2.34	0.69	0.15
Leucine	7.21	4.30	2.60	0.30
Lysine	4.05	3.15	0.37	0.52
Methionine	1.22	0.93	0.30	T
Phenylalanine	2.08	1.77	0.14	0.17
Threonine	3.05	2.54	+	0.51
Valine	3.56	2.44	0.78	0.34
Alanine	5.46	4.22	0.26	0.98
Aspartic acid	6.50	5.22	0.76	0.52
Glutamic acid	7.33	5.05	1.94	0.33
Glycine	6.05	4.35	1.49	0.20
Proline	5.37	3.08	0.25	0.25
Tyrosine	1.27	0.93	0.20	0.13
Serine	3.46	2.70	+	0.62
Total N-NH_2 (g/100 DM)	1.00	0.71	0.16	0.10
N total (g/100 g MS)	1.45	1.08	0.37	0.13

+ not present; T traces.

Voluntary hay intake of yearling wethers averaged 958 g/head. N supplementation increased N digestibility, N balance and blood urea–N levels (Bustillos *et al.*, 1981). The evaluation of Bermuda grass as an alternative to corn forage (*Zea mays*) for ensiling with poultry litter was studied by Rude and Rankins, Jr., (1993). Their results indicated that johnsongrass (*Sorghum halepense*) supported Bermuda grass gain in lambs when ensiled with up to 20 % poultry litter. Treatment of *Cynodon* hay with 50 or 100 kg NaOH/ton dry matter raised the digestibility of the dry matter, organic matter, and cell-wall constituents, and also the voluntary feed intake by sheep (Kategile *et al.*, 1981). The total nonstructural carbohydrate residue of *C. dactylon* was found to be more closely correlated with *in vitro* dry matter disappearance than was neutral detergent fiber (Burns and Smith, 1980).

Beef cows were used by Hall *et al.* (1990) to determine the effects on the intake and digestion of supplementing Bermuda grass (*C. dactylon*) hay (1 % of their body weight BW) with maize (MZ, 0.49 % BW) and fat, singly and in combination, and to compare fat poured on hay (PF, 0.054, beef tallow) with fat mixed with maize. (MZ-PF). The treatments included control (C), maize alone (MZ), fat poured on hay alone (PF), maize plus poured fat (MZ-PF) and maize mixed with fat (MZ-MF). Calcium carbonate (0.011 % body weight) was given to all supplemented animals. The mean ruminal fluid protozoal counts were higher than without supplements ($P < 0.05$), for MZ than for PF, and for simultaneous *vs.* singular offering of maize and fat ($P < 0.05$). Digestion of neutral detergent fiber in the whole tract (duodenum) declined with supplementation, but differences among supplement treatments were not significant. In a similar study Holstein steers received hay and libitum and higher levels of

supplements (maize 0.89, fat 0.099 and calcium carbonate 0.021 % body weight day^{-1}). The total tract neutral detergent fiber digestion was C 72-0, MZ 67.0, PF 69.2, MZ-PF 65.1 and MZ-MF 61.1 % and was depressed by supplementation and lower for simultaneous *vs.* singular supplementation with maize and fat ($P < 0.05$). In conclusion, there were no advantages in the intake or digestion when adding fat to supplemental maize either separately or mixed as compared with supplementation with maize alone.

Garcel and Poppe (1989b) determined the digestibility of the most important nutrients for Bermuda grass cross No. 1. The digestibility of the organic matter decreased with increased duration of growth. Residual dispersion values of 1.8 to 6.9 units (calculated by regression analysis) of digestibility were recorded. The digestibility of the organic matter of Bermuda grass dropped by 19-50 % in the rainy season and by 11-50 % in the dry season (Gercell and Poppe, 1989a).

The study of the effect of cutting age and final molasses levels on the quality of coast cross Bermuda grass silage, showed that the grass could be ensiled at 37 days of regrowth without adding final molasses. Dry matter was increased with higher cutting ages (26.06 *vs.* 35.14 %), but no variation was within the levels of molasses used. Crude protein (9.14 *vs.* 6.39 %) and ash (9.34 *vs.* 6.42 %) diminished as harvesting age increased, but no differences were found for the levels of molasses. Total volatile fatty acids did not differ between the factors studied. Lactic acid was higher (1.29 *vs.* 0.82 %) for a lower cutting age, but did not differ between the extreme levels of molasses (Dominguez and Hardy, 1988). The chemical composition, *in vitro* organic matter digestion, rate and extent of *in vitro* neutral detergent fiber digestion, and intake, organic matter and fiber digestibility of four *Cynodon* species (including *C. dactylon*) are shown in Tables 77-79 (Brown *et al.*, 1988).

Table 77. Chemical composition of four *Cynodon* species

Item[b]	*Cynodon* variety[a]				
	Ona	Cane Patch	Puerto Rico	Callie	SE[c]
Total N	1.4	1.3	1.5	1.3	0.12
NDF-N	0.8	0.7	0.9	0.8	0.06
ADF-N	0.2	0.1	0.2	0.2	0.04
NDF	75.8	77.1	79.4	79.5	0.79
ADF	39.7	38.9	40.6	41.2	0.86
HC	36.2	38.2	38.8	38.3	0.53
ADL	7.0	7.3	6.0	7.7	0.22

[a] Ona, Cane Patch, Puerto Rico star grass (*Cynodon nlemfuensis* Vanderyst var. *nlemfuensis*), Callie 35-3 Bermuda grass (*Cynodon dactylon*).
[b] N = nitrogen, NDF = neutral detergent fiber, ADF = acid detergent fiber, HC = hemicellulose, ADL = acid detergent lignin (dry matter basis).
[c] SE = standard error of the mean.

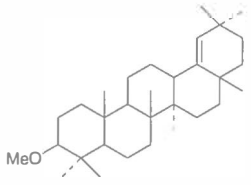
Intake, digestion and daily gain by cattle consuming Bermuda grass (BG) and receiving different concentrate supplements (ground corn, vegetable oil, urea, corn gluten and blood meals) were studied. Fat mixed with grain may have lessened the deleterious effects of grain on fiber digestion by protecting the concentrate from ruminal degradation, but did not greatly affect performance. Supplementation with urea improved gains low-nitrogen BG, but did not affect digestion or daily gain with BG higher in nitrogen. Supplementation with ruminal escape protein sources improved daily gain, suggesting that with prior inclusion of other supplement

The results obtained from responses of grasses (including *D. decumbens*) to water stress, supported the hypothesis that water stress can lead to improved live weight gains during dry periods in the pasture-growing season. Water stress frequently leads to an increase in herbage digestibility because it modifies the chemical composition of the plant and delays both stem development and aging of younger leaves. This higher digestibility was supported by studies in which cattle grazed on N-fertilized tropical grass pastures showed higher daily weight gains during the pasture growing season when conditions were dry rather than wet (Evans and Wilson, 1984). The study of the effect of biuret nitrogen and energy supplementation (5 % corn meal, 25 % corn starch and 25 % glucose) on the utilization of low quality digit grass (*D. decumbens*) hay revealed that supplementation with energy tended to decrease voluntary hay intake, but resulted in increased organic matter digestibility (Bustillos *et al.*, 1981). Twenty-four bulls (3/4 Holstein x 1/4 Zebu hybrids) of ~ 16 month old and 238 kg live weight were used to study the effect of molasses or corn in the protein supplementation to grazing bulls during the dry season. The treatments were: molasses with (A) 8 % urea; (B) 12 % urea; a dried protein supplement with (C) 20 % corn and (D) 45 % corn (Delgado *et al.*, 1980). In animals grazed pangola grass (*D. decumbens*), weight gains were: 531, 624, 549 and 632 g/animal/day for treatments A, B, C and D, respectively. Biological and economical results suggested the use of molasses with 12 % urea and libitum and 150 g/day of fish meal as supplement for growing-fattening animals consuming poor quality pastures (< 7 % of N x 6.25) during the dry season (Delgado *et al.*, 1980).

Records of milk yield, fat percent, body weight, reproduction and health of calving of cows were used for estimating the efficiency of utilization of tropical grass pastures (including *D. decumbens*) by lactating cows fed on grazing alone or grazing with various types of supplement (Yaznan *et al.*, 1982).

Tricin and flavone *C*-glycosides were detected in several *Digitaria* species (e.g. *D. adscendens*, *D. diagonalis*, *D. erlantha*, *D. milanjiana* and *D. perrotretii*) (Harborne and Williams, 1976). Isoorientin was identified from *D. adscendens* (Kaneta and Sugiyama, 1973).

The triterpenoids identified from culms and blades of certain *Digitaria* species were: β-amyrin and miliacin (**838**) from *D. adscendens*; β-amyrin, miliacin, germanicol and the methyl ethers of α-and β-amyrins and lupeol from *D. violascens* (Rizk, 1986).



838 Miliacin

14.1. ***Digitaria sanguinalis*** (L.) Scop, Fl. Carn., ed. 2, 1:52 (1771).
syn. *Panicum sanguinale* L., Sp. Pl., ed. 1,57 (1753).

Dhifra, Dhifira (Ar.)

Weak-stemmed annual ± glabrous grass 40-60 cm high. Culms erect-decumbent with well-spaced long internodes 4.5-8 cm long with long leaf sheath up to 11 cm long, glabrous except

towards the internodes, 5- to 6- noded to inflorescence. Inflorescences of 2-4 divergent slender digitate spikes 8-12 cm long, green turning yellow at maturity; spikelets a pair: the lower sessile and the upper pedicellated; rachis flattened, wavy; spiklets falling entire at maturity.

Habitat and Distribution

Common weed of lawns, gardens and moist ground occurring sporadically.

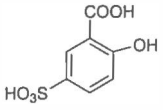
Constituents

The chemical compositions of *D. sanguinalis*, growing in Equador, was as follows: crude protein 10.4, neutral-detergent fiber 66.7, acid-detergent fiber 38.7, acid-detergent lignin 5.66, silica 2.79, cellulose 28.8 % and nitrate 1136 ppm. The *in vitro* dry matter digestibility was 68.7 %. The plant contained the following minerals: Ca 0.41, P 0.29, Mg 0.22, K 3.11 %, Na 0.02 %, Fe 278, Cu 8, Mn 41 and Zn 28 ppm (Nuwanyakpa *et al.*, 1983).

The amino acid composition of *D. sanguinalis* caryopses and leaves was: aspartic acid 6.1, 12.3; threonine 3.7, 5.4; serine 6.0, 6.3; glutamic acid 23.8, 13.7; proline 7.5, 6.2; glycine 2.7, 6.0; alanine 9.2, 7.7; cystine 0.9, 0.8; valine 4.5, 4.4; methionine 3.7, 1.9 isoleucine 3.6, 3.6; leucine 11.7, 9.8; tryrosine 4.2, 4.5; phenylalanine 6.1, 5.7; histidine 2.0, 1.9; lysine 2.2 6.5; tryptophan 0.1,0.0 and arginine 1.9, 3.4 respectively (g % total amino acids). Total amino acids amounted to 11.0 (protein content, g % fresh weight) (Yeoh and Watson, 1981, 1982).

Inhibitional effects of *D. sanguinalis* and its possible role in old-field succession have been reported by Parenti and Norman (1969). Crab grass (*D. sanguinalis*) was prominent early in the first stage of old-field succession in central Oklahoma and southern Kansas, occurring sometimes in almost pure stands. However, it was one of the first species of that stage to be lost. It was postulated therefore, that crab grass might produce substances inhibitory to its own seedlings and to seedling of associated species. Grains germination and seedlings growth of *Amaranthus retroflexus*, *Ambrosia elatior*, *Aristida oligantha*, *Bromus japonicus*, *D. sanguinalis* and *Helianthus annuus* were inhibited by whole plant extracts, except for the germination of *Aristida oligantha* and *B. japonicus* grains. Decaying crab grass had no effects on germination or growth of the test plants. Growth inhibitors were apparently released by crab grass as root exudates and retarded the growth of most species tested. Three inhibitors: chlorogenic acid, isochlorogenic acid and sulphosalicylic acid (**839**) were identified in whole plant extracts. Sulphosalicylic acid was found only in fresh extracts. It was concluded that crab grass was inhibitory to many of the pioneer species of abandoned fields, including its own seedlings (Parenti and Norman, 1969).

Cyanogenic individuals in *D. sanguinalis* have been recently reported (Aikman *et al.*, 1996). The plant was reported to be emetic (Watt and Breyer-Brandwijk, 1962).



839 Sulphosalicylic acid

15. ECHINOCHLOA P. Beauv.

E. frumentacea, known as Japanese banyard millet or billion dollar grass, is a grain and forage millet grown in certain parts of USA, *E. decompositum* is the Australian millet, used as food by the aborigines of that continent. Other species of *Echinochloa* are grown for food in tropical Africa and in South America (Matz, 1959; Hinze, 1972; Casey and Lorenz, 1977). In India, *E. furmantacea* is one of millets mostly used for food purpose, especially by low-income groups (Malleshi and Desikachar, 1985).

The chemical composition of several *Echinochloa* species has been reported *viz. E. frumentacea* (Muralikrishna *et al*., 1982; Malleshi and Desikachar, 1985), *E. pyramidalis* (Henrici, 1928), *E. polystachya* (Howard-Williams and Junk, 1977) and *E. utilis* (Hedges *et al.*, 1978). Takaki (1976) stated that of the warm-season grasses, shikoku-bie (*Echinochloa*) had almost the same nutritive characteristics, as the cold-season grasses. The proximate composition of the kernels of barn yard millet (*E. frumentacea*) was reported by Malleshi and Desikacher (1985) as: protein 8.9, fat 4.3, crude fiber 7.8, ash 4.0 and starch 50.4 %. The nutritional value of *E. polystachya* was as follows: dry matter (17.4 %), ash (10.9 %), protein (9.19 %), polyphenols (1.13 unit g^{-1}), cell-wall (7.19 %) and caloric value 3.92 (kcal g^{-1} dry mass) (Howard-Williams and Junk, 1977). The amino acid composition of *E. crus-galli* caryopses and leaves was: aspartic acid 6.7, 11.8; threonine 3.6, 5.2; serine 5.5, 6.0; glutamic acid 22.8, 14.5; proline 7.2, 5.9; glycine 3.2, 5.2; alanine 9.4, 7.8; cystine 1.7, 0.8; valine 4.4, 4.7; methionine 2.7, 1.9; isoleucine 3.7, 3.5; leucine, 10.6, 9.2; tyrosine 4.5, 4.4; phenylalanine 6.4, 5.6; histidine 2.1, 2.0; lysine 2.7, 6.7; tryptophan 0.1,0.3 and arginine 2.7 and 4.2 (g % total amino acids). Total amino acids of caryopses and leaves amounted to 7.2 and 1.2 respectively (protein content, g % fresh weight) (Yeoh and Watson, 1981, 1982).

Starchy and non-starchy carbohydrates were isolated and characterized from sanwa (*E. frumentacea*). The content of starch and sugars and *in vitro* digestion of starch by α-amylase in *E. frumantacea* was studied by Krichnkumari and Thayumanavan (1995). Gelatinized starch was highly susceptible to enzymic digestion when compared to ungelatinzed starch. The lipids of *E. crus-galli* amounted to 4.66 % of grains weight (Kandeel *et al*., 1988).

The mineral content of the shoots of *E. polystachya* was: Na 0.03, K 3.33, Mg 0.22, Ca 0.29, Si 2.10 and P 0.15 (Howard-Williams and Junk, 1977).

Japanese millet *E. utilis*, which had high sulphur (0.45 %) and N (0.03) contents and very narrow nitrogen:sulphur (5.71:1), was easily acceptable to sheep in Australia. Its disadvantage was its very early maturity with subsequent poor regrowth (Hedges *et al.*, 1978). There are few reported experiments on animal production from *Echinochloa* millets, although some reports indicated that they promoted higher live weight gain per head in sheep (Wheeler and Hedges, 1972), and milk production in cows (Stobbs, 1975), than sorghum. In certain environments the forage yield of Japanese millet (*E. utilis*) was reported as good as or better than those of the forage sorghums (Boyle and Johnson, 1968; Dann, 1970).

Dried swine manure fertilization increased the N, K_2O and P_2O_5 content of *Echinochloa* (Akita and Matsuda, 1977). In a pot experiment B, Cd, Cu, Ni, Se and Zn were higher in Japanese millet (*E. crus-galli* cv. *frumentacea*) on soils ammended with soft coal fly ash and municipal sludge (10 % wt/net) than on untreated soils. Ni and Zn were higher in plants on acid than on neutral soil, whereas Se was higher on neutral than on acid soils (Elfving *et al*., 1981). The effect of high water table (WT) in organic soil on yield and quality of aleman grass

E. polystachia was studied by Pate and Snyder (1978). Aleman grass, grown on high WT treatment, had almost 15 % less leaves ($P < 0.10$) as a percentage of total plant dry matter, than plants grown on low WT treatment. The fibrous components of forage tissue were higher in plants grown under high WT. Both crude fiber and neutral detergent fiber were higher in leaf tissue from the high WT treatment. Calcium levels of tissues from high WT were much lower ($P < 0.05$) than those from the lower WT pots, but adequate to meet the requirements of grazing cattle. However, no consistent trends in plant tissue P levels related to WT treatment were detected.

E. crus-galli can grow in standing water and helps in the leaching of excess salts from saline soils. Being a C_4, plant its growth was reported as fast and was very much relished by animals. The ability of *E. crus-galli* to maintain its tissue water content and selectively absorb K at high salinity could be the contributing factors for its high salt tolerance. *E. crus-galli* seemed to be a good candidate as a fodder plant for the economic utilization of highly salt-affected soils, where ponding may be necessary for leaching salts. Due to the relatively low total salt uptake, the plant could be directly consumed by animals without any health hazards (Aslam *et al.*, 1987). High salt tolerance of Australian channel millet *E. turnerana* was also reported as a grain or a forage crop. As a forage crop, it displayed superior digestibility. It was suggested that the species could be exploited on marginal lands (Shannon *et al.*, 1981). The critical concentration for the germination of *E. hispidula* was 1.8 % (Kim, 1980).

The yield of wax from the panicoid grass (*E. crus-galli* var. *frumentacea*) was low (0.06 % dry weight) and there was no single major component. Hydrocarbons, esters, aldehydes, free acids, free alcohols and the unidentified fractions (comprising many compounds) were 17, 20, 12, 10, 10 and 31 % of the epicuticular wax respectively (Tulloch and Bergter, 1980). Grains of *E. crus-galli* contained 100.3 mg % estrone (Kandeel *et al.*, 1988). The grains of the same species were reported to contain cholesterol, 24-methylenecholesterol, campesterol, campestanol, stigmasterol, sitosterol, sitostanol and isofucosterol (Takatsuto and Kawashima, 1998). Three 4,4-demethylsterols, eleven monomethylsterols and several steroidal 3-ones were found in the grains of *E.. frumentacea* (Narumi *et al.*, 2000, 2001) The triterpenoid crusgallin (**840**), campesterol, stigmasterol and β-sitosterol were also reported in *E. crus-galli* (Rizk, 1986).

Hordenine, tyramine (**841**) and *N*-methyltyramine (**842**) were isolated from the grains of sanwa millet (*E. frumentacea*) (Sato *et al.*, 1970). A variety of barnyard grass (*E. crus-galli* var. *oryzicola*) contained very little *trans*-aconitic acid (Fukami, 1978).

Aqueous extracts of *E. crus-galli* cotyledons inhibited germination of *E. crus-galli* but not of wheat, tomato or cucumber. The inhibitory effect was due to a lipoprotein (I), molecular weight 31,200, and a ribonucleoprotein (II) (molecular weight 30,900). Biological activities of (I) and (II), were attributed to their proteinaceous component, (20 % of I and 18.2 % of II). Predominant amino acids of the proteins included glutamate, aspartate, glycine and valine (Rusev and Atanasova, 1981). The isolation of growth inhibitors from the embryo of *E. crus-galli* has been reported. The active fraction of the inhibiting extracts contained equimolecular concentrations of asparagine, serine, proline, alanine, histidine and valine (Atanasova *et al.*, 1981).

Malt of barnyard millet (*E. frumentacea*) grains was evaluated for its suitability in weaning food formulations. Ungerminated grains contained starch 77.9, free sugars 1.2 and protein 8.2 % (Malleshi and Desikachar, 1986).

The use of *E. coracana* (ragi or finger millet) as a foodstuff is well known. In India, it is an important staple food for locals belonging to the low socio-economic group. Its use as infant and child feed is limited because of its low digestibility and poor availability of nutrients. The possible nutritional advantages of sprouted ragi in the diets of infants and children were assessed. Of the three types of ragi flours assessed (whole, sprouted and vadragi), the growth promoting value of sprouted ragi was higher than whole ragi and vadragi flours. Vadragi can be recommended in the diets of weaned infants, because of its low fiber content, and sprouted ragi flour in the diets of pre-school children, because of its higher growth value, probably due to higher amounts of B-vitamins (Hemanalini *et al.*, 1980). The food value of *E. coracana* was supposed to be approximately equal to that of wheat. The composition was ash 2.7, ether extract 1.7, crude protein 8.4, crude fiber 3.4 and carbohydrates (by differences) 83.8 %. The protein consisted largely of a prolamin or ethanol-soluble protein named eleusinine (Narayana and Norris, 1928). The total protein of the grains of *E. coracana* was claimed to be of high biological value and digestibility (Niyogi *et al.*, 1934). The alcohol-soluble protein prolamin of finger millet was 6.5 g/kg of flouer. About 6 % of the protein was present in the form of non-protein nitrogen (Pore and Magar, 1979). Doesthale *et al.* (1970) reported that the protein level may vary from 5.6 to 11.6 % for finger millet (*E. coracana*) varieties. Of the thirty-six varieties of *E. coracana* (from India), varieties from Karnataka showed a higher amount of protein (10.6 %) (Pore and Magar, 1977). The average protein content of *E. coracana* was 9.8 % (Ravindran, 1991). Fermentation has been found to reduce total crude protein in ragi millet (*E. coracana*) (Aliya and Geervani, 1981). The proximate composition, mineral composition and phytate and oxalate contents of *E. coracana* were suggestive of its protein as source of dietry nutrient (Ravindarn, 1991).

The chemical composition of stems, leaves and inflorescences of *E. indica* was respectively as follows: proteins 9.86, 10.40, 11 %, fats 2.25, 1.58, 1.46 % and ash 13.20, 12.80, 12.00 % (Rajwar *et al.*, 1980). The nutritive value of *E. indica* was reported as follows: *in vitro* dry matter digestibility 67.7 %, crude protein 12.1 % neutral-detergent fiber 68.0 %, acid detergent fiber 36.5 %, acid-detergent lignin 5.55 %, cellulose 27.0 % silica 2.80 % and nitrate 5677 ppm (Nuwanyakpa *et al.*, 1983). The ratio total S:total N of *E. tocusso* grains is 1:10.3 (Orru, 1931a).

The amino acid composition of some *Eleusine* species is shown in Table 84 (Yeoh and Watson, 1981,1982).

Total dry weight of African millet (*E. coracana*) was low at the early growth rate. The highest total sugar contents on the dry weight basis in leaf sheath and culms were 24.5 % (just before heading stage) and 22.8 % (just after heading stage), respectively. Crude starch percentages in the different organs, except ears and culms were approximately 5 % or less (Miura and Nakabayashi, 1978). About 70 % of the carbohydrates, of hybrid varieties of *E. coracana*, were present in the form of starch and only about 2 % free reducing sugars were present (Pore and Magar, 1979). Glucose, fructose and sucrose, were determined in *E. coracana* (Masaki and Ohyama, 1978). In comparison of the native millet, the malted finger millet (*E. coracana*) contained higher levels of free sugars (glucose, fructose and maltose) and water-soluble non-starchy polysaccharides (WSNSP). The WSNSP of malted millet was richer in hexoses than pentoses (Malleshi *et al.*, 1986a). The study of the carbohydrate constituents of four varieties of ragi (*E. coracana*) revealed that they contained a larger proportion of starch

(66.4-70.2 %) than sugars (0.11-0.31). The detected sugars were: glucose, fructose, galactose, maltose, sucrose, lactose and raffinose (Misra, 1992a). Six different varieties of starch were obtained from *E. coracana* (Misra, 1992b). Finger millet starch was found slightly resistant for amylolysis, as compared with pearl millet and foxtail millet (Malleshi *et al.*, 1986b).

Table 84. Amino acids of some *Eleusine* species

Amino acids composition	*E. coracana*[*]	*E. indica*		*E. tristachya*[**]
g/total amino acids	caryopses	caryopses[*]	leaf[**]	leaf
Aspartic acid	6.6	7.3	12.2	12.1
Threonine	4.4	4.5	5.3	5.4
Serine	6.1	5.8	5.7	5.7
Glutamic acid	22.8	24.3	15.3	14.7
Proline	7.2	6.8	6.1	6.3
Glycine	3.5	3.4	5.5	5.7
Alanine	6.6	6.5	8.3	8.6
Cystine	1.5	1.0	0.8	1.2
Valine	5.3	5.2	4.3	4.3
Methionine	3.5	3.5	2.0	1.7
Isoleucine	3.6	3.7	3.3	3.4
Leucine	10.5	9.9	9.0	9.3
Tyrosine	4.6	4.4	4.4	4.4
Phenylalanine	5.9	5.9	5.3	5.5
Histidine	2.3	2.3	1.8	1.6
Lysine	3.3	3.7	6.7	6.5
Tryptophan	0.2	0.0	0.5	0.5
Arginine	2.0	2.9	3.6	3.3
Total amino acid (protein content) (g % fresh wt)	5.8	7.9	2.9	1.6

[*] Yeoh and Watson (1981), [**] Yeoh and Watson (1982).

Finger millet (*E. coracana*) varieties contained a high amount of Ca and was a good source of P. The Ca:P ratio was high as 2:1 in some varieties (Pore and Magar, 1977). Much of P was in the phytic acid (**843**) form (Pore and Magar, 1979). Ash mineral contents of *E. corcana* were reported by Joshi and Joshi (1979). The mineral composition of *E. indica* was as follows: Ca 0.92 %, P 0.29 %, Mg 0.24, K 2.47 %, Na 0.04 %, Fe 298 ppm, Cu 6 ppm, Mn 48 ppm and Zn 51 ppm (Nuwanyakpa *et al.*, 1983).

$C_6H_6[OPO(OH)_2]_6$

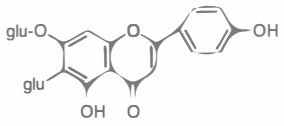
843 Phytic acid

Ramachandra *et al.* (1977) studied the relationship between tannin levels and *in vitro* digestibility in finger millet (*E. coracana*). *In vitro* protein digestibility values of low tannin varieties were higher than those of high tannin varieties. The dry matter digestibility of African millet (*E. coracana*) was higher than in Rhodes grass (*Chloris gayana*) (Kawamura *et al.*, 1979).

The evaluation of *E. indica* as fodder plant has been reported (Prakash *et al*., 1978; Rajwar *et al.*, 1980).

Neutral lipids, glycolipids and phospholipids (1.3 %, 0.25 % and 0.10 % of grains weight) were isolated from the total lipids of finger millet grains (*E. coracana*) and 4 sterol-containing lipids were further isolated. All 4 sterol lipids contained 80-84 % β-sitosterol, the remainder being stigmasterol (Mahadevappa and Raina, 1978). The total lipid content (5.2 %), comprising free, bound, and structural lipids of grains finger millet (*E. coracana*) was 42.3, 46.2 and 11.5 % respectively. The nonpolar lipids (NL) consisted of glycolipids (GL) and phospholipids (PL). The study revealed that esterified sterylgycerol, monogalactosyl diglycerides, and digalactosyl diglycerides in GL; and phosphatidylcholine, phosphatidylethanolamine, and lysophosphtaidylcholine in PL. Linoleic, oleic and palmitic acids were the chief constituents in all the lipid classes. Linolenic acid was present in appreciable proportions in PL (Sridhar and Lakshminarayana, 1994).

In a survey of leaf flavonoids in six *Eleusine* species: *E. africana*, *E. compressa*, *E. coracana*, *E. floccifolia*, *E. multiflora* and *E. tristachya*, twenty phenolic compounds were detected. Those identified were: orientin, isoorientin, vitexin, isovitexin, saponarin (**844**), violanthin, lucenin-1, and tricin (Hilu *et al*., 1978).



844 Saponarin

Eleusine species are known to produce HCN. A brief review of cyanogenesis of this genus was given by Tjon Sie Fat (1977). Triglochinin was isolated from inflorescences of *E. coracana*, *E. Indica* and *E. tristachya* (Tjon Sie Fat, 1977, 1978). Other data concerning HCN content in *Eleusine* species (including *E. indica*) were also reported (Zinsmeister *et al.*, 1980; Aikman *et al*., 1996).

16.1. *Eleusine compressa* (Forssk.) Asch. *et* Schweinf. ex C. Chr., Dansk Bot. Ark. 4(3):12 (1922).

syn. *Ochthochloa compressa* (Forssk.), Hilu, Kew Bull. 36(3):560 (1981).

Nagam (Ar.); Goose grass (En.)

Rhizomatous perennial grass with prostrate branches spreading over large areas producing tufts of erect growth. Inflorescences digitate star-shaped; spikelets pale green-yellow. Flowering and produces new shoots with the onset of rains.

Habitat and Distribution

Widespread on sandy mounds and shallow depression. Most common in central Qatar. Plant heavily grazed almost to the ground level.

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *E. compressa*, collected from different localities in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d). The unsaponifiable matter of the lipids contained sterols (36.24 %), hydrocarbons (29.91 %), aliphatic alcohols (19.21 %), 4-methylsterols (2.29 %) and triterpene alcohols (12.34 %). The hydrocarbon fraction consisted of: $C_{23:0}$, 1.09; $C_{24:0}$, 1.82; $C_{25:0}$, 5.47; $C_{26:0}$, 3.65; $C_{27:0}$, 12.77; $C_{29:0}$, 18.61; $C_{30:0}$, 8.03; $C_{31:0}$, 22.63; squalene, 9.85 and others 16.06 %. The alcohol $C_{28:0}$ represented the main component of the alcohol fraction (70.45 %), other constituents were $C_{20:0}$ 1.70; $C_{22:0}$ 4.55; $C_{23:0}$, 1.14; $C_{24:0}$, 5.11; $C_{26:0}$, 6.82; $C_{27:0}$, 5.68 and others 4.55 %. The sterol fraction contained β-sitosterol (59.04 %) stigmasterol (23.50 %) and campesterol (15.66 %) (Al-Easa *et al.*, 2002).

E. compressa, growing in Pakistan, contained 1.1-1.7 % lipids, 31.7-33.5 % fibers, 6.8-8.7 % proteins, 38.7-45.8 % carbohydrates and 7.0-9.4 % ash (Malik and Khan, 1971). Data about the trace mineral constituents in the leaves of this fodder plant in India have been reported (Nanda *et al.*, 1970).

The effect of season and rainfall on herbage production and nutrient composition of *Eleusine* (probably *E. compressa*)-*Aristida* in India has been studied. There was more reserve carbohydrates in below ground biomass during the winter season as indicated by a low above ground biomass/below ground biomass weight ratio. N and P concentrations in different plant parts varied with the season and rainfall. A significant positive relation was observed between rainfall and above ground biomass / below ground biomass ratio of N and P. Uptake of N and P had a significant positive correlation with above ground biomass yield. On average, 0.761 kg N/ha and 0.149 kg P/ha were required to produce 1 quintal of above ground biomass (Aggarwal *et al.*, 1977).

Investigation of the flavonoid constituents of the plant revealed the presence of lucenin-1, tricin and three unidentified compounds (Hilu *et al.*, 1978). Flavonoid data, as do morphological observations (Phillips, 1972; Hilu and de Wet, 1976), suggested the exclusion of the perennial *E. compressa* from the genus *Eleusine* (Hilu *et al.*, 1978).

Phytochemical screening of the plant, growing in Qatar, revealed the presence of alkaloids, coumarins, flavonoids and sterols (Rizk *et al.*, 1986a).

17. ERAGROSTIS P. Beavu.

Weeping and boer love grass (*E. curvula*) and lehmann love grass (*E. lehmanniana)* have been reported as species that can be of value to cattlemen for conservation and for forage production. In some semi-arid areas, weeping love grass can be effectively used as intensively managed pasture. In some arid areas weeping, boer and lehmann lovegrass have been used effectively for revegetation of rangelands (Voigt *et al.*, 1986). *E. curvula* is a useful pasture grass in parts of the Southern Plains of the United States, in Argentina, and in South Africa. Its excellent seedling establishment and wide adaptability have been well recognized (Vogel, 1970; Voigt *et al.*, 1981).

The nutritive constituents (proximate chemical analysis) of several *Eragrostis* species have been reported *viz. E. abyssinica* (Borgatti, 1938b), *E. curvula* (Voigt *et al.*, 1970,1981,1986), *E. lugens* (Girola, 1918). *E. minor*, *E. superba* (Honcamp and Zimmermann, 1915; Du Toit *et*

al., 1934; Strickland, 1973) and *E. teff* (Orru, 1931b; Borgatti, 1938a; Bondi and Meyer, 1943; Mengesha, 1966, Rizk, 1986). An analysis of forty-five species in Argentina and Uruguay were reported as early as 1918 by Girola.

The flour of *E. teff* has been used to prepare cakes (Massa, 1935). In times of severe famine, the grains of *E. chloromales* were used by Southern Sotho to make bread and in the preparation of beer (Watt and Breyer-Brandwijk, 1962). Although the grains of *E. teff* are small (< 0.002 g), they constitute an important part of the staple diet of Ethiopians, particularly in the urban areas. Their protein content ranges from 6 to 10 % and they were reported as high in iron and calcium (Lester and Bekele, 1981). Mengesha (1966) studied the chemical composition of two strains of teff (*E. teff*) and reported that both had ~ fold more Ca and 2-4 fold more Fe than wheat, barely and grains sorghum. *E. abyssinica* was suggested as a good food for white man in the tropics and could be used in place of wheat if preparation methods were improved (Borgatti, 1938b).

The amino acid composition of grains proteins was determined for eleven cultivar accessions of *E. teff* and ten accessions of related wild species (*E. barrelieri*, *E. bicolor*, *E. cilianensis*, *E. curvula*, *E. diplachnoides*, *E. mexicana*, *E. minor*, *E. papposa* and *E. pilosa*). The eleven cultivars were found similar but quite distinct from the various wild species. In general, the wild species had smaller grains and a higher proportion of protein, but the cultivated species had more lysine. The amount of lysine in the protein was positively correlated with the amount of glycine, arginine, aspartic acid and threonine, but negatively correlated with glutamic acid, isoleucine, leucine and proline. The grains of wild species contained possibly a protein more rich in glutamic acid but of little nutritional value. Glutamic acid is one of the main components of *Eragrostis* grains proteins, constituting approximately 23-25 % of the protein in teff and 26-31 % in the wild species (Lester and Bekele, 1981). The amino acid compositions of the caryopses of some *Eragrostis* species are shown in Table 85 (Yeoh and Watson, 1981).

The forage quality of weeping love grass strains has been extensively studied. Voigt *et al.* (1970) found strain 813 (an introduction of "Ermelo") and strain 994 (later released as 'Morpa') to be higher in cellulose and lower in lignin than the strain selection 673 and a fourth strain selection, respectively. Morpa produced higher animal gains than common teff and 673 cultivar (Voiget *et al.*, 1970; Shoop *et al.*, 1976). Froseth (1970) studied two cultivars of teff in Argentina, and he did not find any significant differences in crude protein or *in vitro* dry matter disappearance (IVDMD) from clipped samples but did find differences in crude protein and *in vitro* digestible organic matter from esophageal samples (Voigt *et al.*, 1981). Holt and Dalrymple (1979) found that "Morpa" and "Renner" tended to be higher than common teff in IVDMD with Ermelo being intermediate but variable. Voigt *et al.* (1981) reported the forage quality of four curvula type weeping love grasses. Their results indicated that on an overall basis significant differences were not detected in all the stages of growth, but were detected for important forage quality characteristics such as IVDMD, cellulose and lignin. The mean performance of four lovegrasses when harvested by initial growth or subsequent regrowth interval was as follows: IVDMD (56.6-58.1 %), protein (16.9-17.5 %) cell contents (26.4-27.5 %), hemicellulose (33.6-36.3 %), ash (1.9-2.2 %), cellulose (29.0-30.8 %), lignin (5.5-6.3 %) and dry matter (28.0-31.7 %).

Table 85. Amino acid compositions of some *Eragrostis* species

Amino acids composition	*E. benthamii*		*E. chloromelas*	*E. ciliarensis*	*E. dielsii*		*E. curvula*
g/total amino acid	L**	C*	C*	C*	L**	C*	L**
Aspartic acid	14.0	6.7	6.8	6.0	12.3	5.6	11.9
Threonine	5.0	3.9	4.1	3.4	5.3	3.6	5.4
Serine	6.2	5.7	6.3	5.5	6.2	4.5	6.3
Glutamic acid	13.4	27.0	24.7	31.4	13.1	36.0	13.5
Proline	5.7	6.6	6.7	6.2	5.8	5.1	6.0
Glycine	5.5	2.9	3.6	2.6	5.7	3.2	5.9
Alanine	8.1	6.2	6.4	6.1	8.4	5.0	8.6
Cystine	0.9	2.7	1.8	1.2	0.9	1.2	0.8
Valine	4.4	4.4	3.8	4.0	4.4	4.9	4.6
Methionine	1.9	4.5	5.4	3.9	2.1	2.8	1.8
Isoleucine	3.3	3.2	3.2	3.4	3.3	3.4	3.5
Leucine	9.4	8.3	8.3	8.6	9.3	8.5	9.7
Tyrosine	4.6	5.3	5.2	5.6	4.7	4.9	4.7
Phenylalanine	5.6	6.0	5.8	6.5	5.6	4.9	5.8
Histidine	1.6	2.0	2.2	1.9	1.9	1.9	1.6
Lysine	6.4	2.3	3.0	1.8	6.7	2.1	0.4
Tryptophan	0.1	0.1	0.0	0.0	0.1	0.1	0.0
Arginine	3.8	2.3	2.5	1.7	4.3	2.4	3.7
Total amino acid (protein content) (g % fresh wt)	3.8	10.2	8.1	11.1	1.9	9.7	2.6

C, caryopses; L, leaves;* Yeoh and Watson (1981); ** Yeoh and Watson (1982).

Relatively poor forage quality could seriously limit the usefulness of weeping and lehmann love grass within their present areas of adaptation (Voigt *et al.*, 1986). Low summertime palatability limits the usefulness of lehmann grass on Arizona rangelands (Cable, 1971). Although good animal performance was obtained from weeping lovegrass (Shoop *et al.*, 1976; Cotter *et al.*, 1983), weight gains were frequently less than other warm-season grasses (Duble *et al.*, 1971). Poorer performance was associated with low *in vitro* dry matter digestibility. Voigt *et al.* (1986) evaluated the variability for digestibility, palatability, and forage weight among relatively winter-hardy selections of *E. curvula* and *E. lehmanniana*. In their study, the germplasm of *E. curvula* and *E. lehmanniana* was divided into 4 types: curvula, conferta, short chloromelas and cold-hardy lehmann. Differences among types were significant for all the characters studied. Curvula type showed the widest range in palatability (Voigt *et al.*, 1986). Both Leigh (1961) and Johnston and Aveyard (1977) suggested that curvula type was among the least palatable of the love grasses. However, the results of Voigt *et al.* (1986) for relatively winterhardy germplasms, suggested that this was not always true, and the results were consistent with those reported by Leigh (1967) in that the curvula type can be among the most productive.

In weeping love grass, crude protein and *in vitro* dry matter disappearance (IVDMD) declined with increase in the stage of growth (Fraps and Fudge, 1945; Diaz *et al.*, 1972; Denman *et al.*, 1953; Strickland, 1973). Seasonal trends showed that both characteristics

declined from spring to late summer (Savage and Heller, 1947; Duble *et al.*, 1971) and that the forage quality of four love grass strains, showed that from jointing to anthesis IVDMD declined at 0.46 % units per day. Following the initial harvests, IVDMD continued to decline at 0.02 % units per day during the remainder of the summer, despite equal interval regrowth harvests. Similar patterns were observed for crude protein and cell contents. Hemicellulose also decreased from jointing to anthesis but increased during regrowth harvests, while cellulose and permanganate lignin increased from jointing to anthesis and showed only little seasonal changes during regrowth harvests. Changes in forage quality characteristics across the stages of growth were much greater than those in the cultivars suggesting that even with irrigation to minimize moisture stress and with equal age of regrowth, IVDMD tended to decline at about 0.2 % units per day from June through August (Voigt *et al.*, 1981). I*n vivo* digestibility of *E. curvula cv. Tanganyka*, declined at 0.08 percentage units per day (Marchi *et al.*, 1973). The more rapid decline of crude protein early in the season reported by Voigt *et al.* (1981) agreed with the results of Savage and Heller (1947) and Farrington (1973), who reported a sharp decline in N content associated with the onset of flowering in late spring. Significant differences in forage vigor and quality among the hybrids (e.g. 'Morpa' weeping lovegrass hybrids) were higher in IVDMD than the common weeping lovegrass hybrids (Voigt, 1984).

The cell wall content of both leaves and stems of *E. teff* has been found to increase markedly with age, corresponding to the decrease in forage digestibility. Detailed analysis concerning variations in chemical composition and digestibility of *E. teff* has also been reported (Tables 86 and 87) (Morris, 1980).

Table 86. Molar ratios of cell-wall components in *E. teff*

Days after planting	Cell wall origin	Glucose/xylose	Xylose/arabinose	Xylose/acetyl
27	Leaf	1.6	4.3	3.7
27	Stem and sheath	1.3	5.8	3.4
28	Stem and sheath	1.4	5.1	2.7
35	Leaf	1.7	4.3	3.3
35	Stem and sheath	1.2	5.7	3.1
43	Leaf	1.6	4.3	3.9
43	Stem and sheath	1.3	5.2	2.9
48	Leaf	1.4	4.5	3.7
48	Stem and sheath	1.3	6.8	2.4
62	Leaf	1.6	4.4	3.1
62	Stem and sheath	1.3	7.1	2.1
93	Leaf	1.5	5.2	3.3
93	Stem and sheath	1.3	7.3	2.5

Leaf cell walls from teff in the vegetative stain contain less than half as much galactose or uronic acid as the ryegrass (*Lolium perenne*) cell walls (Morris and Bacon, 1977), as well as having lower content of arabinose and glucose and a higher lignin content. The vegetative teff cell walls were over 70 % digested in nylon bags in the rumen. Changes with age in the cell wall composition and digestibility of the stem and sheath fraction may be to a large extent indicative of differences in composition between the stem and leaf sheath (Morris, 1980).

Table 87. Cell-wall *preparations of E. teff* and their composition

Days after planting	Cellwall origin	Cell wall (% of fresh weight)	Composition (% by weight of air-dry cell wall, sugars given as anhydro sugar)								
			Lignin	Rhamnose	Arabinose	Xylose	Mannose	Galactose	Glucose	Uronic acid	Acetyl
27	Leaf	5.9	7.6	0.1	4.0	17.4	0.3	0.5	33.9	2.2	1.5
27	Stem and sheath	5.9	8.7	0.1	3.8	21.8	0.2	0.4	35.2	1.9	2.1
28	Stem and sheath	8.1	8.2	0.1	3.8	19.5	0.2	0.3	32.7	2.2	2.3
35	Leaf	8.0	10.2	0.1	4.0	17.3	0.3	0.6	34.8	2.1	1.7
35	Stem and sheath	8.8	11.3	0.1	4.1	23.0	0.2	0.4	34.7	1.9	2.4
43	Leaf	14.7	7.4	0.1	4.1	17.8	0.2	0.5	35.7	1.8	1.5
43	Stem and sheath	15.1	8.9	Trace	4.0	20.6	0.4	0.4	32.8	2.3	2.3
48	Leaf	17.5	8.2	0.1	4.1	18.3	0.3	0.6	32.1	1.9	1.6
48	Stem and sheath	18.5	10.9	Trace	3.2	21.9	0.2	0.7	33.7	1.9	2.9
62	Leaf	ND	9.3	Trace	3.8	16.7	0.5	0.4	33.0	1.7	1.8
62	Stem and sheath	20.1	12.6	Trace	2.9	20.7	0.2	0.2	34.0	1.6	3.2
93	Leaf	27.5	8.6	0.1	3.6	18.4	0.1	0.4	34.6	1.5	1.8
93	Stem and sheath	27.8	12.8	0.1	2.9	21.1	0.1	0.2	33.2	1.9	2.8

ND: not determined

Mineral analysis of grains of two teff varieties showed that the plant does not have an exceptionally higher Fe content than other cereals. A series of sand culture experiments, conducted to study the Fe/Mn balance in the plant showed that the Fe content was within the range, but reciprocal relations existed between Fe and Mn in the plant (Mamo and Parsons, 1987). Acid washing (20 times with 2 % HCl) of grains from 35 cultivars of *E. teff* showed that the Fe content decreased from 8.44-12.14 mg % to 5.25-6.0 mg % (Besrat *et al.*, 1980). Cu and Sn contents of *E. ferruginea*, which grow near railroads, in Japan, were high compared with plants at points further away from the railroad (Suzuki *et al.*, 1987).

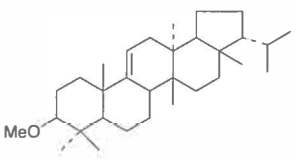
Boer lovegrass (*E. curvula* var. *conferta*) was found to be more drought resistant than weeping lovegrass (*E. curvula*), but was less productive and winter-gardy (Crider, 1945). Wiltshire (1980) found that the biomass of *E. chloromelas* increased by increasing the water content in pots of soils derived from sandstone and from dolerite from 11 to 33 and 100 % water-holding capacity and by increasing the soils N and P content to 2, 5 and 10 times their originated levels. The response was larger to N at high and to P at low water levels.

Epicuticular wax of *E. curvula* contained hydrocarbons (6 %), esters (13 %), acids (3 %), alcohols (4 %), tritriacontanone-12,14-dione (47 %), 5-hydroxytritriacontanone (14 %) as major components (Tulloch, 1982a) and esters represented the major constituents of the epicuticular wax of *E. trichoides* (Tulloch, 1984).

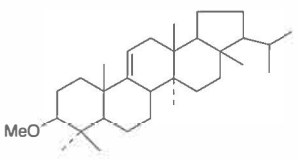
Several triterpenoids have been identified in *Eragrostis* spp. Examples of these are shown in Table 88.

Table 88. Triterpenoids of some *Eragrostis* species

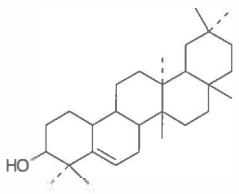
Species	Triterpenoids	References
1. *E. curvula*	α-Amyrin, β-amyrin, arundoin **(845)**, cylindrin **(846)**, glutinol **(847)**, lupeol, fernenone **(848)**, β-fernenol **(849)** and simiarenol **(850)**	Tulloch (1982a); Rizk (1986)
2. *E. ferruginea*	β-Amyrin methyl ether and miliacin	Ohmoto *et al.* (1968)
3. *E. multicaulis*	β-Amyrin and miliacin	Ohmoto and Nikaido (1972)
4. *E. trichoides*	α-Amyrin and β-amyrin	Tulloch (1984)



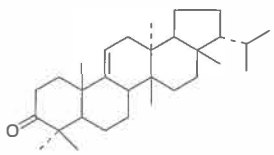
845 Arundoin



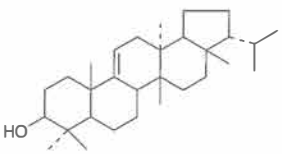
846 Cylindrin



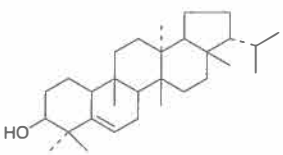
847 Glutinol



848 Fernenone



849 Fernenol

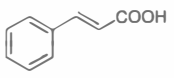


850 Simiarenol

A wide range of variation in flavonoids and proteins was amongst 14 accessions of wild *Eragrostis* species (*E. aethiopica*, *E. barrelieri*, *E. bicolor*, *E. cilianensis* (three accessions), *E. curvula*, *E. diplachnoides*, *E. heteromera*, *E. mexicana*, *E. minor*, *E. papposa*, *E. pilosa* and *E. viscosa*) (Bekele and Lester, 1981). The latter workers stated that when the flavonoid data were subjected to the principal component analysis, they showed a clear distinction between the wild species and the cultivars, whereas Constanza *et al.* (1979) found flavonoid chromatography of little value since there was much variation within as between the accessions of tef, and no pattern differences were found between *E. aethiopica*, *E. macilenta*, *E. pilosa* and *E. tenuifolia*. The protein and flavonoid data presented by Bekele and Lester (1981), corresponded fairly with the morphological data (Jones *et al.*, 1978). However, it was obvious that the genus *Eragrostis* constituted a complex of species, which still require detailed study, postulate their evolutionary relationships (Bekele and Lester, 1981). Tricin, flavone *C*-glycosides (including violanthin) were detected in several *Eragrostis* species including *E. atrovirens*, *E. curvula*, *E. horizontalis*, *E. paniciformis*, *E. plana* and *E. superba*. Luteolin, luteoferol and a flavonoid sulphate have been also identified in some *Eragrostis* species (Kaneta and Sugiyama, 1973; Harborne and Williams, 1976). Five inhibitory compounds, which were tentatively identified as the phenolic compounds cinnamic acid, ferulic acid, gallic acid, gentisic acid and syringic acid were detected in the root exudate of *E. curvula*.

The presence of HCN in *E. abyssinica* (Zinsmeister *et al.*, 1980) and *E. plana* has been reported by Petrie (1913).

Hafeez (1972) evaluated the suitability of *E. superba* for pulp and paper manufacture.



851 Cinnamic acid

17.1. ***Eragrostis barrelieri*** Daveau. in J. Bot. Paris 8:289 (1891).

Variable annual grass with long leaf blades. Inflorescences terminal and axillary panicles; spikelets many-flowered, awnless, breaking up at maturity from down upwards leaving behind a persistent rhachilla; pedicels shorter than spikelets.

Habitat and Distribution

In rodats with dense tree growth and deep soil and a weed of cultivated land. Comparatively rare in Qatar.

Constituents

The amino acids composition of the grains of *E. barrelieri*, growing in Ethiopia, is shown in Table 87. The protein content of the grain flour amounted to 15.59 %. (Lester and Bekele, 1981). Ten phenolic compounds were detected, by chromatography, in the leaves (Bekele and Lester, 1981).

Phytochemical screening of *E. barrelieri*, growing in Qatar, revealed the presence of alkaloids, coumarins, flavonoids, saponins and sterols (Rizk *et al.*, 1986a).

17.2. ***Eragrostis cilianensis*** (All.) F. T. Hubb., Philipp. J. Sci. (Bot.) 8:159 (1913).
syn. *Poa cilianensis* All., Fl. Pedem. 2:246, t. 91, f. 2 (1785); *E. major* (L.) Host. Gram. 181 (1802); *E. megastachya* (Koel.) Link, Hort. Berol. 1:181 (1802).

Annual grass with adventitious roots up to 15 cm high with leafy, bare and upright culms. Leaf blades linear lanceolate. Inflorescences very dense, shiny, light green panicles; spikelets many on stunted pedicals appearing congested.

Habitat and Distribution

Common as an agricultural weed. Occasional after the rains on sandy stony soils and associated with desert shrub.

Constituents

The amino acid composition of *E. cilianensis*, growing in Australia, is shown in Table 85 (Yoeh and Watson, 1981). The protein content of the flour of *E. cilianensis*, in Ethiopia, amounted to 12.41 % (2n = 20) and 11.32 % (2n = 40 chromosomes). The amino acid composition of the same sample is shown in Table 89.

Several phenolic compounds were detected, reaching up to nineteen in the tetraploid cultivar *E. cilianensis* (Bekele and Lester, 1981).

Table 89. Amino acid composition (percent of protein recovered) and protein composition (percent of grain flour) of some *Eragrostis* species

Amino Acids	*E. barrelieri*	*E. cilianensis* diploid*	*E. cilianensis* tetraploid*	*E. pilosa*
Asparagine	5.32	6.29	5.48	6.04
Threonine	3.59	3.55	3.36	4.06
Serine	4.81	4.83	4.51	4.63
Glutamic acid	29.12	28.69	30.48	27.67
Proline	6.48	6.29	6.71	5.95
Glycine	2.95	2.50	2.47	3.21
Alanine	5.52	5.88	5.74	5.38
Cystine	0.90	0.89	0.62	1.13
Valine	5.45	5.56	5.74	5.48
Methionine	4.23	3.30	3.09	3.40
Isoleucine	4.36	4.43	4.86	4.25
Leucine	9.36	9.43	9.28	8.22
Tyrosine	3.72	4.60	4.77	4.72
Phenylalanine	6.03	6.61	6.45	5.95
Histidine	2.57	2.74	2.30	2.64
Lysine	2.05	1.77	1.94	2.83
Arginine	3.46	2.58	2.30	4.25
Protein	15.59	12.41	11.32	10.59

* x=10 chromosomes.

17.3. ***Eragrostis pilosa*** (L.) P. Beauv., Ess. Agrost. 162, 175 (1812).
syn. *Poa pilosa* L., Sp. Pl., ed.1, 68 (1753).

Indian lovegrass (En.)

Slender tufed annual grass with open lax panicles. Leaf blade slightly longer than leaf sheath. Inflorescences of few spikes with few spikelets.

Habitat and Distribution

Weeds of cultivation and arable lands.

Constituents

The protein content of the flour of *E. pilosa*, in Ethiopia, amounted to 10.59 %. The amino acids composition of the same sample is shown in Table 89.

Earlier evaluation of *E. major* and *E. pilosa* as fodder plants has been reported. The average composition of the two species was as follows: ash (12.8 %), crude protein (14.9 %), fat (1.8 %), carbohydrates (42.8 %), crude fiber (27.6 %) and food ratio 1.3 (Girola, 1917).

Thirteen phenolic compounds have been detected in the plant (Bekele and Lester, 1981).

18. HALOPYRUM Stapf

18.1 ***Halopyrum mucronatum*** (L.) Stapf in Hook. Ic. Pl. 25, t. 2448 (1996).
syn. *Uniola mucronata* L., Sp., Pl., ed. 2,1:104 (1762); *Eragrostis mucronata* (L.) Deflers, Bull. Soc. Bot. Fr. 34:69 (1887).

Coarse tough grass with linear leaves and long culms with terminal raceme-like spicate inflorescences. Spikelets about 1 cm long (resembling *Eragrostis*).

Habitat and Distribution

Though a species of coastal sand dunes, it is relatively rare in Qatar. Reproted as a good sand stabilizer and fodder grass in S.W. Salwa.

Constituents

Phytochemical screening of *E. mucronatum*, growing in Qatar, revealed the presence of alkaloids, coumarins, flavonoids and sterols (Rizk *et al.*, 1986a).

Glycinebetaine content of *E. mucronatum*, increased with the increasing of NaCl accumulation in the plant (Khan *et al.*, 1998,1999).

19. HORDEUM L.

Other than *Hordeum vulgare* (cultivated barley), which has been extensively studied, there are relatively few reports on the other *Hordeum* species. In comparison with proso millet (*Panicum miliaceum*), leaves of barley (*Hordeum distichon*) showed higher levels of free amino acids and protein, while the roots showed a lower level of amino acids bound in the

protein fraction and low levels of free amino acids (Edgar and Draper, 1974). The study of the feeding value of the whole-crop of two-rowed barley (*H. distichon*), revealed that the digestibility of the silage crude protein, crude fat and crude fiber decreased with maturity (Kumai *et al.*, 1995). The concentrations of Na, K, Ca, Mg and Cl in the grains of *H. jubatum* have been reported as: 0.33, 0.25, 0.13, 0.03 and 0.07 (mmol g^{-1} dry weight) respectively (Khan and Ungar, 1996).

The flavonoid, tricin, has been detected in *H. distichon* (Harborne and Williams, 1976). Hordenine, a phenylalkylamine alkaloid has been identified in both *H. murinum* and *H. sativum*. Triterpenoids e.g. arundoin, cylindrin and taraxerol were identified in *H. murinum* (Rizk, 1986).

Cyanogens have been reported in some species of *Hordeum* e.g. *H. jubatum* (Aikman *et al.*, 1996).

19.1. *Hordeum murinum* L., Sp. Pl., ed. 1, 85 (1753).
syn. *Hordeum glaucum* Steud., Syn. Pl. Glum. 1:352 (1854).

Shaeer (Ar.); Barley (En.)

Annual erect grass with linear lanceolate leaves and long spicate inflorescences. Spikelets with long awns, green turning to golden yellow on maturity.

Habitat and distribution

Sandy grounds near Al-Shahaneya and north eastern Qatar. Commonly near cultivated areas as a weed of agriculture and arable land.

Constituents

The grains of *H. murinum* contained 23.5 % protein and 1.4 % fat (Duke and Atchley, 1986).

19.2. *Hordeum vulgare* L. Sp. Pl., ed. 1, 84 (1753).
syn. *Hordeum hexastichon* L., Sp. Pl., ed. 1, 85 (1753); *H. sativum* Pers., Syn. Pl. 1:108 (1805).

Shaeer (Ar.); Barley (En.)

Annual medium-sized grass. Culms erect ending in spicate inflorescences. Inflorescences pale green ripening to golden ears; spikelets with long awns not breaking at maturity.

Habitat and Distribution

An escape of agricultural fields that has since become naturalized. Grains passing with animal droppings readily germinate with the onset of the rains. Widespread in all areas where animal pens exist in particular Al-Shahaneeya race grounds.

Constituents

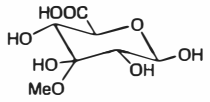
The nutritive constituents (proteins including hordein, edestin, an albumin called leusosin and water-insoluble protein, starch, fat containing oleic, stearic, linoleic and linolenic acids, sucrose, raffinose, porphyrin, several enzymes and others) have been reported by various investigators.

The prolamin (a group of proteins having high proline and glutamic content) of barley is called hordein and consists of a mixture of polypeptides. Amino acid analysis revealed that the two hordein peptides B1 and C2 were different in composition. The B1-hordein contained about 5 times as much lysine as the C2-hordein. It was furthermore higher in content for almost all amino acids, which are essential for human nutrition (Schmitt, 1979). Hordeins are distinguished from the albumin, glolubin and glutelin families of protein by the fact that they are soluble in hot ethanol but not in water or salt solutions (Baxter and Wainwright, 1979). Hordeins have been generally subdivided into three groups, designated A, B and C. The A-hordeins have a low molecular weight (12,500-20,000), higher lysine and lower glutamic acid and proline, than the other two groups (Mesrob *et al.*, 1970; Shewry *et al.*, 1977). The proportion of A-hordeins in high lysine barleys was unchanged or increased and that of B- and C-hordeins were markedly decreased (Shewry *et al.*, 1977). A-Hordeins did not seem to be located in the protein bodies (Holder and Ingversen, 1977; Salcedo *et al.*, 1980) and it was suspected that they were not reserve proteins (Shewry *et al.*, 1977; Køie and Doll, 1979). Because of their amino acid compositions, which are outside the range of prolamins, their designation as A-hordeins according to Aragoncillo *et al.* (1981) was inappropriate and their chemical characteristics closely resembled those of the wheat chloroform-methanol proteins, which were also salt-soluble and hydrophobic. In general barely endosperm prolamins (hordeins) have been extensively investigated (e.g. Miflin and Shewry, 1979; Cameron-Mills *et al.*, 1980), most of the work has dealt with the B- and C-hordeins, which are the main reserve proteins. The results obtained by Schmitt and Svendsen (1980) suggested the presence of several hordein polypeptides with very similar N-terminal sequences in the total hordein preparation. Cooke (1996) analysed the hordein composition of 706 barely varieties from 15 different countries and found a total of 22 C-hordein and 26 B-hordein alleles. The ratio of B to C-hordeins was determined for a range of spring barely cultivars and the values obtained varied from 1.79 for Kneifel to 4.15 for Goldmarker (Griffiths, 1987).

The amino acid composition of *H. vulgare* leaves and caryopses was respectively as follows: aspartic acid 13.5, 5.5; threonine 5.5, 3.1; serine 5.2, 4.5; glutamic acid 14.3, 28.1; proline 5.3, 13.0; glycine 5.5, 3.6; alanine 6.9, 3.6; cystine 2.0,1.7; valine 4.8, 4.4; methionine 1.7, 1.5; isoleucine 3.2, 3.2; leucine, 8.7, 7.7; tyrosine 4.0, 4.1; phenylalanine 5.5, 6.0; histidine 2.0, 2.1; lysine 7.1, 3.6; tryptophan 0.5, 0.2 and arginine 4.2, 4.2 (g % total amino acids). Total amino acids amounted to 4.1 and 3.2 respectively (protein content, g % fresh weight) (Yeoh and Watson, 1981,1982).

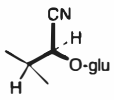
Drought stress caused a significant decrease of the grain yield (16 %), the protein yield (22 %) in mature grain and the protein content of shoots (18 %), leaves and stems, harvested before anthesis. The lignin content of shoots of stressed plants was markedly higher (20 %) than those of well-watered controls. Drought from the shooting to the heading stage caused changes in the patterns of soluble proteins (albumins, globulins) from mature barely grain (Leinhos and Bergmann, 1995). The maximum crude protein content (14.37 %) was observed when barley was cut repeatedly at the 4-leaf stage, whereas the minimum was at the early dough stage. Barley harvested at booting stage proved better for reasonable green-fodder yield (67.32 tonnes/ha), dry-matter yield (11.66 tonnes/ha) and fodder quality (crude protein 10.33 %). At this stage sufficient quantity of fodder yield with moderate quality was obtained (Hussain *et al.*, 1995).

An arabinogalacto(4-*O*-methylglucurono)xylan has been isolated from the leaves of barley. The total hemicellulose isolated from the leaves of mature plants contained arabinose, galactose, glucose and xylose residues (in the molar ratio 1.0:0.5:0.5:3.1), traces of rhamnose and both glucuronic and 4-*O*-methylglucuronic acids **(852)** (Buchala, 1973).



852 4-Methylglucuronic acid

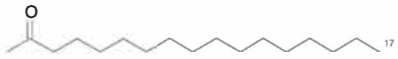
As for cyanogenesis in *H. vulgare*, the leaves of 10-day seedlings yielded a cyanogenic glucoside identified as 2-β-D-glucopyranosyl-oxo-3-methyl-(2*R*)-butyronitrile (epimer of heterodendrin **853, 854**) (Erb *et al.*, 1979). The HCN in primarily leaves and mature caryopses of five barley cultivars has been reported by Erb *et al.* (1981).



853 Heterodendrin

854 *epi*-Heterodendrin

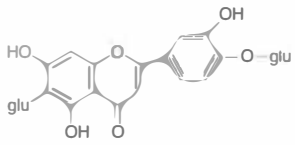
The surface lipid hydrocarbons from barley heads were nearly all *n*-hentriacontane, whereas there were five major normal hydrocarbons with carbon numbers 25, 27, 29, 31 and 33 on the rest of the plant (*i.e.* stem, leaf and sheath). Hydrocarbons composed 12-17 % of the surface lipids extract from heads and 5-7 % of the surface lipid extract from the rest of the plant. A β-diketone, probably a mixture of 8- and 9-hydroxyhentriacontane-14,16-diones, was obtained in a yield of 23-30 % of the surface lipids from glaucous barley. The β-diketone gave on alkaline hydrolysis palmitic acid, myristic acid, heptadecan-2-one **(855)** and pentadecan-2-one **(856)** (Jackson, 1971). The culms and blades of *H. vulgare* yielded miliacin (Ohmoto *et al.*, 1978).



855 Heptadecan-2-one

856 Pentadecan-2-one

C-Glycosylflavones have been identified from *H. vulgare*. Many genotypes of *H. vulgare* have shown that the principal flavonoid constituents of the leaves were saponarin and a 7-glucoside which on hydrolysis yielded an equilibrium mixture of saponaretin and vitexin (Seikel and Geisman, 1957). Another *C*-glycoside, lutonarin **(857)**, has been isolated from barley (Seikel and Bushnell, 1959). Tricin, luteolin, in addition to *C*-glycosylflavones have been identified from the leaves of *H. vulgare* (Kaneta and Sugiyame, 1973; Harborne and Williams, 1976). Luteolin was among the major phenolics detected in the leaves of barley at stages IV, VII, and XI of ontogenesis. Apigenin, tricin, caffeic acid, *trans*-ferulic acid, *cis*-ferulic acid, chlorogenic acid, *trans-p*-coumaric acid, *p*-hydroxybenzoic acid and *o*-coumaric acid were also identified in the leaves (Vilenskii and Shcherbakov, 1980).



857 Lutonarin

β-carotene and leaf xanthophyll of *H. sativum* were reported as 31.7 and 84 ppm respectively (Miller, 1935).

H. vulgare showed relatively good acetycholinesterase inhibition potency over 80 % (Lee *et al.*, 1997a).

20. LASIURUS Boiss.

The chemical composition, as well as, the digestibility of a few species of *Lasiurus* have been reported (Gupta *et al.*, 1975).

20.1. *Lasiurus sindicus* Henrrard, Blumea 4:514 (1941).

syn. *Saccharum hirsutum* Forssk., Fl. Acgypt.-Arab. 16 (1775); *Lasiurus hirsutus* (Vahl) Boiss., Diagn. scr.2, 4:146 (1859).

Dhaa, Da'ah (Ar.)

Table 94. Cont.

Species	References
13. *P. maximum* (Guinea grass)	Du Toit *et al.* (1934); Kok *et al.* (1943); Chicco and French (1960); Perdomo *et al.* (1976); Masaki and Ohyama (1978); Chauhan *et al.* (1980); Funes *et al.* (1980); Yates *et al.* (1981); Franca and Haag (1985); Rosiles Martinez *et al.* (1986); Shehu and Akinola (1995); Smith *et al.* (1995)
14. *P. maximum* var. *trichoglume* (green panic)	Humphreys and Robinson (1966); Okada (1977); Masaki and Ohyama (1978); Ford and Wilson (1981); Wilson (1981); Wilson *et al.* (1986)
15. *P. miliaceum* (broom corn, cheena millet, common millet, hershey, hog millet, panivaragu, proso millet, vari,)	Ito (1931); Bhide and Sahasrabuddhe (1943); Edgar and Draper (1974); Casey and Lorenz (1977); Luis *et al.* (1982a,b); Prasad and Singh (1983); Wilson (1983b); Jiang *et al.* (1993); Krishnakumari and Thayumanavan (1995)
16. *P. miliare* (little millet; samai)	Muralikrishna *et al.* (1982); Saraswathy *et al.* (1999)
17. *P. obtusum* (vine mesquite)	Pieper *et al.* (1978)
18. *P. prionitis*	Hammerly *et al.* (1982)
19. *P. purpurescens* (para grass)	Chicco and French (1960); Appleman and Driven (1962); Pena *et al.* (1977); Hossain *et al.* (1979)
20. *P. queenslandicum* (Queensland blue grass)	McMeniman *et al.* (1986a)
21. *P. repens*	Kok *et al.* (1943); Al-Saadi and Al-Mousawi (1984); Wang *et al.* (1999)
22. *P. stagninum*	Perrot and Tassilly (1908)
23. *P. sumatrense* (little millet)	Rajandran and Thayumanavan, (2000)
24. *P. virgatum* (switchgrass)	Smith (1979); George and Hall (1982); Moore and Buxton (2000); Law *et al.* (2001)

The term "millet" is used for several small seeded annual grasses that are of minor importance in the Western world but staple diets of Africans, Asiatic people in many developing countries and contributes substantial amounts of energy and protein to their diets. Millet is consumed mostly in Northern China, India, Africa, and Southern Russia, where about 85 % of the crop is consumed directly as human food (Lorenz and Dilsaver, 1980a). Millets can be cultivated in a wide range of soils and climates and are of special importance in semiarid regions, because of their short growing seasons (Schery, 1963; Lorenz and Dilsaver, 1980b). The four varieties of millet which are grown extensively in certain parts of the world include: proso (*P. miliaceum*), finger (*Eleusine coracona*), pearl (*Pennisetum typhoideum*), and foxtail (*Setaria italica)* (Luis *et al.*, 1982a). In India, millets are mostly used for food purpose, especially

Table 95. Nutrient composition of some *Panicum* species

Species	Crude Protein %	Fat %	Crude Fiber %	Ash %	Carbohydrates %	References
1. *P. australiense*	10.6	2.40				James (1983)
2. *P. barbinode*	12 *	2.9*	28.2*	11.2*		Mathur *et al.* (1957)
	2.5	0.63		2.10	8.13	Dominguez (1922)
3. *P. maximum*	6.99-8.03	0.78-1.12	27.38	5.17-6.29		Kok *et al.* (1943)
(hay)	6.44-8.91					Laredo C. and Ardila (1984)
	1.68	0.58		2.53	10.91	Dominguez (1922); Arroyo-Aguilu and
	7.0-8.8					Operta-Téllez (1980)
						Henrici (1928)
	3.4	1.2		10.5	42.8	Gomide *et al.* (1979)
	7.9-14.8					
4. *P. miliaceum*						
grains	10.7-12.9	3.1-4.0		2.61-3.79		Lorenz *et al.*, (1976)
grains	15.10-16.68	4.58-5.26		2.81-3.63		Luis *et al.*, (1982a)
grains	14.95					Prasad and Singh (1983)
grains	10.9-12.0	3.7-5.2	6.1-6.9	3.4-3.6		Malleshi and Desikachar (1985)
						Ravindran (1991)
5. *P. miliare*	8.8	3.7	5.9	4.1		Malleshi and Desikachar (1985)
6. *P. repens*	7.72-8.02	1.5	21.6	4.40-5.09		Kok *et al.* (1943)
7. *P. maximum*	11.9-21.8*					Devendra (1977)

* dry basis.

by the people of low-income groups (Malleshi and Desikachar, 1985). *P. stagninum*, a gramineal of the marshy regions of the Niger, is used by locals for food, and in the making of a beverage (Perrot and Tassilly, 1908). Proso (*P. miliaceum*) is the common millet, which has been grown since prehistoric times for human use. Dehulled proso can be consumed as a puffed cereal or cooked as a hot breakfast cereal. Millet flour can be used as a partial substitute in formulations, which call for wheat flour, to impart a distinct nut-like flavour (Hinze, 1972; Lorenz and Hinze, 1976). *P. miliaceum*, also known as hershey, broom corn, or hog millet, is planted in some African countries as a food crop. It is also of economic importance in the United States. Many farmers in eastern Colorado and western Nebraska include proso in their three-year and five-year rotation systems (Lorenz and Dilsaver, 1980b). Flours from millet can be used to partially replace white flour in breads, cookies, and pasta products (Badi *et al*., 1976a,b; Skovron and Lorenz, 1979).

Proso millet is used in feeding rations, as bird grains, and also as human food (Hinze, 1972). Luis *et al*. (1982a) have reviewed, determined, and reported the nutrient composition of proso millets (*P. miliaceum*) in comparison to other feed grains, namely yellow corn (*Zea mays*) and grain sorghum or milo (*Sorghum bicolor*).

Plant age was the main factor affecting guinea grass (*P. maximum*) nutritive value, which also varied with growth succession during the rainy season and growth intervals. Average values for *in vitro* dry matter digestibility, crude protein, P, Ca, Mg, Zn, Cu and Mn for the grass at 21 and 35 days ranged respectively from: 63.3-58.4 %, 14.8-7.9 %, 0.24-0.15 %; 0.45-0.37 %; 0.21-0.16 %; 34-15 ppm; 19-18 ppm; and 299-246 ppm (Gomide *et al*., 1979). Devendra (1977) reported that the chemical composition of *P. maximum*, fed to goats and sheep at 5 stages of growth: 16-19, 21-28, 28-35, 35-42 and 42-49 days, decreased with increasing maturity. The crude protein contents on dry matter basis were 21.8, 20.0; 16.7, 16.7; 13.2, 14.7; 12.5, 14.5; and 11.5, 11.9 % at the five stages of growth respectively.

The influence of cutting intervals on the chemical composition of *P. purpurescens* has been studied by Appleman and Driven (1962). Crude protein dropped by 50 % in 3 to 8 weeks. Crude fiber content was high after 3 weeks, but did not alter noticeably after this. PO_4^{3-} K, Cl, SO^{2-}_4 and ash content decreased with age. Ca, Mg and Na remained at the same level. The effect of cutting management on yield and quality of *P. maximum* has been also reported (Singh *et al*., 1995; Singh, 1996). Mean herbage K, in switch grass (*P. virgatum*) decreased from 1.09 % on 30 June to 0.82 % on 2 September, whereas herbage Ca increased from 0.37 % to 0.56 % (George and Hall, 1982).

Hatch and Tainton (1995) found that the residual herbage mass at the end of summer was significantly related to cumulative summer grazing days, rainfall and range conditions (indexed as the sum of the proportions of *Themeda triandra*, *P. maximum* and *P. coloratum*). The period of forage deficit during which herbage mass declined below a grazing cut-off of 1695 Kg ha^{-1}, was significantly related to the residual herbage mass at the end of summer.

The major chemical components in fall panicum were similar to those of corn. Equally, there was no marked difference in the components of all panicum grown in paddy and upland cultivation conditions with the exception of the crude protein content. The N content of the grass grown in upland cultivation conditions was higher than those grown on paddy fields. The first cut silage was of poor quality due to low water-soluble carbohydrate content (Yashida *et al*., 1983).

In comparison with barley, proso millet (*P. miliaceum*) was characterised by high levels of alanine and glutamic acid in the leaf free amino acid fraction (Edgar an Draper, 1974). *P.*

miliaceum was reported to be rich in lysine (Indira and Naik, 1971). The grains of *Panicum* contained 19 amino acids, including all essential amino acids (Sokolova, 1972). The amino acid compositions of some *Panicum* species are shown in Table 96 (Yeoh and Watson, 1981).

The limiting amino acids in millets (including *P. miliaceum*) are lysine and sulphur-containing amino acids (Casey and Lorenz, 1977). The protein content and amino acid composition of *P. miliaceum* and other millets compared favourably with that of corn and wheat (Table 97) (Casey and Lorens, 1977).

Table 96. Amino acids composition of some *Panicum* species

Amino acids composition g/total amino acid	*P. antidotale*		*P. hians*	*P. milloides*		*P. queenslandicum*
	Caryopses*	Leaf**	Caryopses*	Caryopses*	Leaf**	Leaf***
Aspartic acid	7.5	14.0	6.8	6.6	11.9	9.3
Threonine	3.8	4.9	3.0	2.9	5.5	4.2
Serine	5.8	5.7	5.8	5.7	5.8	5.1
Glutamic acid	22.1	13.2	23.5	23.3	12.8	12.8
Proline	7.8	6.0	8.4	8.5	5.6	5.8
Glycine	2.5	5.4	1.9	2.1	5.7	5.4
Alanine	8.5	8.1	9.5	9.5	6.7	8.6
Cystine	1.5	1.0	0.9	0.9	6.9	1.1
Valine	4.7	4.5	4.4	4.5	2.9	5.8
Methionine	2.3	2.1	3.6	3.5	5.1	2.6
Isoleucine	3.9	3.3	3.8	3.6	1.9	4.2
Leucine	13.4	9.0	12.4	12.6	3.6	9.9
Tyrosine	3.9	4.4	4.6	4.8	9.3	4.2
Phenylalanine	5.4	5.4	6.1	6.0	5.0	5.8
Histidine	2.0	2.0	2.1	2.1	5.8	2.2
Lysine	2.2	6.4	1.5	1.6	2.3	7.3
Tryptophan	0.7	0.7	0.0	0.0	6.5	-
Arginine	2.0	4.2	1.8	1.9	0.0	7.0
Total amino acid (protein content) (g % fresh wt)	14.6	2.3	16.1	13.2	1.4	49

* Yeoh and Watson (1981); ** Yeoh and Watson (1982); *** McMeniman *et al.* (1986b).

Two xylans have been isolated from the mature tissues of the tropical grass *P. maximum* - an arabino-(4-*O*-methylglucurono)-xylan and an acidic galactoarabinoxylan. Both consisted of a main chain of β-(1→4) linked D-xyloparanosyl residues (Buchala, 1974). Hydrolysis of the hemicellulose from the leaf tissue of *P. coloratum* gave mannose, in addition to arabinose, xylose, galactose and glucose (Pitman *et al.*, 1981). The hemicellulose, cellulose and lignin content of Guinea grass (*P. maximum*) hay at 30, 45 and 60 days were respectively as follows: 25.9, 32.1, 30.6; 33.7, 34.7, 37.2 and 7.3, 7.3 and 8.8 % (Arroyo-Aguilú and Oporta-Téllez, 1980). Cell wall composition of a stable suspension of proso millet (*P. miliaceum*) cells was similar to those of the cell suspensions of other graminaceous species. Extraction of hemicelluloses yielded materials that, similar to those of embryonal cells of maize coleoptiles,

comprise mostly glucuronoarabinoxylan, xyloglucan and small amounts of (1→3), (1→4)-β-D-glucan. As in the walls of embryonal cells of the maize coleoptile, 5-arabinosyl and 3-arabinosyl comprised much higher proportions of the total hemicellulosic sugars than in the walls of developed or elongated cells (Carpita *et al.*, 1985). Trifluroacetic acid (TFA) hydrolysis proved to be the most useful for cell wall compositional analysis of forage grasses (including *P. amarum* var. *amarum*, var. *amarulum* and *P. virgatum*). Residue from TFA hydrolysis resembled a pectin-free cellulose fraction, and the hydrolysate contained stable neutral sugar monomers derived from hemicellulose (De Ruiter and Burns, 1987b). Two non-starchy carbohydrates were isolated from *P. miliare* and *P. miliaceum*. Hemicellulose A was a non-cellulosic glucan, whereas hemicellulose B was composed of hexoses, pentoses and uronic acids in varying proportions (Muralikrishna *et al.*, 1982).

Table 97. Amino acids composition of millets[1]

Amino acids	*Pennisetum typhoideum*[2]	*Panicum miliaceum*[3]	*Setaria italica*[4]	Corn[4]	Whole Wheat[4]
Arginine	6.2	3.2	2.3	8.1	4.3
Cystine	1.7	1.0	1.4	2.0	1.8
Histidine	2.4	2.1	1.2	2.6	2.1
Isoleucine	4.6	4.1	6.1	7.9	4.0
Leucine	13.3	12.2	10.5	9.9	7.0
Lysine	3.1	1.5	0.7	3.3	2.7
Methionine	2.3	2.2	2.4	2.6	2.5
Phenylalanine	4.3	5.5	4.2	4.0	5.1
Threonine	4.2	3.0	2.7	2.9	3.3
Tryptophan	1.8	0.8	2.0	1.2	1.2
Tyrosine	-	4.0	1.6	2.0	4.0
Valine	5.5	5.4	4.5	5.3	4.3
Protein (%)	16.0	12.5	12.4	10.9	13.2

[1] Grams of amino acid per 16 grams of nitrogen-dry basis; [2] (Burton *et al.*, 1972); [3] (Jones *et al.*, 1970a); [4] (Mangay *et al.*, 1957).

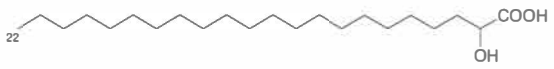
P. miliaceum starch had a higher water binding capacity and a higher gelatinization temperature than the wheat and rye starches. Millet starch was less soluble than wheat or rye starch at 60°C (Lorenz and Hinze, 1976). Starch isolated from *P. miliare* exhibited single stage swelling, moderately soluble in water (Muralikrishna *et al.*, 1982).

Two forms of α-glucosidase, designated as I and II, have been isolated from grains of *P. miliaceum*. The two enzymes readily hydrolysed maltose and malto-oligosaccharides, and native starch weakly. The two enzymes readily hydrolysed amylose liberating α-glucose (Yamasaki *et al.*, 1996).

Lorenz and Hwang (1986) studied the lipid composition of flours and brans of nine proso millet varieties. Free lipids in proso millet flours ranged from 3.20 to 4.06 % and in bran from 3.45 to 6.84 %. Bound lipids ranged from 0.47 to 0.89 % and from 0.30 to 0.70 % in flours and brans, respectively. Linoleic acid, oleic acid and palmitic acid were the predominant fatty acids in the free lipids of flours and brans. These three fatty acids represented over 90 % of the fatty acids in proso millet flour and bran. The major components of the free lipids of flours were triglycerides, sterols, free fatty acids and sterol esters. There were no qualitative differences

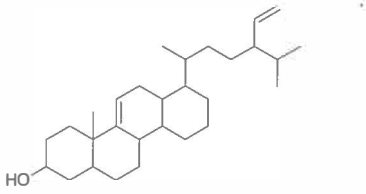
between the free lipids of proso millets and those of barley, corn, triticale and wheat. Phosphatidylcholine and digalactosyl diglycerides were the major components of bound lipids. Other components tentatively identified included phosphatidylserine, phosphatidylethanolamine and monogalactosyl diglycerides (Lorenz and Hwang, 1986). The total lipid content, comprising free, bound and structural lipids in *P. miliaceum*, was 9.0 % (62.2, 27.8 and 10.0 %) (Sridhar and Lakshminarayana, 1994).

The oil from bran of *P. crus-galli* var. *frumentaceum* (sawa-millet) amounted to 12.85 %. The wax, of which contained ceryl alcohol, α-hydroxydocosanoic acid (**876**) and crotic acid. The hydrocarbons of the oil consisted of $C_{29}H_{60}$ and $C_{31}H_{64}$ (Kitamura and Obara, 1958). Leaf and stem wax of *P. virgatum* (switchgrass) contained hydrocarbons (4 %), esters (3 %), free acids (2 %), free alcohols (1 %), triterpene alcohols (2 %), diketones (69 %) and hydroxy β-diketones (6 %). Principal free alcohols range in chain length from C_{26} to C_{32}. β-Diketones consisted almost entirely of triacontane-12,14-dione and the hydroxy β-diketone consisted only of 5(*S*)-5-hydroxytritriacontane-12,14-dione (Tulloch and Hoffman, 1980). The principal components of the leaf waxes from *P. miliaceum* and *P. texanum* were hydrocarbons, esters, aldehydes and alcohols. The major free alcohol was dotriacontanol. Free triterpene alcohols were also present, particularly in the wax of *P. miliaceum*. A mixture of an unusual triacylglycerols, with 1,3-ditetradecanoyl-2-hexanoylglycerol as principal component, was a minor component (5 %) of the wax from *P. texanum* (Tulloch, 1982b).



876 α-Hydroxydocosanoic acid

Two triterpenes, β-amyrin and miliacin, and sterols (β-sitorsterol, stigmasterol and campesterol) were identified from the culms and blades of *P. dichotomiflorum*. The grains of *P. coloratum* contained over 6 % (of the sterol fraction) cholesterol (Ohamoto *et al.*, 1970). Δ^9-Avenasterol (**877**) in addition to β-sitosterol, stigmasterol and campesterol were detected in the grains (Bowden and Williams, 1971). Miliacin, *n*-octacosanol, β-sitosterol and β-sitosterol β-D-glucoside were isolated from *P. miliare* (Saraswathy *et al.*, 1999).



877 Δ^9-Avenasterol

P. purpurescens contained enough carotene to meet the nutritional requirements of cattle (Pena *et al.*, 1977).

Harborne and Williams (1976) investigated twelve *Panicum* species, and found them to contain flavone *C*-glycosides, and tricin was detected in ten of the twelve species. Flavonoid sulphates were identified in only five species; quercetin and kaempferol were found in only *P. procurrens* and luteoforol and apigiforol were detected in *P. maximum*.

grains; it was deficient in lysine, tryptophan, threonine) and the S containing amino acids. The alcohol-soluble prolamins were generally poor in lysine and other nutritionally critical amino acids. Prolamins were relatively rich in glutamine and proline. Because the prolamins are a major fraction of the grain protein, most cereals were deficient in lysine, tryptophan, etc. (Hoseney and Varriano-Marston, 1980). Percentages of the total protein of pearl millet extracted with successive solvents of water, 6 % salt, 70 % cold ethanol, 70 % hot ethanol and 0.04 % NaOH were 13 %, 8.7 %, 33.3 %, 7 % and 9.1 % respectively (Narayamutri and Aiyer, 1930).

The distribution of nitrogen in the protein fractions of several pearl millet varieties was studied. In all the samples analysed, the prolamins and glutelins predominated, accounting for about 60 % of the protein present. The albumin fraction averaged 15 % and the globulins 9 %. The proportions of the different fractions varied among cultivars. The prolamin and glutelin fractions ranged from 21 to 38 % and from 24 to 37 %, respectively, of the total protein present (Sawhney and Naik, 1969). The analysis of prolamin and two globulin fractions from pearl millet for arginine, histidine, cysteine and lysine showed considerable differences in the amino acid composition of the two globulins. The lysine content of the prolamin fraction (2.5 %) was essentially equal to the lysine content of the total protein. The amino acid analyses for 4 protein solubility classes (albumin, globulin, prolamin and glutelin) from one pearl millet sample were reported. As expected, compared to prolamin and glutelin fractions, the albumins and globulins contained higher concentrations of basic amino acids such as lysine, argenine and histidine, as well as the sulphur-containing amino acids. Prolamins were found to be rich in glutamic acid, proline, and leucine as well as tryptophan. Pearl millet prolamin apparently differed markedly from that of other cereals in being unusually high in tryptophan; although like other cereals, pearl millet prolamin was rich in glutamic acid and proline and deficient in lysine (Hosency and Varriano-Marston, 1980). Bailey and Sumrell (1980a) concentrated about 70 % of the pearl millet protein in two fractions that, as a composite assay of 78 % protein. The resultant could be a useful as a protein ingredient in food.

Kurein *et al.* (1971) reported that supplementation with L-lysine increased the protein efficiency ratio (PER) of *P. typhoides* diet to a highly significant extent, from 2.40 to 3.38. Addition of threonine or methionine or a mixture of both along with lysine did not bring about any further increase in PER. By rat feeding, lysine supplementation to pearl millet (*P. glaucum*) was found to raise the portein efficiency ratio to approximately that obtained with Animal Nutrition Research Council (Jansen *et al.*, 1962).

Amino acid analysis of grains of *P. typhoides*, grown in Saudi Arabia, indicated the presence of at least 17 amino acids including most of the essential ones. They were also characterised by the presence of sufficient quantities of essential amino acids and limiting amino acids. Comparison with the results reported by FAO/WHO, the grain proteins showed that the essential amino acid leucine was highest, while isoleucine and valine were within the range, but threonine, lysine and the sulphur containing amino acids were lower. These results indicated that these grains have a good nutritive value (Basahy, 1996).

Shekhawat *et al.* (1980) studied the accumulation of the aromatic amino acids phenylalanine, tryptophan and tyrosine in healthy and *Sclerospora graminicola*-infected *P. typhoides*. These amino acids were highest in diseased tissues as compared to healthy ones. The amounts were highest in the green-ear initial stage, followed by suppressed ear head and completely proliferated ear heads. Ashraf *et al.* (1981) found the total concentration of free amino acids was greater in the roots of *P. typhoides* infected with *S. graminicola*.

The amino acid composition of certain *Pennisetum* species is shown in Table 100.

Table 100. Amino acids composition of some *Pennisetum* species

Amino acids	*P. alopecuroides*		*P. americanum*	*P. clandestinum*	*P. macrourum*	*P. typhoides*
	L*	C**	***	L*	L*	L**
Aspartic acid	11.9	9.5	10.40	11.4	12.3	11.0
Threonine	5.4	3.4	4.80	5.3	5.2	4.8
Serine	6.3	5.1	5.73	6.3	6.4	5.8
Glutamic acid	13.2	23.9	23.0	12.7	14.4	14.1
Proline	6.4	7.1	7.88	6.7	5.9	5.5
Glycine	5.8	2.7	3.59	5.5	6.1	5.4
Alanine	7.6	8.9	9.70	7.4	8.1	7.9
Cystine	1.4	1.3	3.15	3.0	0.7	1.9
Valine	4.2	4.2	7.03	4.5	4.9	4.8
Methionine	1.4	1.9	2.05	1.5	1.8	2.3
Isoleucine	3.4	2.7	5.54	3.6	3.6	3.7
Leucine	9.8	13.1	12.4	9.6	9.1	9.3
Tyrosine	4.8	3.3	3.83	4.6	4.2	4.4
Phenylalanine	5.9	5.2	6.12	5.7	5.5	5.5
Histidine	2.1	1.9	2.05	1.8	2.3	2.2
Lysine	6.9	2.7	3.19	6.9	6.5	6.3
Tryptophan	0.2	0.1	3.26	0.2	0.0	1.0
Arginine	3.4	3.0	5.30	3.3	3.1	4.2
Total amino acid (protein content) (g % fresh wt)	1.3	22.0	119****	1.9	1.2	1.3

C: Caryopses g % total amino acids (Yeoh and Watson 1981); L: Leaves g %. of total amino acids; * grasses collected from the field; ** grasses grown in the greenhouse (Yeoh and Watson 1982); *** mg/g dry weight of crude protein; ****Dry matter (Glew *et al.*, 1997).

In the four *Pennisetum* species, studied by Das *et al.* (1978), stems had higher cellulose content than the leaves, whereas hemicellulose was higher in the leaves in all studied species except for *P. pedicellatum*. Leaves of *P. pedicellatum* and *P. purpureum* had a high cellulose/ hemicellulose ratio (>1), whereas in *P. orientale* the leaves contained more hemicellulose than cellulose; almost equal amounts of both components were found in *P. typhoides*. In whole plant samples, the hemicellulose level (22.7-24.6 %) was much lower than that of the cellulose (27.8-34.9 %), which resulted mainly from the much higher cellulose than hemicellulose content of the stems. According to Kamstra *et al.* (1966), the hemicellulose fraction of kikuyu grass (*P. clandestinum*) contained xylose, arabinose, glucose, and galactose, with xylose accounting for the greater proportion of the sugars. Of the carbohydrates present in four varieties of elephant grass (*P. purpureum*), glucose and fructose were the most important free sugars. Glucose, fructose and sucrose constituted 74.2 % of the total soluble carbohydrates in the samples (Silveira *et al.*, 1979). Five sugars (stachyose, raffinose, sucrose, glucose, and fructose) were identified in nine pearl millet (*P. americanum*) cultivars. Sucrose was predominant in all

the cultivars and ranged from 60-68 % of the total sugars. Raffinose content was high as compared to other cereals (comprising nearly 25 % of the total sugars) and maltose was absent (Subramanian *et al.*, 1981). A total free sugar content of 10 mg glucose /g *P. americanum* flour was reported (Hoseney and Varriano-Marston, 1980).

Glucose, fructose, maltose and a water-soluble non-starchy polyaccharide (rich in hexoses than pentoses) were characterised in pearl millet (*P. typhoides*) (Malleshi *et al.*, 1986a,b). Starch from *P. alopecuroides* had a higher swelling power than did sweet potato starch (Fujimoto *et al.*, 1986).

The sweet-stalked *P. americanum* contained at maturity, more than twice the amount of soluble sugars than the normal types. The high sugar content in the mature stalks apparently makes them sweet, as can be identified by chewing them at the dough stage and onward (Rao *et al.*, 1982). The sweet-stalk types appeared to be good fodder types, because their yield had been shown to be mainly dependent on tiller number, leaf number and size, plant height, maturity and stem thickness (Gupta and Sidhu, 1973).

As in all cereals, starch composes the major carbohydrate in *P. americanum*, ranging from 56 to 65 % of the grain (Freeman and Bocan, 1973; Sheorain and Wagle, 1973). Amylose contents varied from 20 to 22 % for 5 pearl millet cultivars (Badi *et al.*, 1976b). Amylose amounted to 17 % in starch from one pearl millet population. Because millet starch gave a peak viscosity similar to that of sorghum and corn starch, it implied that pearl millet flour has a high amylase activity. Studies on sound millet indicated that amylase activity was 8-15 times greater than that reported for sound wheat (Sheorain and Wagle, 1973; Hoseney and Varriano-Marston 1980). Jain and Date (1975) compared amylase activity in bajra millet (*P. typhoides*) with that in barley and reported that it was higher in bajra. Pearl millet starch has been shown to be more resistant than sorghum starch to attack by pancreatic α-amylase or by amyloglucosidase (Sullins and Rooney, 1977).

Crude fiber values of whole pearl millet grain have been reported to range from 1.96-3.88 % (Carr, 1961; Desikachar, 1977; Reichert and Youngs, 1977).

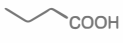
The free lipid content of pearl millet cultivars varied from 3.03 % to 7.40 % (Sharma and Goswami, 1969; Goswami *et al.*, 1969-1970; Rooney, 1978). American cultivars generally have higher free lipid content than cultivars from Africa or India. The composition of the free lipid fraction from *P. typhoides*, has been studied by several workers (Pruthi and Bhatia, 1970; Badi *et al.*, 1976a; Pruthi, 1981). Lipid of *P. americanum* grains amounted to 7.2 % and consisted of 85 % neutral lipids, 12 % phospholipids and 3 % glycolipids. Neutral lipids contained mostly (85 %) triacylglycerols and small amounts of mono- and diacylglycerols, sterols and free fatty acids (Osagi and Kates, 1984). Triglycerides were found to be the major components of the free nonpolar lipids. Monogalactosyl diglyceride was the major component of the free polar lipids (Hoseney and Varriano-Marston, 1980). Agarwal and Sinha (1964) studied the fatty acids present in the free lipids of bajra and found that oleic acid was the major fatty acid (53.84 %), followed by linoleic (34.88 %), palmitic (10.8 %), stearic (0.28 %) and myristic (0.20 %). On the other hand, Jellum and Powell (1971) studied 65 lines of pearl millet and found that linoleic acid was the major fatty acid present (40.3 to 51.7 %) in the free lipid fraction. Oleic acid ranged from 20.2 to 30.6 % and palmitic acid ranged from 17.7 to 25.0 %. In addition, these authors showed that pearl millet lines contained on the average 3.69 % linolenic acid, 3.9 % stearic acid, 0.64 % arachidic acid, and 0.55 % palmitoleic acid. The

latter data showed that differences in fatty acid values reported in the literature for pearl millet not only were due to genetic differences and grains maturity but also they were affected by lipid extraction procedures (Hoseney and Varriano-Marston, 1980). The major fatty acids of *P. clandestinum* were: linolenic (55.82 %), palmitic (21.85 %) and linoleic acid (11.90 %) (Dugo *et al.*, 1981). The fatty acid content of *P. americanum* lipid (115 mg/g dry weight) was as follows: $C_{14:0}$, traces; $C_{16:0}$, 0.88; $C_{16:1}$, traces, $C_{18:0}$, 0.21; $C_{18:1n-9}$, 1.11; $C_{18:2n-6}$, 1.87; $C_{18:3n-6}$, 0.17 and $C_{20:0}$, 0.40 (mg/g dry weight) (Glew *et al.*, 1997).

Pruthi and Bhatia (1970) studied two Indian varieties of bajra and found that the bound lipids (extracted with water saturated *n*-butanol) were composed of 0.5 % of the millet grain. On the other hand, the study of the bound lipid content (0.58-0.90 %) for 18 samples of *P. americanum*, grown in Kansas showed that their free lipid content ranged from 5.55 to 7.08 %. Unsaturated acids averaged 70.3 % of the free and 51.7 % of the bound lipid fractions. Linoleic, oleic and palmitic were the principal fatty acids in both free and bound lipids. Trace levels of myristic and behenic acids were found in the free lipids. Of the total bound lipids, 1.34-2.16 % had an odd number of carbon atoms ($C_{13:0}$, $C_{15:0}$ and $C_{17:0}$). The total percentage of long chain fatty acids ($C_{20:0}$ and above) was greater for the bound than for the free lipids (Lai and Varriano-Marston, 1980a). The major lipid components of the polar, bound lipid fraction detected were phosphatidylcholine, sterol glycosides, and di- and monogalactosyl glycerides. Phosphatidylethanolamine, phosphatidylglycerol, phosphatidylinositol, lysophosphatidylethanolamine, lysolecithin, phosphatidic acid, polyglycerophosphatide, and cerebrosides were also identified in the lipids (Pruthi and Bhatia, 1970; Lai and Varriano-Marston, 1980a). Contrary to these results, Osagie and Kates (1984) reported that lysophosphatidylcholine was the major phospholipid (42 %) in *P. americanum* grains; smaller amounts of phosphatidylcholine (24 %), lysophosphatidylethanolamine (21 %) and trace amounts of phosphatidylglycerol, phosphatidic acid, phosphatidylserine and phosphatidylinositol were also present. The lipid content of 5 hybrids and 1 local (Indian) variety of pearl millet ranged from 56.5 to 66.5 mg/g. The polar lipids varied from 12.0 to 20.0 mg/g but greater variation was noticed in the nonpolar lipid contents. Glycolipids were the major polar lipids and, triglycerides and free fatty acids were the main nonpolar lipids (Vakharia and Chakraborty, 1984).

Pearl millet quality deteriorated quickly once it has been ground into a meal (Hoseney and Varriano-Marston, 1980). Carnovale and Quaglia (1973) suggested that the rapid deterioration in the quality of pearl millet flour (16.3 % moisture) during storage for three months at 30°C stems mainly from the hydrolytic rather than the oxidative decomposition of lipids. These results contradicted other data by Nechaev *et al.* (1973) who showed no change in the total ether extractable lipids in millets during storage. Thiam *et al.* (1976) suggested that although the lipolytic activity occurred in millet flour during storage at 30°C at relative humidity 90-95 %, the major cause of quality deterioration was microbial fermentation. Propagation of microorganisms during storage resulted in the consumption of the sugars and the liberation of alcohols. Essentially no lipoxygenase activity was found. Lai and Varriano Marston (1980b) described the organoleptic evaluations of stored pearl millet meal, which indicated both hydrolytic and oxidative changes in millet lipid components during the first week of storage.

The silage from dry elephant grass (*P. purpureum*) showed lower lactic acid and butyric acid **(884)**, as compared with silage from fresh grass. Compared to corn silage, elephant grass silage had higher lactic acid levels and higher NH_3/N ratio (Tosai *et al.*, 1983).



884 Butyric acid

The sterol fraction of *P. clandestinum* contained cholesterol (4.59 %), campesterol (12.45 %), stigmasterol (27.50 %), β-sitosterol (53.81 %) and Δ^5-avenasterol (1.58 %) (Dugo *et al.*, 1981). Sterols of *P. americanum* consisted of campesterol, stigmasterol and two unidentified sterols, ocurring in the same proportions in the free and esterified forms (Osagie and Kates, 1984). Sterol-containing glycolipids (sterol glycosides and esterified sterol glycosides) were present in appreciable amounts in *P. typhoideum* (Pruthi and Bhatia, 1970). *P. typhoideum*, contained 194.7 mg/kg saponin (Sodipo and Arinze, 1985).

The following compounds were identified in the volatiles of mechanically damaged *P. clandestinum* (a host plant of the desert locust *Schistocerca gregaria*): 3-pentanone **(885)**, hexanal, 1-penten-3-o1, (*E*)-2-hexenal, 4-methyl-3-pentenal, hexyl acetate, (*E*)-3-hexenyl acetate, (*Z*)-3-hexenyl acetate, (*Z*)-2-hexenyl acetate, hexanol, (*E*)-3-hexen-1-ol, (*Z*)-3-hexen-1-ol, and (*Z*)-2-hexen-1-ol (Njagi and Torto, 1996).

885 3-Pentanone

Ash content in *P. americanum* cultivars varied from 1.46 % to 3.88 % (Hoseney and Varriano-Marston, 1980). These values were high as compared to wheat, corn or sorghum (Casey and Lorenz, 1977). Some of the mineral constituents of pearl millet have been identified. The values for Na, Ca, Mg and Cu fall within the range reported for wheat. However, some varieties of millet contain very low levels of Ca. The Mn and Mo content of millet were considerably lower than those found in wheat while in many cases the P, K, and Fe content of the grain were considerably higher than values reported for wheat. High Fe values may be attributed, in part, to the equipment used to mill the grains prior to analysis (Hoseney and Varriano-Marston, 1980). For example Carr (1961) reported a Fe content of 46 mg / 100 g of grain for pearl millet ground on a stone containing high Fe levels. High levels of Si and K were found in the covering layers while P concentrated mainly in the germ and about equal amounts of Fe were found in the germ and the covering layers. The endosperm portions exhibited low mineral concentrations and the predominant elements detected were S, K and Fe (Hoseney and Varriano-Marston, 1980). Some of the data of the minerals of pearl millet are presented in Table 101.

The contents of 9 mineral elements in *P. americanum* flour and bread obtained from Jizan, Saudi Arabia were, respectively: Na, 17 and 102; K, 420 and 239; Ca, 22 and 23; P, 338 and 250; Mg, 44 and 37; Fe, 3.35 and 3.09; Zn, 1.88 and 0.96; Cu, 0.68 and 0.55; and Mn, 3.09 and 1.89 (mg/100 g) (Khalil and Sawaya, 1984). The fodder plant, *P. typhoides* had a sufficient level of Se that was not toxic to livestock (Malik and Singh, 1986).

Giri *et al.* (1987) reported that Cr and Sc levels in pearl millet were 0.004-0.007 and 1.540-1.868 mg/g respectively.

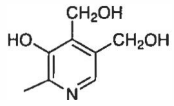
Table 101. Minerals in pearl millet (*P. americanum*)

Element	mg/100 g*	µg/g**
Na	2.2-4.9	14.1
K	366-543	
Ca	7-117	203
Mg	71-156	1220
P	631-1353	3050
Fe	2.1-11.7	35.8
Cu	0.42-0.58	nd
Mn	0.66-0.92	14.8
Zn	0.10-3.8	29.5
Mo	0.014-0.024	nd

* (Carr, 1961; Goswami *et al.*, (1969a,b); Shah and Mehta, (1959); Hoseney and Varriano-Marston, (1980); ** Glew *et al.* (1997).

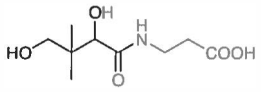
The Ca content of kikuyu grass (*P. clandestinum*) in the dry and wet seasons was 0.51 and 0.79 % respectively, and was considered sufficient for grazing by lactating cows. However, P and Mg contents were insufficient (Laredo C. *et al.*, 1983). Staples (1933) reported that *P. clandestinum* contained SiO_2-free ash 7.44; CaO 0.90, MgO 0.44; P_2O_5 1.62 and Cl 0.68 %. *P. clandestinum* had the highest K content at 36 weeks (0.54 %) (Gomide *et al.*, 1969). The Ca and P contents of stems and leaves of 21 varieties and hybrids of *P. purpureum* varied from 0.18 to 0.44 and 0.29 to 0.57 % respectively (Rodriguez and Blanco, 1970). Mineral concentrations of dwarf *P. purpureum* were higher in leaves for Ca and Fe, while stems had higher quantities of K, Mg, P and Zn. The mean mineral range in leaves is as follows: Ca, 0.39-0.71 %; K, 2.3-3.9 %; Mg, 0.16-0.31 %; Na, 0.02-0.04 %; P, 0.32-0.50 %; Fe, 43-117 ppm; Mn, 15-56 ppm and Zn, 16-26 ppm. For stems, the values were: Ca, 0.21-0.36 %; K, 3.3-5.2 %; Mg, 0.23-0.37 %; Na, 0.02-0.06 %; P, 0.41-0.71 %; Fe, 20-65 ppm; Mn, 17-39 ppm and Zn, 51-107 ppm. For hand plucked leaves, the values were: Ca, 0.25-0.48 %; K, 3.07-4.46 %; Mg, 0.16-0.21 %; Na, 0.03-0.05 %; P, 0.36-0.44 %; Fe, 43-71 ppm; Mn, 18-36 ppm and Zn, 21-28 ppm (Montalvo *et al.*, 1987). The ranges of variability of some minerals in bajra grains (*P. typhoideum*) were: Ca, 0.020-0.69; P, 0.70-0.96 and Fe, 0.0021-0.0117 % (Goswami *et al.*, 1969-1970).

Thiamine and riboflavin content of 0.22 mg/100 g and 0.26 mg/g, respectively, were reported for one sample of *P. americanum*. Hoseney and Varriano-Marston (1980) indicated that there was little variability in the riboflavin content among millet cultivars with 18 studied cultivars, showing riboflavin contents ranging from 0.21 to 0.38 mg/100 g. They reported that these values were similar to those obtained from wheat. The levels of vitamins in the *P. americanum* flour and bread, obtained from Jizan, Saudi Arabia were respectively: thiamine, 0.27 and 0.17; riboflavin, 0.15 and 0.11; pyridoxine (**886**), 0.27 and 0.24; niacin, (nicotinic acid and its amide (**887**) were often given the collective name "niacin") 0.89 and 0.87; pantothenic acid (**888**), 1.40 and 0.71; folic acid 34.9 and 18.3; and vitamin B_{12}, 0.07 and 0.05 (µg/100 g). The concentration of β-carotene (< 0.01 mg/g) was low in both flour and bread (Khalil and Sawaya, 1984). *P. ciliaris* and *P. purpureum* were reported to contain enough carotene to meet the nutritional requirements of cattle (Pena *et al.*, 1977). Horiharan *et al.* (1965) reported a vitamin A content of 133 I.U./100 g for their "poor pearl millet diet".



886 Pyridoxine (Vitamin B_6)

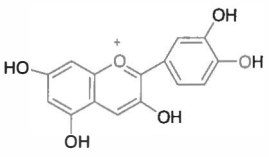
116 Nicotinic acid, R = COOH
887 Nicotinamide, R = $CONH_2$



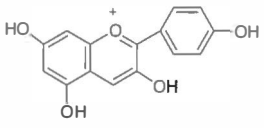
888 Pantothenic acid

Colour plays an important role in the consumer acceptance of millet grains (Hoseney and Varriano-Marston, 1980). Pearl millet varies widely in colour from off-white to dark brown and the most common colours are yellow and slate gray. In some parts of Africa, millet grains are soaked overnight in water containing sour milk or tamarind pods (Vogel and Graham, 1979) to alter the flavour of the resultant products and also to whiten the grains. Reichert and Youngs (1979) investigated the phenomenon of millet bleaching and found that the discolouration was pH dependent. Soaking millet grain in a solution of 0.2 N HCl and citric acid was as effective as sour milk or tamarind pods in bleaching the grain. Further studies by Reichert (1979) suggested that *C*-glycosylflavonoids (glucosylvitexin, glucosylorientin, and vitexin in the ratio of 29:11:4) were responsible for the intense yellow-green discolouration of the flour in the presence of an alkali and may be responsible for the natural grey colour of the peripheral endosperm of the grain. The methanol-extracted millet flour also contained a substantial quantity of alkali-labile ferulic acid (ALFA). The concentrations of total *C*-glycosylflavones and ALFA were 124 and 158 mg/100 g, respectively, in whole grain, which decreased markedly on dehulling (Reichert, 1979). Nutritional studies have shown that these *C*-glycosylflavonoids were not as noxious as the tannins present in the testa layer of some sorghum varieties (Reichert *et al.*, 1980). Tricin and flavone *C*-glycosides were detected in *P. alopecuroides*, *P. polystachyon* and *P. setaceum* (Harborne and Williams, 1976).

Two pigment phenotypes, purple and sun-red are common in *P. americanum*. Both constituents had similar anthocyanidins: cyanidin, delphinidin and pelargonidin, but their relative proportions were different. The purple had phenotype 2.6 % more of delphinidin, whereas the sun-red phenotype had 2.6 % more cyanidin **(889)**. The proportion of pelargonidin **(890)** was the same in both phenotypes (Raju *et al.*, 1985).



889 Cyanidin

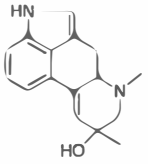


890 Pelargonidin

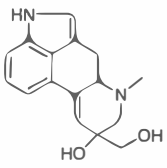
Rao *et al.* (1988) studied the distribution pattern of three biochemical constituents, *viz.* phenolic compounds, proteins, and esterase isoenzymes in the leaves of 12 *Pennisetum* species. A total of 15 phenolic compounds, 23 protein bands and 19 esterase bands were detected by paper chromatography in all the species studied. Data of these 3 chemotaxonomic characters were statistically analysed by cluster analysis, which grouped the 12 species into 5 distinct clusters.

Pollen grains of pearl millet yielded *p*-hydroxybenzoic acid and cinnamic acid derivatives (Mathur, 1969).

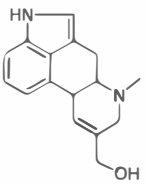
P. typhoideum contained 194.7 mg/kg dry weights saponin (Sodipo and Arinze, 1985). Alkaloids have been detected in napier (*P. purpureum*) (Ismail *et al.*, 1977), pearl millet (*P. americanum*) and a hybrid pearl millet (*P. americanum*-Millex 24; Krejsa *et al.*, 1987). Kumar and Arya (1978) estimated and identified the alkaloids produced by *Claviceps fusiformis* on some varieties of pearl millet. The honey-dew and sclerotia contained 0.182-0.364 % and 0.160-0.548 % respectively. The infected plants contained setoclavine **(891)**, agroclavine, penniclavine **(892)**, elymoclavine **(893)**, chanoclavine and an unidentified alkaloid.



891 Setoclavine



892 Penniclavine



893 Elymoclavine

Osman *et al.* (1983) produced evidence that the millet in Darfur Province (Sudan), contained a goitrogenic thionamide, which could be a factor causing the endemic goiter in Darfur Province. Osman and Walker (1976) earlier reported histological changes in thyroid glands and distortion of the thyroid hormone pattern in millet-fed rats. Thyroid histological changes and alterations in thyroid hormone patterns of blood serum in pearl millet and fermented millet-fed rats were reported by Klopfenstein *et al.* (1983). The latter authors stated that the millet's goitrogenic agent was apparently associated with both the bran and the endosperm fractions of the grain and might be related to the grains high mineral content.

Calcium oxalate crystals were found in *P. clandestinum* and were implicated in nutritional secondary hyperparathyroidism in grazing horses (McKenzie and Schultz, 1983). The oxalate apparently interferes with Ca absorption by the animals. Poisoning of horses by oxalate in mission grass (*P. polystachyon*) and napier (*P. purpureum*) was also reported (McKenzie, 1985). The range of variability for oxalic acid in bajra fodder was 1.19-2.16 % of the dry matter (Goswami *et al.*, 1970c). The oxalic acid of hybrid napier (*P. purpureum* x *P. typhoides*) fodder, decreased from 3.44 % at 60 cm height to 1.63 % at the flowering stage (Raj and Mudgal, 1968).

Poisoning in cattle fed certain *Pennisetum* species has been reported, in blood of young cattle, which ingested large amount of elephant grass (*P. purpureum*). High levels of metHbs were found (10.00-21.06 % *vs.* 2.97-7.41 % in controls). Twelve of 64 animals died after ingestion of elephant grass. Nitrates and nitrites were detected in the urine, rumen, and ocular fluids of the dead animals. The leaves and stems of elephant grass were found to contain 519.0 and 1732.0 ppm nitrates respectively which was much higher than those in the control sample of elephant grass (90 and 253 ppm in leaves and stems, respectively). The high content of nitrates in the grass was related to the previous crops and the animal's susceptibility to intoxication was enhanced by their young age and poor nutritional status (Guzman *et al.*, 1978). Nitrate poisoning resulted in the death of 5 of a group of Kedah-Kelantan breed cattle fed on napier grass were described by Seiler *et al.* (1979); the diet which consisted solely of napier grass fed by cut and carry system. Levels of nitrate in the toxic grass averaged 28.3 mg / g with some samples as high as 44 mg /g while in similar grasses from non-toxic area was

tuberosa (Peruvian grass) was reported as follows: water 86, dry matter 14, lipids 1.13, ash 1.7 and proteins 1.8 % (Schmitz *et al*., 1966). Earlier, Rogozinsky and Glowczynski (1935) reported that the grains of canary grass were similar to the ordinary cereals in chemical composition and digestibility. According to Adrian and Fragne (1970), *P. canariensis* protein and corn protein complemented each other to some extent, the former overcoming the deficiency of tryptophan in corn.

P. truncata contained crude protein 16.9, crude fiber 28.95, lignin 3.48, Ca 0.46, P 0.24, Si 2.43 %, and carotenes 316.81 mg/kg (on dry weight basis). On the basis of these data and the digestibility and other properties, *P. truncata* seemed to be very promising for pastures on clay soils in Central and South Italy (Cenci and Sarti, 1971). Analysis of *P. nodosa* or *P. bulbosa* has been reported earlier by Lomanite (1915).

Schwarz (1934) determined the nutritional value of *P. arundinacea* at the shoots appearance shoots, after blossoming and after maturity of the grains. The highest protein content (12.29 %) was found in cuttings made with the appearance of the shoots. The highest protein yield (770 kg/ha) was found at the beginning of blooming. The protein content of the grain straw was about 1/3 higher than that of the planted stock and in the second year, the highest protein content was obtained (Schwarz, 1934). The whole grain of *P. canariensis* was found to contain 17.75 % protein, with low lysine, methionine and threonine levels, but an average tryptophan level of 2.85 %. Tryptophan was contributed mostly by gliadin (Adrian, 1969). Robinson (1978) found that *P. canariensis* and *Avena sativa* differed significantly in elemental composition of spikelets but not in stem or root composition. Data averages from 3 years and three localities in USA showed that canarygrass caryopses (82 % of the spikelets) had a total amino acid concentration of 19.25 % and a N to protein conversion factor of 6.71. The N conversion factor for canary grass spikelets (6.68) was based on spikelets of 82 % caryopses and 18 % hull. The data obtained by Robinson (1978) compared with data compiled by FAO (1970), indicated that canary grass caryopses had higher concentration of all eight essential amino acids (leucin, phenylalanine, valine, isoleucine, tryptophan, threonine, lysine and methionine) than did caryopses of wheat and corn and were higher than in the seeds of *Pisum sativum* and field bean (*Phaseolus vulgaris*) in tryptophan, cystine and methionine. They were appreciably below the two pulse crops in threonine and lysine. The total amino acid concentration of 19.25 % was exceeded only by teosinte (*Euchlaena mexicana)* among 23 cereal crops and was about the same as those of field bean, pea, faba bean (*Vicia faba*), chickpea (*Cicer arietinum*), prote pea (*Vigna unguiculata*) and mung bean (*Vigna radiata)* (Robinson, 1978). Amino acid concentration of canary grass caryopses was also similar to that of dehulled sunflower, which had an amino acid concentration of 20.38 % (Robinson, 1975, 1978). Canary grass caryopses had higher concentration of all eight amino acids than did those reported for wheat (*Triticum aestivum*) and corn (*Zea mays*). Although the hulls of canary grass were found to be low in the concentrations of all amino acids, the proportions of most of these essential amino acids were higher in the hull protein than in the caryopses protein. The proportions of the non-essential amino acids, particularly glutamate, differed considerably between the hulls and the caryopses (Robinson, 1978).

D-Alanyl-D-alanine was isolated from the leaves of 5 strains of *P. tuberosa* by Frahn and Illman (1975), who found its content, was ~ 0.2 mg/g of the dry weight of the grass.

Bittner and Street (1983) reported considerable amounts of arabinose, xylose, and uronic acids in acid-detergent residue of *P. arundinacea* and suggested the presence of a "linear xylan associated with cellulose in a manner sufficient to render the xylans resistant to dilute acid hydrolysis". *P. aquatica* contained a linear β-2,6-linked series of fructans with a terminal glucose residue (Bonnett *et al.*, 1997).

Total lipids amounted to 6.65 % of *P. canariensis* grains. The same grains contained 131.55 mg % estrone (Kandeel *et al.*, 1988). The oil content of the grains of *P. arundinacea* (Lotti *et al.*, 1985) and caryopses of *P. canariensis* (Robinson, 1978) amounted to 4.25 and 6.03 % respectively. The unsaturated index (unsaturated fatty acid/saturated fatty acid) of *P. arundinacea*, was 3.78 (Saito *et al.*, 1971) and the fatty acid composition of its caryopses oil was: $C_{14:0}$, 0.09; $C_{14:1}$, traces; $C_{15:0}$, 0.01; $C_{15:1}$, 0.04; $C_{16:0}$, 8.24; $C_{16:1}$, 0.05; $C_{17:0}$, 0.02; $C_{17:1}$, 0.06; $C_{18:0}$, 0.78; $C_{18:1}$, 34.18; $C_{18:2}$, 52.10; $C_{18:3}$, 4.00; $C_{20:0}$, traces; $C_{20:1}$, 0.35 and $C_{20:02}$, 0.08 % (Lotti *et al.*, 1985).

Ash concentration of canary grass caryopses and husks averaged 4.69 and 20.39 % respectively (Robinson, 1978).

Sherrell (1978) studied the sodium concentration of pasture species in New Zealand (including red clover, alsike clover, leucrne, browntop, timothy, paspalum and kikuyu) grown as individual species under standard pot conditions. *Phalaris* was outstanding in that its Na concentration was double that of any other species. Robinson (1978) reported that *P. canariensis* and *Avena sativa* were similar in elemental composition (Table 104). Canary grass florets were significantly higher than oats spikelets in the concentrations of N, P, S, Mg and Zn. Canary grass caryopses grains were much higher than the other grain crops in N and Fe and about equal in K.

Table 104. Average elemental composition of spikelets, stems and leaves, and roots of mature canary grass and oat.

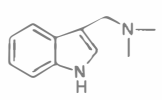
Elements	Florets		Stems and Leaves		Roots	
	Cannary grass	Oat	Cannary grass	Oat	Cannary grass	Oat
			%			
N	2.96	2.14*	0.70	0.62	0.81	0.51
P	0.58	0.43**	0.13	0.12	0.15	0.23
K	0.41	0.43	1.41	2.00	0.40	0.61
S	0.24	0.17**	0.18	0.13	0.17	0.15
Ca	0.04	0.07	0.27	0.31	0.30	0.30
Mg	0.17	0.14*	0.13	0.14	0.11	0.10
Na	0.02	0.01	0.40	0.28	0.12	0.20
			µg/g			
Sr	2	3	13	20	17	15
Fe	67	68	144	194	> 2000	> 2000
Zn	50	37*	17	10	29	44
Mn	46	46	27	57	101	96
B	2	2	12	7	13	21
Cu	12	6	10	19	5	5
Mo	4	4	6	6	45	46

*,** Oat significantly lower than canary grass at the 5 and 10 % levels, respectively.

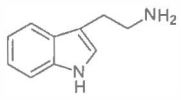
Hulls of canary grass were lower than grains in all elements reported except K, Ca, Na, Mn, B, Al and Cu. The average elemental concentrations in the husks were as follows: N, 0.78 %; P, 0.07 %; K, 0.41 %; S, 0.01 %; Ca, 0.05 %; Mg, 0.06 %; Na, 0.03 %; Fe, 55; Zn, 29; Mn, 53; B, 2; Al, 15; Cu, 1 and Mo, < 5 µg/g (Robinson, 1978).

The mean Pb content in *P. arundinacea*, from non-contaminated areas in Poland, was 0.36 ppm (Sapek, 1980). Read (1980) studied the influence of temperature on nutrient concentration and tetany (hypomagnesemia) potential of harding grass (*P. acquaticus*). Harding grass had a greater potential to produce grass tetany than tall fescue (*Festuca arundinacea*) when grown on the Northern Blackland Prairie of Texas.

Several alkaloids have been identified in *Phalaris* species including one phenol (hordenine), indoles (gramine, **894**) and derivatives of tryptamine (**895**), and derivatives of β-carboline (Rizk, 1986). The following alkaloids were identified in *P. arundinacea*: hordenine, nine indole alkaloids (gramine, *N,N*-dimethyl-5-methoxytryptamine **(896)**, *N,N*-dimethyltryptamine **(897)**, 5-methyltryptamine **(898)**, *N*-methyltryptamine, tryptamine, 5-methoxytryptamine **(899)**, 5-methoxy-*N*-methyltryptamine **(900)** and bufotenine (**901**)) (Wilkinson, 1958; Audette *et al.*, 1969,1970; Woods and Clark 1971a; Williams *et al.*, 1971; Hovin and Marten, 1975; Majak and Bose, 1977; Majak *et al.*, 1978) and three carbolines (6-methoxy-2,9-dimethyl-1,2,3,4-tetrahydro-β-carboline, 6-methoxy-2-methyl-1,2,3,4-tetrahydro-β-carboline and 2-methyl-1,2,3,4-tetrahydro-β-carboline) (Audette *et al.*, 1970; Shannon and Leyshon, 1971; Vijayanagar *et al.*, 1975; Gander *et al.*, 1976). About half of the clones, tested by Woods and Clark (1971a) failed to give a positive test for tryptamines, but the same clones gave a positive test for gramine. *N,N*-Dimethyltryptamine, 5-methoxy-*N,N*-dimethyltryptamine and bufotenine were isolated from *P. tuberosa* (Culvenor *et al.*, 1964). *P. aquatica* (*P. tuberosa*), sometimes contained 2-methyl-6-methoxy-1,2,3,4-tetrahydro-β-carboline and 2-methyl-1,2,3,4-tetrahydro-β-carboline (Frahn and O'Keefe, 1971). Other investigations have revealed the presence of cardioactive *N*-methyltyramine in *P. aquatica* cultivars, and alkaloids of unknown toxicity *i.e.*, the oxindoles coerulescine and horsifoline, and the furanobisindole phalarine, in *P. coerulescens* cultivars (Anderton *et al.*, 2000).



894 Gramine



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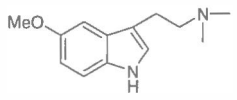
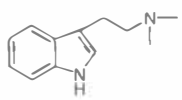


896 *N,N*-Dimethyl-5-methoxytryptamine



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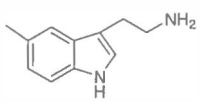
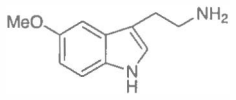
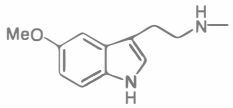


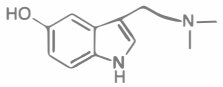
898 5-Methyltryptamine



899 5-Methoxytryptamine



900 5-Methoxy-*N*-methyltryptamine



901 Bufotenine
(5-Hydroxy-*N,N*-dimethyltryptamine)

In unclipped reed canary grass, gramine content rose to maximum at about the time of grain shedding. With regular clipping, the rise was more rapid and it continued into fall. The content of tryptamine alkaloids followed the same pattern as that of gramine (Woods and Clark, 1971b). Rendig *et al.* (1970) reported that the concentrations of *N,N*-dimethyl-5-methoxytryptamine (from the leaves of *P. aquatica*) grown from grains differed considerably from that grown by vegetative propagation and suggested that the variation noted may have important ecological implications with reference to *Phalaris* toxicity. Moore *et al.* (1967) found that in *P. tuberosa*, grown under controlled temperature, light intensity, and NO_3^- supply, the concentrations and yield of tryptamine alkaloids increased with higher day-night temperature in full sun and shade (28 % sunlight), and with increased NO_3^- in full night. Shaded plants had higher concentrations of alkaloids than unshaded plants at all levels of NO_3^- supplied. Alkaloid concentrations responded linearly to temperature, but irregularly to NO_3^- supply. The dominant alkaloid was *N,N*-dimethyltryptamine. In field-grown plants, *N,N*-dimethyltryptamine, 5-methoxydimethyltryptamine, and 5-hydroxydimethyltryptamine responded similarly to reduction in light intensity, the former being the dominant indole alkylamine in plants grown in the phytotron and in the field (Moore *et al.*, 1967).

Drought stress caused greater alkaloid increase, in *P. aquatica*, both in field and environmental chamber studies than did any other factor (N-fertilization and radiation density) (Ball and Hoveland, 1978). The mode of inheritance and genetic relations among indole alkaloid phenotypes of *P. arundinacea* was studied by Marum *et al.* (1979).

Palatability of reed canary grass genotypes was negatively correlated with total alkaloid concentration (Simons and Marten, 1971; Marten, 1973; Marten *et al.*, 1973). During mid to late summer, when alkaloid concentration was highest, live weight gain of grazing ruminant animals was lowest (Jordan and Marten, 1975; Marten *et al.*, 1976). Marten *et al.* (1973) concluded that the relative alkaloid concentration among reed canary grass clones remained nearly the same when grown in diverse latitudes in U.S.A. Hovin *et al.* (1980) compared alkaloid concentration of reed canary grass varieties grown in western Norway and central Minnesota (USA) and found that the Loken variety consistently had the lowest alkaloid concentration and produced less forage yield as compared with several other varieties and experimental strains. Accessions with low and high alkaloid concentrations were identified. Reed canary grass silage made with formic acid as a preservative had about 78 % and the effluent about 14 % of the alkaloid concentration of the fresh grass before ensiling. The average dry matter of the silage was 19.6 % (similar to the grass before ensiling) as compared to 3.5 % for the effluent. The alkaloid concentration of the effluent was about six times higher than that of the silage. The concentration of the alkaloids in the silage tended to be higher at the bottom than at the top of the experimental soils. The alkaloid concentration of the silage after removal of the effluent (Hovin *et al.*, 1980) appeared to be slightly higher than that of air-dried hay (59 %) as estimated from data reported by Donker *et al.* (1976).

Alkaloid concentration in reed canary grass was enhanced by moisture stress (Marten, 1973) and by the high rates of N fertilization (Marten *et al.*, 1974). Alkaloids were concentrated in the leaf blades of immature growth (Hegman *et al.*, 1975) and the alkaloid concentration was greatly reduced by drying the grass (Donker *et al.*, 1976). In several experiments, various cultivars of reed canary grass did not consistently differ in alkaloid concentration (Marten, 1973; Hovin and Marten, 1975), but "Vantage" was unique in that it was the only cultivar free of tryptamines (gramine was its only detectable indole alkaloid) (Marten *et al.*, 1976). Williams

et al. (1971) found that 5-methoxy-*N*,*N*-dimethyltryptamine was up to 18-fold higher in unpalatable clones of *P. arundinacea* as compared to those preferred by grazing cattle. Marten *et al.* (1976) conclusively showed that palatability differences and their associated alkaloid concentration differences among reed canary grass (*P. arundinacea*) genotypes (vegetatively propagated clones) had a substantial biological significance for grazing lambs and steers. Total indole alkaloid concentration of reed canary grass was inversely correlated with average daily gains in lambs and steers over a 3-year period. Lambs grazing the high-alkaloid (unpalatable) pastures were consuming less grass dry matter than were the lambs grazing low-alkaloid (palatable) pastures. This finding was in agreement with other reports (Roe and Mottershead, 1962; O'Donovan *et al.*, 1967; Simmons and Marten, 1971) that voluntary intake was lower when sheep were obligated to consume unpalatable compared to palatable reed canary grass genotypes. Marten *et al.* (1981) reported that the mean threshold level for indole alkaloid concentration in reed canary grass pasturage at or above which lambs would show reduced performance (reduced weight gain) was about 0.2 % dry weight. As the alkaloid concentration progressively increased beyond that level, the adverse animal performance became progressively greater. The latter authors also concluded that the sp. diarrhoea incidence specifically observed in lambs that grazed reed canary grass in other studies (Marten and Jordan, 1974, 1979; Marten *et al.*, 1976) was probably caused by the presence of tryptamine-carbolines in the heterogeneous reed canary grass used in those studies. Ttryptamine-carboline free (gramine containing) would not incite diarrhea in lambs at the alkaloid levels present in cultivars such as Vantage (0.20 to 0.33 % gramine).

The tryptamine alkaloids present in some reed canary grass lines were found to be potentially toxic to sheep and cattle (Gallagher *et al.*, 1964, 1967). Though *Phalaris* spp. are useful pasture components, yet they have been associated with neurological and sudden death intoxication syndromes. Despite agronomic development of *Phalaris* spp. to produce "low-toxicity" cultivars, outbreaks of intoxication have continued to occur. These outbreaks could result from a combination of poorly understood environmental or animal factors accelerating the effect of low concentration of known toxic alkaloids. Alternatively, previously unrecognized alkaloids could have intrinsic toxicity (Anderton *et al.*, 2000). Marten (1973) reviewed reports (especially from Australia) suggesting that "phalaris toxicity" or "phalaris staggers" (an acute disorder of the central nervous system in sheep) and other ruminant disorders were associated with alkaloids in *P. aquatica* (*P. tuberosa*) and *Phalaris* hybrids. Administered tryptamines exert strong action on the central nervous system of sheep and interfered with the pharmacological functions (muscle contraction, cardiac activity, and brain function) of a closely related compound, serotonin, which occurs naturally in mammals (Gallagher *et al.*, 1964). They found that parenterally administered solutions of tryptamines or gramines caused heart failure and death of sheep, guinea pigs, rats, and mice. Also, gramine fed in synthetic diets (0.5 % or more gramine) was lethal to meadow voles (*Microtus pennsylvanicus*) (Marten *et al.*, 1976). However, the latter workers did not detect symptoms of "phalaris staggers" during their two years study of *P. arundinacea*. The tryptamines of *P. arundinacea* have also been implicated in pasture-mediated bovine pulmonary emphysema (Parmar and Brink, 1976).

Meadow voles were used by Goelz *et al.* (1980) to evaluate the relative toxicity of the alkaloids gramine and hordenine sulphate, which were reported in *P. arundinacea* so as to assess their effects on the quality of this grass as a forage. Approximately one-third of the

voles died when fed either on 0.25 or 0.5 % gramine of the diet. Voles that survived on gramine diets had kidney lesions, glycosuria, higher feed intakes and lower weight gains that control animals. Hordenine did not affect the voles diet intake, weight gain, or rate of mortality, but caused development of kidney lesions and glucose was detected in the urine of 62 % of these animals.

Coulman *et al.* (1977b) reported that the addition of a pure sample of alkaloids of hordenine, gramine, 5-methoxydimethyltryptamine (5-MeO-DMT) and *N*-methyltryptamine, to *in vitro* digestion media, appeared to have little effect on the activity of rumen microflora *in vitro*. They found that the organic matter digested *in vitro* (IVDOM) of reed canary grass was not significantly depressed with addition of gramine levels of 10,000 µg/g dry matter (DM) (1.0 %). However, gramine levels as high as 10,000 µg/g (DM) occurred very rarely in reed canary grass genotypes (Couleman *et al.*, 1976). A study of varieties (Hovin and Marten, 1975) showed that the total alkaloid content, averaged over two cuts, ranged from 1,180 to 1,700 µg/g DM. Marten (1973) found no inhibitory effect on *in vitro* digestibility (IVD) of added gramine up to 30,000 µg/g DM, but 5-MeO-DMT at this concentration did significantly depress IVD. The chances of finding such a high concentration of 5 MeO-DMT are unlikely, since tryptamine levels in both reed canary grass and harding grass (*P. aquatica*) have usually been reported to be less than 1,000 µg/g DM (Moore *et al.*, 1967; Oram, 1970; Barnes *et al.*, 1971; Couleman *et al.*, 1977b). No consistent relationship was found between alkaloid content and IVDOM of selected reed canary grass clones. Alkaloid levels were found to be highly correlated between harvests (Couleman *et al.*, 1977b). This is in accordance with reports of low genotype x environment interactions for total alkaloid content (Marten *et al.*, 1973; Barker and Hovin, 1974).

From the results obtained by Couleman *et al.* (1977b) and Marten *et al.* (1973), the former authors concluded that the poor animal performance often reported with reed canary grass was not due to alkaloid interference with the rumen microflora. A more likely cause of poor weight gains was the physiological disturbance, as evidenced by the occurrence of diarrhoea, which has been reported in animals grazing reed canary grass (Woods and Clark, 1974; Marten *et al.*, 1976). A higher incidence of diarrhea was found on high alkaloid pastures and especially on those pastures containing tryptamines and β-carbolines (Couleman *et al.*, 1977b). The dimethyltryptamines were thought to interfere with the normal functions of serotonin (Gallagher *et al.*, 1964), while β-carbolines inhibit monoamine oxidase (Ho *et al.*, 1968), the enzyme responsible for controlling levels of serotonin and other amines in the body. A buildup of serotonin could lead to hyperexcitability and increased respiration, thus burning up food reserves (Couleman *et al.*, 1977b). Wood and Clark (1974) found that under heat stress (24-25° C) sheep respiration rates were higher on a tryptamine-carboline-containing pasture than on a pasture free of these compounds.

Coombe and Christian (1969) found that the digestibility of organic matter and cellulose, of *Phalaris* straw, generally increased following addition of urea. Acid detergent fiber levels increased with increasing Si levels in *P. arundinacea* and *in vitro* dry matter digestibility decreased from 68.73 to 62.95 % (Ranga Rao, 1978).

The relation between cell wall composition and *in vitro* dry matter digestibility (IVDMD) of *P. arundinacea* has been studied. Correlation was observed between percentage of xylose and IVDMD. Acid detergent fiber and acid detergent lignin were the best parameters for

predicting IVDMD. The arabinose:xylose ratio and galactose content may reflect the importance of hemicellulosic polymer branching on the digestibility of the forages (Burritt *et al.*, 1982,1985).

Bourke *et al.* (1988) reported experimental evidence that tryptamine alkaloids did not cause *P. aquatica* sudden death syndrome in sheep. The lowest tested dose rates that produced clinically observed signs were: for 5-methoxydimethyltryptamine, 0.1 mg/kg i.v. and 40 mg/kg orally; for gramine, 10 mg/kg i.v. and 500 mg/kg orally; and for hordenine 20 mg/kg i.v. and 800 mg/kg orally. All induced the clinical signs observed in the nervous form of "phalaris toxicity", but none induced the cardiac, sudden death syndrome.

Cyanogensis of *P. arundinacea* has been reported (Aikman *et al.*, 1996).

The hypomagnesemia observed in serum of cows grazing a *P. tuberosa* pasture, was attributed to the high K/(Ca + Mg) ratio in the pasture and to the physiological condition (pregnant and lactating) of the animals (Cseh *et al.*, 1984).

The isolation of anti-inflammatory and hypocholesterolemic agents from *P. arundinacea* has been reported by Majnarich (1969). Octacosanol and/or hexacosanol have been identified in *P. arundinacea* (Audette *et al.*, 1970; Tulloch, 1981). Tricin and flavone *C*-glycosides were detected in leaves of *P. arundinacea* (Harborne and Williams, 1976).

The responses of *P. tuberosa* to cutting to 0.5- and 3-inch stubble at 3 levels of N (O, 23 and 92 lb/acre after each cut) were investigated by Grimmett (1967). The 3-inch cutting height gave greater dry matter yield than the 0.5-inch cut, but the difference reached significance only with applied N. Under irrigation, a grazing height of 3 inch was recommended and a continuous supply of N would be needed. Kovtunyk *et al.* (1976) reported that the grass mixture composed of *P. canariensis*, reed fescue (*Festuca arundinacea*) and orchard grass yielded the highest green mass, fodder units, digestible proteins, and digestible protein per fodder unit when N 240, P 90 and K 120 kg/ha were applied. Nitrogen fertilization of *P. arundinacea* contributed to a distinct increase of the total N content as well as of Mg, and, to a lesser degree, Zn content (Kowalczyk, 1980). Soil Ca and Mg were associated with Ca and Mg concentrations of *P. aquatica* but concentrations of Ca in the herbage had no effect on *in vitro* dry matter digestibility (Odom *et al.*, 1980). McLachlan (1981) suggested that, in *P. tuberosa* plant, silicophosphates, up to rates supplying 193 kg P/ha, could be effective as the lime-superphosphate combination. Langlands *et al.* (1979) found that *P. aquatica* largely died out from pots that did receive superphosphate.

The straw of *P. bulbosa* has been shown to be suitable as a raw material for the cellulose and paper industry (Khristov, 1958).

24.1. *Phalaris minor* Retz., Obs. Bot. 3:8 (1783).

Thail elqit (Ar.)

Differs from *P. paradoxa* L. in being a much smaller, more slender annual grass with very few slender culms reaching up to 4 cm long and about 1 cm across. Leaves linear. Inflorescences ovate-elongated short spikes, broad at the base, up to 2 cm long and about 1 cm broad. Spikelets solitary, falling entire.

Habitat and Distribution

Rare in Qatar. Reported at Al Majda.

Constituents

The proximate composition, digestibility, cellulose, hemicellulose, tannins, carotenes, and Ca, P, Na, K, Mg, Cu, Zn and Mn, were determined in canary grass (*P. minor*), growing in India, during maximum tillering, 50 % heading and maturity. Accordingly, the grass may serve as an animal feed when harvested at 50 % heading (Gupta *et al.*, 1981). The total amino acids (protein content) of *P. minor* caryopses and the amino acid composition of the caryopses are shown in Table 103 (Yeoh and Watson, 1981).

The chemical composition of canary grass (*P. minor*) is shown in Tables 105 and 106 (Gupta *et al.*, 1981).

Phytochemical screening of the plant, growing in Qatar, revealed the presence of alkaloids, coumarins, flavonoids and sterols (Rizk *et al.*, 1986a). The roots of the polyploid *P. minor* yielded a red anthocyanin dye, pelargonidin, while the diploid species did not contain it (McWilliams and Shepherd, 1964).

The stems possessed an antibiotic activity, when tested upon *Sphacelia segetum* (Celayeta, 1960).

Table 105. Chemical composition of *P. minor* at different stages of growth (dry matter basis)

Coustituents	Maximum tillering	50 % Heading	Maturity (near harvesting of wheat)	Average
DM	20.8	35.4	56.7	37.63
CP	13.12	6.12	5.6	8.28
TP	8.3	4.8	1.3	4.80
CP/TP	1.58	1.27	4.3	-
NDF	45.84	57.46	66.92	56.74
Cell solubles	54.16	42.54	33.08	43.26
ADF	30.45	38.28	41.94	36.89
Cellulose	25.48	30.63	32.62	29.57
Hemicellulose	15.39	19.18	24.98	19.61
ADL	3.48	5.65	7.29	5.47
Silica	1.49	2.00	2.03	1.87
Total soluble sugars	10.10	8.40	6.60	8.36
Total oxalates	1.58	1.0	0.76	1.11
Total tannins	1.1	0.90	0.45	0.91
IVDMD	66.0	60.5	33.0	53.16
GE(Kcal/g)	4.28	4.03	3.45	3.92
Carotene (ppm)	211	58	31	100
NO_3-N (ppm)	2000	1400	600	1333

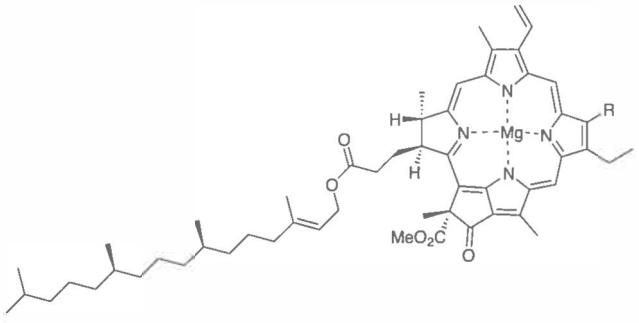
DM: Dry matter; CP: Crude protein; TP: True protein; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; ADL: Acid detergent lignin; IVDMD: *in vitro* dry matter digestibility; GE: Gross energy.

total suspended solids (TSS) after 24 hours in each component of plant-free system was reduced from 114 mg/l to 14 mg/l and 51 to 15 mg/l, respectively. Under the same conditions, the hybrid system reduced the BOD_5 from 110 to 3 mg/l and TSS from 68 to 6 mg/l. The hybrid system also reduced the total Kjeldahl nitrogen (TKN) from 16.1 to 2.5 mg/l, total phosphorus (TP) from 4.4 to 2.0 mg/l, and the ammonia (NH_3-N) from 12.4 to 0.6 mg/l after 24 hours of exposure while the plant-free system demonstrated insignificant reduction of these components (Wolverton, 1982). The use of *P. communis* as an emergent macrophyte for the removal of BOD, N, P and pathogens from primary treated wastewater (Juwarkar *et al.*, 1995) and NH_4^+-N in constructed wetlands (Sikora *et al.*, 1995) has been also reported. The peroxidase activity in lake macrophytes, including *P. communis* and its relation to pollution tolerance has been studied by Roy *et al.* (1992). *P. communis* which had moderately low peroxidase activity and was indifferent or tolerant to pollution had high total glutathione. Peroxidase is one of the major enzymes catalyzing oxidative metabolism of xenobiotics in plants. Glutathione-dependent reactions were found also crucial in such detoxification processes.

Soo *et al.* (1985) found that at > 1 % but not at ≤ 0.5 % NaCl decreased germinability and retarded germination and growth of *P. communis*. NaCl inhibited root growth more than that of shoots.

26. POA L.

The nutritional value (chemical composition and digestibility) of several *Poa* grasses has been determined so as to evaluate them as fodder plants. *P. annua* is a common species, readily grazed by sheep and geese (Davies, 1960; Willman and Riley, 1993). The dry matter, total sugars, and protein yield of some varieties of meadow grass (*P. alpina*, *P. compressa*, *P. palustris*, *P. pratensis* and *P. silvicola*) were reported by Smirnova-Ikonnikova and Shutova (1973) (Table 108). The relative yield of total green mass per 10 m^2 was in the sequence: 3.8, 2.9, 2.5, 2.1 and 1.8 in the spring and 11.5, 14.0, 6.1, 10.0 and 9.0 at blooming stage. Carotene (9.1-10.4 mg %), ascorbic acid (126.6-133.8), chlorophyll *a* **(907)** (66.7-73.4) and chlorophyll *b* **(908)** (30.7-31.8) are valuable nutrient ingredients of the meadow grass varieties. The chemical composition of some *Poa* species are shown in Tables 108 and 109.



907 Chlorophyll a; R = Me
908 Chlorophyll b; R = CHO

Table 108. Nutrient composition of some *Poa* species

Species	Dry matter %	g / 100 g Dry Matter				References
		Crude protein	Crude fiber	Total sugars	Ash	
1. *P. alpigena*	30.2	11.18	22.51	12.78	7.25	Staaland (1984)
grains	31.5	15.67	17.46	15.75	4.67	
2. *P. alpina*	29.1	13.96	19.59	12.85	5.67	Staaland (1984)
	25.6*	6.5		4.7*		Smirnova-Ikonnikova and
	25.7**	3.8 **		2.9**		Shutova (1973)
grains	2.9.8	17.62	15.44	11.48	4.63	Staaland (1984)
3. *P. bulbosa*		4.0 (digestible protein)		3.9 (starch)		Clemens (1968)
4. *P. compressa*	26.0*	5.4*		3.1*		Smirnova-Ikonnikova and
	30.1**	5.3**		3.3**		Shutova (1973)
5. *P. palustris*	23.3*	5.8*		2.9*		Smirnova-Ikonnikova and
	26.1**	5.3**		1.7**		Shutova (1973)
6. *P. pratensis*	23.9*	5.6*		2.2*		Smirnova-Ikonnikova and
	31.3**	3.8**		3.4**		Shutova (1973)
7. *P. sandbergii*		11.3 ± 5.4				Willms *et al.* (1980)
8. *P. silvicola*	29.7*	5.8*		3.2*		Smirnova-Ikonnikova and
	35.5**	4.6**		2.8**		Shutova (1973)
9. *Poa* sp.		11.3 -19.8				Staaland *et al.* (1983)
10. *P. trivialis*				9.2***		Seale *et al.* (1982)

* In summer; ** At blooming; *** Total carbohydrates.

Table 109. Comparison of chemical constituents between the open and treed range in bluebunch wheatgrass, Sandberg bluegrass and cheatgrass*

Range	Chemical constituent (%)						
	Crude protein		NDF	ADF	Lignin	P	Ca
Mg	Bluebunch wheatgrass						
Open	18.0[a]	60.9[a]	37.7[b]	5.3[b]	0.41[a]	0.26[a]	0.11[a]
Tree	18.8[a]	63.1[b]	31.4[a]	2.7[a]	0.32[a]	0.23[a]	0.14[b]
No. samples	1	12	6	6	6	6	6
Sandberg bluegrass							
Open	14.4[a]	63.6[a]	32.5[a]	4.8[b]	0.34[a]	0.24[a]	0.13[a]
Tree	15.3[a]	57.9[b]	33.2[a]	2.9[a]	0.31[a]	0.25[a]	0.17[b]
No. samples	12	12	6	6	6	6	6
Cheatgrass							
Open	14.5[a]	52.4[a]	26.7[a]	3.2[a]	0.38[a]	0.34[a]	0.15[a]
Tree	16.3[a]	52.0[a]	26.9[a]	3.3[a]	0.41[a]	0.35[a]	0.22[b]
No. samples	8	9	5	5	5	5	5

[a,b] Paired means with same letter did not differ significantly ($P > 0.05$).

* The first sampling date for each species was on 14 Feb., 18 Mar. and 2 Apr., 31 May respectively.

The crude protein content of three perennial winter species including *P. ligularis*, in Argentine, was lowest (3.9-5.1 % of the dry matter) in summer and highest (14.8-16.8 % of the dry matter) in autumn; dry matter digestibility (generally high) followed the same time course (Abiusso *et al.*, 1977). Williams (1980) reported the nutritive characteristics of six forage grasses (including *P. sandbergii*) on spring range in south central British Columbia in relation to time, habitat (open and forested range) and fall grazing. Sandberg blue grass (*P. sandbergii*) was comparatively low in crude protein (11.3±5.4) as compared to crested wheatgrass (*Agropyron desertorum*) (17.4±7.7). A comparison of the chemical constituents in bluebunch wheatgrass (*Agropyron spicatum*), Sandberg bluegrass (*P. sandbergii*) and cheatgrass (*Bromus tectorum*) showed that crude protein, phosphorus and calcium did not differ between habitats (Table 109). Magnesium was lower on the open range for all species. The neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin in bluebunch wheatgrass and Sandberg bluegrass differed significantly ($P < 0.05$) between habitats. The changes were not consistent for each species. Bluebunch wheatgrass, for example, had higher NDF content on the treed range than on the open range while NDF in Sandberg bluegrass was greater on the open range. ADF and lignin in bluebunch wheatgrass were higher on the open range but in Sandberg bluegrass they were higher on the treed range (Willms *et al.*, 1980).

The study of the aerial parts (viviparous bulbils, stems, and leaves) and roots of *P. bulbosa* var. *vivipara* at the ripening stage showed that the viviparous bulbils contained 21 free amino acids. The amino acid composition of stems and leaves was similar, but unlike bulbils, the amino acids cysteine, β-alanine, tyrosine, methionine, norvaline, and phenylalanine were lacking. All organs studied contained large amounts of the essential amino acids lysine, histidine, arginine, valine, leucine, and methionine (Tovmasyan, 1973). The amino acid composition of certain Poa species is shown in Table 110.

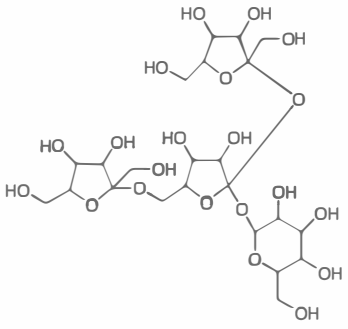
The oligosaccharides, isolated from *P. trivialis*, were reported as linear levans (Challinor *et al.*, 1934; Chatterton *et al.*, 1993b). Of the 150 species studied by Chatterton and Harrison (1997), only *P. ampla* contained a single β-2,6 linked fructan series. All other species grown at 10/5°C day/night temperature (16 h day) contained some β-1,2 linked oligofructans, even when the major fructan series was β-2,6 linked. Leaves of *P. ampla* grown at 15/10°C day/night temperatures contained some β-1,2 linked fructans and raffinose in addition to the dominant β-2,6 series, but did not contain significant amounts of 1-kestose or bifurcose (1→6 kestotetrose). Leaves of *P. arctica* and *P. bulbosa* contained significant amounts of raffinose and various β-1,2-linked oligomers but no 1-kestose. The presence of a "clean", simple, single β-2,6 linked series in cold-grown (10/5°C day/night) *P. ampla* was the first example of an extract of a grass containing inulin (1-kestose and nystose), neokestose or bifurcose **(909)** - based fructans. *P. ampla* was the only species in 110 grasses evaluated by Chatterton and Harrison (1997) that contained only linear β-2,6 linked oligofructosides. However, smaller amounts of β-2,1-linked fructans (including 1-kestose and nystose) and others of unknown structure did occur in the leaves of *P. ampla* grown at warmer (15/10°C) day/night temperatures. Because no bifurcose was detected (if present it was in very minute quantities) in any of the *Poa* species grown in either warm or cold temperatures, it was unlikely that the elongation-trimming pathway (ETP), a specific -2,1-hydrolysis of bifurcose, was the mechanism for 6-kestose synthesis in *Poa*, as proposed for wheat (Bancal *et al.*, 1992). Chatterton and Harrison (1997) concluded that under closely controlled environmental conditions *P. ampla* produced a single DP3 (degree of polymerization) and a single DP4 fructan and only members of the β-

2,6 linked linear fructan series. Their data further supported the hypothesis that 6-kestose synthesis occurred in the absence of significant amounts of either 1-kestose or bifurcose and that a specific 6-SST (sucrose-sucrosefructosyl transferase) was present in *P. ampla*.

Table 110. Amino acids composition of some *Poa* species

Amino acids	*P. helmsii*			*P. labillardieri*		*P. pratensis*		*P. sieberana*
	L*	L**	C	L*	C	L**	C	C
Aspartic acid	11.4	11.2	5.3	13.4	6.6	11.2	5.5	5.7
Threonine	5.8	5.7	3.8	5.9	3.4	5.3	3.5	3.8
Serine	6.5	5.5	5.3	6.8	5.6	5.2	4.9	5.2
Glutamic acid	14.8	15.9	29.3	16.2	32.0	14.4	30.6	27.4
Proline	6.3	5.2	7.2	6.1	7.0	5.9	7.1	7.3
Glycine	5.6	5.6	4.3	5.3	3.8	5.5	3.8	4.3
Alanine	7.7	7.4	4.1	7.3	4.3	7.0	4.0	4.4
Cystine	1.0	1.6	2.6	1.0	1.9	0.8	2.2	4.3
Valine	4.6	5.5	4.3	4.8	3.8	5.1	3.6	4.1
Methionine	1.8	1.6	1.6	1.4	1.8	2.5	2.0	2.0
Isoleucine	3.4	3.6	3.0	3.3	2.9	3.5	2.9	3.2
Leucine	8.7	9.0	7.5	8.2	6.9	9.0	7.7	7.7
Tyrosine	4.4	4.3	3.9	3.9	3.7	4.6	4.1	3.8
Phenylalanine	6.0	5.9	8.4	5.6	8.1	6.0	8.5	8.5
Histidine	2.2	2.2	2.2	2.2	2.0	2.2	2.2	2.1
Lysine	6.4	6.6	3.2	6.5	2.8	6.6	3.1	3.0
Tryptophan	0.0	0.0	0.1	0.0	0.0	0.4	0.0	0.0
Arginine	3.4	3.4	4.2	2.7	3.6	4.7	4.2	3.2
Total amino acid	2.0	2.0	10.7	1.3	13.9	2.7	12.4	8.5

L: Leaves (g % total amino acids); * grasses collected from the field;**: grasses grown in the greenhouse (Yeoh and Watson 1982); C: Caryopses (g % total amino acids) (Yeoh and Watson 1981).



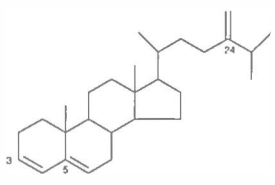
909 Bifurcose

Baron Kentucky bluegrass (*P. pratensis*) had 58 % lower total carbohydrate concentration when grown at the 10 mM NO^-_3. Fructose and glucose concentrations were usually (but not always) lower in plants grown with 10 mM NO^-_3 (Westhafer *et al.*, 1982). The sugars glucose,

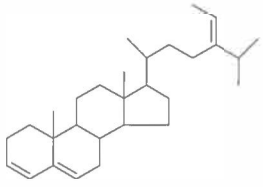
galactose, mannose, arabinose, and rhamnose were isolated from *P. huecu* (Rofi and Pomilio, 1987b).

The oil of the grains of *P. pratensis* was 1.5 % and the fatty acids identified were: $C_{14:0}$, 0.33; $C_{14:1}$, 0.02; $C_{15:0}$, 0.06; $C_{15:1}$, 0.24; $C_{16:0}$, 11.20; $C_{16:1}$, 0.20; $C_{17:0}$, 0.04; $C_{17:1}$, 0.14; $C_{18:0}$, 1.55; $C_{18:1}$, 27.18; $C_{18:2}$, 52.82; $C_{18:3}$, 4.34; $C_{20:0}$, 0.40; $C_{20:1}$, 0.25; $C_{20:2}$, 0.13; $C_{20:3}$, 0.90 and $C_{22:0}$, 0.20 % (Lotti *et al.*, 1985).

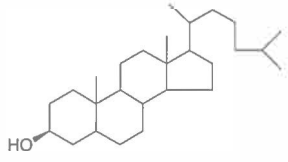
According to Rofi and Pomilio (1982), *P. huecu* contained the following steroids: 24-methyliden-$\Delta^{3,5,24}$-cholestatriene (**910**), 24-ethyliden- $\Delta^{3,5,24}$-cholestatriene (**911**), cholesterol, cholestan-3β-ol (**912**), campesterol, 5,6-dihydrocampesterol (**913**), sitosterol, 5,6-dihydrositosterol (**914**) and stigmasta-3,5-dien-7-one (**915**). The steroidal ketones: campesterone (**916**) and sitosterone (**917**) and the glycosides sitosterol-3-*O*-β-D-glucopyranoside, campesterol-3-*O*-D-glucopyranoside and chloesterol 3-*O*-D-glucopyranoside were also isolated from *P. huecu*. The grass also contained triterpenic ketones, germanicone (**918**), lupenone, cycloaudenone and hopenone, a triterpenic alcohol, lupeol and *n*-hexacosanol (Rofi and Pomilio, 1987b). Other triterpenoids identified from *Poa* species were arundoin and cylindrin from *P. pratensis* (Rizk, 1986) and fernenol, arundoin, glutinone and fridelin from *P. sphondylodes* (Ohmoto *et al.*, 1968).



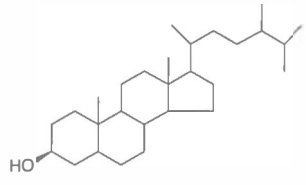
910 24-Methyliden-$\Delta^{3,5,24}$-Cholestatriene



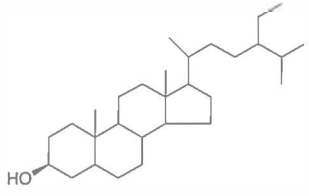
911 24-Ethyliden-$\Delta^{3,5,24}$-cholestatriene



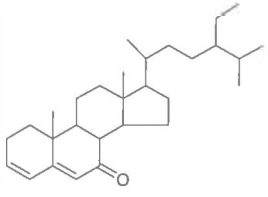
912 Cholestan-3β-ol



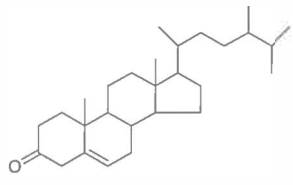
913 5,6-Dihydrocampesterol



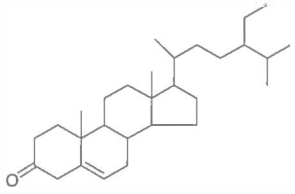
914 5,6-Dihydrositosterol



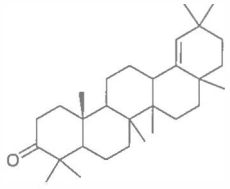
915 Stigmasta-3,5-dien-7-one



916 Campesterone



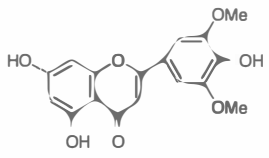
917 Sitosterone



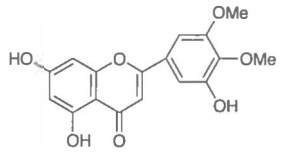
918 Germanicone

Epicuticular wax from the leaves of a glaucous variety of *P. ampla* contained hydrocarbons (5 %, C_{23}-C_{35}), esters (9 %, C_{36}-C_{56}), free acids (3 % C_{16}-C_{34}), free alcohols (6 % mainly C_{26}), hentriacontane-14,16-dione (14 %), 5-oxohentriacontane-14,16-dione (1 %), hydroxy β-diketones (56 %) and an unidentified material (6 %). The hydroxy β-diketones, consisted of 4-hydroxy- (15 %), 5-hydroxy- (70 %), and 6-hydroxy- (15 %) hentriacontane-14,16-diones (Tulloch, 1978). The composition of the epicuticular waxes of *P. colensoi* (Daly, 1964; Hall *et al.*, 1965), *P. combyi*, *P. cusickii* and *P. pratensis* has also been reported by Tulloch (1981).

Whole plants of *P. huecu* yielded 5,7,4'-trihydroxy-3',5'-dimethoxyflavone **(919)** (Rofi and Pomilio, 1982), 5,7,3'-trihydroxy-4',5'-dimethoxyflavone **(920)**, tricin, salagin, umbelliferone and scopoletin (Rofi and Pomilio, 1985). The cinnamic acid derivatives, *p*-coumaric, caffeic and ferulic were isolated from *P. huecu*. The fraction containing cinnamic acid derivatives, showed antimicrobial activity against *Mycobacterium phlei* (Rofi and Pomilio, 1987b). Leaves of *P. ampla* infected with the symbiotic fungus *Neotyphodium typhinium* contained the following bioactive flavonoids: tricin, 7-*O*-(α-D-glucopyranosyl)tricin, isoorientin and 7-*O*-(α-L-rhamnopyranosyl-(1→6)-β-D-glucopyranosyl)tricin (Ju *et al.*, 1998).



919 5,7,4'-Trihydroxy-3',5'-dimethoxyflavone



920 5,7,3'-Trihydroxy-4',5'-dimethoxyflavone

The mineral content of some *Poa* species has been studied. Hoehne (1963) determined Ca, Mg, K, Na, Mn, P, Si and N in the leaves of *P. chaixii* and reported that the plant showed a low capacity for SiO_2. In the three perennial winter species (including *P. ligularis*), minerals were generally low with respect to bovine requirements: Ca was on the borderline and Mg and P were deficient, silica was high and up to 75-80 % of the total ash (Abiusso *et al.*, 1977). *P. pratensis* has been found to contain 0.29 % P (Prakash *et al.*, 1978). The mineral content of a *Poa* species collected from three localities in Norway was reported as follows: Ca (77-153), Mg (31-93), P (45-118), Na (15-19), K (296-478), Cl (185) and S (57) mM/kg dry matter (Staaland *et al.*, 1983).

The mineral composition of *P. alpigena* and *P. alpina* (grain and grass) is shown in Table 111 (Staaland, 1984).

Table 111. Mineral concentrations (mM/kg D.M.) of *P. alpigena* and *P. alpina* collected in mid September (1981)

Species	Ca	Mg	P	Na	K	Cl	S
P. alpigena (vivip. grains)	50	30	90	15	382	80	63
P. alpina (vivip. grains)	33	32	93	26	421	80	88
P. alpigena (grass)	116	35	41	8	373	171	114
P. alpina (grass)	54	37	60	12	387	111	61

Entrup (1979) found that spacing, seeding time and N fertilization affected the seed yield of *P. supina*. N fertilization of *P. pratensis* contributed to a distinct increase of the total N

content as well as of Mg and to a lesser degree, Zn content. The content of other minerals, except for Cu, did not change (Kowalczyk, 1980).

Microbiological and chemical changes during the ensilage of long, chopped and minced *P. trivialis* were studied by Seale *et al.* (1982). The grass made excellent silage as first cut independent of treatment and inspite of the relatively low levels of water-soluble carbohydrates (9.2 %).

Effects of initial plant spacing and lime, P and N application were evaluated in Texas bluegrass (*P. arachnifera*), recognized as a plant with potential for range and pasture (Pitman and Read, 1998). Forage production of dense stands and responses to spring application of N indicated that it was a productive, sustainable cool-season forage grass.

Poa species were among several pollen species that displayed appreciable trypsin inhibitory activity (Berrens and Maranon, 1995). A large panel of T-cell clones specific for the recombinant form of *P. pratensis* allergen was examined by Parronchi *et al.* (1996).

The leaf homogenate of *P. pratensis* was found toxic in soil to the root lesion nematode *Pratylenchus penetrans* (Miller, 1978).

Edophyte-infected *P. alsodes* contained trace quantities of *N*-acetyloline and *N*-formylloline (TePaske and Powell, 1993).

Deaths, presumably due to cyanide poisoning were reported in 10 stress grazing on the reed sweet grass (*P. aquatica*). The plant contained the equivalent of 1.52 mg HCN/g dry material (Sharman, 1967). *P. huecu* was also reported toxic to cattle in Argentina (Rofi and Pomilio, 1982).

26.1. *Poa annua* L., Sp. Pl., ed.1, 68 (1753).
syn. *Poa royleana* Steud., Syn. Pl. Glum. 1:256 (1854).

Maesowgrass, bluegrass (En.)

Annual grass. Inflorescences loose panicles, small spikes with less than 10 spikelets; spikelets with prominamt veins.

Habitat and Distribution

Weed of waste places, cultivated ground and local gardens.

Constituents

The chemical composition of *P. annua*, growing in India, has been determined as: moisture, 39.00; dry matter, 61.00; ash, 17.43; crude protein, 8.31; crude fibre, 27.52; Ca, 0.56; P, 0.26; K, 0.56 and Mg, 0.29 % (Prakash *et al.*, 1978). The nutritive value of *P. annua*, grown in a heated glasshouse at Aberystwth (U.K.) in February-April 1985, is shown in Tables 112 and 113 (Wilman and Riley, 1993). The chemical composition and *in vitro* dry matter digestibility of *P. annua* (growing in India) at five stages of growth (at the vegetative, post-vegetative, full bloom, grain formation and matured grain stage) have been studied by Gupta *et al.* (1982a). Dry matter increased from 14.6 % to 18.3 % from the vegetative to matured seed stage. Neutral-detergent fiber, hemicellulose, cellulose and lignin increased to the seed-formation stage and thereafter declined. Crude protein decreased from 19.3 to 14.9 % by the seed-formation stage, then increased to 15.8 %. Anti-nutrient factor decreased from 80.0 to 70.5 % by the seed-

formation stage, then increased to 72.5 %. Gross energy varied from 2.65 to 3.49 kcal/g and carotene from 135 to 355 ppm. Total soluble sugar was maximum at the matured grain -stage (16 %). Total mineral ash declined with maturation. P (0.18-0.09 %), Mg (0.20-0.12 %), and Mn (60-80 ppm) decreased and Cu (20-26 ppm) and Zn (43-95 ppm) increased with maturity. Na and K ranged from 0.80 to 0.32 and 0.80 to 0.50 % respectively, declining at each successive stage of maturity. Ca (0.20-0.57 %) was independent of plant development. Tannins and oxalic acid ranged from 0.95 to 0.45 and 0.24 to 2.48 % respectively, and nitrate N varied from 1010 to 580 ppm. These data were also discussed with respect to the use of *Poa* forage for dairy cattle by Gupta *et al.* (1982a). Westhafer *et al.* (1982) found that annual bluegrass (*P. annua*) had 49 % lower total carbohydrate concentration when grown at 10 mM NO_3.

Borland and Farrar (1985) studied diel patterns of carbohydrate metabolism in leaf blades and leaf sheaths of *P. annua* and *P. jemtlandica*. Sucrose was the most abundant form of carbohydrate in leaf blades, with lesser amounts of starch and fructans also present. The proportions of fixed C allocated to export, storage and respiration in leaf blades were similar, and carbohydrates showed broadly similar patterns of diel fluctuation in both species. However, the relative rates of sucrose and starch accumulation and depletion and the diel patterns of export in the leaf blade were different in the two stages. Starch was the predominant form of carbohydrate in the sheath, with soluble sugars and fructans also present. Starch and soluble sugars showed diel accumulation and depletion in the sheaths of *P. annua* but not in *P. jemtlandica*.

Table 112. Dry matter (DM) harvested, neutral detergent fiber (NDF) and digestibility of *P. annua*

Plant part (g/pot)	DM harvested (% in DM)	NDF	DM digestiblity (%) Hours in rumen liquor	
			24	48
Leaf	16.1	38.1	58.8	73.3
Stem	12.8	50.0	59.7	75.0
Total	28.9	43.3	59.1	74.1

Table 113. The concentrations (%) in dry matter water-soluble carbohydrate (WSC), N, P, K, Ca, Mg and Na of *P. annua*

Plant part	WSC	N	P	K	Ca	Mg	Na
Leaf	12.7	4.48	0.621	4.89	0.79	0.258	0.17
Stem	17.7	2.58	0.590	4.35	0.42	0.190	0.13
Total	14.9	3.64	0.605	4.63	0.62	0.228	0.15

The herb yielded friedelinol and the sterols campesterol, stigmasterol and β-sitosterol (Ohmoto, 1967b). A glycoflavone (6-*C*-β-ristobioside), luteolin 6-*C*-(2"-*O*-α-D-mannosyl-β-D-glucoside) was characterized from whole plants of *P. annua* (Rofi and Pomilio, 1987a).

Juska and Hanson (1969) conducted pot experiments in the greenhouse to determine the nutritional requirements of *P. annua*. Total top yield was greater for annual bluegrass grown in silt loam soil than in loamy sands. In loamy sands a large decrease in clippings, crowns, and roots was obtained at a pH of 4.5 compared to a pH 6.5. N, P, and K contributed most to top

growth in the order mentioned. Also, Nowak and Panak (1982) found that increasing N-P-K rates increased the crop yield with the highest yield being obtained at a 4-fold increased N-P-K rate; addition of Mg and trace elements to the 4-fold rate had little effect.

The polyamine concentrations in *P. annua* and three other species, *P. compressa*, *P. pratensis* and *P. trivialis*, grown at three levels of nitrate supply were studied by Van Arendonk *et al.* (1998). Under nitrogen limitation, the total concentration of polyamines (spermine, spermidine and putrescine) (free and bound ones together) decreased in both leaves and roots of all *Poa* species, whereas that in the stem remained more or less the same. These effects were to a large extent determined by the free polyamines. For the conjugates there was more differentiation, both between plant organ and among polyamine structures. A positive correlation between RGR (relative growth rate), LAR (leaf area per plant mass), SLA (leaf area per leaf mass), LMR (leaf mass per plant mass) and SMR (stem mass per plant mass) with polyamine concentrations was found. The RMR (root mass per plant mass) showed a negative one. The (putrescine)/(spermine + spermidine) ratio in the leaves increased with decreasing nitrate supply, which is associated with a decrease in leaf expansion, accounting for a decrease in LAR and SLA. For the roots, this ratio tended to decrease with decreasing nitrate supply, whereas for the stems the results were somewhat more variable.

Wu *et al.* (1998) studied the allelopathic effects of phenolic acids detected in buffalograss (*Buchloe dactyloides*) clippings on growth of annual bluegrass (*P. annua*).

Extracts of lipid-soluble material from the surface of leaves of *P. annua* were found to induce the nymphs of *Locusta migratoria* to bite (Bernays *et al.*, 1976).

27. POLYPOGON Desf.

27.1. *Polypogon monospeliensis* (L.) Desf., Fl. Atlant. 1:67 (1798).
syn. *Alopecurus monospliensis* L., Sp. Pl., ed. 1, 61 (1753); *Phalaris cristata* Forssk., Fl. Aegypt.-Arab. 17 (1775).

Zail Alqit (Ar.)

Tufted erect annual grass with numerous basal branches up to 50 cm high (in farms) with 2-4-nodes to inflorescence. Leaves linear-lanceolate with shealth exceeding the lamina length. Inflorescences spicate, branched but compact appearing woolly because of soft awns; spikes broad up to 4 cm across and up to 15 cm long (in field specimens) but usually much smaller (roadside weeds); spikelets minute awned.

Habitat and Distribution

A frequent weed in agricultural fields and occasional by roadsides during the rainy season on shallow sandy soils.

Constituents

The proximate analysis, amino acids and minerals of *P. monospeliensis*, growing in Qatar, are shown in Tables 175, 176 and 178 (AL-Easa, 2002a,b,d).

The amino acid composition of *P. monospeliensis*, growing in Australia, is shown in Table 114.

Table 114. Amino acids composition of *P. monospeliensis*

Amino acids (g% total amino acids)	Leaf*	Caryopses**
Aspartic acid	14.1	8.0
Threonine	5.6	3.4
Serine	6.9	5.1
Glutamic acid	14.3	28.2
Proline	7.8	6.8
Glycine	5.4	4.3
Alanine	6.9	4.2
Cystine	1.1	3.0
Valine	4.4	3.6
Methionine	1.7	1.4
lsoleucine	3.2	2.9
Leucine	8.2	7.6
Tyrosine	3.9	3.9
Phenylalanine	5.7	8.2
Histidine	1.8	2.4
Lysine	5.8	3.4
Tryptophan	0.4	0.0
Arginine	2.9	4.7
Total amino acid (protein content) (g% fresh wt.)	2.1	12.9

* Yeoh and Watson (1982); ** Yeoh and Watson (1981).

the members of this group are divided into the cultivated sorghums and Sudan grass, which are annuals, and Johnson grass, which is a perennial weedy grass (Kingsbury, 1964). Many publications are available about the constituents of *S. vulgare* (a cultivated sorghum).

Grain sorghum (*S. bicolor*) is an important major crop in semiarid region because of its draught resistance (Watson, 1970). It thrives and produces both grain and forage under conditions that cause other crops to fail (Zipf *et al.*, 1950). It is a major crop in areas, particularly where rainfall becomes a limiting factor for corn production (Watson, 1970). Lately, there has been increased interest in sorghum with respect to its potential for starch production because its wet-milling process is similar to that of corn (Subramanian *et al.*, 1994; Buffo *et al.*, 1997, 1998a). There is also interest in the utilization of sorghum by-products such as surface wax and kafirin, the alcohol-soluble (prolamin) protein fraction (Buffo *et al.*, 1998b).

Sorghum ranks third following rice and wheat in world production as a cereal grain (Kramer, 1959). It was reported that it ranks fifth in average of world crops being super passed by wheat, rice, maize and barley. It is grown in areas where the average summer temperature exceeds 20°C and the frost-free season is 125 days or more (Basahy, 1995). In general, *S. bicolor* is being grown in several countries as a staple food grain and or as fodder.

Grain sorghum has been documented to have low protein digestibility relative to other grains. Low protein digestibility of sorghum is most pronounced in cooked foods and is ranked slightly lower than corn as a feed grain (Weaver *et al.*, 1998). *In vitro* methods showed both protein and starch digestibilities of the waxy, flour sorghum to be higher than those of the highly corneous cultivar (Elmalik *et al.*, 1986).

Buffo *et al.* (1998b) reported that sorghum hybrids were characterized as producing medium-sized, moderately dense kernels with soft endosperm, intermediate -to-low protein content, and higher starch content. Among proximal composition factors, protein and fat had wider variability than starch (Table 118).

Table 118. Quality factors of grain *Sorghum* (46 hybrids)

Factors	Mean± SD	Range
Starch %	71.76±2.28	69.11-76.48
Protein %	10.34±0.80	8.98-12.14
Crude free fat %	4.06±0.34	3.44-4.90
Total weight (kg/m^3)	758.52±14.14	725.97-792.90

The proximate composition of grains of 11 sorghum cultivars (*S. bicolor*), grown in Argentina revealed that oil, protein, carbohydrate and ash content varied between 4.1-6.6, 11.1- 15.6, 67.0-73.0 and 1.38-2.0 % (dry matter) respectively (Maestri *et al.*, 1996).

The proximate composition of three varieties of sorghum grains (*S. bicolor*), grown in Gizan Area (Saudi Arabia), is shown in Tables 119 and 120 (Basahy, 1995).

The mineral content of *S. vulgaris* was as follows: Fe, 35.0; Ca, 202; Mg, 1520; Mn, 24.5; Zn, 25.2 and P, 3030 (µg/g dry weight) (Glew *et al.*, 1997).

Suslova and Ishin (1980) found wide genotypic variability of the fifty-nine varieties of *Sorghum* tested with regard to protein and tryptohan content of the grain. With each species (*S. caffrorum*, *S. caudatum*, *S. durra* and *S. nervosum*) studied, forms with consistently high protein content were noted. The amino acid composition of certain *Sorghum* species is shown in Table 121 and 122.

Table 119. Proximate composition of three varieties of *Sorghum* grains

Sorghum varieties	Moisture %	Ash %	Fat %	Protein %
Hamra	11.83±0.120	1.72±0.028	0.26±0.035	14.58±0.02
Baidha	11.13±0.352	1.73±0.032	0.33±0.037	13.12±0.01
Shahla	11.43±0.328	1.78±0.015	0.26±0.031	13.54±0.01

Table 120. Mineral contents of three varieties of *Sorghum* grains (mg/100g dry weight)

Mineral contents	Hamra	Baidha	Shahla
Ca	4.50	4.30	4.95
Na	2.92	3.16	3.00
K	628	650	630
Mg	15.70	15.36	17.08
Mn	0.70	0.72	0.80
Fe	2.64	1.68	2.84
Zn	4.80	4.76	5.04

Table 121. Amino acids composition of some *Sorghum* species

Amino acids g% total amino acids	*S. bicolor*•	*S. vulgare*••	*S. vulgaris*•••
Aspartic acid	11.6	7.3	8.63
Threonine	5.5	3.5	4.25
Serine	5.7	5.3	5.50
Glutamic acid	13.7	21.5	20.6
Proline	5.9	8.5	8.82
Glycine	5.6	3.2	3.83
Alanine	7.9	9.4	10.7
Cystine	0.8	1.7	2.44
Valine	4.8	4.1	6.07
Methionine	2.0	1.9	1.90
Isoleucine	3.5	3.1	4.60
Leucine	9.6	13.6	14.8
Tyrosine	4.7	4.6	3.86
Phenylalanine	5.7	5.2	5.67
Histidine	2.0	2.1	2.34
Lysine	6.5	2.7	2.77
Tryptophan	0.3	0.2	1.87
Arginine	4.3	2.2	5.37
Total amino acid (protein content) (g% fresh wt)	2.5	6.7	114••••

• Leaf of grass grown in the greenhouse (Yeoh and Watson 1982); •• Caryopses (Yeoh and Watson 1981).
••• plant (Glew *et al.*, 1997); •••• mg/g dry weight.

Table 122. Amino acid contents in protein hydrolysates in three varieties of *Sorghum* grains (*S. bicolor*) as (mg/g total N)

Amino acids	Hamra	Baidha	Shahla
Aspartic acid	409	399	578
Threonine	191	186	190
Serine	273	277	224
Glutamic acid	1408	1310	1381
Glycine	168	140	165
Alanine	565	540	510
Cystine	108	103	104
Valine	255	240	240
Methionine	96	87	80
Isoleucine	242	209	236
Leucine	840	824	836
Tyrosine	278	271	264
Phenylalanine	240	238	235
Histidine	150	135	115
Lysine	162	138	115
Arginine	220	218	204
Ammonia	161	142	135

Burns and Smith (1980) studied the relation between total nonstructural carbohydrate residue (TNCR) and neutral detergent fiber (NDF) and the use of each to predict *in vitro* dry matter disappearance (IVDMD) of forage sorghum (*S. bicolor*). They found that TNCR was significantly correlated with NDF and IVDMD. Hanna *et al.* (1981) reported those four weeks after planting IVDMD of a brown midrib mutant of sorghum (*S. bicolor*) forage was 7.2 and 5.6 % higher than normal forage for leaves and stems respectively.

The study of changes in cell wall composition and degradability of sorghum (*S. bicolor sudanese*, a cultivar), showed that among the monosaccharides contributing to cell wall polysaccharides, the degradabilities of arabinose and uronic residues were consistently higher than those of xylose and glucose, the main components of structural carbohydrates. The total nonstarch polysaccharide content increased from 31.1 to 45.1 % between the youngest stage to the milk-ripe stage. Arabinose, xylose, and glucose residues were: 4.9, 27.9 and 63.0 % of the total neutral sugars, respectively. The pattern of glycosidic linkages detected were mainly ascribed to the prrsence of (1→4)-β-glucans (cellulose), arabinoxylan, (1→3)(1→4)-β-D-glucan, (1→4)-β-D-galactan, (1→3)-β-D-galactan, rhamnogalacturonan and possibly xyloglucan. The cellulose content of the 5 studied sorghums was in order of growth, 14.3, 21.8, 22.3, 21.2 and 22.0 % of dry matter. The mixed-linked glucan/cellulose ratio decreased during growth. Arabinoxylan, the predominant hemicellulosic polysaccharide, was about 33 % of the total neutral sugars consistently for all sugar samples. Arabinose, found largely as terminal residues in the cell-walls, carried various amounts of alkali-soluble substituents, particularly at position 0-5 depending on the growth stage of sorghum. The extent of 0-5 substitutions was closely related with both the lignin content (total phenolic minus phenolic acids) and with cellulose degradability (Goto *et al.*, 1991). In sweet stalk sorghum, the sugar content increased from the soft dough stage to the dead-ripe stage. Analysis of the internodes

revealed that the mid-portions of the stalk contained higher amounts of sugars than the other parts (Krishnaveni *et al.*, 1984).

The grain lipids of two sorghum varieties, growing in Nigeria, amounted to 3.68 and 5.28 %. From the lipids, eight glycolipid and six phospholipid classes were separated and characterized. Lysophospholipids constituted over 50 % of the phospholipids. Linoleic acid was the predominant fatty acid (Osagie, 1987). In the white and red varieties of *S. bicolor*, linoleic acid amounted to 46.3 and 46.7 % in the oils (Raie *et al.*, 1995). The major fatty acids of 11 sorghum cultivars were palmitic (15.1-24.8 %), oleic (29.9-41.8 %) and linoleic (35.9-51.3 %) (Maestri *et al.*, 1996). According to Raie *et al.* (1995), the low percentage of linolenic acid in white and red varieties of *S. bicolor* (2.1 and 1.2 % respectively) as compared to the high percentage of linoleic acid in the oils classify them as semi-drying oils and therefore they can be used for edible purposes. The fatty acids of *S. vulgaris* lipids (7.5 %) were: $C_{14:0}$, traces; $C_{16:0}$, 6.1; $C_{16:1}$, 0.19; $C_{18:0}$, 0.65; $C_{18:1n-9}$, 11.1; $C_{18:2n-6}$, 17.5; $C_{18:3n-6}$, 0.61 and $C_{20:0}$, traces (Glew *et al.*, 1997).

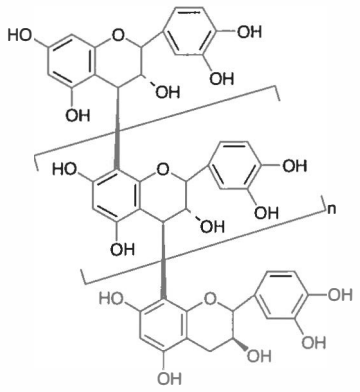
Grain sorghum (*S. bicolor*) produced wax on the outer layers, or pericarp, of its kernel (at levels of 0.20-0.25 %), which was similar to carnouba wax (Lochte-Watson and Weller, 1999,2000). Sorghum wax has a high melting point of approximately 80°C and has a potential to be removed as a co-product of commercial sorghum processing. Eventually it may be used in place of or with carnouba wax in car, shoe and floor polish, as a paper coating or, as a confectionary coating (Lochte-Watson and Weller, 1999). The major wax component was free fatty acids. The typical chain lengths of aldehydes, free alcohols and free fatty acids were C_{28} and C_{30} (Avato *et al.*, 1984).

Sitosterol was the prominent sterol in grains of 11 sorghum cultivars (*S. bicolor*) (43.8-57.9 %), followed by campesterol (18.7-29.1 %) and stigmasterol (12.4-20.5 %) (Maestri *et al.*, 1996). The grains of *S. japonicum* yielded campesterol, stigmasterol, β-sitosterol and friedelin. Both α- and β-amyrins were identified from the culms and blades of *S. bicolor* (Rizk, 1986).

The following compounds were identified in the volatiles of mechanically damaged *S. bicolor* (a host plant of the desert locust *Schistocera gregaria*): 3-pentanone, hexanal, (*E*)-2-pentenal, 1-penten-3-ol, (*E*)-2-hexenal, 4-methyl-3-pentenal, hexyl acetate, (*E*)-3-hexenyl acetate, (*Z*)-3-hexenyl acetate, (*Z*)-2-hexenyl acetate, hexanol, (*E*)-3-hexen-1-ol, (*Z*)-3-hexen-1-ol, (*Z*)-2-hexen-1-ol, (*E*)-3-hexenyl butyrate and (*Z*)-3-hexenyl butyrate (Njagi and Torto, 1996).

The sorghum grains afforded several flavonoids and other phenolic compounds e.g. (±)-catechin, naringenin, procyanidin B_1, taxifolin, eriodictyol, quercetin, taxifolin-7-*O*-β-glucoside, eryodictyol-5-*O*-glucoside, quercetin-7-*O*-β-glucoside and 5,7,3',4'-tetrahydroxyflavan-5-*O*-β-glucosyl-(4,8)-cryodictyol. Trimeric, tetrameric and pentameric procyanidins were also identified (Gujer *et al.*, 1986; Magnolato *et al.*, 1986). Apigenin, luteolin, apigenin and luteolin 7-*O*-glucosides, *p*-coumaric acid, butin and apigeninidin were identified in leaf blades and sheaths from 24 sorghum varieties. The detection of the derivatives of the following compounds was also reported: apigenidin, luteolinidin, chalcone, flavanone and/or dihydroflavanol and cinnamic acid (Mueller-Harvey and Reed 1992). Luteoferol (4,5,7,3',4'-pentahydroxyflavan), which gives luteolinidin on acid treatment has been characterised in leaves and grain coats of *S. vulgare*. Tricin, luteoforol, apigiferol (apigenin flavan-4-ol) and flavone *C*-glycosides have been detected in the leaves of four *Sorghum* species (Harborne and

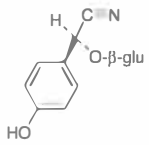
Williams, 1976; Rizk, 1986). Flavan-4-ols have been identified in young leaves of mould-resistant accessions of *S. bicolor* (Jambunathan and Kherdekar, 1991). A stable 3-deoxyanthocyanidin, apigenidin chloride, a potential fungal growth inhibitor and a useful dye, has been isolated with a high yield (10 % dry weight) as the major pigment in the sheaths of *S. caudatum* (Kouda-Bonafos *et al.*, 1994). A red dye consisting of cyanidin, quercetin and pelargonidin, was isolated in a yield of 0.7 % from the bran of sweet sorghum (*S. durra*). A polymeric procyanidin (**922**, n = 4 or 5, average molecular weight 1,700-2,000) was isolated from the grain coat of *Sorghum* grains. Ferulic, syringic, vanillic and hydroxybenzoic acids were also identified in *Sorghum* species (Rizk, 1986). Investigation of three sorghum cultivars showed that the tannin content of ungerminated grains were 220,400 and 410 mg/100 g. For all cultivars, ungerminated grains were found to contain no free or total cyanide. Both free and total cyanide were significantly increased with the length of time of germination of all cultivars (Ahmed *et al.*, 1996). Polyphenols have been found to increase at the rate of 18 g/grain/day, peaking at day 60 (750 g/grain) and then declining (Kleiber *et al.*, 1986).



922 Procyanidin

A potent antifungal substance, 2-hydroxy-5-methoxy-3-(8'*Z*,11'*Z*,14'-pentadecatrien)yl-1,4-benzoquinone, together with its metabolite was isolated from etiolated sorghum seedlings (Suzuki *et al.*, 1998).

Dhurrin (*S*-*p*-hydroxymandelonitrile β-D-glucospyranoside, **923**) was detected in seedlings of various *Sorghum* species (e.g. Haskins and Gorz, 1985; Rizk, 1986; Okoh *et al.*, 1988). The effect of environmental and genetic factors on the cyanogenic content of sorghum varieties (particularly Sudan grass *S. sudanense*) has been extensively studied. Of the fourteen varieties of *Sorghum* analysed by Hauwirth (1954) for their dhurrin content, the perennial sorghum (*S. almum*) had the highest content, kafir (*S. caffrorum*) the lowest, while Sudan grass had an intermediate level. The leaf contains three to twenty-five times as much as the corresponding stalk. Grain sorghum (*Sorghum* spp.) leaf tissue samples ranged from 240 to 480 ppm HCN on a fresh weight basis and from 3,000 to 6,000 ppm on a dry basis. Cyanide potential (amount of nitrile glycoside in the plant) varied with a number of factors, e.g. environmental factors, age of plant and inheritance. Young growth tended to have the highest HCN potential (Rizk, 1986). To a degree, the darker green the plant was, the higher cyanide content it had (Kingsbury, 1964). Poisoning of livestock from *Sorghum* is due to their HCN content (Watt and Breyer-Brandwijk, 1962; Kingsbury, 1964).



923 (*S*)-Dhurrin

31.1 ***Sorghum halepense*** (L.) Pers., Syn. Pl. 1:101 (1805).

syn. *Holcus halepensis* L., Sp. Pl., ed. 1, 1047 (1753); *Andropogon sorghum* (L.) Brot. subsp. *halepensis* (L.) Hackel in DC., Monog. Phan. 6:501 (1889).

Heliban, Zurrah (Ar.); Johnson grass (En.)

Tall perennial grass reaching over a meter high with rhizomes. Culms thick, terminating in large open panicles. Leaves large, linear lanceolate, flat. Panicles green, pale yellow or purple-tinged. Spikelets, a pair:one pedicellated and the other sessile, awned.

Habitat and Distribution

An occasional grass near residential areas on moist sites or in house gardens but not seen in the wild. The introduction of this species in Qatar must have been via the imported brooms from neighbouring countries, used to clean the outer areas of local houses.

Constituents

Sorghum halepense has been reported to furnish hay in arid regions, of a quality that was slightly inferior to the forage of buckwheat and of the following composition: water (15.00, 15.00 %), crude protein (6.58, 8.43 %), crude fat (1.25, 1.85 %), non-nitrogenous compounds

been isolated from *J. effusus*. Many of the isolated 9,10-dihydrophenanthrenes were cytotoxic and had antialgal activity (Della Greca *et al.*, 1995-1997). Tetrahydropyrene glucosides (e.g. **928**, **929**) have been isolated from *J. effusus* (Della Greca *et al.*, 1995a, 1996).

Table 128. Amino acids analysis (mg g^{-1}) of live, dead and decayed *J. rosmarinus* and detritus decomposed *in situ**.

Amino acids	Live	Dead	Decayed	Detritus
Lysine	4.3	1.7	2.6	3.0
Histidine	1.8	0.7	0.6	1.1
Arginine	4.0	1.6	2.8	3.3
Aspartic acid	6.6	3.9	4.8	7.5
Threonine	3.7	2.3	2.3	4.4
Serine	3.5	2.3	2.8	4.1
Glutamic acid	8.7	4.2	5.0	8.2
Proline	11.9	2.1	2.3	3.7
Glycine	3.9	2.4	2.8	4.8
Alanine	4.5	2.4	2.9	4.9
Half Cystine	trace	trace	0.3	0.5
Valine	5.2	2.3	2.5	4.2
Methionine	1.0	0.8	0.8	1.5
Isoleucine	3.4	1.7	2.1	3.1
Leucine	5.8	3.0	3.8	5.5
Tyrosine	2.3	1.1	1.0	2.1
Phenylalanine	3.7	1.8	2.1	3.2
Total amino acid (AA)	74.3	34.3	41.5	65.1
	(78.6)	(36.4)	(45.4)	(92.3)
Crude protein (CP)	79.0	49.5	57.6	87.1
	(83.6)	(52.6)	(63.0)	(123.5)
% AA in CP	94.05	69.29	72.05	74.74

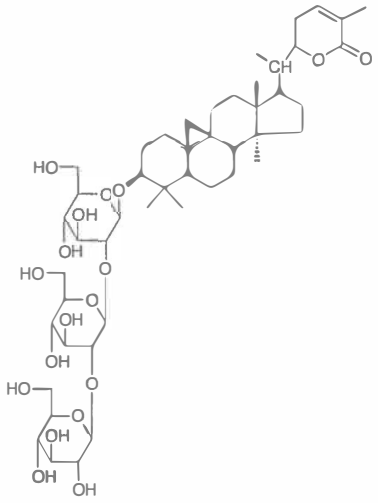
*Values in parentheses are based on ash-free dry weight (De la Cruz and Poe, 1975b).

A cytotoxic compound identified as 2,8-dihydroxy-1,7-dimethyl-6-vinyl-10,11-dihydrodibenz[b,f] oxepin was also isolated from *J. effusus* (Della Greca *et al.*, 1993b).

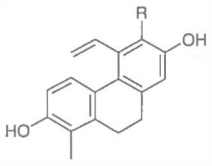
From the medullae of *J. effusus*, 13 compounds were isolated: a (2*S*)-2,3-isopropylidene-1-*O*-*p*-coumaroyl glyceride (juncusyl ester A), 2-*O*-*p*-coumaroyl glyceride (juncusyl ester B), 5α-spinasterol, β-sitosterol, β-sitosteryl-β-D-glucoside, effusol, *p*-coumaric acid, isoscutellarein pentamethyl ether, nobiletin, quercetin, rutinose and vanillic acid (Jin *et al.*, 1996).

Several other flavonoids have been detected in *Juncus* species. Apignin, 7-methoxyapigenin, 7-methoxyapigenin-4'-glucoside, luteolin and its glucoside were identified in *J. acutus* and other species (Rizk, 1986).

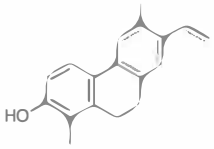
The carotenoids lutein, β-carotene, cryptoxanthin, auroxanthin, neoxanthin, flavoxanthin, chrysanthemaxanthin, violaxanthin and a flavochrome (α-carotene 5,8-epoxide) were detected in *J. bufonius* and *J. gerardii* (Rizk, 1986). α-Tocopherol was identified in *J. effusus* var. *decipiens* (Oyaizu *et al.*, 1991).



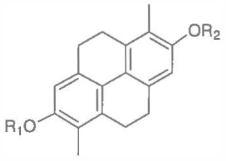
924 Juncoside



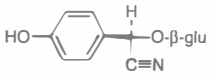
925 Juncusol; R = Me
927 Effusol; R = H



926 Juncunol



928 R_1 = β-D-Glucopyranosyl, R_2 = H
929 $R_1 = R_2$ = β-D-Glucopyranosyl



930 Taxiphyllin

Cyanogenic glycosides (taxiphyllin, **930** and dhurrin) have been reported in several *Juncus* species. Rhizomes of cyanophoric plants are always cyanogenic, whereas the seeds are not. The adult needlerush (*J. rosmarinus*) contained an unexpected high amount (0.2 g/kg) of alkaloids (Rizk, 1986).

J. effusus var. *decipiens* possessed antioxidative and antimicrobial activities (Oyaizu *et al*., 1991).

J. effusus is a well-known source of rushes for mat making, domestic utensils and is used as a fodder plant (Rizk, 1986).

1.1. ***Juncus rigidus*** Desf., Fl. Alant. 1:312 (1798).

syn. *Juncus maritimus* Lam. var. *arabicus* Asch. and Buchenau in Boiss., Fl. Orient. 5:354 (1882), excl. syn *J. spinosus* Forssk.; *J. arabicus* (Asch. and Buchenau) Adamson, J. Linn. Soc. London (Bot.) 50:10 (1935).

Tanda (Ar.)

Perennial rush with deep-burried rhizomes giving off upright leafy shoots appearing sedge-like or grass-like. Shoots upright, rigid, up to a meter high ending in a sharp point. Inflorescences dense panicles arising sideways. Flowers grass-like with perianth (3 + 3) and 6 stamens.

Habitat and Distribution

A common plant of highly saline habitats and coastal areas. Plant extremely tolerant of saline soils with a high water table where most other plants cannot survive.
Common by the shoreline S. of Ras Ushairij, Um Almaa and further south. Frequent on the pure stands South of Fuwairyt and elsewhere and an invader of sewage water disposal pools.

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *J. rigidus*, growing in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d).

Phytochemical screening of *J. rigidus*, growing in Qatar, revealed the presence of alkaloids, coumarins, flavonoids and sterols (and/or terpenes) (Rizk *et al.*, 1986a).

Field experiments with *J. rigidus* and *J. acutus* indicated that these plants can be successfully cultivated in saline soils and could desalinise the soil on which they grew and produce as well seeds rich in oils, proteins, amino acids, carbohydrates, etc. Both species have agro-industrial economic potentials with *J. rigidus* being preferred because of its greater resistance to fungal infections, greater salt tolerance and desalinising action and as well as the rich chemical composition of its seeds (Zahran *et al.*, 1979).

J. maritimus (*J. rigidus*) has been reported to yield 90-92 % of cellulose in the unbleached dry pulp (Rizk, 1986).

XX. MALVACEAE Adans.

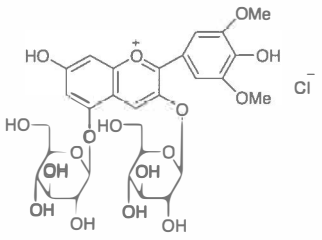
1. *MALVA* L.

Common mallow (*Malva sylvestris*) contained 0.47 % lipids; the fatty acids of which were identified as follows: $C_{14:0}$, 0.77; $C_{16:0}$, 15.60; $C_{16:3\omega3}$, 0.81; $C_{16:2\omega6}$, 0.27; $C_{16:1\omega7}$, 1.99; $C_{18:0}$, 2.07; $C_{18:3\omega3}$, 42.22; $C_{18:4\omega3}$, 0.29; $C_{18:2\omega6}$, 10.40; $C_{18:3\omega6}$, 0.50, $C_{18:1\omega7}$, 1.14, $C_{18:1\omega9}$, 1.73; $C_{20:1}$, 1.04; $C_{20:3\omega6}$, 1.23 and $C_{20:4\omega6}$, 5.30 (Guil *et al.*, 1996a). Four active factors (α,β,γ and Δ) of vitamin E were detected in oil of running mallow (*M. rotundifolia*) seed (Wang, 1996).

A water-soluble arabinogalactan composed of D-galactose and L-arabinose in the mole ratio of 1:1.4 has been isolated from the flowers of *M. mauritiana*. It had a highly branched structure. The core consisted of 1,6-linked β-D-galactopyranose units, about 65 % of which were substituted in position C-3 by side-chains of mainly 1,5-linked α-L-arabinofuranosyl residues (Capek and Kardosova, 1995). A neutral heteropolysaccharide consisting of D-galactose (23.4 %), L-arabinose (34.3 %) and L-rhamnose (42.2 %) has been also isolated from the mucilage of flowers of *M. mauritiana*. It had a branched structure with 3,6-linked D-galactopyranose, 5-linked L-arabinofuranose as well as 4-linked and terminal L-rhamnopyranose residues as the main building units (Capek *et al.*, 1999). The mucous polysaccharides of *M. silvestris*, with peptide chains were able to form a colloidal film on the skin contributing to the inhibition of irritations and inflammations (Eggensberger *et al.*, 1999).

The leaves of *M. silvestris* contained sulphated flavonol glycosides (gossypin 3-sulphate, hypolaetin 8-*O*-β-D-glucoside-3'-sulphate and gossypetin 8-*O*-β-D-glucuronide-3-sulphate) (Rizk, 1986).

The two main anthocyanins detected in *M. silvestris* were malvin and malvidin 3-*O*-(6"-*O*-malonylglucoside)-5-*O*-glucoside (Farina *et al.*, 1995) and its flowers contained scopoletin in a range of 10 to 30 mg/g dry weight (Tosi *et al.*, 1995). Malvidol 3,5-diglucoside chloride **(931)** was identified from the anthocyanins of *M. sylvestris*, treated with HCl (Societe Civila d' Investigations, 1980).

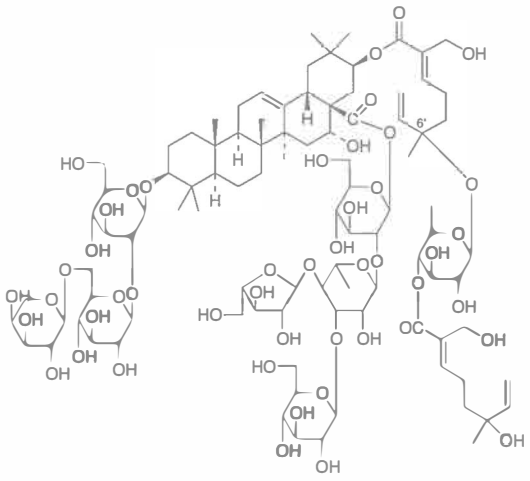


931 Malvidol 3,5-diglucoside chloride

Oral administration of 50 % ethanolic extract of flowers of *M. viscus* (800 mg/day) to healthy adult male rats for 60 days caused degenerative changes in their spermatocytes, spermatides and sperms (Gupta *et al.*, 1985c).

The manufacture of a good spinning fiber from the root of *M. crispa* has been early reported (Rizk, 1986).

nonacosane (60 %), triacontanol, and the phytosterols cholesterol (8.7 %), campesterol (21.6 %), stigmasterol (37.2 %) and sitosterol (32.4 %) (Andhiwal and Kishore, 1982).



992 Kimmonoside A; 6' = *R*
993 Kimmonsoide B;' 6' = *S*

Different classes of flavonoid compounds (flavones, flavonols, flavans, flavanones and chalcones) were isolated from several *Acacia* species (e.g. Rizk, 1986; Ahmed, 2000). Examples of these compounds are shown in Table 132.

A. farnesiana has been reported as both cyanogenic and acyanogenic. Linamarin and lotaustralin are the major cyanogens of the plant. The plant contains several flavonoids and other phenolic substances (e.g. kaempferol and its glycosides, gallic acid), monoterpenoids (and other constituents in the floral oil), and alkaloids (e.g. tyramine) (Rizk and Al-Nowaihi, 1989; Prasad, 1995). The free non-protein amino acids of the plant were identified as *N*-acetyl-L-djenkolic acid (a sulphur amino acid first isolated from *A. farnesiana*), pipecolic acid and 4-hydroxy pipecolic acid (Rizk and Al-Nowaihi, 1989).

The use of the different parts of *A. farnesiana* (root, bark, leaves, flowers and seeds) in folk medicine has been reported (Rizk and El-Ghazaly 1995). The wood is of value as a timber (Rizk and Al-Nowaihi, 1989).

Several other flavans (e.g. catechin, leucoanthocyanidins, leucodelphinidins, leucofisetindin and mollisacacidins) have been isolated from *Acacia* species (Ahmed, 2000). Melacacinidin is the name proposed for the anthocyanidin 3,3',4',7,8-pentahydroxyflavylium (isolated from *A. melanoxylon*) and leucomelacinidins for the corresponding leucoanthocyanidins (Foo and Wong, 1986). Biflavonoid proguibourtindin carboxylic acid (based on (-)-epicatechin or (+)-catechin as constituent units) and their biflavoniod homologies were isolated from the heartwood of *A. luedertizii* (Ferreira *et al.*, 1985). Five (+)-catechin galloyl esters were isolated from the bark of *A. gerrardii* (Malan and Pienaar, 1987). Condensed tannins (procyanidins, prodelphinidins and profisetinidins) were isolated from the heartwood of *A. baileyana* var. *purpurea*. These tannins were heterogeneous, consisting of a mixture of the resorcinol and phloroglucinol series (Foo, 1984). Other phenolics *viz.* ellagic acid, ethyl gallate, gallic acid, gallanin, gallocatechim, gentisic acid and methyl gallate, have been identified in many *Acacia*

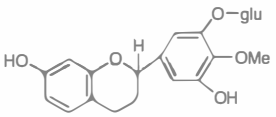
species (Ahmed, 2000). The pods of *A. arabica* are rich in tannins (30.4-41.7 %). *A. arabica*, an important and widespread tree of India and Pakistan has been used locally for tanning. The bark has 12-20 % tannins but contains a large amount of coloured material (Howes, 1953; Seigler *et al.*, 1986). The tannins present in the aqueous extracts of leaves, bark, wood and immature fruits of *A. farnesiana* amounted to 3.04, 3.30, 0.12 and 4.60 % respectively (Seigler *et al.*, 1986). The efficiency of tannins from *A. farnesiana* for the tanning of leather has been determined by Seigler and Hernandez (1989). Tannins penetrated the hide in 9 days and gave an acceptable colour.

Table 132. Examples of different classes of flavonoids in some *Acacia* species

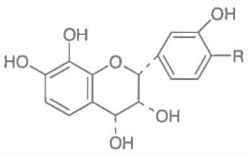
Species	Flavonoids	References
1. *A. aroma*	Apigenin, 7-hydroxyflavone, isorhamnetin, myricetin, myricetin-3-*O*-glucoside and myricetin 3-*O*-rhamnoside	Ahmed (2000)
2. *A. auriculiformis*	Auriculoside **(994)**	Rizk (1986)
3. *A. catechu*	Quercetin, 3-methylquercetin, dihydrokaempferol and dihydroquercetin	Sharma *et al.* (1999)
4. *A. caven*	Isovitexin, luteolin, vitexin, isorhamnetin, quercetin 3-*O*-galactoside and quercetin 3-*O*-glucoside	Ahmed (2000)
5. *A. confusa*	Myricetin 3-*O*-(2"G-galloyl)-α-rhamnoso-7-methyl ether, myricetin 3-*O*-(3"-*O*-galloyl)-α-rhamnose-7-methyl ether, myricetin 3-*O*-(2",3"-di-*O*-galloyl)-α-rhamnose, 2,3-*cis*-3,4- *cis*-4'-methoxy-3,3',4,7,8-pentahydroxylflavan, 2,3-*cis*-3,4-*cis*-3,3',4,4',7,8-hexahydroxyflavan "melacacidin" **(995)** and 3',4',7,8-tetrahydroxyflavonol, 2,3-*trans*-3',4',7,8-tetrahydroxydihydroflavonol	Lee and Chou (2000); Lee *et al.* (2000)
6. *A. cyanophylla*	Apignin 6,8-bis-D-glycosidc, 3-hydroxylfavone, 8-*O*-methylflavan and tetrahydroxychalcone-4-glucoside	Ahmed (2000)
7. *A. farnesiana*	Kaempferol 7-glucoside, kaempferol 7-galloylglucose, apigenin 6,8-*bis*-glucopyranoside, dihydrokaempferol (aromadendrin), naringin and narringenin	Rizk (1986)
8. *A. fructospina*	Isovitexin, isovitexin rhamnoglucoside, vitexin, luteolin, isorhamnetin 3-*O*-glucoside and quercetin 3-*O*-glucoside	Ahmed (2000)
9. *A. galpinii*	Melacacidin, tetracacidin **(996)** and proteracacinidin-type oligoflavonoids (*ent*-oritin (4α-*O*-4)-epioritin-4α-ol and epioritin-(4β-*O*-4) epioritin-4α-ol)	Coetzee *et al.* (1998); Ahmed (2000)

Table 132. Cont.

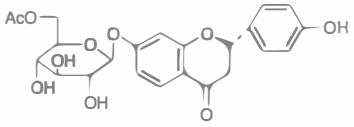
Species	Flavonoids	References
10. *A. latifolia*	Isorhamnetin, myricetin 3-*O*-glucoside, myricetin 3-galactoside, quercetin 3-*O*-glucoside, quercetin 7-*O*-glucoside, and quercetin 3-*O*-rutinoside	Ahmed (2000)
11. *A. longifolia*	Naringenin, kaempferol glucoside and 5,2',5'-trihydroxy-6,7-dimethoxyflavanone	Anam (1997); Ahmed (2000)
12. *A. neovernicosa*	Chrysin, 3-methylkaempferol, 3,3'-dimethylquercetin, 2,4'-dihydroxychalone, 4'-hydroxy-2'-*O*-methylchalone and 2,4'-dihydroxy-3'-*O*-methylchalcone	Ahmed (2000)
13. *A. saligna*	Quercetin 3-rhamnoside, kaempferol glucoside, naringenin, naringenin 7-*O*-β-D-glucoside 6"-acetate (**997**), naringenin 7-*O*-β-D-glucoside, 6-*C*-glucosylnaringenin and quercetin	El-Shafae and El-Domiaty (1998); Ahmed (2000)



994 Auriculoside



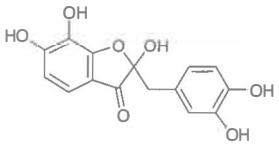
995 Melacacidin; R = OH
996 Tetracacidin; R = H



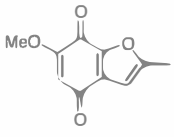
997 Naringenin 7-O-β-D-glucoside 6"-acetate

One of the most important tanning materials is black mimosa extract. Green mattle (*A. decurrens*), the silver or blue mattle (*A. dealbata*) and the golden mattle (*A. pycantha*) were also used in many countries. Tannins yield from *A. mearnsii* was about 39 % dry barks. The tannin content of several *Acacia* species has been reported (Rizk, 1986).

The black heartwood of *A. nigrescens* yielded nigrescin (2,3',4',6,7-pentahydroxy-2-benzylcoumaran-3-one (**998**)). Australian blackwood, *A. melanoxylon* yielded two quinines (2,6-dimethoxy-*p*-benzoquinone and 2-methyl-6-methoxy-furanobenzoquinone, (**999**) "acamelin"), which were responsible for the allergy inducing properties of this species (Rizk, 1986).



998 Nigrescin

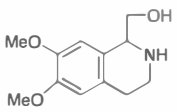


999 Acamelin

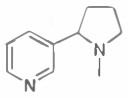
Alkaloids have been identified in many *Acacia* species. Examples of these alkaloids are shown in Table 133.

Table 133. Alkaloids of some *Acacia* species

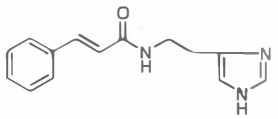
Species	Alkaloids	References
1. *A. berlandeiri*	Hordenine, *N*-methyltyramine, phenylethylamine, tyramine and tryptamine	Ahmed (2000)
2. *A. confusa*	*N*-methyltryptamine and *N*,*N*-dimethyltryptamine	Lee and Chou (2000)
3. *A. concinna*	Calycotomine **(1000)** and nicotine **(1001)**	Rizk (1986); Ahmed (2000)
4. *A. mallissim*	Nicotinic acid and trigonelline	Ahmed (2000)
5. *A. rigidula*	*N*-methyltyramine and *N*-methyl-β-phenylamine	Ahmed (2000)
6. *A. spirobis*	Hordenine and N^{α}-cinnamoylhistamine **(1002)**	Ahmed (2000)



1000 Calycotomine

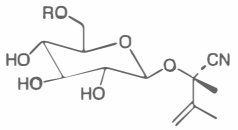


1001 Nicotine



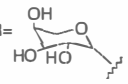
1002 N^{α}-cinnamoylhistamine

Many *Acacia* species have chemical deterrents or anti-nutritional factors, which can be mainly grouped into cyanogenic glycosides and polyphenols (mainly flavonoids and tannins). Cyanogenosis has long been recognised among various *Acacia* species. Numerous reports of positive cyanide tests have appeared in the literature, but few compounds were actually isolated and characterised. Among the cyanogenic glycosides identified are: heterodendrin (Jaroszewski, 1986), proacacipetalin **(1003)**, proacaciberin **(1004)**, acacipetalin, linamarin and lotaustralin (Rizk, 1986). Forty-five Australian *Acacia* species have been found to be cyanogenic (Maslin *et al.*, 1987), of which 19 produce more than the considered danger level (20 μ mol g^{-1} HCN). The toxic potential of these species depends on the presence of both cyanogens and the hydrolysing enzymes, which liberate HCN from the cyanogens (Fagg and Stewart, 1994).



1003 Proacacipetalin; R= H

1004 Proacaciberin R=



Acacias are predominantly bee-pollinated and acacia honey has an international market (Fagg and Stewart, 1994). Crane *et al.* (1984) listed 10 species as important world honey sources.

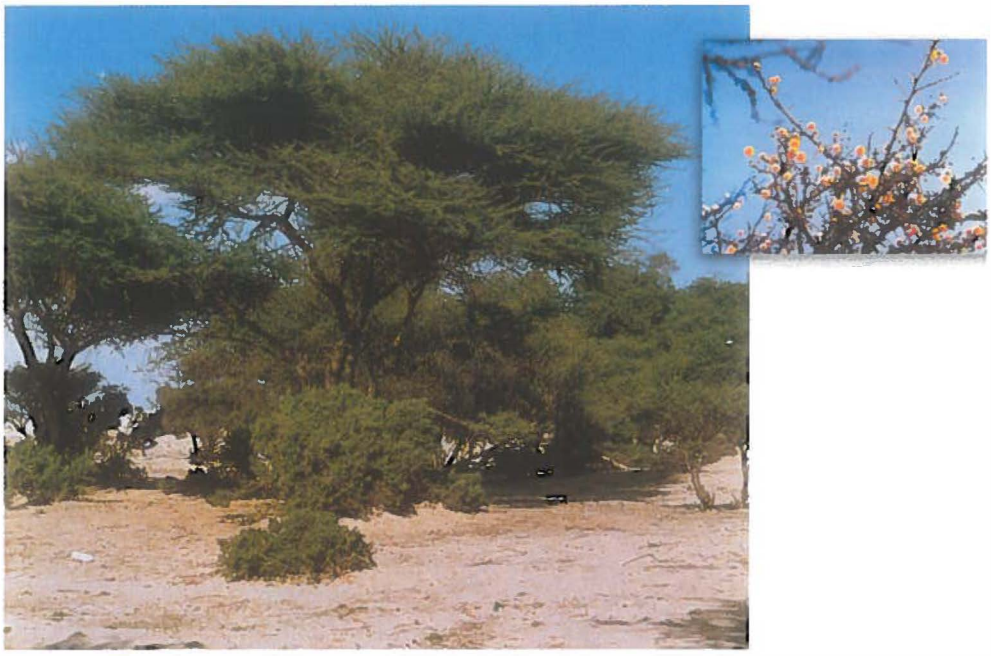
The use of several *Acacia* species in folk medicine has been reported (Watt and Breyer-Brandwijk, 1962; Lewis and Elvin-Lewis, 1977; Rizk and El-Ghazaly, 1995). The molluscicidal activity of certain *Acacia* species has been reported e.g. *A. concina* (Hyalij, 1999) and *A. nilotica* subsp. *nilotica* (Ayoub, 1985).

Published accounts concerning lectin (phytohemagglutinin) activity in seeds of *Acacia* species are contradictory and generally indicate that lectin activity occurs only rarely. The contradictory reports may be related to naturally low levels of activity and its transient nature (Rizk, 1986).

1.1. *Acacia ehrenbergiana* Hayne, Getreve Darstell. Gew. 10, t.29 (1827).

syn. *Mimosa flava* Forssk., Fl. Aegypt.-Arab.176 (1755), nom. illegit.; *Acacia flava* (Forssk.) Schweinf. nom.illegit., non *A. flava* Spreng. ex DC; *A. flava* var. *ehrenbergiana* (Hayne) Roberty.

Sallam (Ar.)



Perennial woody armed shrubs or trees up to 3.5 m high (in good growth condition). Stems many, arising near the base, fissured with occasional dark exudates; new shoots reddish, with soft spines, spines stipular with short prickles equally present on older branches. Leaves compound, pinnate, of 1-2 pairs of pinnae, deciduous in summer; leaflets minute. Inflorescences axillary, capitate, 1-many on peduncles 2.5-3.5 cm long; flowers scented, yellow. Pods pale brown, dehiscent, falcate.

Habitat and Distribution

Widespread in deep rodats all over Qatar.

Constituents

The proximate analysis and minerals of *A. ehrenbergiana*, growing in Qatar, are shown in Tables 175, 177 and 178 (Al-Easa, 2002a,c,d).

The following compounds were detected in the lipid of *A. ehrenbergiana* (Ahmed, 2000):

- Fatty alcohols: cosanol, tricosanol, tetracosanol, pentacosanol, hexacosanol, octacosanol, triacontanol and dotriacontanol.
- Hydrocarbons: hexadecane, octadecane, eicosane, docosane, tricosane, tetracosane, pentacosane and hexacosane.
- Sterols: cholesterol, campesterol, stigmasterol and α-spinasterol.

Fatty acids: myristic (3.68 %), pentadecanoic (15:0) (1.44 %), palmitic (30.40 %) margaric (17:0) (32.16 %), stearic (3.84 %), oleic (15.90 %), and linoleic (12.58 %) acids. The plant contains the flavonoids diosmetin, taxifolin, kaempferol, myricetin, and apigenin together with gallic acid, methyl gallate, flavan-3-ol gallate and gallocatechin 3-gallate (Ahmed, 2000). The species was also reported to contain terpenoides, coumarins, flavonoides and saponins (Rizk *et al.*, 1986a), and has an anti-inflammatory activity (Rizk *et al.*, 1985c). The coumarins (scopoletin **(270)** and umbelliferone) were detected in the roots of plants collected from Saudi Arabia (Khalil *et al.*, 1981).

1.2. ***Acacia nilotica*** (L.) Delile, Descr. Egypte, Hist. Nat. 79 (1814). Subsp. *indica*.
syn. *Mimosa nilotica* L., Sp. Pl., ed. 1, 521 (1753).

Sunt (Ar.), Garadh (Ar.) for fruit

Large trees reaching up to 5 m high. Leaves bipinnate of 5-6 pairs of leaflets. Inflorescences terminal and axillary, capitate, of yellow flowers. Flowers minute with exerted anthers, sweetly-scented. Fruit schizocarpic, lomentum of varying lengths, sometimes exceeding 15 cm, beaded, of up to 15 mericarps.

Habitat and Distribution

Exotic tree grown in Doha and many towns as an avenue and park trees; also planted in many sites for shade.

A. nilotica subsp. *indica* is the most widely used taxon in India and is also a widely planted exotic, as providing valuable fodder sources around Shinyanga province of Tanzania, though other subspecies of *A. nilotica* are indigenous there. It was introduced in the early part of this century as a fodder and shade tree on the treeless grasslands of central western Queensland, Australia. It proved very successful while sheep were managed there, but with the change over to cattle grazing, it became a weed, spreading along drainage lines and forming dense thickets. Feeding trials of its pods showed the reason for its spread, where 81 % of the seed ingested by cattle was recovered in the dung while less than 1 % was recovered from the sheep (Harvey, 1981; Fagg and Stewart, 1994).

Roasted seeds of *A. nilotica* are consumed in the Sahel (Von Maydell, 1986; Fagg and Stewart, 1994).

Constituents

The nutritive value of babul (*A. nilotica*) seeds and their evaluation as livestock feed have been reported. The proximate composition of the seeds is shown in Table 134. The nitrogen-free extract is slightly higher than that of cotton seed cake. The amino acids concentrations of kernels are similar to those of peanut protein. Calcium and sodium contents are low (Kumaresan *et al.*, 1984).

The seeds of Indian babul (*A. nilotica*; syn. *arabica* subsp. *indica*) contained 5.6 % oil, 19.6 % protein and 15.9 % crude fiber.

Table 134. Proximate analysis of seeds of *A. nilotica*[*]

Description	Kernels	Hulls	Whole Seeds	[**]
Dry matter %	94.5	92.5	93.9	-
Crude protein %	45.2	5.6	17.3	19.6
Oil content %	11.5	0.4	3.5	5.2
Crude fiber %	2.5	23.2	16.6	15.9
Ash content %	5.4	3.1	4.0	3.7

[*] Kumaresan *et al.* (1984); [**] Devi *et al.* (1979).

The amino acid composition of the seeds of *A. nilotica*, growing in India, is shown in Table 131. *A. nilotica* was reported to contain relatively high free amino acids (Kadam, 2000).

The free and combined sugars in the different parts of *A. nilotica*, growing in Egypt are shown in Table 135 (El-Sissi *et al.*, 1965).

Table 135. The sugars of *A. nilotica*

Plant part	Free sugars	Combined Sugars
Deseeded pods	Glucose	Galactose, glucose, arabinose, traces of xylose and rhamnose
Seeds	Sucrose and raffinose	Galactose, glucose, fructose and xylose
Bark	Sucrose	Glucose and arabinose

The gum that the tree exudes freely during March and April contains 50.43 % pentosan and 21.85 % galactan and yielded arabinose and galactose and traces of rhamnose on hydrolysis (Rizk and Al-Nowaihi, 1986).

The free-proline content in the leaves of *A. nilotica*, growing in India, has been reported (Bagchi and Singh, 1994).

The fatty acid composition of babul (*A. nilotica*) seed oil is shown in Table 136 (Devi *et al.*, 1979).

Table 136. Fatty acid composition (wt %) of babul seed oil

Fatty acids	*A. nilotica* (India)	*A. arabica* (Sudan)
16:0	15.2	20.8
18:0	8.4	-
18:1	26.3	42.0
18:2	48.7	36.0
20:0	1.4	1.2

The seeds of *A. nilotica* contained two flavonol glycosides *viz.* 5-hydroxy-7,4'-dimethoxy-8-isoprenylflavone-3-*O*-D-xylopyranoside and 5,7,3',4'-tetrahydroxy-6,8,2'-trimethoxyflavone-3-*O*-α-L-rhamnopyranosyl-(1→2)-*O*-β-D-glucopyranoside (Chauhan *et al.*, 2000).

The fruits and bark of *A. nilotica* subsp. *nilotica*, *tomentosa* and *astringens* showed high molluscicidal activity against snail species *Bulinus truncatus* and *Biomphaloria pfeifferi*. This was mainly to flavanol derivatives, isolated from tannin extracts and characterised as (-) epigallocatechin-7-gallate and (-) epigallocatechin-5,7-digallate (Ayoub, 1985)

The pods of *A. nilotica*, collected in India, contained Zn, 19.78 ppm; Mn, 20.0 ppm and Fe, 15.9 mg/100 g (Desai *et al.*, 1984).

The different parts of the plant are rich in tannins and have been evaluated as a source of tanning material. The deseeded pods, seeds, bark and wood of *A. nilotica*, from Egypt, contained 34.95 %, 6.61 %, 27.11 % and 6.35 % tannins respectively (Rizk and Al-Nowaihi, 1989). Pods of *A. nilotica* subsp. *nilotica* have been used for tanning in Egypt for the last 6000 years and pods of *A. nilotica* subsp. *astringens* are traditionally used in West Africa in Ghana and Nigeria (Fagg and Stewart, 1994). Deseeded pods of *A. nilotica* subsp. *tomentosa* (Benth.) Brenan and subsp. *nilotica* can reach up to 60 % tannin levels (Imperial Institute, 1913). Several other phenolics have been identified from the different parts of *A. nilotica* from Egypt (Rizk and Al-Nowahi, 1989). The phenolics of *A. nilotica*, from Ethiopia, amounted to 50 % dry weight (Reed *et al.*, 1985).

A. nilotica is one of the few *Acacia* species planted for timber, in both Sudan and the Indian subcontinent. Its timber from the Nile forests had been harvested since the time of Pharaohs, and is managed at present on a 20-30 year rotation producing termite-resistant logs especially suitable for railways sleepers (Fagg and Stewart, 1994). *A. nilotica* furnishes a valuable wood for house-beams, furniture and also in boat construction (Adewoye and Rao, 1977). The wood is hard, heavy, durable, fine-textured and resistant to rot. The termites and borers and is useful for fencing, local building and is a good fuel (Rizk and Al-Nowaihi, 1989). Hussain (1989) determined the total biomass for the estimation of fuel wood from the green form of *A. nilotica*, using fine growth models. Out of these, allometric models gave better results.

Table 139. Chemical scores of essential amino acids of some legumes[a]

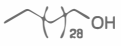
Legume	Amino acids							Limiting amino acid	
	Thr	Val	Met + Cys	Ile	Leu	Phe + Tyr	Lys	first	second
Mesquit (*Prosopis* spp.[b])	55	76	71	75	90	105	71	Thr	Met + Cys, Lys
Djenkol bean (*Pithecellobium lobatum*)									
immature	40	36	80	32	31	65	45	Leu	Ile
mature	48	46	111	40	38	88	58	Leu	Ile
Tamarind (*Tamarindus indica*)	80	98	100	125	121	161	138	Thr	Val
Soybean[d] (*Glycine max*)	96	97	74	114	110	133	117	Met + Cys	Thr, Val
Winged bean[c] (*Psophocarpus tetragonolobus*)	107	99	79	122	128	148	147	Met + Cys	Val
Peanut[d] (*Arachis hypogaea*)	65	84	68	84	91	146	65	Lys, Thr	Met + Cys
Cowpea[d] (*Vigna* spp.)	90	91	64	96	100	128	126	Met + Cys	Thr, Val
Chickpea[d] (*Cicer arientium*)	94	92	63	111	106	142	126	Met + Cys	Val
Dry bean[d] (*Phaseolus vulgaris*)	99	93	54	105	108	127	132	Met + Cys	Val
Broad bean[d] (*Vicia faba*)	84	89	44	100	101	124	119	Met + Cys	Thr

[a] Calculated according to the provisional amino acid scoring pattern (FAO/WHO, 1973). The overall chemical score for the legume is the lowest score for any of the essential amino acids. [b] Calculated from the average amino acid values of 13 *Prosopis* accessions listed in Table 138.

with petroleum ether for 2 hours, were described as "dark green, medium soft" by Kurtz (1958), who estimated the amount of wax present to be 5.7 mg dm^{-2} of total leaf area. Similar amounts of epicuticular wax were present on honey mesquite (*P. glandulosa*) leaves growing in Texas (Mayeux and Jordan, 1984). Epicuticular wax on leaves of field-grown honey mesquite trees consisted of 35 % esters, 32 % alkanes, 25 % free fatty alcohols and 7 % free fatty acids. Aldehydes were present in very low concentrations. The number of carbon atoms (C_n) of alkanes ranged from 25 to 31, with a maximum (57 %) at 29. Esters consisted of fatty acids with C_n of 16,18 and 20, with most (70 %) at 18 and fatty alcohols with C_n of 24-32. The C_n of free fatty alcohols and free fatty acids also ranged from 24 to 32. Only primary alcohols were present (Mayeux and Wilkinson, 1990). The seed oil of *P. spicigera* amounted to 4.5 % and contained the following fatty acids: palmitic (17.18 %), stearic (1.85 %), oleic (39.32 %) and linoleic (41.65 %) (Rao and Nigam, 1976). The unsaponified matter of the oil contained β-sitosterol.

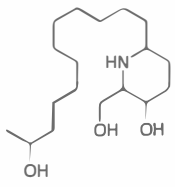
The seed oil of *P. africana* contained high proportions of linoleic and oleic acids as well as palmitic and linolenic acids (Balogun and Fetuga, 1985; Ezeagu *et al.*, 1998). The fatty acids identified in seeds of *P. africana* (both unfermented and fermented product "okpehe") were linoleic, oleic, stearic and palmitic acids. Oleic acid was present in large proportion as free fatty acid and linoleic acid in appreciable amounts in the fermented sample (Sanni *et al.*, 1993). Comparative chemical study of *P. caldenia* and *P. flexuosa* var. *fruticosa* showed that species grown in soils with high nutrient content contained higher long chain hydrocarbons. Those species from soils with a deficit in nutrients contained high β-diketone concentration (Frontera *et al.*, 1997).

Oleanolic acid, ursolic acid, a series of higher aliphatic alcohols, β-sitosterol, glycosides of campesterol, stigmasterol and β-sitosterol, prosopol (triacontanol, **(1006)**), prosopenol and pinitol (3-*O*-methylinositol) have been identified from *P. glandulosa* (Zirvi *et al.*, 1977; Abbas and Mison, 1983; Ahmed and Razaq, 1986).

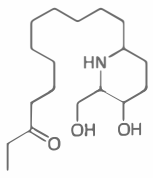


1006 Triacontanol

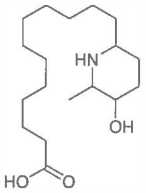
Alkaloids (mainly of the piperidine type) have been identified from the different parts (leaves, stems, bark, roots) of several *Prosopis* species e.g. prosopine **(1007)**, prosopinine **(1008)**, prosophylline from *P. africana*; cassine, *N*-methylcassine from *P. alpataco*, *P. ruscifolia*, *P. sericantha* and *P. vinalillo* and spicigerine (**1009**) from *P. spicigera* (Rizk and Al-Nowaihi, 1989). The flowers of *P. glandulosa* contained 0.388 % alkaloids (Ahmed and Razaq, 1986).



1007 Prosopine

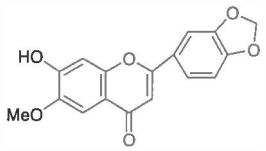


1008 Prosopinine

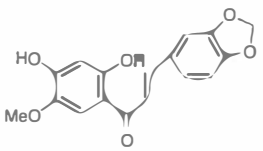


1009 Spicigerine

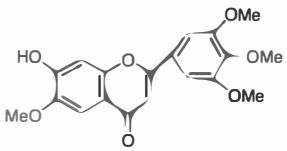
Several flavonoids (including both *O* and *C*-glycosides) have been identified from *Prosopis* species e.g. quercetin 3-methylether from *P. chilensis*; vitexin, isovitexin and rutin from *P. kuntzei*, *P. strombulifera* and *P. torquata*; rutin from *P. stephaniana*; luteolin from *P. flexuosa*, *P. spicigera*, *P. strombulifera* and *P. vinalillo* (Rizk and Al-Nowaihi, 1989) and prosogerins A, B, D and E (**1010-1013**) from *P. spicigera* (Bhardwaj *et al.*, 1978, 1979; Rizk and Al-Nowaihi, 1989). Young *et al.* (1986) reported that (2*R*,3*S*)-2,3-*trans*-3',4',7,8-tetrahydroxyflavan-3-ol [(+)-mesquitol), the predominant metabolite in the heartwood of *P. glandulosa*], represents a putative precursor of a variety of oligomers, including conventional [4,6]- and [4,8]-biflavan-3-ols, a [1,6]-1,3-diarylpropylflavan-3-ol, [5,6]- and atropisomeric [5,8]-biphenyl-type biflavan-3-ols, and [5,6:5,8]*m*-terphenyl-type triflavan-3-ols. Other participants in these condensations are mainly (±) catechin, and also the flavan-3,4-diol analogue of (+) mesquitol.



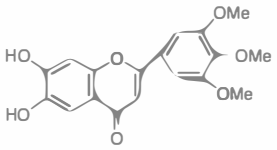
1010 Prosogerin A



1011 Prosogerin B

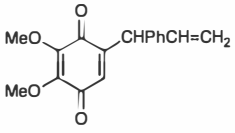


1012 Prosogerin D

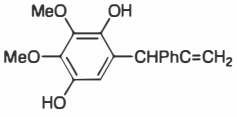


1013 Prosogerin E

The heartwood of *P. kuntzei* contained 3,4-dimethyldalbergione (**1014**) and a related quinol (**1015**). *P. stephaniana* contained tannins of gallotannin nature with a percentage of 18.55 (Rizk and Al-Nowaihi, 1989).



1014 3,4-Dimethyldalbergione



1015

Sharma and Ogra (1990) studied the efficiency of khejri (*P. cineraria*) leaves for Barbari kids as a sole growth ration and added advantage of supplementary feeding of concentrate. The salient findings indicated that though khejri leaves can be used as a sole feed for kids during their active growth (3-9 months age), the supplementation of concentrate at 1 % of body weight significantly improves the efficiency of nutrient utilization for growth and economic returns. The effect of feeding khejri leaves upon parotid glands and its trichloroacetic acid (TCA) soluble proteins in sheep has been studied by Vaithiyanathan *et al.* (1994). Sheep fed with untreated khejri leaves (containing approximately 10 % tannins), showed marked

increase in the weight of parotid glands. The apparent hypertrophy of the glands may be due to the presence of higher amount of TCA-soluble proteins. Animals fed with khejri leaves treated with polyethylene glycol-4000 (1.5 % w/w) (PEG-4000 annuls the deleterious effects of tannins) did not show such effects. Upadhyaya (1985) also reported edema in the inframandibular region of sheep maintained solely on khejri leaves. Animals receiving untreated khejri leaves lost weight and had negative nitrogen balance. This implied that the defense mechanism was inadequate to cope with high amount of tannins in the leaves.

Growing season changes and concentrations of N, P, K, S, Ca, Mg, Zn, Cu, Mn, Fe, Cl, Na and B in tamarind (*P. tamarugo*) leaves growing under natural conditions in Northern Chile, were in general similar to those reported for other perennial species inspite of the high concentration of ions in the soil. This suggested high absorption selectivity in tamarind tree (Munoz S. *et al*., 1978).

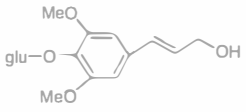
Phenolics (total phenols and *o*-dihydroxyphenols) contents of *Lobopteromyia*-induced gall and non-infected tissues of *P. cineraria* and change in the activity of enzymes have been studied by Ramani and Kant (1989). Total phenolics were higher in the normal compared to gall tissues both *in vitro* and *in vivo*. Hypophenolicity in the gall tissues was correlated to high activities of peroxidase and polyphenol oxidase. High activity of phenyl ammonia lyase and low activity of tyrosine ammonia lyase was recorded in the gall tissues both *in vitro* and *in vivo* conditions. Muneoz *et al*. (1998) stated that acid phosphatase activity increased in *P. chilensis* seedlings under both drought and salinity stress.

Some species of *Prosopis* (e.g. *P. spicigera*) are used in Indian indigenous system of medicine as a remedy of rheumatism and scorpion sting. Women eat the flowers, powdered and mixed with sugar during pregnancy as a safeguard against miscarriage. Its ash when rubbed over skin was a hair remover (Chopra *et al*., 1956). In Sudan, pods of *P. africana* are used as a fish poison (Wickens, 1980).

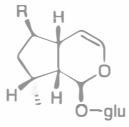
In U.S.A., Matheson and Travis (1998) reported that although *P. velutina* is not as widely distributed as some other allergenic species, its pollen could induce serious pollinosis in areas where it is localized. They isolated and characterized a peptidase from pollen with trypsin-like specifity (peptidase IImes).

Prosopis wood provides very good quality of firewood and charcoal, with a high calorific value. The primary modern use of *Prosopis* wood is as fuel for cooking and heating; commonly used species in Argentina are *P. affinis*, *P. alba*, *P. caldenia*, *P. chilensis*, *P. kuntzei*, *P. nigra*, *P. ruscifolia* and *P. torquata* (D'Antonio and Solbrig, 1977). The high quality of *Prosopis* wood for fuel has led to over-exploitation of natural stands in many areas. In Argentina, this was particularly severe during the two World Wars when the wood was used as a coal substitute (D'Antonio and Solbrig, 1977; Fagg and Stewart, 1994). *P. cineraria* also provides excellent fuel wood and charcoal, the latter with a calorific value of 20,000 $kJkg^{-1}$ (NAS, 1980), and is a very important fuel resource throughout its native range e.g. Rajasthan (Mann and Saxena, 1980) and Oman (Brown, 1992). In the southwestern United States, mesquite (*P. glandulosa* var. *glandulosa*) is used as a barbecue fuel and to make flooring, furniture and handicrafts (El-Fadl *et al*., 1989).

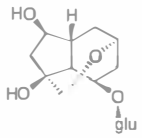
Prosopis timber is typically very hard and durable, with high tensile strength, and is widely used for high quality furniture manufacture in South America, notably Argentina and Paraguay. The generally crooked tree form precludes the production of large timber, though it is likely



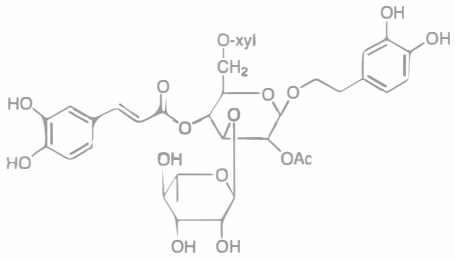
1039 Syringin



1040 Ajugol; R = OH
1041 Gluroside; R = H



1042 Phelypaeside



1043 Pheliposide

XXV. PLANTAGINACEAE Durande

1. PLANTAGO L.

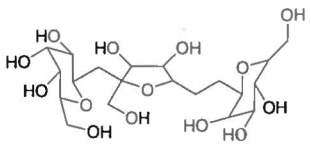
The seeds of plantain (*Plantago*) are well known as an excellent source of acid polysaccharides (Ahmed and Hammouda, 1965; Rizk, 1986), the mucilage of which appeared to be mixtures of at least two polysaccharides differing in their uronic acid content. The seeds of the Indian wheat (*P. fastigrata*) contained 19 % of mucilage, which is a mixture of acids varying from 8-17 pentosan molecules combined with 1 mole of D-galacturonic acid. The mucilage obtained from the seeds of *P. arenaria* consisted of D-xylose (60 %), L-arabinose (17 %), D-galactose (6 %), 2-*O*-α-D-galactopyranosyluronic acid, L-rhamnose (13 %) and an insoluble residue, which appeared to be a mixture of cellulose and lignin (Ahmed and Hammouda, 1965). The percentages of the mucilages, isolated from *P. major* with cold and hot water successively, amounted to 13.25 and 6.27 respectively. Both fractions contained D-galacturonic acid (24.0 and 6.2 %), L-arabinose (13.2 and 11.4 %), and D-xylose (61.0 and 78.0 %). D-galactose (3 %) was only detected in the hot fraction (Ahmed *et al.*, 1965b). Tomoda *et al.* (1981) isolated a mucous polysaccharide, named *Plantago*-mucilage A, from the seeds of *P. major* var. *asiatica* (*P. asiatica*) which was readily soluble in water and its solution gave an intrinsic viscosity value of 39.5. This mucilage was composed of L-arabinose, D-xylose, D-glucuronic acid, and D-galacturonic acid in the molar ratio of 4.0:10.8:3.3:0.7, and its molecular weight was estimated as ~ 1,500,000. *O*-Acetyl groups were identified in it and their content amounted to 4.8 %. The mucilage was shown to possess a main chain composed of β-1-→4 linked D-xylopyranose residues having other D-xylopyranoside chains at positions 3 and branches composed of *O*-α-(D-glucopyranosyluronic acid)-(1→3)-α-L-arabinofuranose and of *O*-α-(D-galactopyranosyluronic acid)-(1→3)-α-L-arabinofuranose at position 2 of the residual D-

xylopyranose units (Tomoda *et al.*, 1981). The *O*-acetyl groups in *Plantago*-mucilage A were located at position 2 of about one-fourth of L-arabinofuranosyl residues, about two-fifths of the terminal D-xylopyranosyl residues and about one-ninth of the non-terminal D-xylopyranosyl residues (Tomoda *et al.*, 1984).

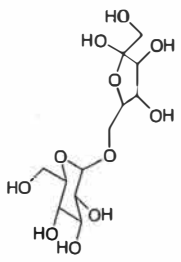
Samuelsen *et al.* (1998) isolated an arabinogalactan with anti-complement activity from the leaves of *P. major*. It had a molecular weight of 77,000-80,000 Da and consisted of arabinose (38 %), galactose (49 %), rhamnose (6 %), galacturonic acid (7 %) and protein (1.5 %) with hydroxyproline, alanine and serine as the main amino acids. Characterisation of the arabinogalactan showed that it consisted of 1,3-linked galactan chains with 1,6-linked galactan side chains attached to position 6. The side chains are further branched in position 3 with 1,3-linked galactose residues which had 1,6-linked galactose attached to position 6; these 1,3- and 1,6- linked galactose chains altogether probably form a network. Terminal and 1,5-linked arabinose in furanose form are attached to the galactan mainly through position 3 of the 1,6-linked galactose side chains.

The carbohydrate components of *P. asiatica* pectin included D-galacturonic acid, D-galactose, D-glucose, D-mannose, D-xylose, L-arabinose and L-rhamnose (Lebedev-Kosov, 1981).

The study of the free sugars of some plantain seeds has been reported. The trisaccharide planteose, isomer to raffinose, was isolated from the seeds of *P. major* and *P. ovata* (*P. ispaghula*). The roots of *P. major* and *P. rugelii* contained sucrose, raffinose, planteose **(1044)**, stachyose and a higher molecular weight oligosaccharide. The latter, after hydrolysis gave fructose, glucose, galactose, melibiose, planteobiose **(1045)** and manninotriose (Ahmed and Hammouda, 1965). The mono- and oligosaccharides of eight Egyptian *Plantago* species were identified as D-glucose, L-fructose, D-xylose, L-rhamnose, sucrose, planteose and planteobiose (Table 141) (Ahmed *et al.*, 1965b).



1044 Planteose



1045 Planteobiose

The mucilages obtained from the plantain seeds remained in a gel form and not a sol, a matter that make them useful as a laxative (e.g. seeds of *P. psyllium*). The seeds of *P. psyllium* and *P. ovata* are used as a laxative on a commercial scale (Rizk, 1986). The dried, ripe seeds of *P. afra* (*P. psyllium*), *P. indica* (*P. arenaria*) and *P. ovata* are used in medicine. The U.S. National Formulary includes all three species under the name "Plantago Seed". In the British Pharmaceutical Codex, the seeds of the first two species are included as Psyllium BPC while those of *P. ovata* form the source of Isphagula Husk BPC (Trease and Evans, 1987).

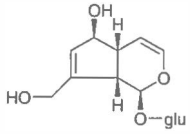
Table 141. Mono- and oligosaccharides and percentage of aucubin of seeds of Some Egyptian *Plantago* species*

Species	Pl	Pb	Su	Gl	Fr	Xy	Rh	Un	Aucubin %
1. *P. albicans*	+	+	+	+	+	+	+		0.56
2. *P. coronopus*	+	+	+	+	+		+		0.10
3. *P. crassifolia*	+		+	+	+		+		0.11
4. *P. crypsoides*	+	+	+	+	+		+		0.17
5. *P. cylindrica*	+	+	+			+	+		0.14
6. *P. major*	+		+	+	+	+	+		0.37
7. *P. notata*	+		+	+	+		+		0.62
8. *P. ovata*	+		+				+	+	0.21

*Pl, planetose; Pb, planteobiose; Su, sucrose; Gl, D-glucose; Fr, L-fructose; Xy, D-xylose; Rh, L-rhamnose; Un, unidentified.

The seeds of *P. psyllium* and *P. arenaria* are known commercially as Spanish or French psyllium, while those of *P. ovata* are known as blonde psyllium, isphagula, spogel seeds or Indian plantago seeds. All the seeds contain mucilage in the epidermis of the testa (Trease and Evans, 1987).

Aucubin **(1046)**, an iridoid glucoside, has been early reported to be the active principle of *Plantago* species, and was considered for many years in the "French Pharmacopoeia" as a general panacea (Rizk, 1986). Koedam (1977) presented a review on the history and the use of *Plantago* as one of the oldest medicinal plants. Microbial investigations on *Plantago* preparations showed that a product formed by hydrolysis of aucubin was responsible for an antibacterial effect (Koedam, 1977). Aucubin, which had low toxicity, appeared to be an antidote for fatal mushroom poisoning caused by *Amanita phalloides* (Chang *et al.*, 1984b).



1046 Aucubin

The structure-complement activation relationship of *Plantago*-mucilage A, a partially *O*-acetylated glucuronoarabinoxylan isolated from the seeds of *P. asiatica* was studied by Yamada *et. al.* (1986). They found that the anti-complementary activity was markedly enhanced when the polysaccharide was deacetylated, while carboxyl-reduction and partial hydrolysis had little effect. The deacetylated product of *Plantago*-mucilage A, the main mucilage present in the seeds of *P. asiatica*, also showed remarkable hypoglycemic activity (Tomoda *et al.*, 1987). The results obtained by Kim *et al.* (1996) demonstrated that *Plantago*-mucilage A markedly enhanced both humoral immune and allergic reaction to sheep red blood cells at concentrations, which do not affect the relative weight of the liver.

Ahmed *et al.* (1965b) isolated mucilages from the seeds of eight Egyptian *Plantago* species by extraction with successive cold and hot water treatments. The percentages, physical properties, as well as the sugar components of the different mucilage fractions are shown in Tables 142 and 143.

Table 142. Percentages, specific viscosities, ash, insoluble residues (after hydrolysis) and final $(\alpha)_D$ of soluble hydrolysates of mucilages of seeds of some Egyptian *Plantago* species[a]

Species	Mucilage Fraction	%	ηsp	Ash %	Insoluble residue %	$^{(\alpha)}D^{25}$
1. *P. albicans*	cold	26.82	1.015	2.61	2.82	52.3
	hot	2.40	0.459	2.79	3.14	38.1
2. *P. coronopus*	cold	16.52	24.870	2.42	2.06	53.2
	hot	1.30	0.024	2.77	2.20	42.5
3. *P. crassifolia*	cold	9.95	0.304	2.34	3.42	47.1
	hot	13.66	0.182	1.95	2.83	34.7
4. *P. crypsoides*	cold	14.73	5.375	3.12	2.31	45.1
	hot	10.04	0.062	2.84	2.14	36.4
5. *P. cylindrica*	cold	20.42	0.802	2.90	2.78	56.1
	hot	2.55	0.134	2.64	2.38	41.6
6. *P. major*	cold	13.25	17.496	3.24	2.36	51.4
	hot	6.27	0.344	2.75	2.14	35.3
7. *P. notata*	cold	9.62	1.347	2.17	2.07	36.3
	hot	4.05	0.319	2.38	2.70	39.5
8. *P. ovata*	cold	22.34	1.009	2.35	2.63	48.5
	hot	3.24	0.141	2.44	2.92	37.4

[a] Mean values of three determinations.

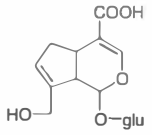
Table 143. Percentages of different sugar components of the mucilage fractions of seeds of some Egyptian *Plantago* species[a]

Species	Mucilage Fraction	GaU	Ga	Gl	Ar	Xy	Rh
1. *P. albicans*	cold	27.2	6.5		9.3	44.8	10.4
	hot	9.3	4.0		10.1	76.0	
2. *P. coronopus*	cold	24.3	6.9		15.2	41.2	13.6
	hot	7.6	4.5	3.1	13.8	70.1	
3. *P. crassifolia*	cold	20.2			14.6	52.6	13.5
	hot	6.4		4.3	12.5	62.1	16.0
4. *P. cylindrica*	cold	22.4	5.1		18.1	52.7	
	hot	8.6			16.5	73.0	
5. *P. crypsoides*	cold	15.5	6.2		14.0	55.4	10.3
	hot	4.0	3.4	2.1	12.5	63.2	13.6
6. *P. major*	cold	24.0			13.2	61.0	
	hot	6.2		3.0	11.4	78.0	
7. *P. notata*	cold	21.5				64.0	13.1
	hot	6.8	4.0		12.6	75.1	
8. *P. ovata*	cold	20.4			18.0	51.4	11.3
	hot	5.8			13.3	70.1	

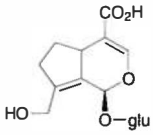
[a] GaU, D-galacturonic acid; Ga, D-galactose; Gl, D-glucose; Ar, L-arabinose; Xy, D-xylose; Rh, L-rhamnose.

Pendse and Sikhibhnshan (1934) stated that the highly important indigenous medicinal plant *P. ovata* known as isphagol in Hindustane, was used chiefly in chronic diarrhoea and dysentry, especially in the particular form of intestinal irritation known as hill diarrhoea. The diuretic effect of the seeds of *P. major* L. var. *asiatica* has been also reported (Pin and Soung, 1936). The choleretic activity of the iridoid geniposidic acid **(1047)** from *P. asiatica* has been reported (Tsumura Juntendo Co., 1981). Geniposidic acid also possessed an antioxidant activity (Toda *et al.*, 1985).

Several iridoids have been identified in *Plantago* species. Ronsted *et al.* (2000) investigated 21 *Plantago* species with regard to their content of iridoid glucosides and caffoeyl phenylethanoid glycosides. Arborescoside and arborescosidic acid **(1048)**, both of the uncommon type 8,9-double bond, were present in several species. Deoxyloganic acid, caryptoside and rhamnioside were also isolated from the genus. Examples of iridoids, isolated from *Plantago* species (except species growing in Qatar which are mentioned in detail) are shown in Table 144.



1047 Geniposidic acid



1048 Arborescosidic acid

Table 144. Iridoids of some *Plantago* species

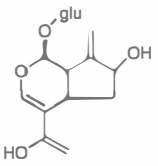
Species	Iridoids	References
1. *P. albicans*	Aucubin	Ahmed *et al.* (1965b)
2. *P. alpina*	Aucubin, gardoside **(1049)**, geniposidic acid, 8-epiloganic acid, mussaenosidic acid **(1050)**, monomelittoside **(1051)**, melittoside **(1052)**, and alpinoside and 10-*O*-acetyl-geniposidic acid	Jensen *et al.* (1996)
3. *P. altissima*	Aucubin, gardoside, catalpol, 8-epiloganic acid, hookerioside **(1053)** and desacetylhookerioside	Jensen *et al.* (1996)
4. *P. arenaria*	Aucubin, plantarenaloside **(1054)** and melittoside	Popov (1978); Popov *et al.* (1981); Andrzejewska-Golec and Swiatek (1984)
5. *P. asiatica*	Aucubin, 3,4-dihydroaucubin, 6'-*O*-glucosylaucubin, catalpol and geniposidic acid	Lebedev-Kosov (1980); Oshio and Inouye (1982); Toda *et al.* (1985); Cheng *et al.* (1992)
6. *P. cornuti*	Aucubin and 10-hydroxymajoroside	Handijeva *et al.* (1993)
7. *P. crassifolia*	Aucubin	Ahmed *et al.* (1965b)

Table 144. Cont.

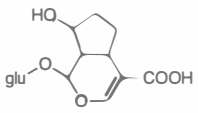
Species	Iridoids	References
8. *P. crypsoides*	Aucubin	Ahmed *et al.* (1965b)
9. *P. cylindrica*	Aucubin	Ahmed *et al.* (1965b)
10. *P. depressa*	Aucubin	Cheng *et al.* (1992)
11. *P. hookeriana*	Aucubin, catalpol, 10-benzoylcatalpol **(1055)**, 8-epiloganic acid and hookerioside	Damtoft *et al.* (1994)
12. *P. lagopus*	Aucubin, catalpol, 10-benzoylcatalpol, harpagoside and 6-α-hydroxygeniposide **(1056)**	Velázues-Fiz *et al.* (2000a)
13. *P. major*	Aucubin, catalpol, gardoside, geniposidic acid, majoroside **(1057)** and melittoside	Lebedev-Kosov (1980); Long *et al.* (1995); Murai *et al.* (1996)
14. *P. major* var. *asiatica*	Aucubin	Ahmed and Hammouda (1965)
15. *P. major* var. *japonica*	Aucubin and geniposidic acid	Endo *et al.* (1981)
16. *P. media*	Aucubin, melittoside and plantarenaloside	Swiatek *et al.* (1981); Andrzejewska-Golec and Swiatek (1984); Long *et al.* (1995)
17. *P. myosuros*	Aucubin	Franczyk *et al.* (1998)
18. *P. notata*	Aucubin	Ahmed *et al.* (1965b)
19. *P. sempervirens*	Bartsioside and plantarenaloside	Andrzejewska-Golec *et al.* (1993)
20. *P. subulata*	6-Deoxymelittoside	Ronsted *et al.* (2000)

Plantamajoside (**1058**), a phenylpropanoid glycoside, was isolated from *P. major* subsp. *major* and its structure was deduced to be 3,4-dihydroxy-β-phenylethyl-*O*-β-D-glucopyranosyl (1→3)-4-*O*-caffeoyl-β-D-glucopyranoside (Ravn and Brimer, 1988). The same compound, designated as compound A, was found earlier as a chemotaxonomic marker in two subspecies of *P. major* subsp. *major* and subsp. *pleiosperma* (Mølgaard *et al.*, 1980). *P. major* was screened for polymorphism of this compound in relation to protection against slugs (Mølgaard, 1986). Plantamajoside has been found to possess antibacterial activity (Ravn and Brimer, 1988). Several other phenylethanoid glycosides were also isolated from *Plantago* species. Verbascoside (aceteoside) (β-3',4'-dihydroxylphenyl)-ethyl-*O*-α-L-rhamnopyranosyl-(1→3)-β-D-(4-*O*-caffeoyl)-glucopyranoside) was identified from *P. altissima* (Jensen *et al.*, 1996), *P. hookeriana* (Damtoft *et al.*, 1994) and *P. myosuros* (Franczyk *et al.*, 1998). The former species contained, in addition, verbascoside (Jensen *et al.*, 1996). The following six phenylethanoid glycosides

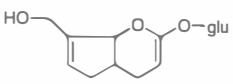
were isolated from *P. depressa*: cistanoside F, β-hydroxyacetoside, campenoside I, aceteoside, orobanchoside (**1059**) and β-oxoaceteoside. The structure of the latter was deduced as β-oxo-β-(3,4-dihydroxyphenyl)-ethyl-*O*-α-L-rhamnopyranosyl-(1→3)-β-D-(4-*O*-caffeoyl) glucopyranoside (Nishibe *et al.*, 1993). The caffeoyl phenylethanoid glycoside, plantallosidc and verbascosidc were isolated from *P. myosuros*. Plantalloside is a verbascoside analogous with α-β-allopyranosyl moiety (Franzyk *et al.*, 1998).



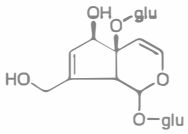
1049 Gardoside



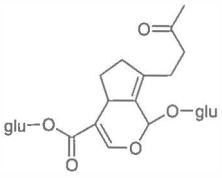
1050 Mussaenosidic acid



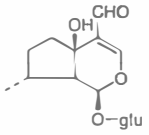
1051 Monomelittoside



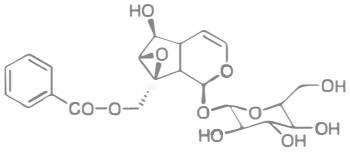
1052 Melittoside



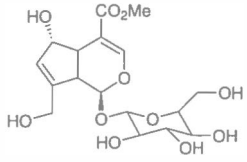
1053 Hookerioside



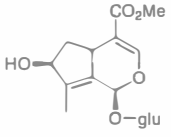
1054 Plantarenaloside



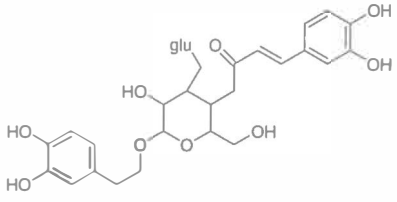
1055 10-Benzoylcatalpol



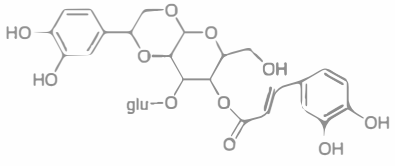
1056 6α-Hydroxy-geniposide



1057 Majoroside



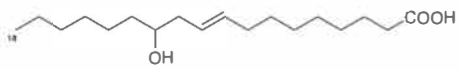
1058 Plantamajoside



1059 Orobanchoside (Crenatoside)

The study of the lipids of plantain seeds has been a subject of interest to several investigators (Ahmed *et al.*, 1968; Kuiper and Kuiper, 1978; Swiatak *et al.*, 1980; Rizk, 1986; Stankovic *et al.*, 1991). Ahmed *et al.* (1968) reported that the fatty acids revealed certain differences in the seeds of eight different *Plantago* species (*P. albicans*, *P. coronopus*, *P. crassifolia*, *P. crypsoides*,

P. cylindrica, *P. major*, *P. notata* and *P. ovata*). The unsaturated fatty acids *viz*., oleic, linoleic and linolenic, though were detected in the eight species, yet oleic acid (49.2 % of the total fatty acids in *P. cylindrica*) and linoleic acid (47.7 % of the total fatty acids in *P. ovata*) were the two major components. The study of the saturated fatty acids revealed certain qualitative differences. Palmitic and stearic acids were invariably present in all studied species, while the other acids were only encountered in a particular *Plantago* species. Myristic acid was present in five species and missing from *P. crypsoides*, *P. major* and *P. notata*. Arachidic acid was present only in *P. major*. Behenic acid was detected in four species (*P. albicans*, *P. major*, *P. notata* and *P. ovata*), while lignoceric acid was only present in *P. albicans* and *P. ovata* (Ahmed *et al*., 1968). Linoleic acid was the main fatty acid in the oils of *P. lanceolata*, *P. major* and *P. media* (56.8, 38.8 and 43.8 %), oleic acid constituted 18.3, 15.3 and 28.5 % and linolenic acid 14.5, 39 and 8.3 % of the oils of the three studied species, respectively. The content of myristic acid was least (0.04, 0.04 and 0.4 %) followed in increasing order by stearic acid content (2.8, 1.2 and 3.1 %), palmitic acid (6.8, 5.3 and 15.1 % respectively) and an unidentified substance at 0.76, 0.36 and 0.8 %. The oil of *P. lanceolata* was relatively high in saturated fatty acids and those of the other two species were high in unsaturated fatty acids (Swiatek *et al*., 1980). High content of the essential fatty acids (linoleic 53 %, linolenic 23 %) characterized the oil of *P. major* seeds collected from Belgrade (Stankovic *et al*., 1991). An isomer of ricinoleic acid (**1060**), constituted 1.5 % of the seed oil of *P. major* and was characterized as 9-hydroxy-*cis*-11-octadecenoic acid (Ahmad *et al*., 1980).



1060 Ricinoleic acid

The percentages of oil, fatty acids, and unsaponifiable matter of eight Egyptian *Plantago* species are shown in Tables 145-147 (Ahmed *et al*., 1968).

The fatty acids detected in the edible plant *P. major* were as follows: $C_{14:0}$, 1.77; $C_{16:0}$, 15.90; $C_{16:3\omega3}$, 11.00; $C_{16:2\omega6}$, 0.43; $C_{16:1\omega7}$, 1.47; $C_{16:1\omega9}$, 0.12; $C_{18:0}$, 2.12; $C_{18:3\omega3}$, 33.32; $C_{18:4\omega3}$, 2.02; $C_{18:2\omega6}$, 11.18; $C_{18:1\omega9}$, 2.32; $C_{20:0}$, 1.31; $C_{20:5\omega3}$, 1.27; $C_{20:4\omega6}$, 1.02; $C_{22:6\omega3}$, 1.47; $C_{22:1\omega9}$, 3.45 and $C_{24:0}$, 0.98 %. The lipid of the plant amounted to 0.18 %. (Guil *et al*., 1996a).

Table 145. The percentages of oil, total fatty acids (TFA) and unsaponifiabale matter of some *Plantago* species

Species	Oil	TFA	UM
1. *P. albicans*	6.86	73.55	5.09
2. *P. coronopus*	20.66	62.01	13.51
3. *P. crassifolia*	11.39	70.63	4.28
4. *P. crypsoides*	15.92	55.50	5. 14
5. *P. cylindrica*	7.44	71.72	7.48
6. *P. major*	9.43	59.02	13.34
7. *P. notata*	7.91	70.90	7.16
8. *P. ovata*	5.11	78.19	7.60

Table 146. The percentages of the component fatty acids of some *Plantago* species

Species	Olcic	Linolcic	Linolenic	Conjugated Dicnes	Total Unsat.	Satd.
1. *P. albicans*	26.0	42.0	0.8	2.1	70.9	29.1
2. *P. coronopus*	33.0	36.0	2.6	1.1	72.7	27.3
3. *P. crassifolia*	28.0	42.3	3.0	1.6	74.9	25.1
4. *P. crypsoides*	31.5	46.0	3.4	0.4	81.3	18.7
5. *P. cylindrica*	49.2	29.0	0.9	0.6	79.7	20.3
6. *P. major*	37.4	25.3	0.9	1.2	64.8	35.2
7. *P. notata*	34.1	37.8	0.4	0.9	73.2	26.8
8. *P. ovata*	38.1	47.7	1.0	0.2	87.0	13.0

Table 147. The component fatty acids of some *Plantago* species

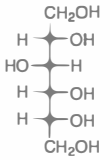
Species	14:0	16:0	18:0	18:1	18:2	18:3	20:0	22:0	24:0
1. *P. albicans*	+	+	+	+	+	+	+	+	
2. *P. coronopus*	+	+	+	+	+	+			
3. *P. crassifolia*	+	+	+	+	+	+			
4. *P. crypsoides*		+	+	+	+	+			
5. *P. cylindrica*	+	+	+	+	+	+			
6. *P. major*		+	+	+	+	+	+	+	
7. *P. notata*		+	+	+	+	+		+	
8. *P. ovata*	+	+	+	+	+	+		+	+

β-Sitosterol, stigmasterol and campesterol were identified in *P. albicans* (Ahmed *et al.*, 1968). These sterols together with cholesterol were found in the seed oil of *P. major* (Stankovic *et al.*, 1991). *P. asiatica* was found to contain β-sitosterol and β-sitosteryl-3-*O*-D-glucopyranoside (Chang *et al.*, 1981), oleanolic acid and urosolic acid (Yuan *et al.*, 1999). Ursolic acid; a selective inhibitor of cyclooxygenase-2 catalyzed prostaglandin biosynthesis, together with oleanolic acid (less active than ursolic acid) was isolated from *P. major* (Ringbom *et al.*, 1998). Oleanolic acid was identified in the leaves of *P. bismarckii* (Maldoni, 1999).

In a study of the adaptation of *Plantago* species to their specific environment, the lipid composition of the roots of six *Plantago* species (*P. coronopus*, *P. lanceolata*, *P. major* subsp. *major*, subsp. *pleiosperma*, *P. maritima* and *P. media*) and the effect of the nutritional regime (Tables 148 and 149) were studied by Kuiper and Kuiper (1978). Upon exposure to low salt conditions, *P. major* subsp. *major* and *P. maritima* maintained the level of free sterols in the roots, despite a depressed level of total sterols, and the root lipids were more saturated than under high-salt conditions. The two taxa could be distinguished from other *Plantago* species, since upon exposure of the plants to low-salt conditions the lipid composition of the roots was similarly affected: a depressed level of total lipid, a very pronounced decrease of sterol esters, an elevated level of total fatty acids, among which linolenic acid, and an increase in the degree of saturation of the fatty acids. All *Plantago* species showed a decreased level of galactolipid upon exposure to low-salt conditions except for *P. coronopus* and a decreased level of sitosterol except for *P. maritima*; the latter being compensated by an elevated level of cholesterol + tocopherol in *P. lanceolata*, *P. major* subsp. *pleiosperma* and *P. media*. The level of sulpholipid

was constant in all *Plantago* species, with the highest level observed in *P. maritima* (Kuiper and Kuiper, 1978).

The hexitol sorbitol (**1061**) was detected earlier in substantial amount in the petioles of *P. major* (Galkowski *et al.*, 1966). All species of *Plantago* investigated by Wallaart (1981); contained appreciable amounts of sorbitol in dried whole leaves; the contents varied between 0.5 % (*P. lagopus* and one sample of *P. arenaria*) and 4.1 % (*P. alpina*). The study comprised 10 species of *Plantago* representing the two subgenera *Plantago* and *Psyllium* and *Littorella uniflora*, which were investigated for the presence of hexitols. Accumulation of hexitol, thus turned out to represent a chemotaxonomic character at the family level. The studied species were: *P. alpina*, *P. carinata*, *P. coronopus*, *P. lagopus*, *P. lanceolata*, *P. major*, *P. maritima*, *P. serpentina* (syn. *P. alpina* subsp. *serpentina*), *P. arenaria* (syn. *P. indica*, *P. psyllium*), *P. sempervirens* (syn. *P. cynops*), *P. suffruticosum* [subgenus *Psyllium*] and *Littorella uniflora*.



1061 Sorbitol

In the course of the investigation carried out by Walaart (1978), a rather unique feature was observed in *P. carinata* and samples of *P. coronopus*; sorbitol proved to be accompanied by appreciable amounts of mannitol. The sorbitol content varied from 0.05 (% dry weight of leaves) in one sample of *P. coronopus* to 5.8 % in *P. major* (petiole). The two stereoisomeric hexitols, sorbitol and mannitol were detected only in *P. carinata* and *P. coronopus*. The sorbitol content of *P. maritima* reached as high as 8.9 % of the dry matter in the shoots. It dramatically decreased while the water content of the tissue rose. On the other hand, when plants were transferred to a medium containing NaCl (200 mM), the sorbitol level decreased or increased according to the severity of stress produced by the salt concentration as compared to that occurring under field conditions (Briens and Larher, 1983). The effect of salinity on the ionic balance and hexitol content of the halophyte *P. maritima* and the nonhalophytes *P. major*, *P. lanceolata* and *P. media* was studied by Kocnigshofer (1983). Acylic polyhydric alcohols (sorbitol and mannitol), the dominant soluble carbohydrates in all studied *Plantago* species increased (with one exception) in all plants under saline conditions. Ahmad *et al.* (1979) showed that the sorbitol content of *P. maritima* augmented with increasing salinity of the nutrient solutions. They observed sorbitol contents of shoots between 0.6 % (no NaCl added) and 6 % (*ca.* 2.4 % NaCl added) and discussed "the possible role of sorbitol as a compatible cytoplasmic solute" in halophytic adaptation.

Several flavonoids have been identified from plantains. In the six plantain species investigated by Lebedev-Kosov (1977) 9, 11, 12, 17, 21 and 21 flavonoid substances, divided into 5 groups were found. The flavonoid aglycons of these species consisted of 5 compounds, 3 of which were identified as apigenin, luteolin, and scutellarcin (**1062**). Highest amounts of flavonoids were found in *P. major* and *P. asiatica*. Later, Lebedev-Kosov *et al.* (1978) isolated

Plantain seeds (National Formulary, 1955) are the cleaned, dried, ripe seeds of *P. psyllium* or *P. indica* known in commerce as Spanish or French Psyllium seeds. According to the British Pharmacopoeia Codex (1963), Psyllium (seeds of *P. psyllium*), has the property of absorbing and retaining water and has therefore been used as a bulk-providing medium in the treatment of chronic constipation. Preparation of Psyllium was also used to assist the production of smooth, solid faecal mass after colostomy. Psyllium, on account of its content of mucilage, has been used as a demulcent (Rizk, 1986). *P. psyllium* in doses of ml/kg hastened the clotting process (Nikolskaya, 1954).

The cholesterol-lowering effects of psyllium have been proved (Chao *et al.*, 1993; Stoy *et al.*, 1993; Turley *et al.*, 1994; Hicks *et al.*, 1995; Kritchevsky *et al.*, 1995; Segwa *et al.*, 1998). Psyllium was reported as an effective mean of reducing colon cancer (Roberts-Anderson *et al.*, 1987; Alabaster *et al.*, 1993).

1.3. ***Plantago ciliata*** Desf., Fl. Allant. 1:137, tab.39, f.3 (1769).

Widhaina (Ar.)

Small hairy annual herb not exceeding 5 cm high, fawn-coloured with a tap root reaching up to 6 cm long. Stemless with basal leaves covered with long silky hairs. Leaves spatulate, tapering at the base and apiculate, sessile, 2.5-3 cm long and 0.8-1 cm across. Inflorescences on long peduncles 3-15 per plant, 1-2 cm long, hairy, equal to or shorter than leafy plant. Spikes hairy, rugose, cylindrical, 1-2 cm long, about 1 dozen ovate fruits each 2 mm long. Fruits April-May.

Habitat and Distribution

Common on sandy soils in central Qatar (Ash Shahaneya, Al Suwairya, Rodat Rashid, road to Um Bab).

Constituents

The proximate analysis, amino acids and minerals of *P ciliata*, growing in Qatar, are shown in Tables 175, 176 and 178 (Al-Easa, 2002a,b,d).

Investigation of the plant, growing in Qatar, revealed the presence of alkaloids and sterols (and/or terpenes) (Rizk, 1982).

1.4. *Plantago coronopus* L., Sp. Pl., ed. 1, 115 (1753).

Rubla, Widhaina (Ar.)

Small annual or biennial stemless herb up to 10 cm high with a rosette of linear-lanceolate leaves. Inflorescences dense cylindrical spikes with peduncles arising from base and terminating in dense rather long spikes. Spikes cylindrical representing the length of the plant. Fruit capsules. Flowers and fruits in April.

Habitat and Distribution

Appearing after the initial rains in depressions, water catchment areas, wet sites, near farms, in wadis with hard compact soils, in northern and central Qatar. Rare in Qatar. Reported at Dukhan.

Constituents

Earlier investigation of the seeds yielded 44.2 % mucus and 4.6 % of a water-soluble gum which showed the reaction of pentoses and was converted by nitric acid to mucic acid (Emmanuel and Papavasilion, 1920). *P. coronopus* seeds, growing in Egypt, contain about 18 % mucilage; the sugar components of which are shown in Table 143. The same seeds also contain aucubin (0.10 %) (Ahmed *et al.*, 1965b). The seed contains 20.66 % oil; the chemical composition of which is shown in Tables 145-147.

The seeds contain alkaloids (0.02 %); from which plantagonine and base "A" have been identified (Ahmed *et al.*, 1965a). The entire plant exclusive of the seeds yielded plantagenic acid $C_9H_{12}O_2$ (m.p. 210°C), coronopic acid $C_{54}H_{66}O_2$ (m.p. 281-282°C) and a small amount of an essential oil (Emmanuel and Papavasilion, 1920).

Of the seven samples of *P. coronopus*, investigated by Wallaart (1981), the two stereoisomeric hexitols sorbitol and mannitol were detected in seven and six samples respectively. The sorbitol content of the leaves varied between 0.05 and 1.7 % and the mannitol content between 0 and 0.53 %. Two samples contained more mannitol than sorbitol. Gorham *et al.* (1981b) stated that sorbitol increased when *P. coronopus* was subjected to NaCl stress.

The level of total lipids, total fatty acids, sterols, galactolipids, sulpholipids and linolenic acid in roots of *P. coronopus*, as affected by mineral nutrition are shown in Tables 148 and 149 (Kuiper and Kuiper, 1978).

1.5. ***Plantago lanceolata*** L., Sp. Pl., ed. 1, 113 (1753).

Lisan al hamal (Ar.)

Perennial herb with lanceolate 3-5-nerved leaves. Inflorescences long pedunculate, spicate; spikes cylindrical, comparatively long, up to 6 cm long. Fruit an oblong capsule.

Habitat and Distribution

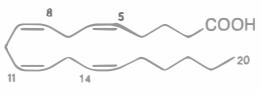
Rare in Qatar. Recorded as a weed in cultivated and arable fields.

Constituents

Earlier investigation of ribgrass (*P. lanceolata*) seeds revealed that they contained 5 % polysaccharide, which consisted of 15.2 % uronic acid, 72 % pentosan and 11 % methyl pentosan. Hydrolysis of the polysaccharide with 3 % oxalic acid, gave D-xylose, a small amount of D-galactose and a degraded acid, which contained D-galacturonic acid, L-arabinose, D-xylose and D-galactose (Mullan and Percival, 1941). The neutral sugars of the mucilage from ribwort (*P. lanceolata*) leaves were L-rhamnose 7, L-arabinose 32, D-mannose 4, D-galactose 44, and D-glucose 9 %, in addition to trace amounts of D-xylose and L-fucose. The uronic acid content of the crude mucilage was 41.7 %. The crude mucilage from the leaves consisted of ≥ 4 polysaccharides (Braeutigam and Franz, 1985a). The water soluble crude polysaccharide from the leaves was composed of L-arabinose (20 %), D-galactose (28 %), D-glucose (6 %), D-mannose (2 %), L-rhamnose (4 %), D-galacturonic acid (31 %), D-glucuronic acid (7 %) and minor amounts of L-fucose and D-xylose (Braeutigam and Franz, 1985b).

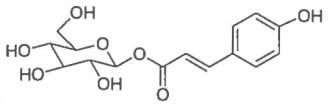
The different parts of the plant contained two iridoid glucosides: aucubin and catalpol. Aucubin has been early isolated from the herb and from the seeds by Ahmed and Hammouda (1965). Its presence has been confirmed by others (e.g. Miething *et al.*, 1986; Cheng *et al.*, 1992; Klockars *et al.*, 1993 and Long *et al.*, 1995). Chemical analysis of individual leaves of five *P. lanceolata* plants showed that iridoid glycoside content increased from undetectable in the oldest photosynthetic leaves to over 9 % dry weight in the youngest leaves. The relative proportion of the two iridoid glycosides also changed with leaf age: older leaves had significantly more aucubin, whereas the youngest leaves had primarily or solely catalpol (Klockkars *et al.*, 1993). Dragland and Aslaksen (1995) reported that the aucubin content of the leaves of *P. lanceolata*, growing in Norway, was 1.1-1.4 % of dry matter, after drying at 20°C (or 40°C), decreasing to 0.7-1.0 % and further to 0.4-0.5 % when dried at 60°C and 80°C respectively. Oviposition tests with female *Junonia coenia* (Nymphalidae) butterflies specialist on plants that contain iridoid glycosides, showed that they laid most of their eggs on new leaves of *P. lanceolata* (Klockars *et al.*, 1993). Bowers (1984) and Pereyra and Bowers (1988) confirmed the use of females of *J. coenia* of aucubin and catalpol, iridoid glycosides typical of a host plant, *P. lanceolata*, as oviposition cues.

Five phenylethanoids, aceteoside, cistanoside F, lavandulifolioside, plantamajoside and isoacteoside were isolated from *P. lanceolata*. Aceteoside, the major phenylethanoid in the herb, showed inhibitory effects on arachidonic acid (**1070**) -induced mouse ear edema (Murai *et al.*, 1995).



1070 Arachidonic acid

Fons *et al.* (1998a) reported that *P. lanceolata* contained two main caffeic acid glycoside esters: plantamoside and verbascoside. It was found that, whatever the age of the plant was plantamoside and verbascoside were concentrated in the roots with plantamoside levels double those of verbascoside. When *P. lanceolata* was transferred into a medium containing 10^{-3} M (*E*)-cinnamic acid, this chemical stress induced a slow degeneration of the initial roots. These were supersed by neoroots whose morphology was normal during the first eight days following their appearance. In the initial roots, (*E*)-cinnamic acid induced a temporary appearance of two cinnamic acid derivatives (NCD), but did not change the plantamoside and verbascoside levels. In the neoroots, high NCD levels were detected for only eight days. After the large decrease of these NCD, plantamoside and verbascoside appeared and increased. The NCDs have been identified as glucoside esters of ferulic and *p*-coumaric acids. These two compounds, which were absent from the traditional chemical profile of ribwort, probably arose from a (*E*)-cinnamic acid detoxification pathway (Fans *et al.*, 1998a). The cinnamic component (*E*)-*p*-coumaroyl-1-*O*-β-D-glucopyranoside (**1071**) was detected in root cultivars of the plant (Fons *et al.*, 1998b,1999).



1071 (*E*)-*p*-Coumaroyl-1-*O*-β-D-glucopyranoside

Apigenin-7-*O*-monoglucoside was the only flavonoid identified from *P. lanceolata* (Haznagy *et al.*, 1976). The presence of coumarins in *P. lanceolata* was also reported (Haznagy, 1970).

The seed oil content, saponifying substances and phytosterols of *P. lanceolata* seed oil were 5 %, 12.5 % and 3.6 % of the oil respectively. Linolenic acid was the main fatty acid (43.8 %); oleic acid constituted (28.5 %) and linolenic acid (8.3 %) of the oil. The content of myristic acid was least (0.4 %), followed in an increasing order by stearic acid (3.1 %) and palmitic acid (15.1 %) and an unidentified substance (0.8 %) was detected (Swiatek *et al.*, 1980). Seeds of *P. lanceolata*, harvested at Argentina yielded 2.3 % crude oil (Nolasco *et al.*, 1999).

Wallaart (1981) reported that *P. lanceolata* contained 2.1 % sorbitol. On the other hand, Briens and Larher (1983) stated that the sorbitol content of *P. lanceolata*, growing in a dry habitat amounted to 6.2 % dry matter. The sorbitol content of the plant under the influence of salt stress has been studied by Koenigshofer (1983).

The volatile components of the different parts of wild *P. lanceolata* (ribwort plantain) corresponds to 0.05 %, 0.03 % and 0.001 % of fresh weight for fruits, leaves and scapes respectively. Thirty-five and twenty-six components were identified from fruits and leaves, respectively, while scapes contained only seven volatile components. The major constituents of fruits were oct-1-en-3-ol (24.9 %), hexahydrofarnesylacetone (15.7 %), vanillic acid (9.8 %) and neophytadienes (> 10 %), the leaves contained mainly oct-1-en-3-ol (41.1 %), (*E*)-4-(3-oxo-2,6,6,-trimethylcyclohex-2-en-1-yl)-3-buten-2-ol (15.6 %), 6-(3-hydroxy-1-butenyl)-1,5,5,-trimethyl-7-oxabicyclo[4.1.0]heptan-3-ol (6.9 %) and benzoic acid (6.3 %). Neophytadienes were mainly found in scapes (Fons *et al.*, 1998c).

The level of total lipids, total fatty acids, sterols, galactolipids, sulpholipids and linolenic acid in roots of *P. lanceolata*, as affected by mineral nutrition are shown in Tables 148 and 149. The obtained data suggested that upon transfer of the plants of low-salt conditions, part of the sitosterol biosynthetic pathway was blocked and that the excess of squalene was quantitatively converted into cholesterol since the amounts of sitosterol, which disappeared, matched the accumulation of the cholesterol (+ tocopherol) fraction (Kuiper and Kuiper, 1978).

The plant is used medicinally in several countries (Rizk and El-Ghazaly, 1995). A biological antiseptic substance was found in the plant (Siddiqui *et al.*, 1964). In traditional medicine, *P. lanceolata* is used for antibacterial, anti-inflammatory, healing, anti-asthmatic and diuretic. Among its several active components, caffeic acid glycoside esters are antibacterial, antifungal, antiviral, antioxidant and selective inhibitors of aldose reductase, 5-lipoxygenase and protein kinase (Fons *et al.*, 1998b). The antitumor activity of plantamoside and verbascoside has also been reported (Herbert *et al.*, 1991; Saracoglu *et al.*, 1995). The leaves of *P. lanceolata* and their aqueous extracts promoted epithelial growth, diminished hyperemia and accelerated the formation of a protective scab (Ahmed and Hammouda, 1965). Aucubin and a hemolytic saponin fraction from the leaves were active against *Micrococcus flavus*. Aucubin was also active against *Streptococus aureus* (Tarle *et al.*, 1981). Nishibe and Murai (1995) studied the biological activities of the major components (13 phenylethanoid glycosides, 9 flavonoids and 5 iridoid glucosides) isolated from *P. asiatica*, *P. depressa*, *P. lanceolata* and *P. major*, for their antibacterial activity, enzyme inhibitory activity of cAMP phosphodiesterase and 5-lipoxygenase antihistamine release activity. The results suggested that the therapeutic effects of *Plantago* herb might be mainly ascribed to biological activities of the major components, plantamajoside, acetoside, plantaginin, aucubin and catalpol. Hose *et al.* (1996) reported that extracts of fresh or dried *P. lanceolata* showed an anti-inflammatory activity and are useful in the treatment of skin irritation or dermatitis. An ointment base, useful in preparations of dermatological creams for multiple uses (including application to burns), contained *P. lanceolata* as one of its ingredients (Esteban Villalobos, 1996). Following a review on *P. lanceolata*, including its botany, historical background, ingredients, indications and anti-inflammatory effects, these effects were confirmed (Marchesan *et al.*, 1998).

In 21 species of weeds, including *P. lanceolata*, collected at different places of Hessia (Germany) in early spring, the content of crude protein in the dry matter ranged from 19.7 (*Lamium purpureum*) to 37.3 % (*Achillea millefolium*). The pure protein content ranged from 13.1 (*L. purpureum*) to 26.0 % (*Corydalis bulbosa*). The highest contents of pure protein in whole protein were found in *P. lanceolata* (77.7 %). The insoluble fraction of total N amounted to 62.4 % of the whole N in *P. lanceolata*. The highest essential amino acids indexes of 80 to 84 were calculated for the protein of some weeds including *P. lanceolata*. Methionine was the first limiting amino acid in all plants (Ullrich and Jahn-Deesbach, 1984).

The leaf yield of ribwort plantain (*P. lanceolata*), growing in Norway, varied from 2.47 to 6.17 mg dry matter (DM) ha in the first year of growth. The highest yield was obtained with a single cut per season. The carbohydrate content was 80-88 % of DM after drying at 20°C or 40° C, but this was reduced to 55-56 % when dried at 6°C and 45-49 % when dried at 80°C (Dragland and Aslaksen, 1995). The composition and digestibility of some weeds, including *P. lanceolata*, were reported in feeding experiments with wethers (Weisser, 1924). Analysis results of digestive experiments with cattle showed that *P. lanceolata*, has a considerable food value (Weisser, 1927). The plant growing in Kenya was found to be rich in protein, low in

fiber, high in ash content and well supplied with P and Ca (Dougall, 1954). The nutritive value of *P. lanceolata*, growing in a heated greenhouse at Aberystwth (U.K.) in February-April 1985, is shown in Tables 150 and 151 (Wilman and Riley, 1993).

Table 150. Dry matter (DM) harvested, neutral detergent fiber (NDF) and digestibility of *P. lanceolata*

Plant part	DM harvested (g/pot)	NDF (% in DM)	DM digestibily (%) Hours in rumen liquor	
			24	48
Leaf	14.4	23.5	54.8	72.3
Stem	4.3	29.6	52.3	67.8
Total	18.7	25.0	54.1	71.2

Table 151. The concentrations (%) in dry matter soluble carbohydrate (WSC), N, P, K, Ca, Mg and Na of *P. lanceolata*

Plant part	WSC	N	P	K	Ca	Mg	Na
Leaf	8.5	4.11	0.479	4.36	2.03	0.250	0.74
Stem	21.5	2.23	0.378	4.44	1.96	0.208	0.67
Total	11.8	3.65	0.454	4.38	2.01	0.239	0.72

The concentrations of water-soluble carbohydrate, N, nitrate-N, P, K, Ca, Mg and Na were determined in *P. lanceolata*, grown at Aberyswth (U.K.) in 1985, 1986 and 1987 (Table 152) (Wilman and Derrick, 1994).

Table 152. Concentration (%) in dry matter of water-soluble carbohydrate, N, nitrate-N, P, K, Ca, Mg and Na of *P. lanceolata*

	Experiment 1 (harvested 28 Oct. 1985)	Experiment 2 (harvested 23 June 1986)	Experiment 2 (harvested 1 Oct. 1986)	Experiment 3 (mean of four periods, 24 Aug-10 Oct. 1987)
Water-soluble Carbohydrate	9.2	17.8	11.5	8.8
N	4.20	1.90	2.40	1.52
Nitrate-N	0.272	0.019	0.162	0.016
P	0.402	0.252	0.315	0.361
K	3.50	2.62	2.62	2.89
Ca	1.860	1.220	1.430	1.086
Mg	0.245	0.235	0.242	0.233
Na	0.315	0.112	0.130	0.109

1.6. ***Plantago ovata*** Forssk., Fl. Aegypt.-Arab. 31 (1775).

Lokmet ennadji, Lokmet en nagi (Ar.)

Small stemless annual herb 6-8 cm high with short tap root 1.5-2 cm long. Leaves a rosette linear, grass-like, sparingly hairy, about 5 cm long and 3 mm broad. Inflorescences on long

peduncles, 2-5 (rarely up to 15 per plant), exceeding leaf length. Spikes cylindrical, of 12-15 flowers, 1.5 cm long and 0.7 cm across. Fruit ovate, bout 2 mm long.

Habitat and Distribution

On fine soils and moist areas north of Qatar particularly agricultural fields and their vicinity (University Farm, Al-Suwairya).

Constituents

The proximate composition of *P. ovata*, growing in the Eastern Prouince of Saudi Arbia, is as follows: crude protein, 12.6; fat, 2.01; crude fiber, 26.8 ash, 22.0 and sand 8.9 % (dry matter). The elements of the plant were: P, 1182; Ca, 1.96; Mg, 0.31; Na, 0.30; K, 2.0; Cu, 20.4; Mn, 87.0; Fe, 2500; Zn, 175.0 and Mo, 6.2 µg/g dry matter (Al-Noaim *et al.*, 1991). The seed content of moisture, ash, protein, crude fiber, and carbohydrates of *P. ispaghula* (*P. ovata*), from different localities, in India, have been reported (Pendse *et al.*, 1976).

The seeds of four *Plantago* species including (*P. psyllium*, and *P. ovata*) yielded mucilages similar to *P. psyllium* (Greenberg, 1948). The study of the polysaccharide of the seeds of *P. ovata* revealed that the mucilage extracted by cold water had a higher uronic acid content (20 %) and a lower pentosan content (52 %) than the polysaccharide isolated by extracting the residue with hot water at 90-95°C. The latter polysaccharide contained approximately 3 % uronic acid and 90 % pentosan. The sugar constituents of the mucilage were D-xylose, L-arabinose, L-rhamnose and D-galacturonic acid (Laidlaw and Percival. 1949,1950). Similar results were obtained by Ahmed *et al.* (1965b) who isolated from the seeds of *P. ovata*, growing in Egypt two polysaccharides by extraction with cold and hot water successively. The cold and hot fractions which amounted to 22.34 % and 3.24 % of the seeds respectively (Table 137), contained 20.4 % and 5.8 % D-galacturonic acid respectively. Also, the sugar constituents of both fractions were L-arabinose and D-xylose; L-rhamnose was only detected in the cold fraction (Table 137). Fractionation of the mucilage of *P. ovata* and *P. arenaria* by stepwise

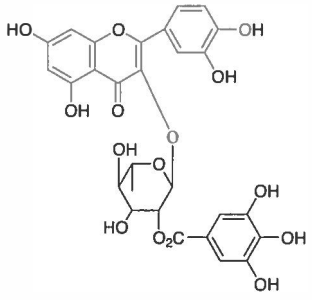
Table 158. Cont.

Species	Flavonoids	References
8. *P. lapathifolium*	Kaempferol, quercetin, quercetin 3-*O*-glucoside, quercetin 3-*O*-galactoside, quercetin 3-*O*-glucoside-2"-gallate, quercetin 3-*O*-arabinoside, kaempferol 3-*O*-galactoside, kaempferol 3-*O*-glucoside-2"-gallate and 5-methoxy-6,7-methylenedioxyflavone	Kul'pina *et al.* (1986); Tahara *et al.* (1993)
9. *P. minus*	6,7-Methylenedioxy-5,3',4',5'-tetra-methoxyflavone and 6,7-4',5'-dimethylenedioxy-3,5,3'-trimethoxyflavone	Urones *et al.* (1990)
10. *P. nepalense*	5,4'-Dimethoxy 6,7-methylenedioxyflavanone, 5,6,7,2',3',4',5'-heptamethoxyflavanone, quercetin 3-*O*-glucoside, quercetin 3-*O*-galactoside, quercetin-3-*O*-rhamnobioside and luteolin-6-*C*-glucoside	Rathore *et al.* (1986,1987); Isobe and Noda (1987a)
11. *P. nodosum*	Kaempferol, quercetin 3-*O*-glucoside, kaempferol 3-*O*-glucoside-2"-gallate, quercetin 3-*O*-glucoside-2"-gallate, quercetin 3-*O*-rhamnoside-2"-gallate, quercetin 3-*O*-rhamnoside, and kaempferol 3-*O*-glucoside	Isobe *et al.* (1980; Isobe and Noda (1987a)
12. *P. orientale* (Princ's feather)	Quercetin, taxifolin, quercetin 3'-*O*-rhamnoside, rutin, quercetin 7-*O*-rhamnoside, isorhamnetin, taxifolin 3-*O*-glucoside, kaempferol 3-*O*-rhamnoside, chrysoeriol-7-*O*-glucoside and isoorientin-6"-gallate	Zhang *et al.* (1990a); Zheng *et al.* (1997,1999 b,c)
13. *P. perfoliatum*	Quercetin 3-*O*-glucuronide, perfoliatumin A **(1091)** and perfoliatumin B **(1092)**	Isobe and Noda (1987a); Zhu *et al.* (2000)
14. *P. rumex* var. *patientia*	Isorhamnetin, kaempferol 3-*O*-glucoside and 5-hydroxy-4'-methoxyflavanone 7-*O*-rutinoside	Su *et al.* (2000b)
15. *P. salicifolium*	Kaempferol 3-*O*-glucoside (astragalin), kaempferol 3-*O*-galactoside, quercetin 3-*O*-glucoside (isoquercitrin), quercetin 3-*O*-galactoside (hyperoside), quercetin 3-*O*-(2"-*O*-galloyl)- glucoside and quercetin 3-*O*-glucuronide	Calis *et al.* (1999a)
16. *P. sieboldi*	Quercetin 3-*O*-glucoside, quercetin 3-rhamnoside, kaempferol 3-*O*-glucoside, quercetin and kaempferol	Isobe and Noda (1987a)
17. *P. stelligerum* (leaves)	Quercetin 3-*O*-glucoside-3'-methylether and rutin	Sartor *et al.* (1999)

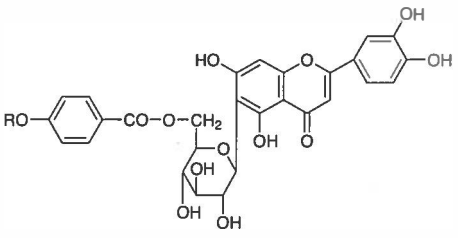
Table 158. Cont.

Species	Flavonoids	References
18. *P. viscosum*	Quercetin, 3,5-dihydroxy-3,4',5',7-tetra-methoxyflavone , quercetin 3-*O*-(6"-caffeoyl)-β-D-galactopyranoside, quercetin 3-*O*-(6"-feruloyl)-β-D-galactopyranoside and quercetin 3-*O*-(6"-galloyl)-β-D-galactoside	Datta *et al.* (2000a-c)
19. *P. weyrichii*	Quercetin, avicularin, hyperoside, quercitrin and rutin	Levashova and Zhdanova (1990)
20. *P. yokusaianum*	Quercetin 3-*O*-rutinoside, querectin 3-*O*-glucoside, quercetin 3-*O*-galactoside and kaempferol 3-*O*-glucoside	Isobe and Noda (1987a)

Four neoflavonoids, 3,4-dihydro-4-(4'-hydroxyphenyl)-5,7-dihydroxycoumarin, 3,4-dihydro-5-hydroxy-7-methoxy-4-(4'-methoxyphenyl)-coumarin, 3,4-dihydro-5-hydroxy-4-(4'-hydroxyphenyl)-7-methoxycoumarin, and 3,4-dihydro-5,7-dihydroxy-4-(4'-methoxyphenyl) coumarin, were isolated from *P. perfoliatum* (Sun and Sneden, 1999).

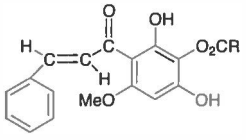


1090 Quercetin 3-rhamnoside-2"-gallate



1091 Perfoliatumin A, R = H
1092 Perfoliatumin B, R = Me

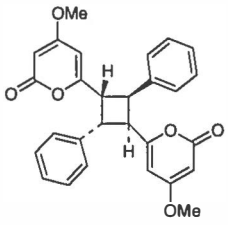
A chalcone (2,4'-dihydroxy-3',6'-dimethoxychalcone) has been isolated from *P. senegalense* (Rizk, 1986). *P. lapathifolium* contained in addition to 2'-hydroxy-4',6'-dimethoxychalcone, three chalcone derivatives **(1093-1095)** (Ahmed *et al.*, 1988). A dihydrochalcone diglucoside, 4'-*O*-[β-D-glucopyranosyl-(1→6)-glucopyranosyl]oxy-2'-hydroxy-3',6'-dimethoxy-dihydroxychalcone, was isolated from *P. salicifolium* (Calis *et al.*, 1999).



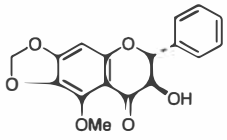
1093 R = Angeloyl
1094 R = CH_2CHMe_2
1095 R = $CH_2CH_2CHMe_2$

A cyclobutane derivative, named compound B **(1096)**, a flavanonol named compound C (**1097**) and compound A (**1098**) were isolated from *P. nodosum*. Plastochromanols were detected

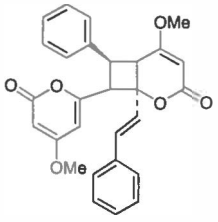
in *Polygonum* species. Scopoletin and herniarin were isolated from *P. aviculare* (Rizk, 1986). Coumarin and herniarin were identified in roots of *P. weyrichii* (Levashova and Zhdanova, 1990). 5,7-Dihydroxychromone was isolated from the seeds of *P. lapathifolium* (Spencer and Tjarks, 1985). Polygonolide **(1099)**, an isocoumarin possessing anti-inflammatory activity, was isolated from the root of *P. hydropiper* (Furuta *et al.*, 1986).



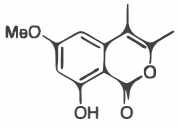
1096 Compound B



1097 Compound C



1098 Compound A



1099 Polygonolide

Malvin (malvidin 3,5-diglucoside) and cyanidin were identified in several *Polygonum* species (Yoshitama *et al.*, 1984). Delphinidin glycosides were present in the sepals of *P. nepalense* and *P. thunbergii* (Yoshitama *et al.*, 1987).

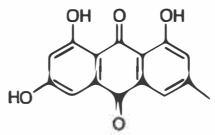
Anthraquinones have been identified from different *Polygonum* species, particularly from the roots (Table 159).

2,6-Dimethoxybenzoquinone was isolated from *P. thunbergii* (Tahara *et al.*, 1993). 2-Methoxy-6-acetyl-7-methyljuglone was identified in roots of *P. multiflorum* (Li and Lin, 1993).

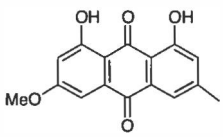
Several phenolic acids have been identified in *Polygonum* species (e.g. *P. aviculare*, *P. bistorta* and *P. hydropiper*). Among the compounds identified were *cis/trans*-ferulic, *cis/trans*-sinapic, vanillic, syringic, melilotic, *cis/trans p*-coumaric, *p*-hydroxybenzoic, gentisic, *cis/trans*-caffeic, protocatechuic, gallic, *p*-hydroxyphenylacetic, chlorogenic, salicylic and ellagic acids (Swiatek and Dombrowicz, 1987).Tannins have been identified in several *Polygonum* species, particularly in the roots. In *P. coriarium*, tannins were found to be distributed throughout the plant with a maximum concentration of 28.32 % in the root, while the stoks and leaves contained only 0.85-6.87 % (Rizk, 1986). *P. coriarium* provided the highest yield of tannins (32 %) in the 3rd year of growth during flowering and 18-20 % tannins during the vegetative phase. High tannins content was also reported in the roots of *P. divaricatum*, *P. panjutinii* and *P. weyrichii* (Pipinys, 1985). The roots of *Polygonum* species have been reported to contain the same catechols: epigallocatechol, gallocatechol, epicatechol, epigallocatechol gallate and epicatechol gallate (Rizk, 1986). (+)-Catechin and (-)-epicatechin have been identified in the aerial parts of *P. divaricatum* and *P. weyrichii* (Levashova and Zhdanova, 1990). Keneshov *et al.* (1997a,b) isolated four oligmeric proanthocyanidins (T1-T4) from the roots of *P. coriarium*.

Table 159. Anthraquinones of some *Polygonum* species

Species	Anthraquinones	References
1. *P.aubertii*	Emodin **(1100)** and/or its glucoside	Rizk (1986)
2. *P. ciliinerve*	Emodin and physicon **(1101)** and/or their glucosides	Rizk (1986)
3. *P. cuspidatum* (roots) (giant knot wood)	Chrysophanol and emodin	Rizk (1986); Yang *et al.* (1996c)
4. *P. ellipticum* (roots)	Emodin, emodin-8-*O*-glucoside and physicon	Chi and Kim (1986)
5. *P. hypoleucum* (stems)	Emodin, emodin-1-*O*-glucoside physicon and physicon-1-*O*-β-D-glucoside	Sun *et al.* (1996); Kuo *et al.* (1997)
6. *P. multiflorum* (roots) (fleece-flower)	Emodin, physicon, emodin-8-*O*-β-D-glucoside, 2-acetylemodin, physicon 8-*O*-β-D-glucoside, questin, questinol, citreorosein, chrysophanol and chrysophanol-8-*O*-β-D-glucoside	Li and Lin (1993); Yang (1993); Yang *et al.* (1998)
7. *P. rumex* var. *patientia*	Emodin, chrysophanol, physicon, emodin dimethyl ether, emodin 8-*O*-β-D-glucoside and xanthorin-5-methyl ether	Su *et al.* (2000a)
8. *P. sachalinense* (roots)	Emodin, emodin 8-*O*-glucoside and physicon	Chi and Kim (1986); Rizk (1986)



1100 Emodin

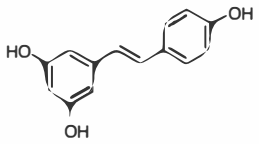


1101 Physcion

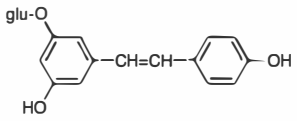
Stilbenes have been isolated from some *Polygonum* species. *P. multiflorum* roots contained 2,3,5,4'-tetrahydroxystilbene-2,3-*O*-β-glucoside (polygonimitin C) (Zhou *et al.*, 1994) and 2,3,5,4'-tetrahydroxystilbene-2-*O*-β-D-glucoside. 3,5,4'-Trihydroxystilbene and its 3-*O*-β-D-glucoside were isolated from the roots of *P. ellipticum* and *P. sachalinense* (Chi and Kim, 1986). The whole plants of *P. cuspidatum*, *P. filiforme*, *P. multiflorum* and *P. orientale* contain the biologically active stilbenes resveratrol **(1102)**, bisade **(1103)** and 2,3,5,4'-tetrahydroxystilbene. These four species are health food additives that decrease serum lipids and enhance the metabolic activity of liver (Osaka Yakuhin Kenkyusho, 1985). 5,4'-Dihydroxy-2-*O*-β-D-glucopyranosyl-3-*O*-α-L-rhamnopyranosyl- stilbene was identified from *P. orientale* (Zheng *et al.*, 1997). Stilbene derivatives, isolated from plants including *P. cuspidatum* and *P. multiforum* were claimed as hypolipidemics (Kawai, 2001).

Vanicosides A-F (e.g. **1104**,**1105**), phenylpropanoid glycosides (protein kinase C inhibitors) have been isolated from *P. pensylvanicum* (Zimmermann and Sneden, 1994; Brown *et al.*, 1998). Polygoacetophenoside **(1106)**, an acetophenone glucoside was identified in *P.*

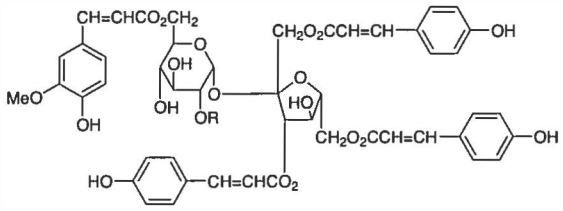
multiflorum (Yoshizaki *et al.*, 1987). Polydatin, an active glycoside on free radicals in ischemic brain injury, was isolated from the roots of *P. cuspidatum* (Leung and Mo, 1996).



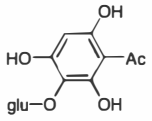
1102 Resveratrol



1103 Bisade



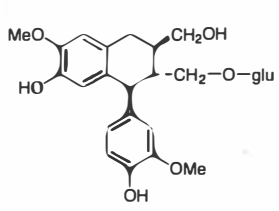
1104 Vanicoside A; R = Ac
1105 Vanicoside B; R = H



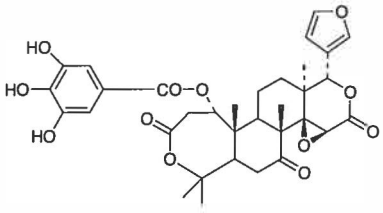
1106 Polygoacetophenoside

Aviculin **(1107)**, a lignan glycoside, was isolated from the whole plant of *P. aviculare* (Kim *et al.*, 1994). Three other lignans: arctiin, lappoal B, and orientalin, were isolated from the aerial parts of *P. orientale* (Zheng *et al.*, 1998).

Deactylnomilin-1-*O*-gallate **(1108)** and four other limonoids were isolated from *P. perfoliatum* (Liu *et al.*, 1999). Polygonimitin B (1,3-dihydroxy-6,7-dimethylxanthone-1-*O*-β-D-glucoside) (Zhou *et al.*, 1994), *N-trans*-feruloyl-3-methyltyramine, *N-trans*-feruloyl-3-methyldopamine (Li and Lin, 1993) and an indole derivative methylindole-3-(L-α-amino-α-hydroxypropionate) (Yang *et al.*, 1998) have been isolated from *P. multiflorum.*



1107 Aviculin



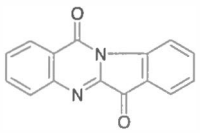
1108

Indirubin, indigo and *N*-phenyl-2-naphthylamine were isolated from *P. tinctorium* (Chen and Xie, 1984).

24-Hydroxy-3-tetracosanone and 29-hydroxy-3-nonacosanone were isolated from *P. capitatum* (Wu and Wang, 1985). Oxalic, maleic, citric and cinnamic acids were identified in the stems of *P. cuspidatum* (Kojima *et al.*, 1984). Tryptanthrin **(1109)**, a specific antimicrobial substance against dermatophytes was isolated from *P. tinctorium* (Rizk, 1986).

The uses of *Polygonum* species in folk medicine have been reported. *Polygonum* species are commonly used in Chinese and Japanese folk medicine for the treatment of bronchial and

pulmonary disorders, suppurative dermatitis, gonorrhea and hyperlipemia (Lin and Hsu, 1987; Ogwuru and Adamczeski, 2000). Resveratrol, isolated from *Polygonum* species is a kinase ihibitor (Jayatilake *et al.*, 1993). The anthelmintic properties of *P. glabrum* (Muddathir *et al.*, 1987), anti-inflammatory activity of *P. bistorta* (Duwiejua *et al.*, 1994), and the antilipid peroxidation and liver protective effects of *P. aviculare* (Choi *et al.*, 1997) were reported. *P. tinctorium* possessed strong antianaphylactic activity (Kim *et al.*, 1998b).



1109 Tryptanthrin

1.1. ***Polygonum equisetiforme*** Sm., Fl. Graec. Prodr. 1:266 (1809).

Qabab (Ar.)

Perennial herb from a strong tap root producing slender soft elongated branches. Branches with linear sessile or very shortly pedicellated leaves. Inflorescences axillary, minute, with 3-6 congested pink or purple-tinged minute flowers. Fruits winged.

Habitat and Distribution

Occasional on stony ground throughout central and north Qatar but never in large stands.

Constituents

The following flavonoids have been isolated from *P. equisetiforme*, growing in Jordan: quercetin, quercetin-3-*O*-rhamnoside, quercetin-3-*O*-glucuronide, quercetin-3-*O*-arabinoside and isorhamnetin (Ghazal *et al.*, 1992).

2. *RUMEX* L.

The leaves of *R. acetosa* have been reported to be of much higher nutritive value and are probably good supplement for protein of cereals, and that of *R. transchanicum* showed good potential for cattle feed (Rizk, 1986). The presence of all the essential amino acids, some far above the levels of the FAO reference proteins, and the low levels of some antinutitional factors, suggest that the leaf of sorrel (*R. acetosa*) may be a cheap source of protein of a high nutritive value (Landeji and Okoye, 1993).

The nutritive value of *R. obtusifolius*, grown in a heated greenhouse at Aberyswth (U.K.) in February-April 1985, is shown in Tables 160 and 161 (Wilman and Riley, 1993).

Table 160. Dry matter (DM) harvested, neutral detergent fiber (NDF) and digestibility of *R. obtusifolius*

Plant part	DM harvested (g/pot)	NDF (% in DM)	DM digestibily (%) Hours in rumen liquor	
			24	48
Leaf	4.9	22.0	67.3	68.0
Stem	1.0	26.9		76.8
Total	5.9	23.0		69.7

Table 161. The concentrations (%) of dry matter soluble carbohydrate (WSC) and some minerals of *R. obtusifolius*

Plant part	WSC	N	P	K	Ca	Mg	Na
Leaf	7.9	5.26	0.630	6.49	1.03	0.920	0.20
Stem		2.63	0.628	10.15	0.67	0.417	0.12
Total		4.77	0.630	7.19	0.96	0.829	0.19

The concentration of water-soluble carbohydrates, N, nitrate-N, P, K, Ca, Mg and Na were determined in dock (*R. obtusifolius*), grown in Aberyswth (U.K.) in 1985, 1986 and 1987 (Table 162) (Wilman and Derrick, 1994).

The roots of *R. acetosa* and *R. japonicus* yielded starch 7 and 6 % of fresh weight respectively (Fujimoto *et al.*, 1985). The water-soluble polysaccharide complex from the roots plus rhizomes of horsesorrel (*R. confertus*) contained 21.8 % reducing sugars. Glucose, arabinose, xylose, galactose and glucuronic acid were identified in the hydrolysate (Glukhovetskaya *et al.*, 1991). Sucrose was detected in the roots of *R. gmelini* (Wong *et al.*, 1996).

Table 162. Concentration (%) in dry matter of water-soluble carbohydrate, and some minerals of *R. obtusifolius*

	Experiment 1 (harvested 28 Oct. 1985)	Experiment 2 (harvested 23 June 1986)	Experiment 2 (harvested 1 Oct. 1986)	Experiment 3 (harvested mean of four periods, 24 Aug. - 10 Oct. 1987)
Water-soluble carbohydrate	9.9	12.7	9.7	7.8
N	4.72	2.12	3.98	3.39
Nitrate-N	0.078	0.034	0.069	0.022
P	0.622	0.308	0.448	0.475
K	4.82	2.95	4.12	4.30
Ca	0.500	0.720	0.605	0.515
Mg	0.415	0.262	0.458	0.423
Na	0.285	0.090	0.088	0.115

R. patientia accumulated high amounts of Cd, Cu and Zn (Marquard *et al.*, 1995).

Seeds and pericarp of *R. paulsenianus* contained 7.8 and 0.58 % lipids, respectively. The fruit and seed lipids were almost identical. The fruits contained 11 saturated, and 4 mono-, 2 di, and one (18:3) trienic free fatty acids. The triacylglycerides contained 2 rare monoaceto compounds: 1,3-dimyristoyl-2-acetyl- and 1-myristoyl-2-capronoyl-3-acetyl-*sn*-glyceride, and 1,3-dimyristoyl-2-capronoylglyceride, C_{27}; C_{29} and C_{31} comprised ≤ 78 % of fruit paraffins (Gusakova *et al.*, 1990). Hydroxy acids, isolated from *P. paulsenianus* fruits, contained 22 $C_{14\text{-}20}$ monohydroxy acids including isomers and 4 $C_{18\text{-}20}$ dihydroxy acids, among them a new isomeric acid, 9-OH-10,12-17:2 (an isomer of 13-OH-9,11-17:2) (Gusakova *et al.*, 1991).

The fatty acid percentage of curly dock (*R. crispus*) lipid (0.24 %) was as follows: $C_{14:0}$, 0.48; $C_{16:0}$, 12.32; $C_{16:3\omega3}$, 0.87; $C_{16:2\omega6}$, 0.24; $C_{16:1\omega39}$, 1.93; $C_{18:0}$, 1.10; $C_{18:3\omega3}$, 41.21; $C_{18:4\omega3}$, 1.73; $C_{18:2\omega6}$, 10.35; $C_{18:1\omega7}$, 0.06; $C_{18:1\omega9}$, 1.08; $C_{20:0}$, 0.50; $C_{20:5\omega3}$, 0.12; $C_{20:1\omega9}$, 1.08; $C_{22:0}$, 0.61; $C_{22:1\omega11}$, 0.42 and $C_{24:0}$, 0.34 % (Guil *et al.*, 1996). The oil content of field dock (*R. pseudonatornatus*) amounted to 3.8 %. The fatty acid composition of the oil was: $C_{14:0}$, 4.5; $C_{14:1}$, 0.6; $C_{16:0}$, 6.5; $C_{16:1}$, 0.2; $C_{18:0}$, 2.7; $C_{18:1}$, 29.8; $C_{18:2}$, 37.9; $C_{18:3}$, 0.3; $C_{20:1}$, 2.7; $C_{22:0}$, 2.3; $C_{22:1}$, 1.8; $C_{24:0}$, 4.8; $C_{26:0}$, 3.4 and $C_{28:0}$, 2.4 % (Daun and Tkachuk, 1976).

The fatty alcohols of seed lipid of *R. paulsenianus* were $C_{23:0\text{-}32:0}$ alkanols, the major ones being $C_{24:0}$ and $C_{26:0}$. The sterols identified in the seed lipid were β-sitosterol, campesterol and stigmasterol (Gusakova *et al.*, 1990). Daucosterol was isolated from the root of *R. gmelinii* (Wang *et al.*, 1996b). The aerial parts of *R. nepalensis* contained β-sitosterol and lupeol (Khetwal *et al.*, 1987).

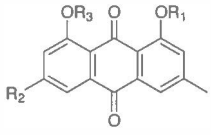
The genus *Rumex* is one of the genera, which are characterised by the presence of anthraquinones. Several anthraquinones, particularly chrysophanol, emodin and physicon were found in the different parts of *Rumex* species (Midiwo and Rukunga, 1985; Rizk, 1986; Demirezer and Kuruuzum, 1997). The anthraquinones, isolated from some *Rumex* species are shown in Table 163.

Table 163. Anthraquinones of some *Rumex* species

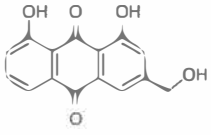
Species	Anthraquinones	References
1. *R. abysinica* (roots)	Chrysophanol, emodin and physicon	Munavu *et al.* (1984)
2. *R. abyssinicus* (tubers)	Chrysophanol, physicon, palmidin C (emodin chrysophanol-bianthrone), chrysophanol-β-D-glucoside (**1110**) and emodin 8-*O*-β-D-glucoside (**1111**)	Fassil *et al.* (1985)
3. *R. acetosa* (leaves)	Chrysophanol, 1,8-dihdroxyanthraquinone and aloe-emodin (**1112**)	Varma *et al.* (1984)
(roots)	Chrysophanol, physicon, emodin, chrysphanol-8-*O*-β-D-glucopyranoside, physicon 1-*O*-β-D-glucopyranoside (**1113**) and physicon 8-*O*-β-D-glucopyranoside (**1114**)	Kato and Morita (1987)
4. *R. acetosella* (whole plant)	Emodin, citreorosein, and chrysophanol-8-*O*-β-D-glucopyranoside	Choe *et al.* (1998).
5. *R. alpinus*	Chrysophanol, emodin and physicon	Chubinidze *et al.* (1987)
6. *R. bequaertii* (all parts)	Chrysophanol, emodin and physicon	Midiwo and Rukunga (1985)
7. *R. bucephalophorus* (aerial parts)	Chrysophanol, emodin and aloe-emodin	Abd El-Fattah *et al.* (1994a)
8. *R. chalepensis* (leaves)	3-Methyl-1,6,8-trihydroxyanthraquinone-1-*O*-[α-D-glucopyranosyl-(1→4)-α-L-rhamnopyranoside]	Hasan *et al.* (1997)
9. *R. crispus* (all parts)	Chrysophanol, emodin and physicon	Midiwo and Rukunga (1985)
10. *R. dictyocarpus*	Chrysophanol and emodin	Guo *et al.* (1990)
11. *R. gmelini* (roots)	Chrysophanol-1-*O*-β-D-glucopyranoside and emodin 1-*O*-β-D-glucopyranoside	Kang *et al.* (1996)
12. *R. gracilescens* (roots)	Chrysophanol, emodin, emodin-8-*O*-β-D-glucopyranoside and chrysophanol 8-*O*-β-D-glucopyranoside	Demirezer *et al.* (1995)
13. *R. japonicus* (Japanese dock) (roots)	Chrysophanol, emodin and physicon	Kim *et al.* (1998a)
14. *R. luminiastrum* (all parts)	Chrysophanol, emodin, physicon and emodin 8-*O*-glucoside	Abd El-Fattah *et al.* (1994a,b)
15. *R. nepalensis* (aerial parts)	1,8-Dihydroxy-3-methylanthraquinone, 1,6,8-trihydroxy-3-ethylanthraquinone and 1,8-dihydroxy-6-methoxy-3-methylanthraquinone	Khetwal *et al.* (1987)

Table 163. Cont.

Species	Anthraquinones	References
16. *R. obtusifolius* (roots)	Chrysophanol, emodin and physicon	Arellano (1988)
17. *R. patientia*	Chrysophanol, emodin, physicon, chrysohanol-*O*-β-D-glucopyranoside, physicon-8-*O*-β-glucopyranoside and emodin 8-*O*-β-D-glucopyranoside	Yuan *et al.* (2000)
18. *R. paulsenianus* (fruit)	Chrysophanol, aloe-emodin and physicon	Gusakova *et al.* (1990)
19. *R. ruwenzoriensis*	Chrysophanol, emodin and physicon	Midiwo and Rukunga (1985)
21. *R. tingitanus*	Chrysophanol, physicon, emodin, aloe-emodin and crysophanein (chrysophanol 8-*O*-glucoside)	Zaghloul and Abd El-Fattah (1999)
22. *R. usambarensis* (roots)	Chrysophanol, emodin and physicon	Midiwo and Rukunga (1985)



301 Chrysophanol; $R_1 = R_2 = R_3 = H$
1110 $R_1 = R_2 = H$, $R_3 = \beta$-D glucose
1111 $R_1 = H$, $R_2 = OH$, $R_3 = \beta$-D glucose
1113 $R_1 = \beta$-D glucose, $R_2 = OMe$, $R_3 = H$
1114 $R_1 = H$, $R_2 = OMe$, $R_3 = \beta$-D glucose



1112 Aloe-emodin

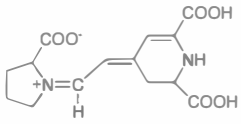
Two sulphate anthraquinones (emodin 1- or 8-monoglucoside sulphate and the related emodin dianthrone diglucoside sulphate) were isolated from *R. pulcher* (Rizk, 1986).

Investigation of the total content of free, bound, neutral and acid anthraquinones of five *Rumex* species, studied by Brazdova *et al.* (1969), revealed that the high content of anthraquinone derivatives was found in the roots of *R. obtusifolius* (4.31, 4.16, 4.15 and 0.56 % respectively). The anthraquinone glycosides content in the roots, stems, leaves and fruits was 2.93, 0.08, 0.21 and 0.08 % respectively in *R. gracilescens*, and 1.17, 0.54, 0.66 and 0.49 % respectively in *R. crispus* (Demirezer, 1994).

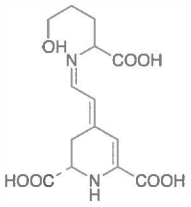
The accumulation of dianthrones and naphthalene-1,8-diols (in addition to anthraquinones) is characterstic of the genus *Rumex*. Orientalone (**1115**), a 1,4-naphthoquinone, has been isolated from *R. orientalis* (Rizk, 1986). Nepodin (dianellidin and musizin, **1116**) occurred in several species e.g. *R. alpinus*, *R. nepalensis* (Rizk, 1986), *R. bequaertii*, *R. crispus*, *R. ruwenzoriensis* (Midiwo and Rukunga, 1985) and *R. japonicus* (Miyazawa and Kameoka, 1991; Kim *et al.*, 1998a). Nepodin, nepodin monoglucoside and methoxynepodin have been identified in tissue cultures of *R. alpinus* (Rizk, 1986). An epoxynaphthoquinol derivative, (+)-3-acetyl-2-methyl-1,5-dihydroxy-2,3-epoxynaphthoquinol (**1117**), was isolated from the root of *R. japonicus* (Zee *et al.*, 1998). Five napthalene glycosides were isolated from the roots of *R. patientia*: 2-acetyl-3-methyl-6-carboxy-1,8-dihydroxynaphthalene-8-*O*-β-D-glucopyrnoside (rumexoside, **1118**), 4,4"-binaphthalene-8,8"-*O*-*O*-di-β-D-glucopyranoside (labadoside, **1119**), 2-acetyl-3-

suffruticosa yielded *n*-hentriacontane, *n*-triacontane, *n*-hexacosanol, β-sitosterol, β-sitosterol-β-D-glucoside, stigmasterol and lupeol (Joshi *et al.*, 1987).

A betalain pigment, indicaxanthin **(1144)**, was isolated from *P. grandiflora* (Chiji, 1976). The flowers of *P. grandiflora*, also contained the betaxanthins humilixanthin (**1145**, 5-hydroxynorvaline-immonium conjugate of betalamic acid) (Strack *et al.*, 1987b), portulacaxanthin II (tryrosine - immonium conjugate of betalamic acid) and portulocaxanthin III (glycine-immonium conjugate of betalamic acid (Trezzini and Zryd, 1991). Quercetin 3-rhamnoside was isolated from the aerial parts of *P. suffruticosa* (Joshi *et al.*, 1987).



1144 Indicaxanthin



1145 Humilixanthin

Mn was more concentrated in the leaves than in the roots and stems of *P. grandiflora*. Old leaves are richer in alkali carbonates than new leaves, which contained more Ca (Seto, 1957).

1.1. ***Portulaca oleracea*** L., Sp. Pl., ed. 1, 445 (1753).

Birbeer, Rigla (Ar.); Purslane (En.)

Glabrous annual or short-lived perennial fleshy herb. Branches basal, decumbent - prostrate, green or reddish with opposite or clustered leaves*. Leaves obovate-spathulate, about 2 cm long and 1 cm broad, sessile, fleshy. Inflorescences axillary and terminal, congested, few-flowered cymes (inset in branch axils); flowers yellow, close up mid-day with 2 boat-shaped sepals and 5 imbricate petals. Fruit a capsule dehiscing across the middle (circumscisle); seeds many, minute, reniform, tubercled and black.

*sometimes lower parts of branches swollen due to infestation.

Habitat and Distribution

By far the most common weed on Doha's roadsides. Common where moisture is available in agricultural fields, lawns, gardens, sewage disposal sites, water spillage and taps, etc. Flowers and fruits throughout the year.
A cultivated form is eaten as a salad or cooked.

Constituents

It is an edible plant and is eaten fresh and as a cooked vegetable. The proximate analysis of *P. oleracea* (pigweed, purslane, munyeroo), growing in Australia, was as follows: water 85.5 %, protein 5.9 %, fat 0.2 %, energy 232 (kJ/100 g), thiamine 131 (μg/100 g) and ascorbic acid (traces) (James, 1983). *P. oleracea*, prior to flowering, collected in spring and winter, contained vitamin A 6,100, 8,300 units/100 g and ascorbic acid 26 mg/100 g (Zennie and Ogzewalla, 1977). The composition of the leaves of *P. oleracea* used by locals in Mozambique as food, was reported as follows: water 91 %, food energy 255 (calories/100 g dry matter), nitrogen 5.52, total protein 34.48 %, fat 5.25, cellulose 10.50, nitrogen-free extract 25.04 and ash 24.73 % dry matter. The amino acid composition was: arginine 10.31, histidine 5.17, lysine 10.11, methionine 2.77, cystine 1.28, phenylalanine 11.90, tyrosine 6.24, leucine 19.92, isoleucine 10.64, valine 13.60, threonine 9.67 and tryptophan (mg/1 g dry matter) (Oliveira and De Carvalho, 1975). The β-carotene content in Australian purslane (*P. oleracea*) varieties ranged from 22 to 30 mg/g fresh mass in leaves (Liu *et al.*, 2000).

Whole purslane (*P. oleracea*) plants contained 3.5 % lipid (dry weight basis) of which 25 % was free fatty acids and 19 % sterols. Of the total fatty acids, major constituents were $C_{18:3}$ 47.5, $C_{18:2}$ 19.8 and $C_{16:0}$ 15.1 % (Boschelle *et al.*, 1991). The dry seeds yielded 17.4 % oil (Handa *et al.*, 1956). The total fatty acid content ranged from 1.5 to 2.5 mg/g fresh leaves, 0.6 to 0.9 mg/g in stems and 80 to 170 mg/g in seeds. α Linolenic acid ($C_{18:3\omega3}$) accounted for around 60 and 40 % of the total fatty acid content in leaves and seeds respectively (Liu *et al.*, 2000). Simopoulos and Salem (1986) reported that the plant contained 8.5 mg fatty acid/g wet weight and was a good source of α-linolenic acid (4 mg/g wet weight). The study of the total lipids and omega-3 fatty acids in leaves, stems and whole plants and 3 ages revealed significant differences, but no relationship of age to plant part was found. Contents of $C_{18:3\omega3}$, $C_{20:5\omega3}$, $C_{22:5\omega3}$, $C_{22:6\omega3}$, $C_{18:2\omega6}$ and $C_{18:1\omega9}$ showed that leaves were the richer source of omega-3 acids at each age (Omara-Alwala *et. al.*, 1991). The described omega-3 fatty acids could not be traced in the Austrian purslane sample studied by Jirovetz *et al.* (1993) which contained myristic, palmitic, stearic, oleic and linoleic acids. The fatty acids of the seeds were palmitic, stearic, behenic, oleic, linoleic and linolenic (Handa *et al.*, 1956). Liu *et al.* (1995b) reported that the main fatty acids of the seeds were linoleic acid (45.8 %) and linolenic acid (30.61 %).

other insects feeding on the pollen; female flowers producing white oval berries about 1 cm long with black seeds on ± sweetish pulp always eaten by birds.

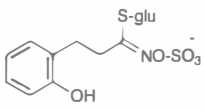
Habitat and Distribution

Common in Doha in disturbed areas. Widespread on University of Qatar grounds, rare in rodats and sometimes occurs under *Acacia* trees on fine to sandy -stony soils.

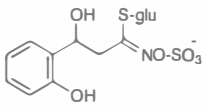
Constituents

The unsaponifiable matter of the lipid of *O. baccatus*, growing in Qatar, contained sterols (32.06 %), hydrocarbons (56.88 %), aliphatic alcohols (11.01 %) and triterpene alcohols (0.05 %). The following components were identified in the hydrocarbon fraction: $C_{21:0}$, 0.19; $C_{23:0}$, 1.13; $C_{24:0}$, 1.95; $C_{25:0}$, 3.85; $C_{26:0}$, 5.17; $C_{27:0}$, 11.82; $C_{29:0}$, 21.20; $C_{30:0}$, 8.99; $C_{31:0}$, 23.86; squalene (9.74) and others (3.32 %). The components of the aliphatic alcohols fraction were: $C_{20:0}$, 7.98; $C_{22:0}$, 8.97; $C_{24:0}$, 9.09; $C_{26:0}$, 17.33; $C_{27:0}$, 9.62; $C_{28:0}$, 20.80; $C_{30:0}$, 21.49 and others (4.72 %). The sterol fraction contained β-sitosterol (57.67 %), stigmasterol (23.54 %), campesterol (8.58 %) and cholesterol (10.22 %) (Al-Easa *et al.*, 2002).

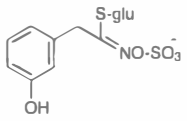
The following compounds were isolated from the lipid fraction of *O. baccatus*, growing in Egypt: long chain alcohol, lupeol, lanostane derivative, and a sterol mixture consisting of 7-stigmasterol and 7-ergostenol. Sixteen fatty acids and β-sitosterol glucoside were identified. Four glucosinolates were isolated from the leaves and inflorescences of the plant, identified as: 2-(*o*-hydroxyphenyl)ethyl glucosinolate (**1147**), 2-hydroxy-2-(*o*-hydroxyphenyl)ethyl-glucosinolate (**1148**), *m*-hydroxybenzyl glucosinolate (**1149**) and 2-hydroxy-(2',4'-dihydroxy-phenyl)ethyl glucosinolate (**1150**) (Sarg *et al.*, 1995).



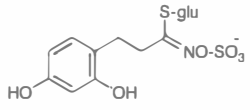
1147



1148



1149



1150

The following flavonoids were identified in the aerial parts of *O. baccatus*, growing in Egypt: apigenin, kaempferol, quercetin, kaempferitrin, rutin, quercetin 3-*O*-galactosyl-(1→2)-α-rhamnoside-7-*O*- α-rhmnoside, quercetin 3-*O*-*p*-coumaroyl-(1→2)-glucosyl-(1→6)-β-glucoside-7-*O*-α-rhamnoside, quercetin 3-gentiobioside, quercitrin, isoquercitrin, astragalin (kaempferol 3-glucoside) and afzelin (kaempferol 3-rhamnoside) (Barakat *et al.*, 1991; Sarg *et al.*, 1994).

XXX. RHAMNACEAE Durande

1. ZIZIPHUS Mill.

The proximate analysis of some *Ziziphus* species are shown in Table 165 (Duke and Atchley, 1986).

Table 165. The proximate analysis of some *Ziziphus* species

Species/ Plant part	Protein %	Fat %	Total carbohydrates %	Fiber %	Ash %
1. *Z. jujuba*					
leaves	11.8	6.3	75.3	14.3	8.6
shoots and fresh leaves	8.8	1.7	78.9	30.1	10.8
seeds	39.4	27.6			
	36.9	33.5			
fruits	6.9	1.7	88.7	4.8	2.6
	10.6	0.6	85.3	3.5	3.5
	4.0	0.7	92.6	4.7	2.7
	5.3		75.4	3.8	2.7
2. *Z. mauritiana*					
fruits	6.7	0.5	88.4	4.0	3.5
	5.3	0.0	91.0	6.5	5.8
	13.7	0.7	79.9		
	4.3	1.6	92.4		
3. *Z. mucronata*					
shoots and fresh leaves	14.3	2.6	73.7	8.4	9.4
4. *Z. nummularia*					
leaves	11.5	1.6	80.7	33.8	6.2
5. *Z. spina-christi*					
fruits	5.3	1.0	88.9		4.9

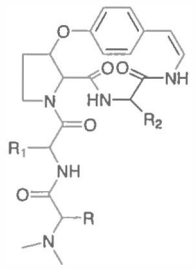
Several cyclopeptide alkaloide have been isolated from *Ziziphus* species, particularly from the barks. In addition, the fruits of *Z. sativus* contained isoquinoline alkaloids. Examples of the alkaloids, isolated from some *Ziziphus* species are listed in Table 166.

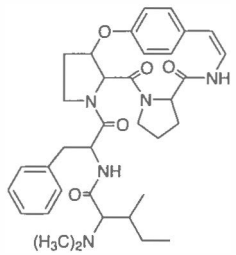
Table 166. Alkaloids of some *Ziziphus* species

Species	Alkaloids	References
1. *Z. amphibia*	Amphibines B (**1151**), D (**1152**) and E (**1153**)	Rizk (1986)
2. *Z. hutchinsonii*	Hysodricanine A (**1154**)	Rizk (1986)
3. *Z. hysodrica* (leaves)	Hysodricanine A and hysodricanine B	Rizk (1986); Khokhar and Ahmad (1993)
4. *Z. lotus* (bark)	Lotusine A (**1155**) and lotusine D (**1156**)	Ghedira *et al.* (1993)
5. *Z. mucronata* (bark)	Mucronines A-H, J (e.g. **1157-1160**), abyssenine A and two other cyclopeptide alkaloids (**1161,1162**)	Rizk (1986); Shah *et al.* (1987); Barboni *et al.* (1994); Auvin *et al.* (1996)

Table 166. Cont.

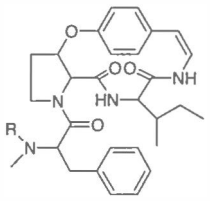
Species	Alkaloids	References
6. *Z. oenoplia*	Ziziphinine and ziziphines A-C (**1163-1165**)	Rizk (1986)
7. *Z. sativa* (bark)	Frangulanine (**1166**), sativanines A-G (e.g. **1167-1171**), frangufoline (**1172**), nummularine B, mucronine D, stepharine (**1173**), *N*-nornuciferine and asimilobine (**1174**)	Shah *et al.* (1985a,b,1986a,b); Rizk (1986)
8. *Z. spinosus*	Sanjoinine A	Park *et al.* (1996a)
9. *Z. vulgaris* var. *spinosus* (seeds)	Sanjoinine G1 (**1175**)	Park *et al.* (1996a)



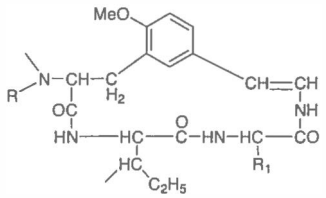


1151 Amphibine B; R = $C_6H_5CH_2$-, R_1 = $CH(CH)_3C_2H_5$, R_2 = $C_6H_5CH_2$
1152 Amphibine D; R = $C_6H_5CH_2$-, R_1 = $CH(CH)_3C_2H_5$, R_2 = -$CH(CH_3)C_2H_5$
1153 Amphibine E; R = $CH_2CH(CH_3)_2$-, R_1 = indolyl-CH_2, R_2 = -$CH(CH_3)C_2H_5$

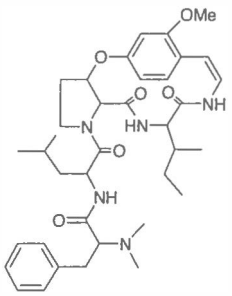
1154 Hysodricanine **A**



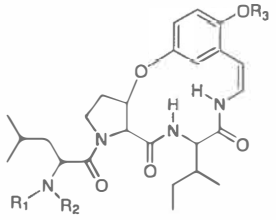
1155 Lotusine A; R = Me
1156 Lotusine D; R = H



1157 Mucronine A; R = CH_3, R_1 = CH_2-C_6H_5
1158 Mucronine B; R = H, R_1 = CH_2-C_6H_5
1159 Mucronine C; R = CH_3, R_1 = CH_2-$CH(CH_3)_2$

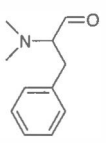


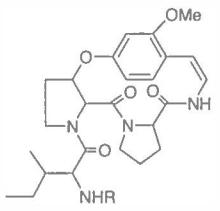
1160 Mucronine D



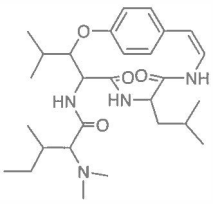
1161 R_1 = R_2 = R_3 = Me

1162 R_1 = R_2 = H, R_2 =

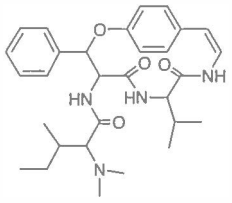




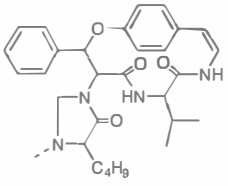
1163 Ziziphine A, R = N,N-dimethyl-Ile
1164 Ziziphine B, R = N-methyl-Ile
1165 Ziziphine C, R = N,N-dimethyl-Ph.



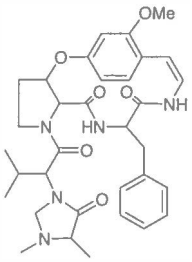
1166 Frangulanine



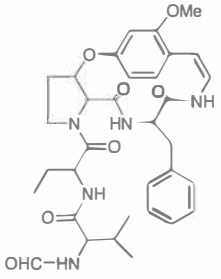
1167 Sativanine A



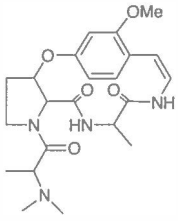
1168 Sativanine B



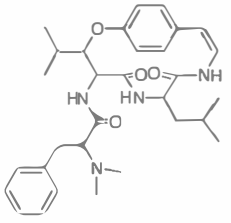
1169 Sativanine D



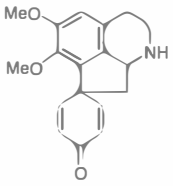
1170 Sativanine F



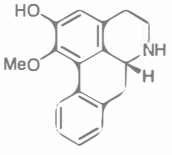
1171 Sativanine G



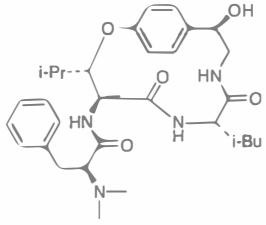
1172 Frangufoline



1173 Stepharine



1174 Asimilobine



1175 Sanjoinine G1

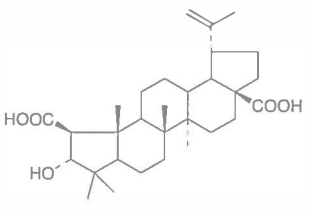
Caffeine has been detected in *Z. joazerio* (Myiake Kato and Alvarenga, 1997). The identification of several triterpenoids has been reported in *Ziziphus* species. Betulin and betulinic acid have been found to occur in varying amounts in most of the *Ziziphus* species (Murya *et al.*, 1989). Both triterpenoids have been identified in *Z. jujuba*, *Z. nummularia*, *Z. oenoplea*, *Z. rugosa*, *Z. sativa*, Z. *trinervia* and *Z. xylopyra* (Devi *et al.*, 1987; Tripathy *et al.*, 1988; Murya *et al.*, 1989). The stem bark of the Brazilian medicinal plant *Z. joazeiro* contained the following triterpenes: betulinic acid, lupeol, ursolic acid, alphitolic acid and 3 derivatives of betulinic acid, 7β-(4-hydroxybenzoyloxy)-betulinic acid, 7β-(4-hydroxy-3-methoxybenzolyloxy)-betulinic acid and 27-(4-hydroxy-3-methoxybenzoyloxy)-betulinic acid (Myiake Kate and Alvarenga, 1997; Schuhly *et al.*, 1999). The presence of oleanolic acid, 2α-hydroxy ursolic acid and ceanothic acid were also identified in *Ziziphus* species (Rizk, 1986). Lupeol, betulinic acid and isoceanothic acid (**1176**) have been identified in stem wood of *Z. xylopyra* (Jagadeesh *et al.*, 2000).

Four dammarane-type saponins were isolated from the root bark of *Z. lotus*: jujuboside A (**1177**), jujuboside C, lotoside I and lotoside II (Renault *et al.*, 1997). Jujubosides A and B (**1178**) were also isolated from the seeds of *Z. spinosa* (Wang and Lin, 1996). The stem bark of *Z. joazeiro* yielded two dammarane-type saponins: joazeirosides A and B (Schuhly *et al.*, 2000).

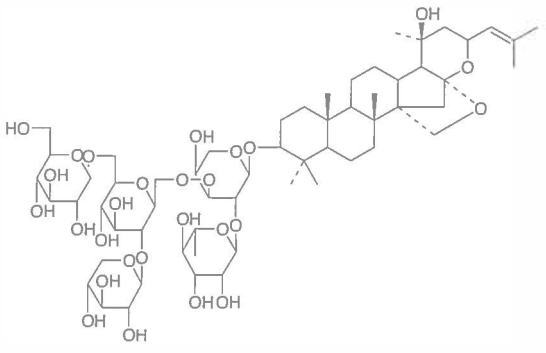
Rugoside A (**1179**) was isolated from *Z. rugosa* (Pandey and Tripathi, 1993). A saponin, which gave upon acid hydrolysis ebelin lactone was characterised from *Z. joazeiro* bark (Rizk, 1986).

β-Sitosterol and β-sitosterol glucoside were isolated from the bark of *Z. sativa* (Devi *et al.*, 1987). Glyceryl stearate was identified in the bark of *Z. joazeiro* (Myiake Kato and Alvarenga, 1997).

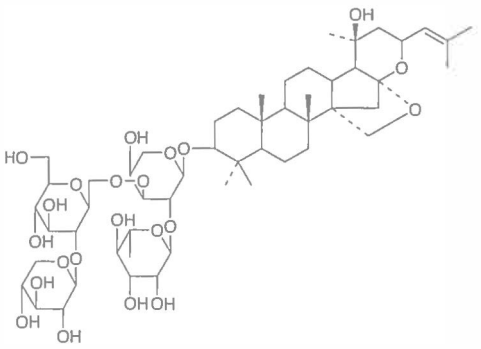
The seeds *of Z. vulgaris* var. *spinosus*, contained a number of flavone *C*-glycosides e.g. spinosin (2"-*O*-β-glucosylswertisin), derivatives of spinosin (**1180**) and swertisin (**1181**) (Rizk, 1986). The bark of *Z. rugosa* yielded kaempferol, quercetin, myricetin, apigenin and apigenin 7-*O*-glucoside (Tripathy *et al.*, 1988). Kaempferol and myricetin were identified in *Z. sativa* (Devi *et al.*, 1987). An antiallergic agent, identified as ethyl-α-D-fructopyranoside (**1182**), was isolated from *Z. fructus* (Rizk, 1986).



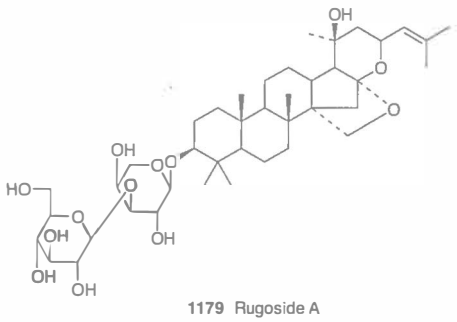
1176 Isoceanothic acid



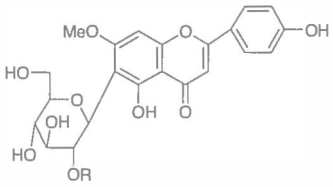
1177 Jujuboside A



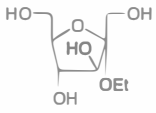
1178 Jujuboside B



1179 Rugoside A



1180 Spinosin; R = glucose
1181 Swertisin; R = H



1182

The use of *Ziziphus* species in folk medicine has been reported. *Z. rugosa* is reported to be used for the treatment of diarrhoea and menorrhagia in India (Tripathy *et al.*, 1988). *Z. mucronata*, known in South Africa as the "buffallo thorn", is reported to have numerous magico-medicinal uses. A widespread remedy for almost any pain is a poultice of the powdered and baked roots, which is eaten after removal from the affected area. The leaves are used for skin infections, while a root decoction is the accepted treatment among some Africans for tubercular gland-swellings. Sufferers from dysentery and lumbago also use the root. An infusion of the bark cures coughs (Palgrave, 1988, Barboni *et al.*, 1994). Some *Ziziphus* species have been found to possess sedative, analgesic, anti-inflammatory, hypoglycemic, antibacterial and antifungal activities (Jossang *et al.*, 1996). The water extracts of *Z. spinosa* seeds, leaves and fruits, but not jujuboside A, had inhibitory effects on the central nervous system (Wu *et al.*, 1993). Total saponins of *Z. spinosa* seed reduced the content of water and malondialdehyde in ischemic brain tissues in rats, elevated the activity of super oxide dismutase, creatin kinase and lactate dehydrogenase, decreased the content of lactate and alleviated the damage of nerve cells in the brain. These results suggested that *Z. spinosa* has protective effects on the cerebral ischemic injuries (Bai *et al.*, 1996). The sedative activity of cyclopeptide alkaloids isolated from the seeds of *Z. vulgaris* var. *spinosus* and stem bark of *Z. jujuba* var. *inermis*, has been reported (Han *et al.*, 1993). Mucronines F-H have been found to possess bacteriostatic and fungicidal activities (Tschesche *et al.*, 1974). The betalinic acid derivatives, isolated from *Z. joazeiro* showed antibacterial activity (Schuhly *et al.*, 1999).

1.1. *Ziziphus mauritiana* Hamilt.

syn.. *Z. jujuba* Lam., Encycl. 3:318 (1789).

Sidr (Ar.), Nabag, Kenar (Ar.) for fruits.

Large evergreen tree exceeding 5 cm in height with lush green leaves. Leaves ovate, palmatetly tri-nerved, shiny above, greyish beneath. Inflorescences cymose, pale yellow-green; flowers small. Fruit globose, orange drupes with sweet pulp

Habitat and Distribution

An exotic tree introduced to Qatar and now self-seeding. In private gardens in Doha and all major towns and a very popular tree grown for shade and fruit and as a hedge plant and a windbreaker in most farms.

Constituents

The proximate analysis and amino acids of *Z. mauritiana*, growing in Qatar, are shown in Tables 175 and 176 (Al-Easa, 2002a,b). The proximate analysis of the different parts of *Z. jujuba* and fruits of *Z. mauritiana* are shown in Table 165. The proximate composition of two samples of the fruits of Indian jujube (*Z. mauritiana*) was as follows: water 77.0, 73.7 %; protein 0.8, 0.5 %; fat 2.4, traces %; energy 388, 425 (KJ /100g); thiamine 0.46 (g/100 g) and ascorbic acid, traces, traces (James, 1983).

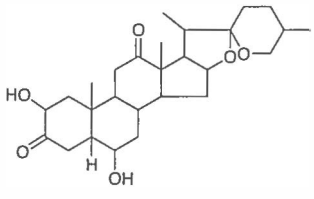
The amino acid composition of *Z. mauritiana*, growing in Niger, was as follows: aspartate 13.2, glutamate 12.6, serine 2.9, glycine 301, histidine 1.3, arginine 6.6, threonine 2.5, alanine 3.9, proline 3.1, tyrosine 2.2, valine 3.9, methionine 0.8, cysteine 1.9, isoleucine 3.0, leucine 5.1, phenylalanine 3.0, lysine 2.9 and tryptophan 1.7 mg/g dry weight. The total protein amounted to 73.7 mg/g dry weight. The fatty acid content of the same sample was: $C_{12:0}$, 0.05; $C_{14:0}$, 0.13; $C_{16:0}$, 3.90; $C_{16:1}$, 0.15; $C_{18:0}$, 2.20; $C_{18:1}$, 18.0; $C_{18:2}$, 7.20; $C_{18:3}$, 0.27; $C_{20:0}$, 0.52 and $C_{20:1}$, 0.13 mg/g dry weight. The mineral content of the plant was reported as follows: Ca

(4400), Cr (< 5.0), Cu (7.0), Fe (43.1), K (7250), Mg (1120), Mn (12.1), Mo (< 5.0), Na (7.7), Ni (< 5.0), P (1780), Se (< 5.0) and Zn (15.0) μg/g dry weight (Sena *et al.*, 1998).

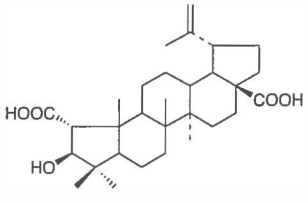
The fruits of ten cultivars of *Z. jujuba* contain 0.94-3.12 % crude protein, and 8.00-13.16 % sugars. The vitamin C content was 51.98-87.85 mg/100g of edible portion (Rizk, 1986).

The leaves of *Z. mauritiana* are an excellent source of the essential fatty acid linoleic acid, and several of the metals including Fe, Ca, Mg and Zn. Its content of other essential nutrients, however, was rather low (Sena *et al.*, 1998). The different composition (N, P, K, Ca, Mg, Fe, Zn and Mn) of the leaves of *Z. mauritiana* during different stages of the crop has been reported (Rizk, 1986). A mucilage was obtained from *Z. mauritiana* (Ghosh *et al.*, 1993). Sucrose was identified in *Z. jujuba* (Rizk, 1986). A lectin from *Z. mauritiana* has been purified and characterised from seeds and cotyledonary leaf callus extracts (Gupta and Srivastava, 1998). Fatty acids from the dried pulp of *Z. jujuba* contained 33 components with a chain length from 7 to 28 carbon atoms and approximately an equal ratio of total saturated and unsaturated, mainly monoenic, acids. Among them, the isomers of palmitoleic acid 16:1(7) and 16:1 (9) predominate (Gusakova *et al.*, 1999). Dihydroalphitolic acid methyl ester along with 14 oily constituents, were identified in fruits of *Z. jujuba* (Bai *et al.*, 1992). Seventy-eight compounds, among which aliphatic acids and carbonyl compounds accounted for 62.97 % and 29.56 % of the total, were identified in fruit of *Z. jujuba* var. *inermis*. The major compounds were decanoic acid (19.98 %) and dodecanoic acid (15.64 %) (Wong *et al.*, 1996).

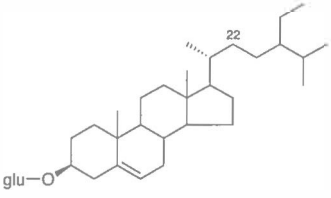
The stems of *Z. mauritiana* contained zizogenin (**1183**), a sapogenin, betulinic acid, lupeol, betulin, β-sitosterol and β-sitosterol acetate (Rizk, 1986). Betulin and betulinic acid were identified in the stem bark of *Z. jujuba* (Murya *et al.*, 1989). The roots of *Z. jujuba* var. *spinosa* contained the following compounds: betulin, betulinic acid, ursolic acid, ceanothic acid (**1184**), 2α-hydroyursolic acid, β-sitosterol-3-*O*-β-glucoside (**1185**) stigmasterol 3-*O*-β-glucoside (**1186**), 24-*O*-feruloyl-lignoceric acid (**1187**) (Lee *et al.*, 1995b), 2-*O*-protocatechuoylaliphitolic acid (**1188**), 2α-hydroxypyracrenic acid (**1189**) and 3-*O*-protocatechouylceanothic acid (**1190**) (Lee *et al.*, 1996).



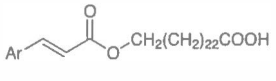
1183 Zizogenin



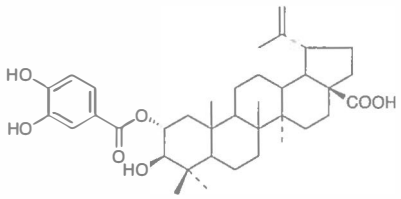
1184 Ceanothic acid



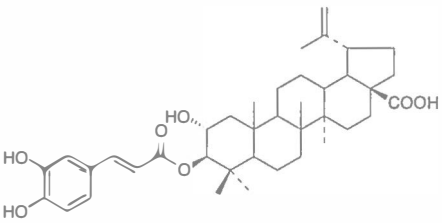
1185 β-Sitosterol 3-*O*-glucoside
1186 Stigmasterol 3-*O*-glucoside, Δ^{22}(*trans*)



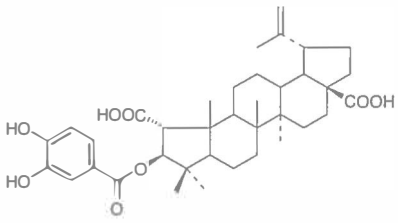
1187 24-*O*-Feruloyllignoceric acid



1188 2-*O*-Protocatechouylaliphitolic acid

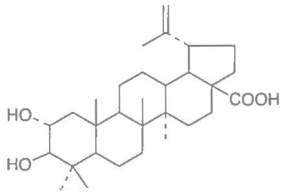


1189 2α-Hydroxypyracrenic acid

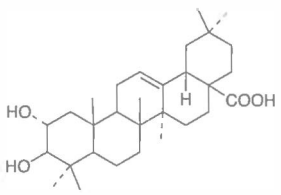


1190 3-*O*-Protocatechouylceanothic acid

The fruits of *Z. jujuba* contained in addition to the triterpenoid acids betulonic, betulinic, oleanolic and maslinic, several *p*-coumaroylates of alphitolic (**1191**) and maslinic **(1192)** acids identidied as: 3-*O-trans-p*-coumaroyl-, 2-*O-trans-p*-coumaroyl and 3-*O-cis-p*-coumaroyl alphitolic acid, 3-*O-trans-p*-coumaroyl and 3-*O-cis-p*-coumaroyl maslinic acid (Rizk, 1986).



1191 Alphitolic acid

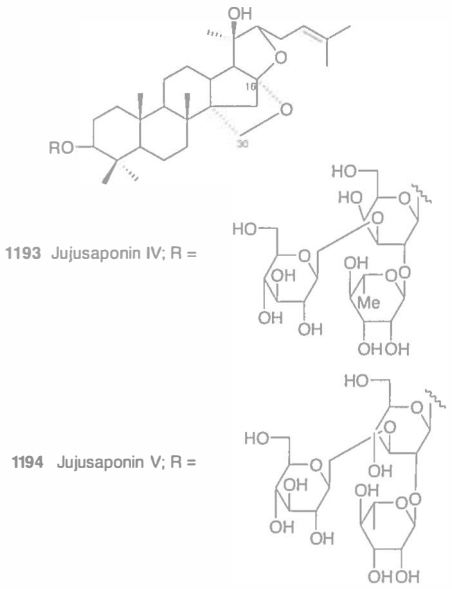


1192 Maslinic acid

The fruits of *Z. jujuba* var. *inermis* contain pentacylcic triterpenes and dammarane-type saponins. The seeds of *Z. jujuba* yielded jujobosides A and B and the fruits saponins I, II and III, all of which give on acid hydrolysis the sapogenin jujubogenin. Saponins (of the same type) together with pentacyclic triterpenes were identified in fruits of *Z. jujuba* var. *inermis* (Rizk, 1986).

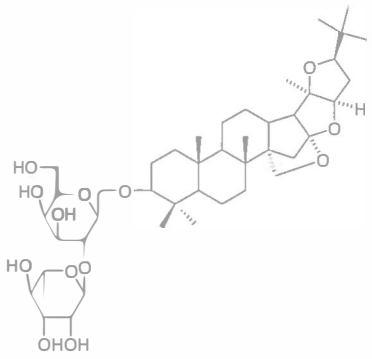
The leaves of *Z. jujuba* contained several dammarane saponins: jujusaponins I-VI (e.g. **1193-1195**), ziziphus saponins I-III (**1196-1198**) and jujuboside B. All these compounds showed sweet-reducing activity (antisweet principles) (Yoshikawa *et al.*, 1991,1992a,b).

The seeds of *Z. jujuba* var. *spinosa* contained several bioactive saponins: jujubosides A1 and C, acetyljujuboside B, protojujubosides A, B and B1. Protojujuboside A and jujubosides A-C were found to show potent immunological activity (Matsuda *et al.*, 1999).

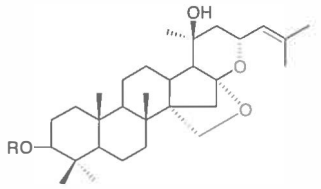


1193 Jujusaponin IV; R =

1194 Jujusaponin V; R =



1195 Jujusaponin VI



1196 Ziziphus saponin I; R = -ara-(3)glu, 6-deoxy-talose (2)

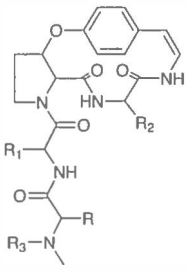
1197 Ziziphus saponin II; R = -ara-(3)glu, rha (2)

1198 Ziziphus saponin III; R = -ara-(3)glu-(2)xy, 6-deoxy-talose (2)

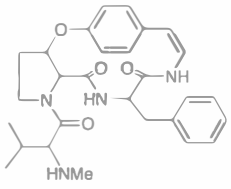
Several peptide akaloids have been isolated from the plant. The bark of *Z. mauritiana* contained mauritines A, B, C, D, E, F, H and J **(1199-1206)**, frangufoline and amphibines B, D, E, F **(1207)** and H **(1208)**, mucronine D, numularines A **(1209)** and B **(1210)** and jubanines A-C (e.g. **1211**, **1212**). The stem bark of *Z. jujuba* contains mauritine A, mucronine D, amphibine H, numularines A and B and jubanines A and B. Five alkaloids of the 13-membered cyclopeptide alkaloids were also isolated from *Z. jujuba* leaves. Also the leaves contained coclaurine, isoboldine **(1213)**, norisoboldine **(1214)**, asimilobine, juziphine **(1215)** and juzirine **(1216)** (Rizk, 1986). Cyclopeptide alkaloids were also present in seeds of the friut of *Z. jujuba* (Ahmad, 1991).

The glycosidic fraction of the fruits of *Z. jujuba* var. *inermis* reported to have hypotensive and sedative actions, has been found to contain the following *O*-glycosides of benzyl alcohol and vermifoliol: zizybeoside I (**1217**), zizybeoside II (**1218**), zizyvoside I (**1219**), zizyvoside II (**1220**), roseoside (**1221**), 6,8-di-*C*-glucosyl-2(*S*)-naringenin (**1222**) and 6,8-di-*C*-glucosyl-2(*R*)-naringenin (**1223**) (Rizk, 1986).

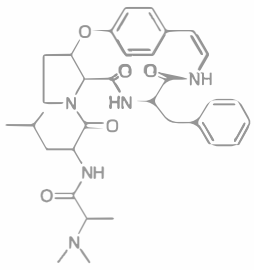
The seeds of *Z. jujuba* (*Z. vulgaris* var. *spinosa*) contain in addition to the flavone C-glycosides "spinosin" and swertisin, three acylated spinosins: spinosin A (6"-sinaposylspinosin, **1224**), spinosin B (6"-feruloylspinosin, **1225**) and spinosin C (6"-*p*-coumaroylspinosin, **1226**) (Rizk, 1986).



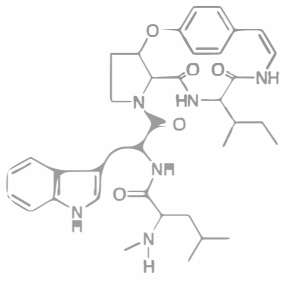
1199 Mauritine A; R = Me, R_1 = $CH(CH_3)_2$, R_2 = CH_2-C_6H_5, R_3 = Me
1200 Mauritine B; R = $CH(CH_3)C_2H_5$, R_1 = $CH(CH_3)_2$, R_2 = CH_2-C_6H_5, R_3 = Me
1202 Mauritine D; R = $CH(CH_3)C_2H_5$, R_1 = CH_2-$CH(CH_3)_2$, R_2 = $CH(CH_3)C_2H_5$, R_3 = Me
1203 Mauritine E; R = Me, R_1 = $CH(CH_3)_2$, R_2 = CH(OH)-C_6H_5, R_3 = Me
1204 Mauritine F; R = Me, R_1 = $CH(CH_3)_2$, R_2 = CH_2-C_6H_5, R_3 = H



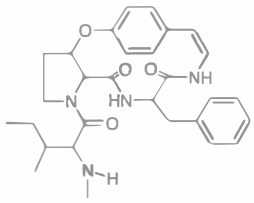
1201 Mauritine C



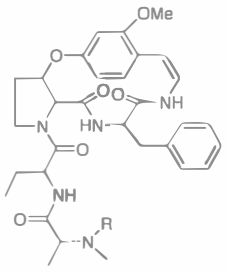
1205 Mauritine H



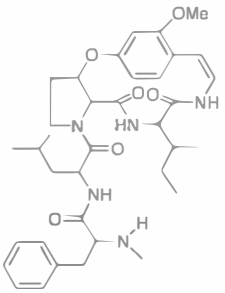
1206 Mauritine J



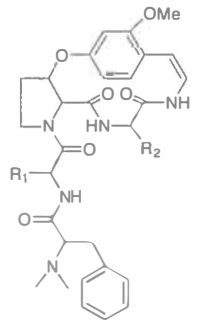
1207 Amphibine F



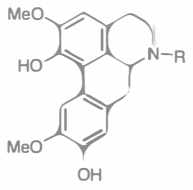
1208 Amphibine H; R = Me
1210 Nummularine B; R = H



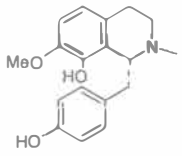
1209 Nummularine A



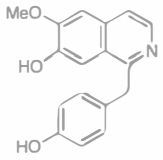
1211 Jubanine A; $R_1 = CH_2$-Ph, $R_2 = CHCH_3C_2H_5$
1212 Jubanine B; $R_1 = R_2 = CH_2$-Ph



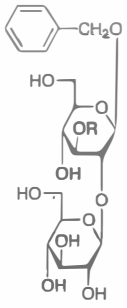
1213 Isoboldine, R = Me
1214 Norisoboldine; R = H



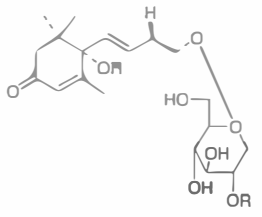
1215 Juziphine



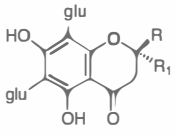
1216 Juzirine



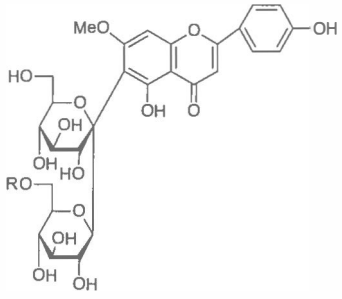
1217 Zizybeoside I; R = H
1218 Zizybeoside II; R = β-D-glucose



1219 Zizyvoside I; R = α-L-rhamnose, R_1 = H
1220 Zizyvoside II; R = R_1 = β-D-glucoe
1221 Roseoside; R = R_1 = H



1222 R = H, R_1 = Ph-OH
1223 R = Ph-OH, R_1 = H

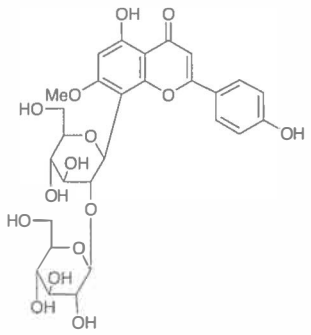


1224 Spinosin A; R = sinapoyl
1225 Spinosin B; R = feruloyl
1226 Spinosin C; R = *p*-coumaroyl

The leaves of *Z. jujuba* contained quercetin 3-*O*-glucoside, quercetin 3-*O*-diglucoside, quercetin-3-*O*-rutinoside, rhamnetin and eriodictiol (Souleles and Shammas, 1988). The seeds of *Z. jujuba* var. *spinosa* contained eight flavonoids: swertisin, puerarin, 6"-feruloylspinosin, apigenin-6-*C*-β-D-glucopyranoside, epinosin, 6"-feruloylisospinosin, isospinosin (**1227**) and isovitexin-2"-*O*-β-D-glucopyranoside (Cheng *et al.*, 2000).

Z. jujuba twigs contained 2.9 % tannins, while the bark contained 4.9 % (Rizk, 1986). Malik *et al.* (1997a) studied the catechin and proanthocyanidin compositions of the leaves and bark of *Z. jujuba* over the vegetation periods. This has led to the isolation of 16 compounds,

including 8 monomeric catechins: (-)-epiafzelechin, (-)-epicatechin, (-)-epigallocatechin, (-)-epicatechin gallate, (-)-epigallocatechin gallate, (+)-catechin, (+)-catechin gallate, and (+)-gallocatechin and 4 dimeric proanthocyanidins: (-)-epiafzelechin-(4β-8)-(-)-epicatechin, proroanthocyanidin B-2, (-)-epicatechin-(4β-8)-6-epigallocatechin and (-)-epiafzelechin-(4β-8)-(-)-epigallocatechin; and 4 oligomeric proanthocyanidins consisting of epiafzelechin, epigallocatechin, catechin and epicatechin.



1227 Isospinosin

Z. jujuba (syn. *Z. sativus*, *Z. vulgaris*) has been used in Greek folk medicine as a nutrient, emollient and laxative. The infusion of the fruits is used as a sedative, stimulant and duretic (Souleles and Shammas, 1998). The seeds of *Z. jujuba* var. *spinosa* are a famous Chinese medicine used for the treatment of insomnia (Lee *et al.*, 1996). Peng *et al.* (1995) reported the protective effect of seed of *Z. jujuba* in mice with endotoxin fever induced by superoxide dimutase deficiency.

1.2. ***Ziziphus nummularia*** (Burm. f.) Wight & Walk., Arn. Prodr. 162 (1834).
syn. *Rhamnus nummularia* Burm. f., Fl. Ind. 61 (1768).

Sidir (Ar.); Kanar, Nabag (Ar.) for fruits

Armed perennial stout woody trees or rambling shrubs reaching up to 3.5 m high or more but usually stunted by extensive over-grazing forming low thickets of dense growth. Branches zigzaging with alternate stipulate leaves. Stipules a pair of spines: one erect and the second down-curved. Leaves ovate-orbicular, palmately 3-nerved, glabrous and shiny above, dull green and tomentose beneath, about 1-2 cm long; smaller leaves may be produced on lower tree trunks by activated buds in response to extreme stress. Inflorescences fascicles of greenish yellow small flowers with distinct strong fruity smell. Fruit spherical orange drupe about 1 cm across bitter or sweet, edible and usually infested with insect larvae. Flowers and fruits Feb.-May.

Habitat and Distribution

In rodats with deep fine soils indicative of proximity of the water level and deep depressions with seasonal flooding. More common in central and north Qatar.
A much favoured heavily grazed plant by all animals in particular camels and goats.

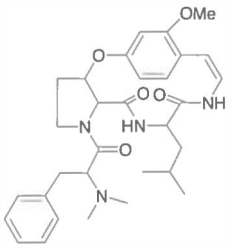
Constituents

The Fatty acids and minerals of *Z. nummularia*, growing in Qatar, are shown in Tables 175, 178 (Al-Easa, 2002c,d).

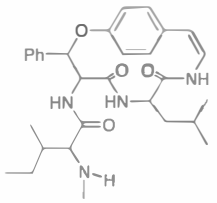
The evaluation of *Z. nummularia* leaves as a fodder for sheep and goat has been reported; it contained 5.84 % digestible crude protein and 47.51 % total digestible nitrogen (Rizk, 1986).

The root bark of *Z. nummularia* contained alkaloids of both the 13-membered and 14-membered cyclopeptide ring system: nummularines A, B, C **(1228)**, D **(1229)**, F **(1230)**, G **(1231)**, H **(1232)**, K **(1233)**, amphibine H and mucronine D (Rizk, 1986). The following alkaloids were isolated from the stem bark of *Z. nummularia*, growing in Saudi Arabia: amphibine-A, franganine, nummularine-F and sativanine-C (Shah *et al.*, 1990).

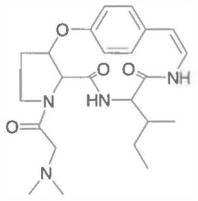
Zizynumin, a dammarane saponin (β-D-glucopyranosyl (1→2)-6-deoxy-α-L-talopyanosyl-(1→3)-α-L-arabinopyranosyl-(1→3)-jujubogenin) has been isolated from the leaves. A steroidal sapogenin, manogenin **(1234)** together with the flavonols taxifolin and its 3-glucoside have been identified from the whole plant. The bark yielded sitosterol, stigmasterol, betulinic acid, oleanolic acid, ceanothic acid and the β-glucosides of sitosterol and stigmasterol; and the leaves contained *n*-octacosanol and quercetin 3-*O*-galactoside (Rizk, 1986).



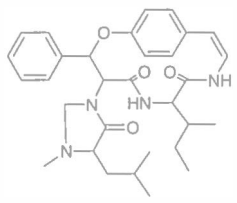
1228 Nummularine C



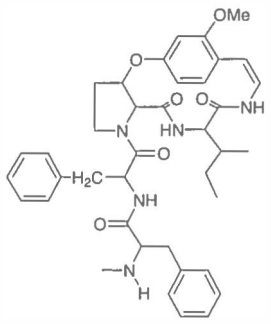
1229 Nummularine D



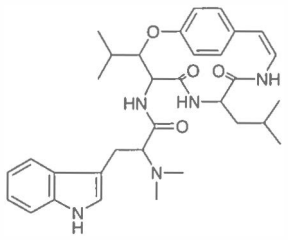
1230 Nummularine F



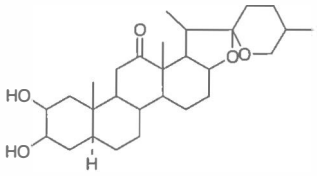
1231 Nummularine G



1232 Nummularine H



1233 Nummularine K



1234 Manogenin

Z. nummularia is reputed for is medicinal importance (Rizk, 1986). The edible fruit is cooling, astringent, appetizer and stomachic (Rizk and Ghazaly, 1995). The decoction of the bark is used for the treatment of joint pain, as gargle in sore throat and bleeding gum (Kirtikar and Basu, 1984). The crude alkaloids of the stem bark inhibited the growth of *Bacillus subtilis* (Shah *et al.*, 1990).

1.3. ***Ziziphus spina-christi*** (L.) Desf., Fl. Atlant. 1:201 (1798).
syn. *Rhamnus spina-christi* L., Sp. Pl., ed.1, 195 (1753).

Areen, Sidir (Ar.); Kanar, Nabag (Ar.) for fruits

Similar to *Z. nummularia* but a much larger tree with larger almost circular crown and more shiny leaves. Fruit always larger (slightly over 1 cm across), orange with sweet taste.

Habitat and Distribution

Less common in the wild and in fewer rodats. More common in farms reaching extremely large size in the availability of water e.g. As-Shahaneyia and north-eastern Qatar.

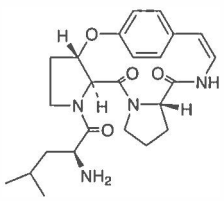
Constituents

Fructose, glucose, sucrose and raffinose were identified in the plant (Rizk, 1986). Total soluble solids, sugars, carotenoids and ascorbic acid contents of jujube fruit (*Z. spina-christi*) increased titratable acidity, total chlorophylls and total phenolics decreased with fruit maturity (Al-Niami *et al.*, 1992).

The leaves contained ceryl alcohol, β-sitosterol, ursolic acid and betulinic acid. The fatty acids were identified as myristic, stearic, oleic, linoleic, linolenic, and arachidic acids (Ali *et al.*, 1985). In addition to β-sitosterol, the following compounds have been identified from the

plant, β-sitosterol β-D-glucoside, octacosenol, octacosanol, octacosanyl behenate, *n*-nonacosane, betulic acid and ceanothic acid (Rizk, 1986).

The following alkaloids have been identified from the plant: amphibines A, E and F and mauritine C (Rizk, 1986). Franaganine, mauritine-C, sativanine-A, zizyphine-F, jubanine-A, amphibine-H and spinanine-A **(1235)** were isolated from the stem bark of the plant (Shah *et al.*, 1986b; Abdel-Galil and El-Jissry, 1991).



1235 Spinanine A

Saponin glycosides: christinins A-D have been isolated from the leaves (Glombitza *et al.*, 1994; Mahran *et al.*, 1996).

The leaves of *Z. spina-christi* contained the following flavonoids: dihydrokaempferol, apigenin 7-*O*-glucoside, taxifolin and taxifolin 3-*O*-glucoside (Ali *et al.*, 1985). The fatty acids of the leaves of *Z. spina-christi* (nabc), growing in Egypt, were identified as palmitic, the main constituent (72 %), followed by stearic (13 %), myristic (2 %) and traces of valeric, caproic, pelargonic, arachidic, henicosanoic, behenic and tricosanoic acids.

The neutral hydrocarbons identified in the unsaponifiable matter of the lipids, containd *n*-pentacoane (81 %), *n*-triacontane (8 %), *n*-nonadecane (5 %), *n*-tetratriacontane (3.7 %) and traces of C_{17}-C_{35} (Younes *et al.*, 1996).

The following compounds were identified in the volatile oil of the leaves: acetone (3.3), ethanol (5.20), acetic acid (0.63), butyric acid (2.83), diethylketone (4.46), 2-pentanone (3.96), β-ionone (1.84), *n*-propanol (10.26), 2-methylbutanol (2.72), methyl isovalerate (0.88), 3-methylbutanol (3.08), linalool (11.15), 2-pentanol (1.56), terpineol (16.42), β-pinene (0.26), amyl alcohol (0.74), benzaldehyde (0.53), geraniol (0.64), benzyl alcohol (0.21), *trans*-farnisol (3.76) and *cis*-farnisol (9.3 %). β-Sitosterol, oleanolic acid and maslinic acid, as well as arabinose, xylose, rhamnose and galactose were detected in the acid hydrolysate of the plant (Younes *et al.*, 1996).

The following flavonoids were isolated from the leaves, fruits and seeds of *Z. spina-christi*: quercetin, hyperoside, rutin and quercetin-3-*O*-[β-xylosyl-(1→2)-α-rhamnoside] 4'-*O*-α-rhamnoside (Nawwar *et al.*, 1984b; Shahat *et al.*, 2001).

The bark contained 9.25 % tannins. The tannins of both *Z. jujuba* and *Z. spina-christi* belong to the condensed class. The bark was reported to contain leucocyanidin (Rizk, 1986). The plant is used for various medicinal purposes. It is used as a demulcent, depurative, analgesic, emollient, against stomach pains and toothaches, as an astringent and a mouthwash (Duke, 1985). In Saudi Arabian folk medicine, the leaves are used to heal wounds, treat some skin-diseases, some inflammatory conditions and sores, against ringworm, fever, gonorrhoea, sex diseases and ulcers. The decoction of the bark and fresh fruits were used to promote the healing of fresh wounds and also as a body wash, while the fruits were used to control dysentery. The fruits were also used for bronchitis, cough and tuberculosis (Shahat *et al.*, 2001). The butanol extract of the leaves or its main saponin glycoside (christinin-A) improved glucose utilization in diabetic rats (Shahat *et al.*, 2001).

XXXI. *SOLANACEAE* Adans.

1. LYCIUM L.

Lycium barbarum, one of the common roughage feed of livestock in India, contained 28.14 % crude protein and 36.73 % crude fiber on a dry matter basis (Harsh *et al.*, 1981). The fresh fruit of *L. barbarum* contained lipid (1.87 g), protein (3.13 g), carbohydrates (9.13 g), fiber (1.62 g), Ca (22.53 mg), P (56.04 mg), Fe (1.33 mg), carotene (19.61 mg), thiamine (0.082 mg), riboflavin (0.14 mg), nicotinic acid (0.67 mg) and ascorbic acid (42.60 mg) per 100 g. The water content of top-grade fruit of *L. barbarum* was < 13 %, and the material contained lipids 8.72 g %, reducing sugars 34.83 g %, total sugar 37.95 g %, vitamin A 277.06 IU/g and ascorbic acid 23.1 mg %. Dry fruit contained Ca, Fe and P at concentrations of 107, 10.1 and 208 mg/g respectively (Qi and Li, 1981). The fresh fruits of *L. vulgare* contained 7.92 % reducing sugars (Weitz, 1921). The leaves of *L. barbarum* contained high levels of Ca (1087-4579), P (111-340), Fe (64.6-89.2) and nicotinic acid (10.58 mg/100 g) (Qi *et al.*, 1986).

Two kinds of arabinogalctan-protein (Cp-1-C and D) were obtained from the fruit of *L. barbarum*. In Cp-1-C, the carbohydrate was composed of arabinose and galactose at a ratio of 3:1 and *O*-glycosidically linked to both serine and threonine residues of the protein. In Cp-1-D, the ratio of arabinose to galactose was 1:1 and the *O*-glycosidal junction between the carbohydrate and the protein was composed of serine residue (Qin *et al.*, 2000).

Anticholesteremic proteins (344 mg from 20 g dry leaves) were extracted by water from boxthorn or matrimony vine (*Lycium*) (Sanwa Kagaku Kenkyusho Co., Ltd., 1980).

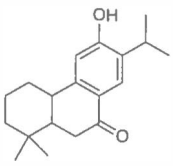
Ten amino acids, including leucine, isoleucine, phenylalanine, valine, tyrosine, proline, alanine, glycine, lysine, and glutamine, as well as lyceamin and trimethyl glycine were found in the fruits of *L. barbarum* (Qi and Li, 1981). The acid hydrolyste of the leaves of *L. chinense* showed the presence of 18 amino acids, being rich in basic amino acids. Free amino acids detected in the leaves were leucine, valine, alanine, lysine, glycine, glutamic acid and aspartic acid. The fruits contained leucine, valine, proline, alanine, tyrosine, glutamine, glycine, glutamic and aspartic acids, asparagine and histidine as free amino acids. Tryptophan was detected in the fruits but not in the leaves (Nishiyama, 1962). Meng *et al.* (1987) reported that the amino acid contents in the fresh fruit and fresh leaves of *L. chinense* were 3.01 and 2.90 % respectively. Relatively high content of aspartic acid, glutamic acid, alanine and proline were observed. The leaves of *L. chinense* contained 0.69 µmol nicotinamine/g fresh weight which corresponds to 8.9 % of the total free amino acids in the tissue except for the amides (Noma and Noguchi, 1976).

Configurational and conformational analyses of a unique cyclic octapeptide, lyciumin A (from *L. chinense*), showing an inhibitory activity on angiotensin-converting enzyme, was made by spectroscopic and computational chemical methods (Morita *et al.*, 1996).

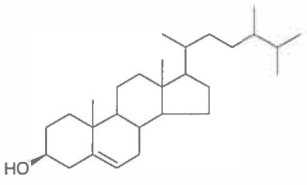
The floral nectary exudate of *L. cestroides* (a psychophilous and ornithophilous South American shrub) included amino acids, proteins, reducing acids and sugars. It was hexose dominant with 57.38 % glucose, 34.39 % fructose and 8.21 % saccharose. Lipids, phenols, and alkaloids were not present, although the vegetative parts contained alkaloids (Bernardello, 1986).

Oil from ripe fruit of *L. turcomanicum* showed antimutagenic activity. Its main saturated and unsaturated acids were palmitic and linoleic respectively. The oil of the pulp plus peel contained 61.8 and 38.2 % unsaturated and saturated acids respectively. The seed oil contained 86.3 and 13.7 % respectively with more oleic and linoleic acids than did the pulp oil (Aslanov and Mamedova, 1985). The seed oil of *L. barbarum* showed appreciable contents of palmitic, oleic and linoleic acids (Ahmad *et al.*, 1987b). The fatty acids of *Lycium* seed oil were reported by Chen *et al.* (2000) as followes: palmitic acid 10.34, stearic acid 4.02, oleic acid 23.31 and linoleic acid 46.07 %.

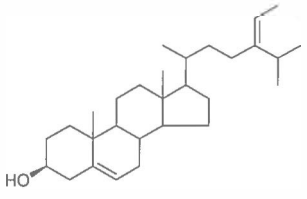
Several sterols have been identified in *L. chinense* e.g. β-sitosterol and its glucoside, campesterol, stigmasterol, 28-isofucosterol, cholesterol (Imai *et al.*, 1963; Jeong *et al.*, 1978), sugiol (**1236**) a diterpene and 5α-stigmastane-3,6-dione (Noguchi *et al.*, 1985). 24-Methylcholest-5-en-3β-ol (**1237**), 24-ethylcholest-5,22-dien-3β-ol (**1238**), 24-ethylcholest-5-en-3β-ol (**1239**), 24-ethylidenecholest-7-en-3β-ol (**1240**) and cholest-5-en-3β-ol (**1241**) were identified in dried fruits of *L. chilense* (Maldoni, 1993). The isolation of β-sitosterol and others has been reported from *L. barbarum* (Harsh and Nag, 1981), *L. ciliatum* (Dasso *et al.*, 1980) and *L. europaeum* (Manzoor-i-Khuda and Sultana, 1968).



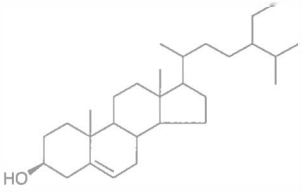
1236 Sugiol



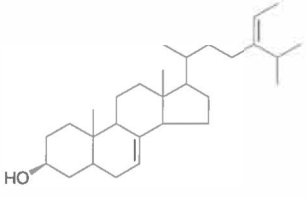
1237 24-Methylcholest-5-en-3β–ol



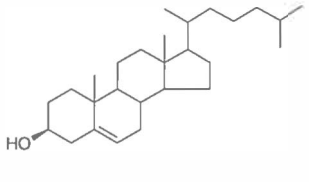
1238 24-Ethylcholesta-5,22-dien-3β–ol



1239 24-Ethylcholest-5-en-3β–ol



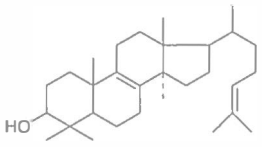
1240 24-Ethylidenecholest-7-en-3β–ol



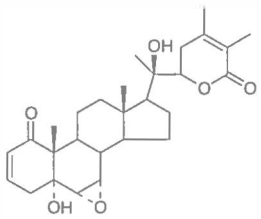
1241 Cholest-5-en-3β–ol

Several triterpenes have been identified in *L. chinense* (e.g. β-amyrin, cycloartenol and cycloeucalenol (Jeong *et al.*, 1978). Lanosterol (**1242**) and diosgenin were detected in *L. barbarum* (Harsh and Nag, 1981). Two withanolides (A (**1243**) and B) were isolated from the leaves of *L. chinense* (Haensel *et al.*, 1975). The roots of *L. europeum* yielded lanosterol, cycloartenol and urosolic acid (Afza *et al.*, 1987).

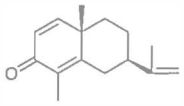
Two sesquiterpenes, solavetivone (**1244**) and (1,2-dehydro-α-cyperone) were isolated from the steam-volatile components of the semi-dried berries of *L. chinense* (Sannai *et al.*, 1982). 3-Hydroxy-7,8-dehydro-β-ionone (**1245**) was isolated from the neutral volatiles of *L. chinense* leaves (Sannai *et al.*, 1984). Kukamine A (**1246**), a spermine alkaloid possessing a hypotensive activity was isolated from *L. chinense* root barks (Funayama *et al.*, 1980). Imidazolic alkaloids *viz.* N^{α}-cinnamoylhistamine (Cabrera and Juliani, 1981), its *cis*-isomer form (Chiale *et al.*,



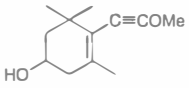
1242 Lanosterol



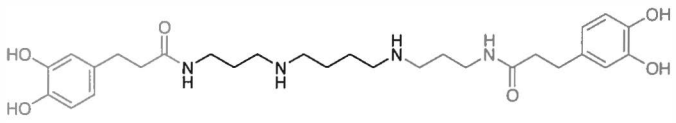
1243 Withanolide A



1244 Solavetivone



1245 3-Hydroxy-7,8-dehydro-β-ionone



1246 Kukamine A

1984), isomeric quasibicyclic forms of *N*'-cinnamoylhistamine and their methyl derivatives (Chiale *et al.*, 1990) have been isolated from the leaves of *L. cestroides*. Choline and/or betaine were isolated from leaves and/or roots of *L. barbarum* (Ahmad and Sultan, 1980), *L. chinense* (Maldoni, 1984), *L. halimifolium* (Drost-Karbowska *et al.*, 1984) and *L. tenuispinosum* (Maldoni, 1984). Leaves of *L. halimifolium* were devoid of alkaloids (Christen and Kapetanidis, 1987a). An unidentified alkaloid was isolated from *L. salsum* (Maguiña, 1951).

Five flavonol glycosides and two genins have been isolated from the leaves of *L. halimifolium*: quercetin-3-*O*-rutinoside, kaempferol-3-*O*-rutinoside-7-*O*-glucoside, rutin nicotiflorin, isoquercitrin, quercetin and kaempferol (Christen and Kapetanidis, 1987c). Quercetin and kaempferol were isolated from the leaves of *L. barbarum* (Harsh and Nag, 1988). Other studies revealed the presence of scopoletin (a coumarin) and vanillic acid in leaves of *L. chinense* (Haensel and Huang, 1977). Vanillic and salicylic acids were identified from the leaves of *L. barbarum* (Zhao *et al.*, 1987). The fruits of *L. barbarum* contained lyciumide A, 3-(4-methoxyphenyl)-N-[2-(3,4-dihydrophenyl)ethyl]-2-*Z*-propenamide) and scopolin (Zou *et al.*, 1999).

Zeanthin (34 mg) was obtained from dried (100 g) berries of *L. chinense* (Harashima and Yajima, 1969).

Rish and Ezdakova (1960) reported that the club moss (*L. ruthenicum*) has the ability to accumulate Li (up to 0.42 % in ash) and it serves as an indicator of Li content of soil. The results obtained from the study of frequency distribution of Li in leaves of *L. andersonii* imply that the variation in accumulation of Li depended upon the native supply of Li. The mean leaf concentration of Li in all locations (200 samples from 6 different locations) was 29 µg/g, but the maximum was 166 µg/g. Romney *et al.* (1977) studied the frequency distribution and correlation among 12 mineral elements in *L. andersonii* (from the Northern Mojave Desert). Li as previously reported and Na, Cu, Mn and B and Ba at some locations, were not normally

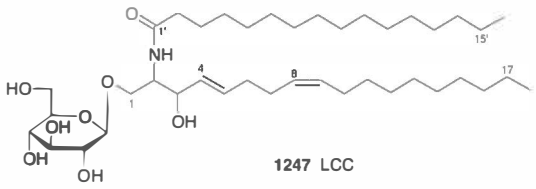
distributed. Wide variations in the concentrations of individual elements in leaves of these species were confirmed by Wallace *et al.* (1980a).

L. halimifolium was early reported by Rosenthlar (1926) to be cyanogenic. Glucosidic fractions (containing no N) were separated from the alkaloidal fractions of the alcoholic extract of *L. halimifolium* (Pizarroso *et al.*, 1965).

The oriental medicine "jikoppi", obtained from the root bark of *L. chinense*, has been shown to be clinically effective for hypertension, exhibiting hypotensive, hypoglycemic, antipyretic and anti-stress ulcer activity in experimental animals (Funayama *et al.*, 1980). *L. vulgare* has a parasympatholytic action resembling that of atropine (Delphaut and Balansard, 1949). A water-soluble, non-dialyzable substance extracted from *L. chinense* induced ovulation in adult female rabbits (Suzuki *et al.*, 1972).

L. barbarum polysaccharides (LBP) have been found to possess several activities. The results obtained by Wang *et al.* (1990) provided evidence of a protective effect of LBP in augmenting T-cell mediated immunity and NK-cell activity in normal and cyclophosphamide treated mice. LBP could prevent lipid disturbances in various tissues due to physical and chemical factors (CCl_4-induced lipid peroxidation in the liver, spleen and brain tissues of rats and mice) (Zhan *et al.*, 1989). Zhang *et al.* (1989b) found that LBP could activate peritoneal macrophages (M-PHI) of mice to certain extent and LBP combined with a small dose of *Cynobacterium parvum* (CP) showed a synergistic effect which was helpful to augment tumoristatic activity of M-PHI and to decrease the toxic action of CP, thereby suggesting a new immunotherapy method for cancer. Geng *et al.* (1989) stated that LBP could increase the activity of interleukin-2 (IL-2) of the spleen of adult mice (2 months old) and aged mice (16 months old) and restored the IL-2 activity of aged mice.

LCC **(1247)**, a cerebroside (1-*O*-(β-D-glucopyranosyl)-(2*S*,3*R*,4*E*,8*Z*)-2-*N*-palmitylocta-decasphinga-4,8-diene), isolated from the fruits of *L. chinense* exerted significant hepatoprotective activity against CCl_4-injured primary cultures of rat hepatocytes (Kim *et al.*, 1997a,1999). The results obtained by Kim *et al.* (2000) suggested that LCC, has a protective effect against galactosamine-induced hepatotoxicity in primary cultured rat hepatocytes by protecting RNA synthesis.



1247 LCC

1.1. ***Lycium shawii*** Roem. *et* Schult., Syst. Veg. 4:693 (1819).
syn. *Lycium arabicum* Schweinf. ex Boiss., Fl. Orient. 4:289 (1879).

Awsaj (Ar.); Musaa (Ar.) for fruit

Spiny perennial shrubs or bushes up to 2.5 m high usually much shorter and stunted by over-grazing. Branches stiff, pale, radiating in all directions and ending in thorns. When growing under the canopy of other trees, the branches are softer, leaves larger and habit scandent.

Leaves numerous, sessile, dark green, oblanceolate, about 2-5 cm long on thorny branches; spines 1-1.5 cm long. Inflorescences solitary, axillary; flowers tubular, mauve-white. Fruit orange-red berries, about 0.5 cm across, edible with a sweet-sour tomato taste. Flowers.and fruits Dec.-May.

Habitat and Distribution

Lycicum shawii is the most common shrub in Qatar and occurs in all habitats and land-forms; more common in rodats in association with *Ziziphus* and *Acacia* trees and in stony desert pavements in depressions, wadies, runnels and depressions. At Al Magda it forms a dense thicket. Equally, it occurs with well established lush green growth in the vicinity of moist habitats (agricultural fields, gardens, roadsides, sewage disposal areas). Plants respond phenotypically to water availability from dried twiggy bare spiny bushes to green leafy plants.

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *L. shawii*, growing in Qatar, are listed in Tables 175-178 (Al-Easa, 2000a-d).

Phytochemical screening of *L. shawii*, growing in Qatar, revealed the presence of alkaloids and sterol (and/or terpenes) (Rizk, 1982).

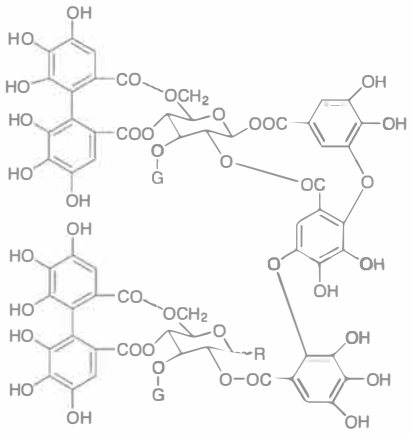
The unsaponifiabale matter of the lipids of *L. shawii*, growing in Qatar, consisted of sterols (23.05 %), hydrocarbons (44.18 %), aliphatic alcohols (19.67 %), 4-methylsterols (3.63 %) and triterpene alcohols (9.48 %). The hydrocarbons were identified as: $C_{21:0}$, 0.49, $C_{23:0}$, 4.70, $C_{24:0}$, 1.07, $C_{25:0}$, 17.25, $C_{26:0}$, 1.36, $C_{27:0}$, 23.55, $C_{29:0}$, 8.19, $C_{30:1}$, 2.77, $C_{31:0}$, 32.75, $C_{32:0}$, 2.06, squalene (1.76) and others (4.04 %). The alcoholic fraction consisted of $C_{20:0}$, 2.78, $C_{22:0}$, 12.00, $C_{24:0}$, 9.43, $C_{26:0}$, 16.99, $C_{27:0}$, 9.17, $C_{28:0}$, 37.07 and others (12.57 %). The identified

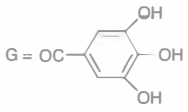
sterols were β3-sitosterol (53.17 %), stigmasterol (7.44 %), campesterol (19.69 %) and cholesterol (19.69 %) (Al-Easa *et al.*, 2002).

XXXII. TAMARICACEAE Berch & J. Presl.

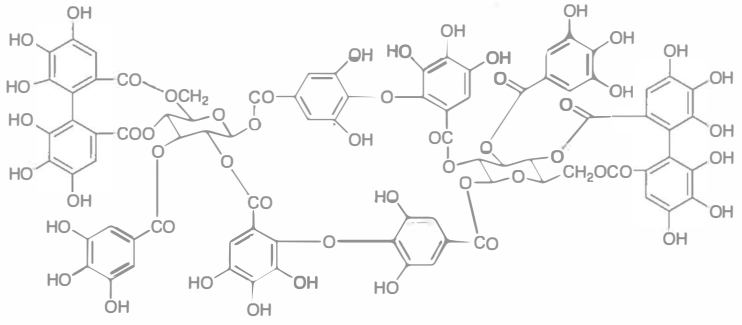
1. TAMARIX L.

Several secondary metabolites have been isolated from *Tamarix* species (Rizk, 1986; Sharma and Parmar, 1998). *Tamarix* species bear galls which are usually rich in tannins (up to 50 %) e.g. *T. aphylla*, *T. articulata*, *T. dioicia* and *T. gallica.* The bark of *Tamarix* spp. also contained tannins ranging from 5 to 14 %. *Tamarix* tannins belong to the pyrocatechol or mixed group and give fully tanned elastic, yellow-green leather (Rizk, 1986). Yoshida *et al.* (1991a,b,1993a,b) reported the isolation of several dimeric hydrolysable tannins: tamarixinins A (**1248**), B (**1249**), C (**1250**) and hirtellins A (**1251**), B (**1252**), C (**1253**), from *T. pakistanica.* These dimeric tannins had a dehydrogalloyl or dehydrotrigalloyl (hellinoyl) group as a linking unit between monomers. Trimeric ellagitannins (tamarixinins T1 and T2) were also isolated from the flowers of *T. pakistanica* (Ahmed *et al.*, 1994).





1248 Tamarixinin A; R = OH
1252 Hirtellin B; R = β-O-G



1249 Tamarixinin B

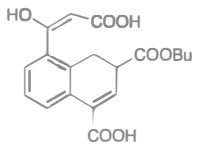
T. domingensis pollen had an energy value of 287.7 kcal/100 g (Rozycki *et al.*, 1997).

The temporal variation of dry weight, organic matter, chlorophyll a + phaeopigments and organic carbon of the periphyton on leaves of *T. domingensis* growing in Brazil were studied. A continual increase in the values of all parameters during colonization by periphytic organism was shown, with the highest values occurring during the intermediate and final phases. In summer, a larger increase of biomass occurred over a shorter time interval, and also the chlorophyll a + phaeopigment values were higher (Fernandes and Esteves, 1996). The contents of organic matter, organic carbon, N, P, starch, soluble carbohydrates, lipids, soluble tannins, cell wall fraction, and energy were quantified in the biomass of *T. domingensis* (Imboacica Lagoon, Brazil) (Furtado and Esteves, 1996).

Flowers of *T. angustata* contained β-sitosterol, β-sitosterol palmitate, 5α-stigmastane-3,6-dione, pentacosane, nonacosane-6,8-diol and nonacosane-6,10-diol (Liu *et al.*, 1985). The rhizome of *T. angustata* contained β-sitosterol, cholesterol and lanosterol (Rizk, 1986). Pentacosane, β-sitosterol palmitate, 7-methyl-4-triacontanone and 6-tritriacontanol, were isolated from the pollen of *T. angustifolia* (Jia *et al.*, 1990).

T. angustifolia and *T. angustata* contained quercetin, isorhamnetin and isorhamentin 3-*O*-rutinoside (Yang *et al.*, 1986b). Five flavonoid glycosides were isolated from the pollen of *T. angustifolia*: typhaneoside, kaempferol 3-*O*-(2^G-α-L-rhamnosyl) rutinoside, isorhamnetin 3-*O*-neohesperidoside, kaempferol 3-*O*-rhamnogucoside and quercetin 3-*O*-neohesperidoside (Jia *et al.*, 1986).

Typhic acid (**1274**) was identified in the flower of *T. angustata* (Xu *et al.*, 1987). The female inflorescences of *T. angustata* contained vanillic acid, *trans*-*p*-hydroxycinnamic acid, protocatechuic acid, *trans*-propenoic acid-3-(4-hydroxyphenyl)-2,3-dihydroxypropyl ester, succinic, *p*-hydroxybenzaldehde and D-mannitol (Xu *et al.*, 1986a).



1274 Typhic acid

Phytochemical screening of *T. domingensis*, growing in Qatar, revealed the presence of alkaloids, saponins, tannins and sterols (and/or terpenes) (Rizk, 1982).

T. domingensis was reported suitable for boards or mixed with some sulphite, for packing paper (Rizk, 1986a).

XXXIV. ZYGOPHYLLACEAE R. Br.

1. FAGONIA L.

The proximate analysis of six *Fagonia* species, growing in Egypt, has been reported by Ahmed *et al.* (1969b) (Table 169).

Table 169. Proximate analysis of six Egyptian *Fagonia* species

Species	Moisture *%	Lipid **%	Ash **%	Total nitrogen**
1. *F. arabica*	10.20	0.45	7.55	4.45
2. *F. burguieri*	10.85	0.30	5.65	5.95
3. *F. cretica*	10.20	0.35	11.56	4.73
4. *F. glutinosa*	10.45	0.57	10.88	6.25
5. *F. mollis*	11.20	1.14	13.38	3.00
6. *F. parviflora*	8.35	0.85	9.95	1.68

*calculated on air dried material; **calculated on the anhydrous materal.

The lipids of six *Fagonia* species contained high percentage of saturated fatty acids ranging from 48.66 in *F. arabica* to 61.00 in *F. mollis*. Linoleic acid was the most predominant unsaturated acid of all the lipids; its percentage varied from 14.75 in *F. glutinosa* to 24.34 in *F. arabica*. The other fatty acids were represented by variable amounts (Table 170) (Ahmed *et al.*, 1969c).

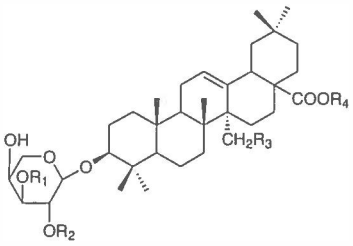
Table 170. The percentage of fatty acids in six *Fagonia* species

Species	14:0	16:0	18:0	18:1	18:2	18:3	20.0	22:0	24:0
1. *F. arabica*	6.66	32.83	7.12	20.35	24.34	6.65	-	2.05	-
2. *F. burguieri*	3.34	13.41	4.30	7.72	22.59	16.89	-	24.24	7.51
3. *F. cretica*	11.52	23.54	14.41	19.98	22.08	7.41	-	1.06	-
4. *F. glutinosa*	4.15	9.08	5.88	7.21	14.75	17.60	11.58	15.40	14.35
5. *F. mollis*	3.53	11.08	5.54	5.65	14.97	18.18	13.08	20.44	7.35
6. *F. parviflora*	3.35	9.74	6.84	6.53	16.11	17.90	15.05	24.48	

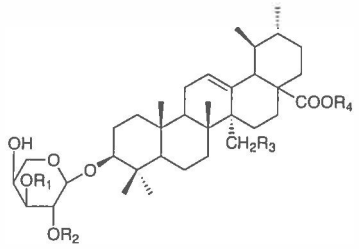
β-Sitosterol, campesterol, stigmasterol and 1-triacontanol were identified in several *Fagonia* species (Ahmed *et al.*, 1969c). The free sugars of the six Egyptian *Fagonia* species studied by Ahmed *et al.* (1969a) were glucose and maltose.

Seven triterpenoid saponins were isolated from the aerial parts of *F. arabica*, they were characterised as 3-*O*-β-D-xylopyranosyl-(1→2)-[β-D-glucopyranosyl-(1→3)]-α-L-arabinopyranosyl oleanolic acid 28-*O*-β-D-glucopyranoside (**1275**), 3-*O*-β-D-glucopyranosyl-(1→2)-[β-D-glucopyranosyl-(1→3)]-α-L-arabinopyranosyl oleanolic acid 28-*O*-β-D-glucopyranoside (**1276**), 3-*O*-β-D-xylopyranosyl-(1→2)-[β-D-glucopyranosyl-(1→3)-α-L-arabinopyranosyl oleanolic acid (**1277**), 3-*O*-β-D-glucopyranosyl-(1→2)-[β-D-glucopyranosyl-(1→3)]-α-L-arabinopyranosyl oleanolic acid (**1278**), 3-*O*-β-D-xylopyranosyl-(1→2)-[β-D-glucopyranosyl(1→3)]-α-L-arabinopyranosyl 27-hydroxyoleanolic acid 28-*O*-β-D-glucopyranoside (**1279**), 3-*O*-β-D-xylopyranosyl-(1→2)-[β-D-glucopyranosyl-(1→3)]-α-L-arabinopyranosyl ursolic acid 28-*O*-β-D-glucopyranoside (**1280**) and 3-*O*-β-D-xylopyranosyl-(1→2)-[β-D-glucopyranosyl(1→3)]-α-L-arabinopyranosyl 27-hydroxyoleanolic acid 28-*O*-β-D-glucopyranoside (**1281**) (Miyase *et al.*, 1996). *F. mollis* yielded three saponins, identified as oleanolic acid 3-*O*-6'-methyl-β-D-glucuronopyranoside (**1282**), oleanolic acid 3-*O*-α-L-rhamnopyranosyl-(1→3)-6'-*O*-methyl- β-D-glucuronopyranoside (**1283**), and oleanolic acid 3-*O*-α-L-thamnopyranosyl-(1→3)-6'-*O*-methyl-β-D-glucopyranosyl-28-*O*-β-D-glucuronopyranoside (**1284**) (Melck *et al.*, 1998). Two oleanolic acid glycosides and three steroid glycosides of pregnane series were isolated from

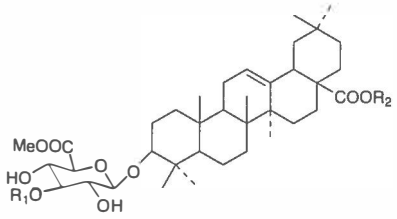
F. arabica (Shoeb *et al.*, 1994). Lupeol, lupeol acetate and lupeol palmitate were identified in *F. mollis* var. *grandiflora* (Attia and Youssef, 1999).



1275 R_1 = glu, R_2 = xyl, R_3 = H, R_4 = glu
1276 R_1 = glu, R_2 = glu, R_3 = H, R_4 = glu
1277 R_1 = glu, R_2 = xyl, R_3 = H, R_4 = H
1278 R_1 = glu, R_2 = glu, R_3 = H, R_4 = H
1279 R_1 = glu, R_2 = xyl, R_3 = OH, R_4 = glu



1280 R_1 = glu, R_2 = xyl, R_3 = H, R_4 = glu
1281 R_1 = glu, R_2 = xyl, R_3 = OH, R_4 = glu



1282 R_1 = H, R_2 = H
1283 R_1 = α-L-rha, R_2 = H
1284 R_1 = α-L-rha, R_2 = β-D-glu

Alkaloids were detected in several *Fagonia* species. In the six studied species by Ahmed *et al.* (1969b), their percentages was as follows: *F. arabica* 0.16, *F. burguiere* 0.07, *F. cretica* 0.11, *F. glutinosa* 0.17, *F. mollis* 0.09 and *F. parviflora* 0.03.

Several flavonoids have been identified in *Fagonia* species (Table 171).

Table 171. Flavonoids of some *Fagonia* species

Species	Flavonoids	References
1. *F. arabica*	Isorhamnetin 3-glucoside, herbacetin 8-rutinoside, herbacetin 8-methylether-3-rutinoside, herbacetin 3,7-diglucoside, herbacetin 3-rutinoside-7-glucoside and apigenin glycosides	El-Negoumy *et al.* (1986); Shoeb *et al.* (1994)
2. *F. mollis*	Kaempferol and isorhamnetin 3-rutinosides	Al-Wakeel *et al.* (1987b)
3. *F. mollis* var. *grandiflora*	Kaempferol, herbacetin 8-methylether, isorhamnetin and quercetin	Attia and Youessef (1999)
4. *F. taeckholmiana*	Isorhamnetin 3-glucoside, isorhamnetin 3-rutinoside, herbacetin 8-rutinoside, herbacetin 8-methyl ether-3-rutinoside, herbacetin 3,7-diglucoside and herbacetin 3-rutinoside-7-glucoside	El-Negoumy *et al.* (1986)

Table 171. Cont.

Species	Flavonoids	References
5. *F. thebaica*	Quercetin 3-rutinoside, quercetin 3,7-diglucoside, isorhamnetin 3-glucoside, isorhamnetin 3-rutinoside, isorhamnetin 3, 7-diglucoside, herbacetin 8-rutinoside, herbacetin 3-glucoside and herbacetin 8-methylether-3-rutinoside	Al-Wakeel *et al.* (1987a)
6. *F. tristis*	Kaempferol 3-rutinoside, isorhamnetin 3-rutinoside and 8-*O*-methylherbacetin	Al-Wakeel *et al.* (1987b)

1.1. *Fagonia burguieri* DC., Prodr. 1:704 (1824).

Shouka, shuweika (Ar.)

Spiny low subfrutescent semi-perennial herb forming compact semi-globular plant. Leaves unifoliolate-trifoliate, longer than spines. Inflorescences axillary, solitary. Flowers white-deep pink; calyx persistent. Fruit dry, schizocarpic, of 4-5 mericarps.

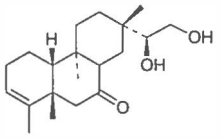
Habitat and Distribution

Widespread in disturbed areas in all towns along roadsides and edges of cultivated land.

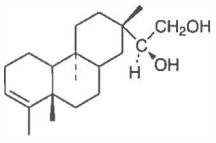
Constituents

The proximate analysis and fatty acids of *F. burguieri*, growing in Egypt, are shown in Tables 169 and 170. The plant was also reported to contain glucose and maltose (Ahmed *et al.*, 1969a).

The plant growing in Egypt contained several saponins identified as: fagonin glycoside and oleanolic acid glycoside (Ahmed *et al.*, 1969a). *F. burgieri*, yielded 4-erythroxan diterpenes: fagonone (**1285**, 15,16-dihdroxy-7-oxo-*cis-ent*-erythrox-3-ene), 16-*O*-acetylfagonone (Abdel-Kader *et al.*, 1993) and fagonene (**1286**, 15,16-dihydroxy-*cis-ent*-erythrox-3-ene) and 7β-hydroxyfagonene (Abdel-Kader *et al*, 1994).



1285 Fagonone



1286 Fagonene

Abdel-Kader *et al.* (1993) reported the identification of five substituted 8-methoxyflavones in *F. burgieri.*

1.2. ***Fagonia glutinosa*** Delile, Descr. Egypte., Hist. Nat. 86 (1814).

Shouka, shuweika (Ar.)

Viscid glandular perennial herb. Branches many, prostrate, sub-woody. Leaves compound, trifoliolate, longer than the spines. Inflorescences axillary, solitary. Flowers pink; calyx persistent in fruit. Fruit dry, schizocarpic, with 4-5 mericarp.

Habitat and Distribution

Less common than other *Fagonia* species. Rare on sandy-stony ground in central and southern Qatar.

Constituents

The proximate analysis and fatty acids of *F. glutinosa*, growing in Egypt, are shown in Tables 169 and 170. The plant contained β-sitosterol, stigmasterol, campesterol, hexacosanol, glucose, maltose and octacosanol (Ahmed *et al.*, 1969a,c; Al-Nagdy and Rizk, 1978).

Two cytotoxic erthroxan diterpenes: 1α,10α-epoxy-2-oxofagonene and 1β,10β-epoxy-2-oxofagonene and two inactive diterpenes, 2-oxofagonene and its isomer 2-oxo-5-*epi*-fagonene were isolated from the aerial parts of *F. glutinosa*, growing in Egypt (Abdel-Kader *et al.*, 1997).

Twelve triterpenoid saponins were identified from the plant: 3-*O*-[β-D-glucopyranosyl-(1→2)]-[β-D-glucopyranosyl-(1→3)]α-L-arabinopyranosyl-27-hydroxy oleanolic acid 28-*O*-β-D-glucopyranosyl ester, 3-*O*-[β-D-glucopyranosyl-(1→3)]-α-L-arbinopyranosyl ursolic acid, 3-*O*-α-L-arabinopyranosyl ursolic acid 28-*O*-β-D-glucopyranosyl ester, 3-*O*-[β-D-xylopyranosyl-(1→2)][β-D-glucopyranosyl-(1→3)-α-L-arbinopyranosyl ursolic acid, 3-*O*-[β-D-glucopyranosyl-(1→2)[β-D-glucopyranosyl-(1→3)-α-L-arbinopyranosyl ursolic acid 28-*O*-β-D-glucopyranosyl ester, 3-*O*-[β-D-glucopyranosyl-(1→2)][β-D-glucopyranosyl-(1→3)]-α-L-arabinopyranosyl-27-hydroxy ursolic acid 28-*O*-β-D-glucopyranosyl ester (Melek *et al.*, 2000). Oleanolic acid was identified in the saponins hydrolysate of the plant growing in Qatar (Al-Nagdy and Rizk, 1978; Melek *et al.*, 2000). Fagonin and oleanolic saponins were also reported in the plant (Rizk, 1986).

1.3. ***Fagonia indica*** Burm. f., Fl. Ind. 102, t. 34, (1768).
syn. *F. parviflora* Boiss., Fl. Orient. 1:908.(1867).

Showcika (Ar.).

Spiny low perennial herb with numerous basal glabrous branches forming a subglobose woody plant. Leaves simple, lanceolate, shorter than spines. Inflorescences axillary, solitary. Flowers pale rose-deep pink; calyx persistent. Fruit dry, schizocarpic, with 4-5 mericarps.

Habitat and Distribution

Widespread in all disturbed areas in particular along roadsides in Doha and all major towns in Qatar.

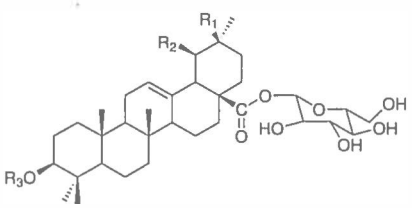
Constituents

The proximate analysis, amino acids, fatty acids and minerals of *F. indica*, growing in Qatar, are shown in Tables 175-178 (Al-Easa, 2002a-d).

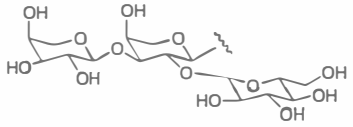
Several triterpenoid saponins have been isolated from *F. indica viz.* 23,28-di-*O*-β-D-glucopyranosyltaraxer-20-en-28-oic acid, 3β, 28-di-*O*-β-D-glucopyanosyl-23-hydroxytaraxer-20-en-28-oic acid (Ansari *et al.*, 1987), 3-*O*-{[β-D-glucopyranosyl-(1→2)]-[α-L-arabinopyranosyl-(1→3)]-α-L-arabinopyranosyl}-ursolic acid-28-*O*-[β-D-glucopyranosyl] ester (indicasaponin A, **1287**), 3-*O*-{[β-D-glucopyranosyl-(1→2)]-[α-L-arabinopyranosyl)-(1→3)-α-L-arabinopyranosyl}-oleanolic acid-28-*O*-[β-D-glucopyranosyl] ester (indicasaponin B, **1288**), 3-*O*-[β-D-glucopyranosyl-(1→3)-α-L-arabinosyl]-ursolic acid-28-*O*-[β-D-glucopyranosyl] ester (matesaponin 1, **1289**) anad 3-*O*-[β-D-glucopyransoyl-(1→3)-α-L-arabinopyranosyl]-oleanolic acid-28-*O*-[β-D-glucopyranosyl] ester (guaiacin B, **1290**) (Shaker *et al.*, 1999). Two sulfonated triterpenoids have also been isolated from the plant: 3-*O*-{[β-D-4-*O*-sulfonylglucopyranosyl-(1→3)-α-L-arabinopyranosyl}-ursolic acid-28-*O*-[β-D-glucopyranosyl] ester (indicasaponin C, **1291**) and 3-*O*-{[β-D-4-*O*-sulfonylglucopyranosyl-(1→3)]-[β-D-glucopyranosyl-(1→2)-α-L-arbinopyranosyl]-ursolic acid-28-*O*-[β-D-glucopyranosyl] ester (indicasaponin D, **1292**) (Shaker *et al.*, 2000). The sapogenins oleanolic acid, ursolic acid, betulic acid, hederagenin, nahagenin **(1293)** and fagonin were detected after acid hydrolysis of the EtOH extract of the aerial parts of *F. indica* (Ahmed *et al.*, 1969a; Atta-Ur-Rahman and Ansari, 1984).

The identification of nine flavonol glycosides from four samples of four taxa of the *F. indica* complex occurring in Egypt was reported. The compounds were based primarily on the aglycons: kaempferol, quercetin and isorhamnetin (El-Hadidi *et al.*, 1988).

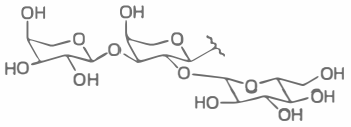
The plant is claimed to be a remedy for cancer in its early stages (Chopra *et al.*, 1956; Atta-ur-Rahman, 1983). An aqueous decoction of the leaves and young twigs is a popular remedy for treatment of various skin lesions. An Ames mutagenicity test has also indicated marginal activity (Atta-ur-Rhman *et al.*, 1982).



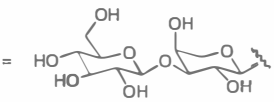
1287 Indicasaponin A $R_1 = H, R_2 = 29\text{-Me}, R_3 =$



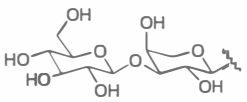
1288 Indicasaponin B $R_1 = 30\text{-Me}, R_2 = H, R_3 =$

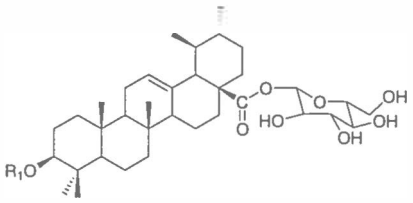


1289 Matesaponin 1 $R_1 = 29\text{-Me}, R_2 = H, R_3 =$

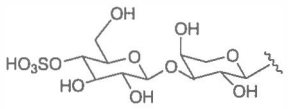


1290 Guaiacin B $R_1 = 30\text{-Me}, R_2 = H, R_3 =$

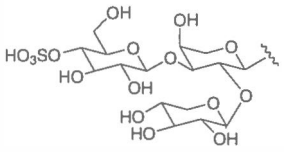


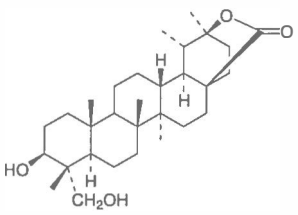


1291 Indicasaponin C R =



1292 Indicasaponin D R =





1293 Nahagenin

1.4. ***Fagonia ovalifolia*** Hadidi in Rech., Fl. 98 : 2 (1972).
syn. *F. critica*

Showeika (Ar.)

Spiny decumbent prostrate sub-woody herb. Branches glabrous. Leaves simple, ovate, with prominent veins, longer than spines. Inflorescences axillary, solitary. Flowers pink; calyx deciduous. Fruit dry, schizocarpic, with 4-5 mericarps.

Habitat and Distribution

Widespread in Qatar particularly on sandy soils at Um Bab and road to Dukhan. Elsewhere on blown sands covering stony ground.

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *F. ovalifolia*, growing in Qatar, are shown in Tables 175,176 and 178 (Al-Easa, 2002a,b,d).

Phytochemical screening of the plant, growing in Qatar, revealed the presence of alkaloids, favonoids, saponins, sterols (and/or terpenes) and tannins (Rizk, 1982).

1.5. ***Fagonia tenuifolia*** Stued. & Hochst. ex Boiss., Fl. Orient. 1:909 (1867).
syn. *F. cretica* L.; *F. bischarorum* Schweinf., Bull. Herb. Boiss. 7, App. 2:276 (1899).

Showeika (Ar.)

Spiny, perennial low woody prostrate herb. Leaves compound, trifoliolate longer than spines, aromatic. Inflorescences axillary, solitary. Flowers violet. Fruit dry, schizocarpic, with 4-5 mericarps.

Habitat and Distribution

On sandy depressions in central Qatar (Al-Shahaneya, Al-Karaana).
Reported as grazed by some animals.

Constituents

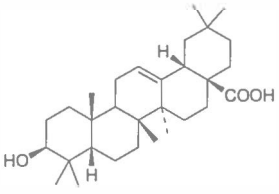
The proximate analysis and fatty acids of *F. cretica*, growing in Egypt, are shown in Tables 169 and 170. Caproic, caprylic and lauric acids were detected in the plant (Rizk, 1986).

Trace elements (Al, Ag, Ba, Ca, Cr, Cu, Fe, Mn, Ni, Pb, Sr, Ti and Zn) were determined in the ashes of leaves, shoots, flowers, seeds and roots of *F. cretica*, collected from the sandy areas of Karachi, Pakistan. The plant was reported to have large amounts of nutrient elements (Fatima *et al.*, 1999). The uptake and concentration of uranium in *F. cretica* were reported (Qazi and Jafri, 1996).

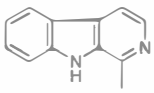
The friut of *F. cretica* contained 150 mg/100 g free ascorbic acid (Nag *et al.*, 1986).

F. cretica contained β-sitosterol, stigmasterol, campesterol, 1-triacontanol (Ahmed *et al.*, 1969c), docosyl docosanoate (Hamid *et al.*, 1989) and three triterpenoids ($C_{30}H_{46}O_4$, $C_{30}H_{48}O_5$, $C_{30}H_{46}O_5$) which have the skeleton **(1294)** (Iyer and Joshi, 1975).

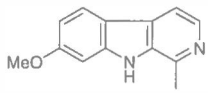
The alkaloids harman **(1295)** (Rizk, 1986) and harmine **(1296)** (Iyer and Joshi, 1975) were identified in *F. cretica*.



1294



1295 Harman



1296 Harmine

Four triterpenoid saponins were isolated from the aerial parts of *F. cretica*: 3-*O*-[β-D-glucopyranosyl]-(1→2)-α-L-arabinopyranosyl]-hederagenin 28-*O*-β-D-glucopyranosyl ester, 3-*O*-[β-D-glucopyranosyl-(1→2)-α-L-arabinopyranosyl]-oleanolic acid 28-*O*-[β-D-glucopyranosyl-(1→6)-β-D-glycopyranosyl]-ester, 3-*O*-[β-D-glycopyranosyl-(1→2)-α-L-arabinopyranosyl]-27-hydroxyoleanolic acid 28-*O*-[β-D-glucopyranosyl-(1→6)-β-D-glycopyranosyl]-ester and 3β- *O*-[β-D-glucopyranosyl-(1→2)-α-L-arabinopyranosyl] olean-12-en-27-al-28-oic acid 28-*O*-[β-D-glycopyranosyl-(1→6)-β-D-glycopyranosyl] ester (Abdel-Khalik *et al.*, 2000).

The sapogenins, fagonin, fagogenin, genin A and genin B (in addition to oleanolic acid) were identified in the acid hydrolysates of the plant (Rimpler and Rizk, 1969; Rizk, 1986).

The flavonoids quercetin and kaempferol were isolated from leaves and floweres of *F. certica* (Harsh and Nag, 1988).

In traditional medicine, *F. cretica* has been used for various ailments (Hamid *et al.* (1989). The saponin mixtures of *F. cretica* and *F. mollis* (at levels of 250-500-1000 mg/kg) showed significant anti-inflammatory activity and considerable analgesic and antipyretic effects (El-Shabrawy *et al.*, 1997). Both saponins I and II, isolated from *F. cretica*, had significant decrease in prolactin and in the serum TSH levels. The thyroxine level was also signinficantly reduced by saponin-II. A significant increase in serum cortisol occurred with powdered plant and with both saponins (Saeed *at al.*, 1999).

2. *SEETZENIA* R. Br.

2.1. ***Seetzenia lanata*** (Willd.) Bullock, Kew Bull. 19:204 (1965).

syn. *Zygophyllum lanatum* Willd., Sp. Pl., ed. 4, 1:564 (1799); *Seetzenia orientalis* Decne., Ann. Sci. Nat., ser.2, 3:281 (1835).

Habein (Ar.)

Glaucous green, prostrate, soft woolly perennial herb with short leafy branches. Leaves compound, pinnate, sub-sessile; leaflets oblong, apiculate. Inflorescences axillary, solitary. Flowers greenish, small, apetalous. Fruit globose, lobed, unarmed.

Habitat and Distribution

Rare in Qatar on sandy soils in central and southern Qatar. Recorded at Al-Wakra, Mukeinis, Al-Karaana.

Constituents

The amount of free ascorbic acid increased from roots to fruit in *S. orientalis* (Nag *et al.*, 1986). *S. orientalis* gave postive test for saponins. *S. lanata* contained kaempferol 3-dirhamnoglucoside, kaempferol 3-rutinoside and quercetin 3-dirhamnoside (Rizk, 1986).

3. *TRIBULUS* L.

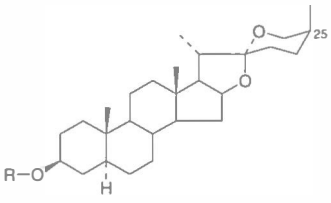
Several compounds, belonging to different classes (e.g. steroid sapogenins and saponins, acetogenins, cyclitols ...etc.), among them the cardioactive cistocardin, saponin-3, saponin-4

and saponin-7 have been isolated from the aerial parts (Achenbach *et al.*, 1994) and roots (Achebach *et al.*, 1996) of *T. cistoides* (Table 172 and 173).

Table 172. Compounds isolated from the aerial parts of *T. cistoides*[*]

Compound class	Compound
Sapogenins	Neotigogenin **(1297)**
	Neogitogenin **(1298)**
	Neohecogenin **(1299)**
Acetognins	*N*-Docosanoyltramine **(1300)**
	N-Tetracosanoyltyramine **(1301)**
Saponins	
(i) Spirostanol-type	Saponin-1 **(1302)**
	Tribulosin **(1303)**
	Saponin-3 **(1304)**
	Saponin-4 **(1305)**
	Cistocardin **(1306)**
	Saponin-6 **(1307)**
	Saponin-7 **(1308)**
	Saponin-8 **(1309)**
(ii) Furostanol-type	Saponin-9 **(1310)**
Cyclitols	D-(+)-Pinitol **(1311)**
Sugars	Sucrose
Inorganic	$Ca(NO_3)_2$
Others	5-(Hydroxysulphonyloxy) jasmonic acid **(1312)**

[*]Achenbach *et al.* (1994).



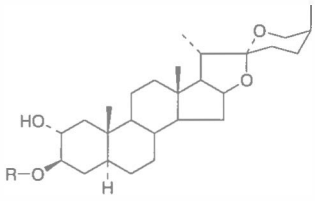
1297 Neotigogenin; R = H

1302 R = -β-gal-β-glu-β-xyl
β-D-xyl

1303 R = -β-D-gal--β-D-glu-β-D-xyl
α-L-rhal β-D-xyl

1305 R = -β-D-gal-β-D-glu-β-D-glu
β-D-glu

1307 R = -β-D-gal-β-D-glu-β-D-gal-β-xyl
β-D-glu



1298 Neogitogentin; R = H

1306 R = -β-D-gal-β-D-glu-β-D-glu
β-D-glu

1309 R = -β-D-gal-β-D-glu-β-D-glu-β-xyl
β-D-glu

3.1. ***Tribulus terrestris*** L., Sp. Pl., ed. 1, 387 (1753).

Gutba, Dereisa (Ar.); Malta cross, Caltrops, Puncture vine (En.)

Prostrate trailing to slightly decumbent semi-perennial herb with many basal radiating branches from a short woody stem ending in a stout short tap root. Whole plant hairy. Leaves compound, paripinnate of 4-7 pairs; leaflets ovate, about 5-8 mm long. Inflorescences axillary, leaf-opposed of solitary flowers; peduncles about 1-2 cm long. Fruit a schizcarp of 4-5 spiny mericarps; spines broad, sharp pointed, 4 per mericarp (upper pair larger than lower pair).

Habitat and Distribution

More common in Doha than in the wild, where it occurs by roadsides and vicinity of plantations. It may be an introduction from neighbouring countries either with plants or entangled on hairs of imported animals. The spines on the fruit are a nuisance to humans and animals. There are conflicting reports as to its preference by grazing animals. While some report *Tribulus* as a good range plant, others suggest that old plants may be poisonous. Perhaps it is best grazed with the onset of the rains and at the seedling or non-fruiting stages.

Constituents

The proximate analysis of the different parts of *T. terrestris* is shown in Table174 (Duke and Atchley, 1986).

Table 174. The proximate analysis of the different parts of *T. terrestris*

Part	Protein %	Fat %	Total Carbohydrates %	Fiber %	Ash %
Seeds	46.2				
	38.5				
Leaves	19.3	2.1	52.1	22.9	26.4
	34.4	2.4			22.0
Wet hay	18.9	2.7	66.6	25.7	11.8

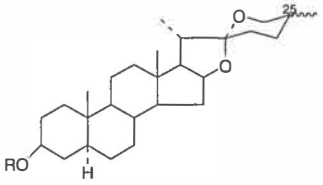
The chemical composition and nutritive value of the plant have been evaluated. The digestibility of the proteins (12.06 %) is 75.2 %. It was rich in Ca and the Ca: P ratio was large (17:1). Of the twenty-two free amino acids identified in the root nodules, glutamic acid, glutamine, aspartic acid and asparagine are the major amino acids (Rizk, 1986). The largest concentration of free amino acids and amides were observed at fruiting stage 1 (3rd node fruits). The marked decline in the amount of γ-methyleneglutamic acid and γ-methyleneglutamine after fruiting stage 1, indicated their rapid utilization along with asparagine and glutamine during fruit growth. In leaves and in different fruit growth stages, γ-methyleneglutamic acid dominated over γ-methyleneglutamine (Jain and Gupta, 1981). The nitrate content of the different organs of the plant varied greatly with the time of day and with the nature of the soil (Rizk, 1986). The amount of the ascorbic acid content increased from root to fruit in *T. terrestris* (Nag *et al.*, 1986). The highest content of polysaccharides was in the plants collected in October (Shi *et al.*, 1997).

Steroidal saponins have been isolated from the different parts of *T. terrestris*. The aerial parts contained the following saponins: hecogenin 3-*O*-β-D-glucopyranosyl-(1→4)-β-D-galactopyranoside, 26-*O*-β-D-glucopyranosyl-3-O[{β-D-xylopyranosyl-(1→3)}{β-D-glactopyranosyl-(1→2)}-β-D-glucopyranosyl-(1→4)-β-D-glucopyranosyl]-5-α-furost-20(22)-en-13-one-3β,26-diol,26-*O*-β-D-glucopyranosyl-3-*O*-[{β-D-xylopyranosyl-(1→3)}-{β-D-glactopyranosyl-(1→2)}-β-D-glucopyranosyl-(1→4)-β-D-glucopyranosyl]-5α-furostan-12-one-3β,22,26-triol (Wu *et al.*, 1996) glucopyranosyldihydroxyfurostenone glucopyranosyl galactopyranoside, glucopyranosyltrihydroxyfurostanone glucopyranosyl galactopyranoside (Cai *et al.*, 1999), hecogenin 3-*O*-β-xylopyranosyl-(1→3)-β-glucopyranosyl-(1→4)-β-galactopyranoside, hecogenin 3-*O*-β-glucopyranosyl-(1→2)-β-glucopyranosyl-(1→4)-β-galactopyranoside, 3-*O*-[β-xylopyranosyl-(1→2)-[β-xylopyranosyl-(1→3)]-β-glucopyranosyl-(1→4)-[α-rhamnopyranosyl-(1→2)-β-glactopyranosyl]-26-*O*-β-glucopyranosyl-22-methoxy-(3β,5α,25*R*)-furostan-3,26-diol and others (Jin *et al.*, 2000; Xu *et al.*, 2000).

The fruits contained several steroidal saponins: terrestrosin A **(1323)**, terrestrosin B **(1324)**, terrestrosin C **(1325)**, terrrestrosin D **(1326)**, terrestrosin E **(1327)**, desgalactotigonin **(1328)**, F-gitonin **(1329)**, desglucolanatigonin **(1330)**, gitonin **(1331)**, tigogenin 3-*O*-β-D-xylopyranosy-(1→2)-[β-D-xylopyranosyl-(1→3)]-β-Dglucopyranosyl-(1→4)-[α-L-rhamnopyranosyl-(1→2)-β-D-galactopyranoside **(1332)** (Yan *et al.*, 1996); terrestronsin F **(1333)**, terrestrosin G **(1334)**; terrestrosin H **(1335)**, terrestrosin I **(1336)**, terrestrosin J **(1337)**, terrestrosin K **(1338)** (Wang *et al.*, 1997), 26-*O*-β-D-glucopyranosyl-(25*S*)-5β-furost-20(22)-en-3β,26-diol-3-*O*-α-L-rhamnopyranosyl-(1→2)-[α-L-rhamnopyranosyl-(1→4)]-β-D-glucopyranoside,26-*O*-β-D-glucopyranosyl-(25*S*)-5β-furost-20(22)-en-3,26-diol-30-α-L-

rhamnopyranosyl-(1→2)-[β-D-glucopyranosyl-(1→4)-β-D-galactopyranoside and 25(*S*)-5β-spirostan-3β-ol-3-*O*-α-L-rhamnopyranosyl-(1→2)-[β-D-glucopyranosyl-(1→4)-β-D-galactopyranoside (Bedir and Khan, 2000).

The plant is considered as a rich source of steroid sapogenins utilizable as raw materials in the synthesis of hormones on an industrial scale. The following steroidal sapogenins have been identified from *T. terrestris*: diosgenin, tigogenin, hecogenin **(1339)**, neotigogenin, ruscogenin **(1340)**, chlorogenin, 25-D-spirosta-3,5-diene (Rizk, 1986), hecogenone, 25*R*-spirostan-4-ene-3,6,12-trione and (5α,25*R*)-spirostan-3,6,12-trione (Xu *et al.*, 1998).



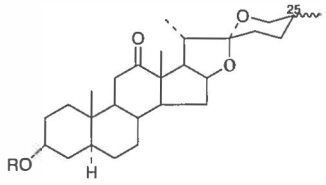
1323 Terrestrosin A; (25*R,S*); R = -β-D-gal-β-D-glu-β-D-gal

1324 Terrestrosin B; (25, *R,S*); R = -β-D-gal-β-D-glu
β-L-rha

1328 Desgalctotigonin; (25*R*); R = -β-D-gal-β-D-glu-β-D-glu
β-D-xyl

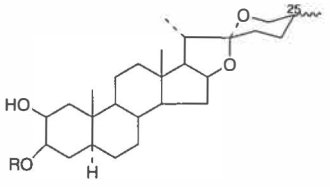
1330 Desglucolanatigonin;, (25*R*); R = -β-D-gal-β-D-glu-β-D-gal
β-D-xyl

1332 (25*R*); R = -β-D-gal--β-D-glu-β-D-xyl
α-L-rha β-D-xyl



1325 Terrestrosin C; (25 *R,S*); R = -β-D-gal-β-D-glu-β-D-gal

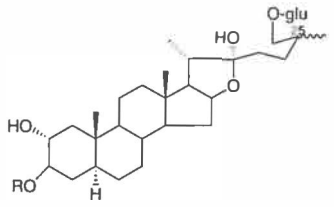
1326 Terrestrosin D; (25, *R*); R = -β-D-gal-β-D-glu-β-D-gal
β-D-xyl



1327 Terrestrosin E; (25 *R,S*); R = -β-D-gal-β-D-glu-β-D-gal

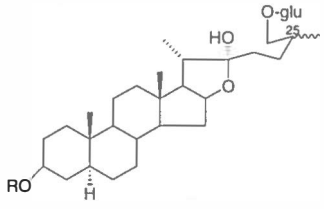
1329 F- Gitonin; (25*R*); R = -β-D-gal-β-D-glu-β-D-glu
β-D-xyl

1331 Gitonin; (25*R*); R = -β-D-gal-β-D-glu-β-D-gal
β-D-xyl

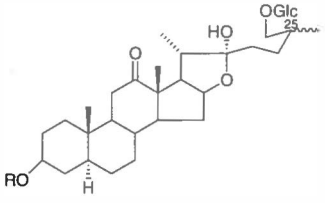


1333 Terrestrosin F; (25 *R*); R = -gal-glu

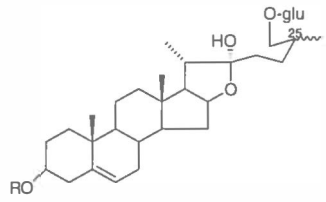
1334 Terrestrosin G; (25 *R,S*); R = gal-glu-gal



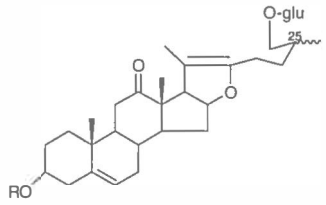
1335 Terrestrosin H; (25 *R,S*); R = gal-glu-gal



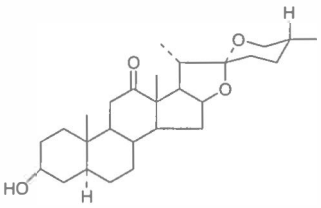
1336 Terrestrosin I; (25*R,S*); R = Gal-Glc-Gal



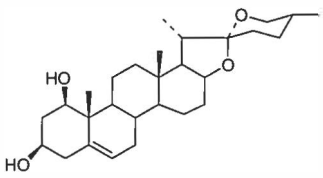
1337 Terrestrosin J; (25 *R,S*); R = gal-glu-gal



1338 Terrestrosin K; (25 *R*); R = gal-glu-gal



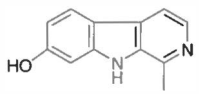
1339 Hecogenin



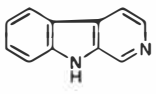
1340 Ruscogenin

The following compounds were identified in the mechanically damaged host *T. terrestris* of the desert locust *Schistocerca gregaria* (Njagi and Torto, 1996): 3-pentanone, hexanal, (*E*)-2-pentenal, 1-penten-3-ol, pentyl acetate, limonene, 4-methyl-3-pentenal, hexyl acetate, (*E*)-3-hexenyl acetate, (*Z*)-3-hexenyl acetate, (*Z*)-2-hexenyl acetate, hexanol, (*E*)-3-hexen-1-ol, (*Z*)-3-hexen-1-ol, (*E*)-2-hexen-1-ol, (*Z*)-2-hexen-1-ol, (*E*)-3-hexenyl butyrate, (*Z*)-3-hexenyl butyrate, (*Z*)-3-hexenyl isovalerate, (*E,Z*)-2, 6-nonadienol, hexyl hexanoate and (*Z*)-3hexenyl hexanoate.

T. terrestris contains the simple carboline alkoloids harmane, harmol (**1341**), norhamane (**1342**) and the seeds contain harmane and probably harmine (Rizk, 1986). The harman alkaloids amounted to 0.1 % of the overground parts (Obreshkova *et al.*, 1999).



1341 Harmol



1342 Norharmane

The plant contained kaempferol, quercetin (Zafar and Nasa, 1987) and the following flavonoid glycosides (Rizk, 1986):

- Kaempferol: 3-gentiobioside, 3-rutinoside, 3-*p*-coumaroylglucoside, 3β-(6"-*p*-coummaroyl) "tribuloside") and 3-gentiobioside-7-glucoside.
- Quercetin: 3-glucoside, 3-gentiobioside, 3-rutinoside, 3-gentiotrioside, 3-rhamnogentiobioside and 3-gentiobioside-7-glucoside.
- Isorhamnetin: 3-glucoside, 3-gentiobioside, 3-rutinosides, 3-*p*-coumaroylglucoside, 3-gentiotrioside, 3,7-diglucoside, 3-gentiobioside-7-glucoside and 3-gentiotrioside-7-glucoside.

The flowers also contained kaempferol and quercetin glycosides (Rizk, 1986). Caffeoyl derivatives were also detected in the plant. A high level of quercetin glycosides was

characteristic of *T. terrestris*, especially in some individuals for which rutin constituted the primary compound (Louveaux *et al.*, 1998).

The trypsin inhibitor content of leaves and flowers of *T. terrestris* amounted to 0.37 µg/mg dry weight of plant (Vanderjagt *et al.*, 2000).

Ingestion of *T. terrestris* by sheep, in Australia, resulted in outbreaks of a locomotor disorder. These outbreaks were repeatedly associated with drought periods during which sheep grazed large areas of *T. terrestris* for many months at a time. The course of the disease was characterised by being a slowly developing, irreversible, asymmetrical weakness of the hind limbs. First recorded in 1937, the disorder has been known as coonabarabran staggers, cathead staggers or *Tribulus* staggers. It is an asymmetric locomotor in sheep, which developed as a result of a functional abnormality in the central nervous system (Bourke, 1987). The clinical effects of β-carboline alkaloids (harmane, norhamane, tetrahydronorhamane, harmine, harmaline and harmol), identified in Zygophyllaceous plants, have been reported (Bourke *et al.*, 1990). Harmane and norhamane, identified in *T. terrestris*, growing in Australia, caused similar nervous effects. The main effect observed was limb paralysis. The clinical signs observed in the experimental sheep were consistent with those described for naturally occurring cases of *T. terrestris* staggers. It was proposed that harmane and norharmane accumulate in tryptamine-associated neurones of the central nervous system, during months of *Tribulus* ingestion, and interfered with gene DNA sequence (Bourke *et al.*, 1992).

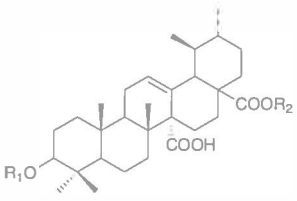
In traditional Chinese medicine, the fruits of *T. terrestris* have long been used for the treatments of eye trouble, oedema and abdominal distension, emission and morbid leucorrhea as well as vitiligo (Wang *et al.*, 1997). The crude saponin fraction of the whole plant has been used as a cordial drug (Yan *et al.*, 1996). The saponin, 25(*S*)-5-3β-ol-3-*O*-α-L-rhamnopyranosyl-(1→2)-[β-D-glucopyranosyl-(1→4)-β-D-galactopyranoside, showed cytotoxicity against a human malignant melanoma cell line (SK-MEL) (Bedir and Khan, 2000). The polysaccharide of *T. terrestris* was not mutagenic in mice, but obviously protected mouse chromosome and DNA from damage induced by cyclophosphamide (Liu *et al.*, 1995a). The effect of *T. terrestris* on experimental urolithiasis induced by ethylene glycol in albino rats was studied. The drug-treated animals showed increased urinary output, decreased the serum urea and crystalluria on day 14, and a tendency for alkalinization of urine compared with the ethylene glycol-treated animals, thus providing preliminary evidence for the clinical use of this drug (Satish *et al.*, 1996). Brown *et al.* (2000) provided evidence that the addition of *T. terrestris* extracts to androstenedione did not result in increased serum testosterone concentrations, reduced the estrogenic effect of androstenedione, and did not augment the adaptations to resistance training. A pharmaceutical preparation, tribestan, developed from *T. terrestris* (used in folk medicine against impotency) increased the libido, improved and prolonged the period of erection and increased the number and motility of sperm in man. In women, Tribestan improved ovarial functions and was effective against frigidity, infertility and for the prevention of climacteric disturbances (Tomova, 1987). Reviews of Gokhuro (*T. terrestris*) for the treatment of impotency and urinary disorders (Wasti *et al.*, 1992) and its pharmacological aspects (Gupta *et al.*, 1997) were reported. Ether extract of *T. terrestris* possessed a juvenile hormone effect on *Dysdercus eingulatus* (Gunasekaran and Chelliah, 1985). A cream, containing *T. terrestris* extract had a very strong antibacterial, anti-inflammation, antivirus, anti-herpes effect and has been found to be highly useful in treating vulvo-vaginitis, vulvo-hemorrhoids, varicose veins and acne (Alexis, 2001).

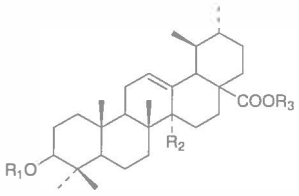
4. ZYGOPHYLLUM L.

Triterpenoid saponins have been isolated from the aerial parts and roots of several *Zygophyllum* species. The saponins, so far, identified in *Zygophyllum* species are summarized below:

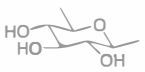
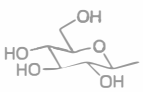
1-*Z. aegyptium*: quinovic acid 3β-*O*-β-D-glucopyranoside, quinovic acid 3β-*O*-β-D-glucopyranoside, 3-*O*-[α-L-arabinosyl-(1→2)-β-D-glucopyranosyl]-quinovic acid, 3β-*O*-D-quinovopyranosylquinovic acid-28-*O*-β-glucopyranosyl ester, zygophyloside F, 3β-*O*-β-D-glucopyranosyl quinovic acid 28-*O*-β-D-glucopyranosyl ester, and zygophyloside G (Mohamed, 1999).

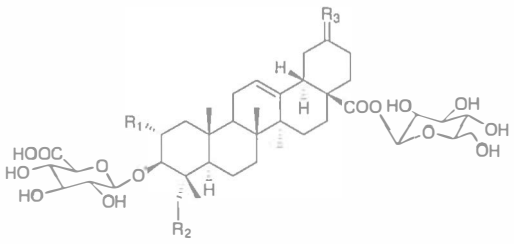
2-*Z. album* (aerial pars): β-xylofuranosyl-(1→2)-α-rhamnopyranosyl-(1→28)-quinovic acid ester, α-rahamnopyranosyl-(1→4)-β-glucuronyl-(1→3)-quinovic acid, 3-*O*-α-rhamnopyranosyl-(2→1)-α-rhamnopyranosyl-(2→1)-α-rhamnopyranosyl-14-decarboxyquinovic acid-(28→1)-β-xylofuranosyl ester (Hassanean *et al.*, 1992), quinovic acid-3β-*O*-β-D-quinovopyranoside (**1343**), quinovic acid-3β-*O*-[β-D-quinovpryanosyl-(3→7)-β-D-xylopyranoside] (**1344**), 3β-*O*-β-D-quinovpyranosylquinovic acid-(28→1)-β-D-glucopyranosyl ester (**1345**), 3β-*O*-D-quinovopyranosylquinovic acid-(28→1)-quinovopyranosyl ester (**1346**) (Hassanean *et al.*, 1993a), 14-decarboxyquinovic acid-3β-*O*-β-D-quinovopyranosyl-(1→4)-quinovopyranoside (**1347**), quinovic acid-28-*O*-β-D-glucopyranosyl-(2→1)-β-D-glucopyranoside ester (**1348**), quinovic acid-27-*O*-β-D-glucopyranosyl-(2→1)-β-D-glucopyranosyl (**1349**), quinovic acid 3β-*O*-β-D-glucopyranosyl-(2→1)-rhamnopyranoside (**1350**) (Hassanean *et al.*, 1993b), and zygophyloside F (Elgamal *et al.*, 1995). Nine saponins of quinovic acid, oleanolic acid, ursolic acid and an unidentified sapogenin with sugar moieties glucose, xylose, rhamnose and glucuronic acid, were identified (Ibrahim *et al.*, 1997).



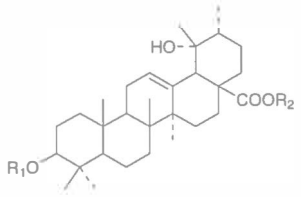


1347 R_1 = quinovose1 → 4quinovose, R_2 = R_3 = H
1348 R_1 = H, R_2 = COOH, R_3 = glu1 → 2glu
1349 R_1 = H, R_2 = CO_2-glu1 → 2glu, R_3 = H
1350 R_1 = rha1 → 2glu, R_2 = COOH, R_3 = H

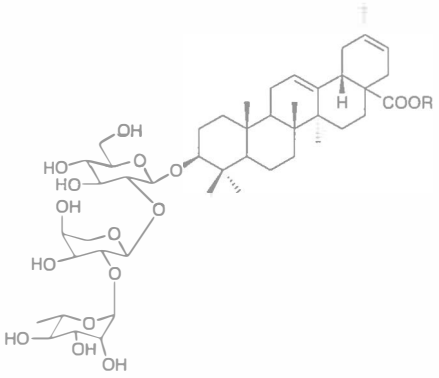
	R_1	R_2
1343		H
1344		H
1345		
1346		



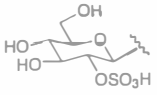
	R_1	R_2	R_3
1361 Zygophyloside I	OH	OH	$\overset{30}{\diagup}$ $\overset{29}{\diagdown}$
1362 Zygophyloside J	OH	OH	$=^{29}$
1363 Zygophyloside K	H	H	$\overset{30}{\diagup}$ $\overset{29}{\diagdown}$—OH



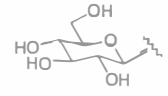
1365 Glycoside C; R_1 = α-L-ara *p*, R_2 = H
1366 Glycoside E; R_1 = α-L-ara *p*, R_2 = b-D-glu *p*
1367 Zygoeichwaloside I; R_1 = β-D-xyl *p*, R_2 = Me

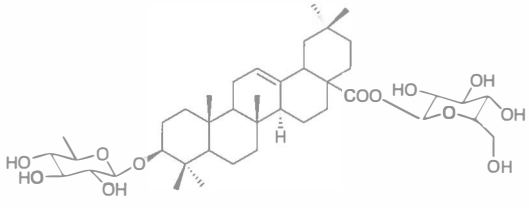


1368 Zygophyloside I (Safir *et al*., 1998) R =

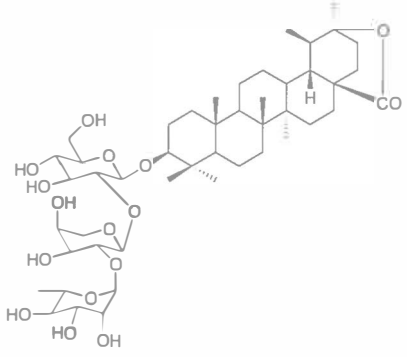


1369 Zygophyloside L R =

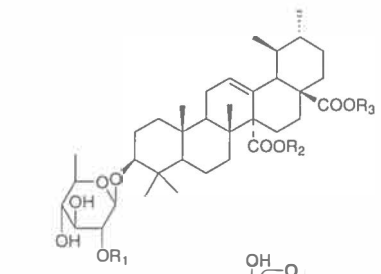


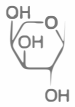


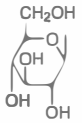
1370 Zygophyloside M

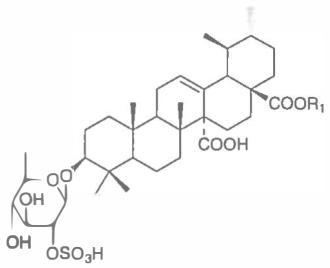


1371 Zygophyloside N



1372 Zygophyloside A R_1 =  $R_2 = R_3 = H$

1373 Zygophyloside B $R_1 = R_3 = H$ R_2 = 



1374 Zygophyloside D; R = H
1375 Zygophyloside E; R = Glc

Zygophyllum species are reputed to possess certain remedial values and biological activities. The fruits, leaves and stems of *Z. coccineum* constitute a drug known on the Egyptian market under the name "kammun kahramany" or "kammun quaramany", which is used as a folklore medicine in the treatment of rheumatism, gout, asthma, hypertension and as a diuretic, anthelmintic and antidiabetic (Saber and Shoaib, 1966; Eskander and Won, 1995). The aqueous extract of *Z. decumbens* showed hypotensive, antipyretic, spasmolytic, diuretic and local anesthetic effects in animal test (Saad *et al.*, 1967). The roots of *Z. fabago* were reported useful against some diseases as syphylis and staphyloccal infections (Saber and Shoaib, 1966). The aerial parts of *Z. gaetulum* have many traditional uses in the Moroccan indigenous system of medicine, including antispasmodic, antieczema, the treatments of diabetes, stomach and liver diseases (Bellakhadar *et al.*, 1991). Extracts of the aerial parts of *Z. gaetulum*, some partially purified fractions, as well as, zygophyloside M and 3-*O*-β-D-glucopyranosylquinovic acid 28-β-D-glucopyranosyl ester were reported to reduce both electrically-stimulated contractions and morphine withdrawal in isolated guinea-pig ileum (Capasso *et al.*, 1998). Quinovic acid 3-*O*-α-L-rhamnoside (isolated from *Zygophyllum* species) was reported to have cytotoxic activity. An inhibitory effect against stand RNA virus (vesicular stomatitis virus VSV) was evident for quinovic glycosides, with maximum activity in compounds, having only a *C*-3-glycosylation (Hassanean *et al.*, 1993a,b). The crude saponins, as well as the oleanolic acid, isolated from *Z. album* showed significant analgesic activity and some antibacterial one (Ibrahim *et al.*, 1997). The root extract of *Z. dumosum* possessed antifungal activity (Oui *et al.*, 1994). The study of Belchi-Hernández *et al.* (2001) showed that *Z. fabago* pollen elicited an IgE response and, like other pollens, contributes towards triggering allergic symptoms and should be considered a relevant allergen.

4.1. ***Zygophyllum qatarense*** Hadidi in Boul., Webb. 32, 3:394 (1978).

Harm Qatari (Ar.)

Low succulent xerophytic shrub with succulent young shoots, petioles and leaf blades and woody older stems. Leaves lamina globose or bifid or bi-foliolate. Inflorescences axillary, solitary. Flowers about 1 cm long, pale cream. Fruit obovate, yellow, fleshy.

Habitat and Distribution

The most widespread plant in Qatar growing in all habitats but dominating stony-gravelly soils throughout Qatar.

Constituents

The proximate analysis, amino acids, fatty acids and minerals of *Z. qatarense*, collected from Qatar are shown in Tables 175-178 (Al-Easa, 2002a-d).

The plant gives positive tests for alkaloids, coumarins and sterols (and/or terpenes) (Rizk, 1982).

4.2. ***Zygophyllum simplex*** L., Mant. 68 (1763 ?)

syn. *Zygophyllum portulacoides* Forssk., Fl. Aegypt.-Arab. 88 (1775).

Huraim (Ar.)

Annual prostrate fleshy herb forming circular mats. Leaves simple linear, fleshy, sessile. Inflorescences axillary, solitary. Flowers small, yellow. Fruit globose, dry, schizocarpic of 4-5 mericarps.

Habitat and Distribution

Widespread on sandy saline soils throughout Qatar equally at the edges of irrigated land and in depressions where moisture collects.

Constituents

The aerial parts of *Z. simplex*, growing in Egypt, contained the following compounds: kaempferol 3-glucoside, quercetin 3,7-diglucoside (Rizk, 1986), isorhamnetin, isorhamnetin 3-*O*-glucoside, kaempferol 3-*O*-rutinoside, 6"-(2-*E*-butenoyl) isorhamnetin-3-*O*-glucoside, sitosterol glucoside and quinovic acid 3-α-L-rhamnoside (Hassanean and Desoky, 1992).

The following compounds were identified in the mechanically damaged host *Z. simplex* of the desert locust *Schistocerca gregaria*: 3-pentanone, hexanal, (*E*)-2-pentenal, 1-penten-3-ol, 4-methyl-3-pentenal, hexyl acetate, (*Z*)-3-hexenyl acetate, (*Z*)-2-hexenyl acetate, hexanol, (*E*)-3-hexen-1-ol, (*Z*)-3-hexen-1-ol, (*Z*)-2-hexen-1-ol, 2-methylpropionic acid and (*Z*)-β-farnesene (Njagi and Torto, 1996).

The seeds of *Z. simplex*, growing in Pakistan, were found to contain Cl, 4.14; Na, 1.16; Mg, 0.16; K, 0.33 and Ca, 0.581 (mmol g^{-1} dry weight) (Khan and Ungar, 1996).

It was reported that the expressed leaf juice acted as a skin cleanser. The plant, growing in North Africa and the Arabian region, was reported for treatment of horny patches on the skin (Hassanean and Desoky, 1992).

Table 176. Cont.

Species	Essential Amino Acids %									Other Amino Acids %								Protein
	Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Val	Asp	Ser	Glu	Pro	Gly	Ala	Cys	Tyr	%
Stipagrostis obtusa	0.32	0.14	0.32	0.75	0.35	0.23	0.39	0.36	0.45	1.16	0.44	1.37	0.52	0.40	0.55	0.09	0.27	9.3
Stipagrostis obtusa	0.35	0.13	0.28	0.55	0.37	0.13	0.34	0.33	0.38	1.73	0.44	0.92	0.34	0.36	0.45	0.09	0.23	9.9
Stipagrostis plumosa	0.21	0.10	0.23	0.54	0.23	0.18	0.27	0.26	0.32	0.71	0.25	0.83	0.42	0.30	0.41	0.09	0.19	7.1
Stipagrostis plumosa	0.34	0.12	0.10	0.37	0.30	0.09	0.26	0.25	0.31	0.63	0.33	0.93	1.05	0.34	0.32	0.12	0.18	8.1
JUNCACEAE																		
Juncus rigidus	0.14	0.06	0.17	0.32	0.15	0.10	0.19	0.18	0.21	0.41	0.17	0.44	0.30	0.23	0.24	0.15	0.13	4.2
MALVACEAE																		
Malva parviflora	0.93	0.34	0.61	1.20	0.89	0.27	0.83	0.62	0.85	3.84	0.58	1.93	1.22	0.81	0.87	0.47	0.48	22.9
MIMOSACEAE																		
Acacia tortilis	0.44	0.16	0.39	0.69	0.55	0.14	0.49	0.45	0.48	1.06	0.45	1.00	0.53	0.48	0.48	0.17	0.31	12.8
NEURADACEAEA																		
Neurada procumbens	0.50	0.24	0.41	0.70	0.50	0.19	0.50	0.34	0.48	2.16	0.43	1.46	1.24	0.53	0.54	0.25	0.32	14.5
PLANTAGINACEAE																		
Plantago amplexicaulis	0.44	0.16	0.33	0.58	0.34	0.17	0.36	0.35	0.44	0.80	0.38	1.21	0.33	0.47	0.45	0.12	0.25	8.6
Plantago ciliata	0.50	0.20	0.36	0.65	0.45	0.20	0.60	0.41	0.48	1.41	0.42	1.35	0.42	0.47	0.50	0.21	0.30	10.1
PLUMBAGINACEAE																		
Limonium axillare	0.13	0.10	0.11	0.20	0.16	0.06	0.13	0.13	0.15	0.27	0.15	0.34	0.30	0.31	0.16	0.05	0.08	5.4
POLYGONACEAE																		
Rumex dentatus	1.05	0.47	0.61	1.19	0.92	0.30	1.01	0.68	0.92	1.58	0.76	3.75	1.16	0.83	0.92	0.22	0.63	23.9
Rumex vesicarius	0.38	0.15	0.26	0.50	0.28	0.12	0.32	0.24	0.35	0.59	0.27	0.99	0.31	0.39	0.37	0.19	0.12	9.1
RHAMNACEAE																		
Ziziphus nummularia	0.40	0.16	0.40	0.69	0.42	0.16	0.42	0.38	0.53	1.05	0.37	1.27	0.41	0.45	0.49	0.12	0.28	9.6
SOLANACEAE																		
Lycium shawii	0.38	0.14	0.29	0.53	0.39	0.10	0.35	0.28	0.35	1.10	0.33	0.71	0.21	0.35	0.37	0.18	0.25	9.9

Table 176. Cont.

Species	Essential Amino Acids %									Other Amino Acids %								Protein
	Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Val	Asp	Ser	Glu	Pro	Gly	Ala	Cys	Tyr	%
TYPHACEAE																		
Typha domingensis	0.17	0.06	0.16	0.33	0.15	0.07	0.20	0.16	0.20	0.44	0.17	0.59	0.19	0.24	0.25	0.10	0.11	5.2
ZYGOPHYLLACEAE																		
Fagonia indica	0.54	0.20	0.41	0.77	0.52	0.20	0.50	0.38	0.50	1.11	0.40	1.30	0.55	0.61	0.57	0.30	0.41	11.3
Fagonia ovalifolia	0.45	0.14	0.30	0.53	0.37	0.91	0.35	0.30	0.35	0.77	0.33	0.90	0.44	0.47	0.40	0.14	0.32	8.4
Zygophyllum qatarenese	0.30	0.10	0.14	0.30	0.21	0.07	0.22	0.15	0.20	0.60	0.16	0.82	0.26	0.27	0.26	0.13	0.15	6.2

Table 177. Fatty acids (%) of some Qatari Range Plants

Species	12:0	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:0	22:0	24:0	X1	X2	X3	X4	X5	X6	X7
ASCLEPIADACEAE																		
Leptadenia pyrotechnica	5.65	0.77	24.35	2.50	*	39.98	8.45	0.94	6.64	6.00	*	*	*	*	4.71	*	*	*
AVICENNACEAE																		
Avicennia marina	3.21	7.46	40.89	2.83	*	7.09	9.86	4.62	3.79	8.42	*	2.08	4.71	*	5.14	*	*	*
CAPPARACEAE																		
Capparis spinosa	*	2.33	55.81	3.74	*	14.12	1.38	*	1.99	10.66	*	*	*	*	3.32	6.64	*	*
CHENOPODIACEAE																		
Chenopodium murale	0.32	2.22	20.13	3.49	0.35	11.93	30.28	0.77	2.53	7.85	*	*	1.65	*	16.99	*	*	*
Haloxylon salicornicum (Hammada elegans)	*	1.11	13.29	3.56	*	12.34	1.15	2.66	3.68	14.33	*	*	6.71	*	22.57	*	18.61	*
Salsola imbricata (S. barysoma)	3.03	5.64	38.98	2.18	*	9.78	1.78	1.44	4.93	15.89	*	*	2.40	*	10.62	*	7.53	*
Seidlitzia rosmarinus	5.11	1.34	32.58	3.83	*	15.28	0.92	2.15	13.60	9.65	*	*	*	2.02	83.89	*	4.63	*
COMPOSITAE																		
Launaea capitata	0.04	3.59	14.59	tr	4.89	3.39	3.73	5.70	26.45	7.47	*	*	*	*	9.47	*	18.67	*
Launaea mucrenata	2.82	13.32	26.16	2.62	*	21.56	0.97	1.50	7.79	9.87	*	*	*	*	12.56	0.83	*	*
Rhanterium eppaposum	*	1.18	30.43	*	*	6.10	4.42	*	11.50	54.67	*	*	*	4.54	3.54	*	*	3.61
Sonchus oleraceous	*	2.43	2.20	2.97	*	20.74	17.60	2.46	6.34	7.74	*	*	0.41	17.31	*	*	*	*
CONVOVULACEAE																		
Convolvulus arvensis	*	3.47	36.62	1.52	1.54	17.13	5.42	8.43	7.23	6.26	*	2.17	3.18	1.45	3.90	*	1.69	*
Convolvulus deserti	3.15	5.21	36.41	2.61	5.37	12.76	1.20	13.38	4.70	8.16	*	*	2.97	*	10.51	*	6.09	2.65
Convolvulus glomeratus	*	3.40	45.10	tr	2.80	11.01	tr	5.40	3.90	8.13	*	*	0.83	*	14.40	*	5.00	*
FABACEAE																		
Lotus garcini	1.56	2.96	34.30	*	*	6.24	tr	2.34	12.48	18.63	*	1.10	*	*	9.23	11.14	*	*
Lotus halophilus	8.15	1.75	37.36	2.95	*	10.91	0.63	0.98	6.70	6.97	*	*	*	*	23.60	*	*	*
Medicago laciniata	2.85	5.93	25.39	3.18	*	29.19	0.50	*	8.27	8.94	*	1.86	0.59	*	11.64	*	1.67	*
Melilotus indicus	1.86	5.23	40.68	8.14	1.36	5.93	1.74	*	7.56	20.92	*	0.97	*	*	5.62	*	*	*

Table 177. Cont.

Species	12:0	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:0	22:0	24:0	X1	X2	X3	X4	X5	X6	X7
Trigonella hamosa	2.44	4.82	15.90	2.10	*	8.01	0.32	0.56	22.90	35.31	*	0.68	*	1.42	2.58	*	1.11	1.84
GRAMINAEA																		
Aeluropus lagopoides	1.87	4.82	18.51	7.84	*	31.83	14.61	11.56	10.47	10.25	11.11	2.30	0.36	2.00	6.06	*	2.20	4.71
Cenchorus pennisetformis	*	1.67	36.10	2.29	*	24.93	*	*	10.70	17.38	*	*	*	*	6.92	*	*	*
Chloris virgata	*	5.50	25.28	12.09	*	29.66	4.55	7.58	2.74	6.11	*	*	2.95	*	3.54	*	*	*
Chrysopogon plumulosus	4.17	5.91	18.88	7.66	*	26.48	2.87	5.36	8.48	8.90	*							
Cynodon dactylon	*	2.43	17.34	3.53	*	21.45	8.07	2.52	11.35	12.11	*	*	*	*	21.19	*	*	*
Echinocloa colona	1.59	3.49	28.80	3.43	*	11.02	1.11	1.04	11.97	14.47	*	2.88	*	4.23	10.06	6.01	*	*
Elusine compressa	*	1.62	9.75	7.92	*	14.08	5.69	3.25	3.66	*	*	*	*	*	*	*	54.03	*
Lasiurus sindicus (L. hirsutus)	*	2.94	30.49	3.49	*	7.29	6.48	7.58	8.26	16.22	*	*	*	*	5.23	*	3.05	*
Pennisetum divisum	*	3.53	25.49	2.63	*	14.33	2.15	2.07	8.29	13.13	*	3.10	5.40	0.87	10.63	4.52	3.85	*
Sporobolus ioclados (S. arabicus)	3.20	4.82	28.45	2.99	*	7.71	11.25	5.55	6.24	14.42	11.28	2.50	3.70	1.94	4.84	*	5.55	7.10
*Sporobolus spicatus** *(S. obtusa)*	tr	4.78	2.98	*	45.60	19.89	*	5.96	20.74	*	*	*	*	*	*	*	*	*
Stipagrostis obtusa	*	tr	12.14	3.28	*	9.07	4.05	12.95	11.17	15.30	*	*	*	*	*	*	32.02	*
Stipagrostis plumosa	*	2.82	42.74	1.93	*	20.83	1.93	*	6.50	9.40	*	1.74	*	*	9.64	*	2.41	*
JUNCACEAE																		
Juncus rigidus	*	9.72	45.33	4.88	*	14.38	*	*	4.55	15.47	*	1.17	*	*	6.25	*	3.25	*
MALVACEAE																		
Malva parviflora	1.10	1.50	49.29	1.54	*	10.98	2.01	1.21	7.92	4.17	*	*	6.14	*	9.15	*	4.98	*
MIMOSACEAE																		
Acacia ehrenbergiana	2.41	5.87	23.78	1.46	*	8.31	1.19	2.60	3.68	18.17	*	4.54	0.91	18.17	0.52	*	4.80	3.60
Acacia tortilis	*	4.36	38.61	3.87	*	16.50	4.40	*	3.63	9.50	*	0.99	4.05	*	8.91	*	5.17	*
OROBANCHACEAEA																		
Cistanche phelypaea	*	5.56	48.76	tr	2.54	13.01	*	*	*	*	*	*	18.50	*	*	*	11.62	*

Table 177. Cont.

Species	12:0	14:0	16:0	16:1	18:0	18:1	18:2	18:3	20:0	22:0	24:0	X1	X2	X3	X4	X5	X6	X7
PLANTAGINACEAE																		
Plantago amplexicaulis	*	8.79	42.93	2.00	*	11.26	0.87	1.10	2.20	7.19	*	*	*	*	20.67	3.00	*	*
PLUMBAGINACEAE																		
Limonium axillare	1.55	4.46	35.24	3.09	*	20.79	2.22	*	5.54	12.37	*	*	*	1.48	9.70	*	3.56	*
POLYGONACEAE																		
Rumex dentatus	*	4.82	44.71	3.24	*	9.44	2.16	2.16	3.93	7.82	*	5.48	2.89	*	13.36	*	*	*
RHAMNACEAE																		
Ziziphus nummularia	*	1.67	11.72	3.91	*	19.53	6.65	4.56	5.86	6.69	*	*	*	*	39.42	*	*	*
SOLANACEAE																		
Lycium shawii	2.39	7.51	26.56	1.41	*	9.49	4.25	2.02	13.17	9.98	9.43	*	*	*	5.65	*	14.10	6.20
TAMARIACEAE																		
Tamarix aphylla	1.81	7.13	52.31	1.99	*	10.40	2.80	2.30	4.89	6.61	*	*	*	*	9.78	*	*	*
TYPHACEAE																		
Typha domingensis	2.47	2.79	10.21	1.34	*	6.62	0.45	0.49	12.21	26.38	19.54	0.86	*	1.28	3.97	*	2.58	0.89
ZYGOPHYLLACEAE																		
Fagonia indica	0.83	8.46	48.88	*	*	15.01	*	0.86	9.19	8.15	*	0.64	*	*	3.14	4.85	*	*
Zygophyllum qatarenese	3.31	12.74	27.35	1.11	*	11.09	1.29	0.52	20.41	23.24	5.78	*	1.10	6.12	5.98	*	1.43	*

tr traces (less than 0.1%); * not available; X unknown

Table 178. Mineral composition (ppm) of some range plants growing in Qatar

Species	Na	Zn	Fe	Pb	Ni	Cd	Mn	Al	Co	Cu	Mg	Si	Cr
ACANTHACEAE													
Blepharis ciliaris	0.047	nd	0.115	*	0.014	*	0.544	*	0.045	0.009	1.25	7.09	0.20
AIZOACEAE													
Aizoon canariense	0.597	0.0120	0.382	*	0.011	0.000002	0.143	0.00311	0.320	0.008	1.02	7.28	0.21
AMARANTHACEAE													
Aerva javanica	0.042	nd	0.128	*	0.012	*	0.150	*	0.037	0.021	1.25	6.52	0.13
Amaranthus viridis	0.036	nd	0.126	*	0.006	*	0.178	0.00638	0.021	0.010	0.95	7.89	0.13
ASCLEPIADACEAE													
Glossonema edule	0.041	nd	0.123	*	0.012	0.000251	0.141	*	0.038	0.015	1.25	7.04	0.13
Leptadenia pyrotechnica	0.089	0.0033	0.067	*	0.010	*	0.088	0.00164	0.025	0.005	0.93	4.35	nd
AVICENNIACEA													
Avicennia marina	0.101	0.0159	0.132	0.000005	0.110	*	0.124	*	0.030	0.009	1.23	8.03	0.13
CAPPARACEAE													
Capparis spinosa	0.052	0.0167	0.098	0.001210	0.008	*	0.120	0.00109	0.352	0.006	1.12	7.34	nd
CHENOPODIACEAE													
Atriplex leucolada	0.054	nd	0.129	0.002980	0.018	*	0.151	*	0.078	0.018	1.30	6.31	0.17
Chenopodium murale	0.049	nd	0.082	0.000162	0.006	*	0.007	*	0.009	0.005	1.40	5.48	0.15
Cornulaca monocantha	0.075		0.120	*	0.009	*	0.160	0.00700	0.038	0.035	1.24	2.22	0.13
Haloxylon salicornicum (Hammada elegans)	0.055	0.0099	0.389	*	0.009	*	0.104	*	0.020	0.010	1.22	4.88	0.01
Salsola imbrecata (S. barysoma)	0.029	nd	0.130	*	0.027	*	0.233	*	0.063	0.013	1.31	2.88	0.16
Seidlitzia rosmarinus	1.660	0.0005	0.144	0.000005	0.008	*	0.141	*	0.033	0.009	1.53	7.85	nd
Suaeda vermiculata	0.080	0.0154	0.127	0.001090	0.051	*	0.211	0.00228	0.520	0.014	1.25	7.21	0.14
COMPOSITAE													
Launaea capitata	0.052	0.0034	0.060	*	0.008	*	0.055	0.00412	0.078	0.006	1.09	7.31	nd

Table 178. Cont.

Species	Na	Zn	Fe	Pb	Ni	Cd	Mn	Al	Co	Cu	Mg	Si	Cr
Launaea mucronata	0.058	0.0159	0.088	0.000008	0.006	*	0.088	*	0.221	0.007	1.55	5.42	nd
Rhanterium eppaposum	0.045	0.0162	0.066	*	0.015	*	0.076	0.00081	0.011	0.008	1.96	6.74	nd
Sonchus oleraceus	0.062	nd	0.071	*	0.007	*	0.005	*	0.013	0.006	1.11	7.62	0.13
CONVOVULACEAE													
Convolvulus deserti	0.199	0.0134	0.963	*	0.001	*	0.123	*	0.302	0.008	1.72	8.37	nd
Convolvulus glomeratus	0.159	0.0106	0.096	*	0.006	*	0.098	0.00219	0.035	0.011	1.21	9.37	nd
CYPERACEAE													
Cyperus conglomeratus	0.123	0.0037	0.071	*	0.014	0.000003	0.058	0.00102	0.028	0.015	0.94	6.39	nd
FABACEAE													
Alhagi graecorum	0.022	0.0148	0.143	0.000033	0.034	*	0.115	*	0.049	0.012	1.27	7.74	0.24
Indigofera articulata	0.066	0.0175	0.058	0.000007	0.018	*	0.112	*	0.053	0.013	1.30	7.70	0.19
Lotus garcinii	0.123	0.0091	0.058	*	0.004	*	0.159	0.00067	0.046	0.007	1.65	3.09	nd
Lotus halophilus	0.044	0.0096	0.089	*	0.010	*	0.089	0.00108	0.057	0.023	1.43	4.05	nd
Medicago laciniata	0.055	0.0067	0.084	0.000310	0.011	*	0.173	0.00718	0.039	0.015	0.87	5.90	0.14
Melilotus indicus	0.088	nd	0.116	*	0.010	*	0.046	0.00100	0.068	0.019	1.06	8.07	0.13
Trigonella anguina	0.141	0.0089	0.058	0.000008	0.008	*	0.054	*	0.043	0.016	0.55	7.85	nd
Trigonella hamosa	0.009	nd	0.127	*	0.017	*	0.239	0.00402	0.059	0.016	1.01	7.57	0.16
GRAMINAEA													
Aeluropus lagopoides	0.175	0.0084	0.092	*	0.015	*	0.135	0.00712	0.165	0.011	1.32	6.63	0.14
Cenchrus pennisetiformis	0.037	0.0172	0.122	*	0.007	*	0.054	*	0.007	0.011	1.07	2.88	nd
Chloris virgata	0.050	nd	0.097	*	0.006	*	0.123	*	0.008	0.003	0.90	6.52	0.01
Chrysopogon plumulosus (*C. aucheri*)	0.176	0.0221	0.101	*	0.007	*	0.116	0.00094	0.008	0.002	0.83	8.38	0.17
Cynodon dactylon	0.052	nd	0.060	*	0.005	*	0.150	*	0.010	0.003	0.98	7.60	*
Dactyloctenium aegyptium	0.042	nd	0.092	*	0.006	*	0.094	0.00159	0.027	0.006	1.07	7.49	0.01
Echinocloa colona	0.036	nd	0.081	*	0.008	*	0.180	*	0.022	0.008	0.94	6.85	0.12

Table 178. Cont.

Species	Na	Zn	Fe	Pb	Ni	Cd	Mn	Al	Co	Cu	Mg	Si	Cr
Ochthochloa compressa (*Eleusine compressa*)	0.067	0.0083	0.121	*	0.006	*	0.050	*	0.31	0.014	0.96	2.70	0.06
Lasiurus sindicus	1.081	0.0169	0.094	0.002110	0.014	*	0.133	0.00295	0.231	0.010	1.33	3.26	0.19
Panicum turgidum	0.630	0.0161	0.104	*	0.013	0.000017	0.111	*	0.023	0.006	1.17	8.34	0.15
Pennisetum divisum	0.036	nd	0.079	*	0.009	0.000002	0.126	0.00061	0.010	0.005	0.95	4.32	0.09
Polypogon monospeliensis	0.052	nd	0.110	0.002360	0.011	*	0.282	0.00864	0.073	0.009	0.34	6.84	0.17
Setaria verticillata	0.044	nd	0.114	*	0.007	*	0.150	0.00404	0.027	0.014	0.93	8.35	0.12
Sporobolus ioclada	0.128	nd	0.056	*	0.023	*	0.204	0.00690	0.105	0.015	1.12	6.13	0.08
Stipa capensis	0.045	0.0021	0.102	*	0.005	*	0.099	0.00008	0.042	0.014	0.90	3.77	nd
Stipagrostis obtusa	1.656	0.0007	0.067	*	0.007	*	0.092	*	0.012	0.009	1.06	3.87	nd
Stipagrostis plumosa	0.331	0.0079	0.960	0.00087	0.010	0.000002	0.130	0.00170	0.032	0.013	0.77	4.26	0.19
JUNCACEAE													
Juncus rigidus	0.060	0.0198	0.109	*	0.012	*	0.146	*	0.024	0.005	0.79	8.35	nd
MALVACEAE													
Malva parviflora	0.047	nd	0.097	*	0.008	*	0.186	*	0.019	0.010	1.15	4.41	0.08
MIMOSACEAEA													
Acacia ehrenbergiana	0.029	nd	0.111	*	0.011	*	0.159	*	0.038	0.010	1.13	6.76	0.12
Acacia tortilis	0.031	nd	0.073	*	0.006	*	0.152	*	0.002	0.009	1.02	0.96	0.08
OROBANCHACEAE													
Cistanche phelypaeae	0.250	0.0079	0.112	0.001090	0.001	*	0.150	*	0.011	0.007	1.65	7.23	nd
PLANTAGINACEAE													
Plantago amplixicaulis	*	0.0099	0.079	*	0.009	*	0.171	0.00000	0.047	0.011	0.90	7.11	nd
Plantago ciliata	0.031	nd	0.054	0.002250	0.026	*	0.180	*	0.106	0.011	1.44	5.77	0.17
PLUMBAGINACEAE													
Limonium axillare	0.112	0.0150	0.156	0.00071	0.027	*	0.151	0.00283	0.071	0.010	1.18	2.27	0.07
POLYGONACEAE													
Rumex dentatus	0.910	0.0037	0.095	*	0.010	0.000005	0.040	0.00185	0.036	0.016	1.30	5.34	0.15

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