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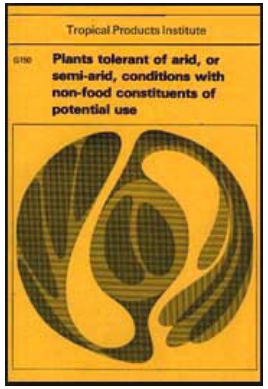

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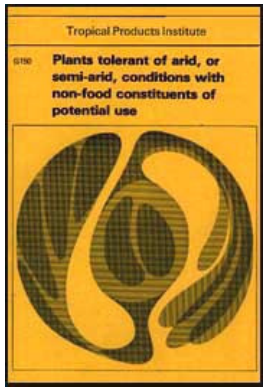

Plants Tolerant of Arid, or Semi-arid Conditions and with Non-food Constituents of Potential Use (NRI)
- ***(introduction...)***
- **Acknowledgements**
- **Introduction**
- **Section 1: List of plants tolerant of arid or semi-arid conditions with non-food constituents of potential use**
- **Section 2: References**

J. B. Davis, D. E. Kay and V. Clark

1983 Tropical Products Institute 56/62 Gray's Inn Road London WC1X 8LU

Overseas Development Administration

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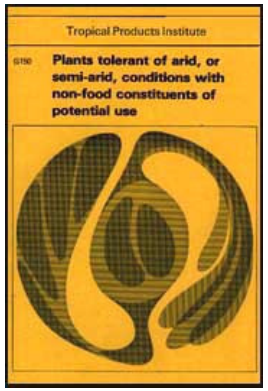
(introduction...)



Acknowledgements

This report was produced by the Tropical Products Institute, a British Government organisation which co-operates with developing countries in helping them to derive greater benefit from their plant and animal resources. It specialises in post-harvest problems and will be pleased to answer requests for information and advice addressed to the Director.

Davis, J. B., Kay, D. E. and Clark, V. (1983) Plants tolerant of arid, or semi-arid, conditions with non-food constituents of potential use. Report of the Tropical Products Institute, G 150, iv + 172 pp.

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Tropical Products Institute

ISBN: 0 85954 135 5

ISSN: 0144 - 9982

The authors wish to acknowledge with gratitude the advice and comments received from their many colleagues within the

Institute, Dr G. E. Wickens of the Royal Botanical Gardens, Kew and Mr William Gardener, FLS.

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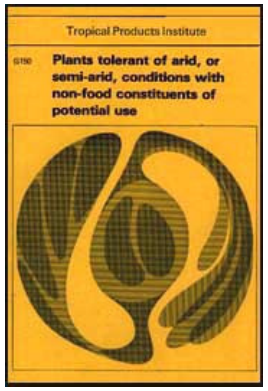


Introduction

In recent years there has been considerable interest in using more productively the renewable natural resources of the arid and semi-arid zones which make up almost 40 per cent of the Third World's land surface (Miegs, 1953; Paylore and Greenwell, 1979; UNESCO, 1979). This report is an attempt to bring together basic information concerning plants which are reported to tolerate arid, or semi-arid, conditions and which have, or might have, potential as raw materials for industrial, i.e. non-food, use.

The information has been presented in tabular form for convenient reference. The resulting tables list alphabetically 298 species which have been reported by various authors, (for example, Arnon, 1972; Chopra et a/., 1960; Cruse, 1949, 1959, 1973; Duisberg and Hay, 1971 and Krochmal et al., 1954) to tolerate arid, or semi-arid, conditions and which yield one or more of the following commodities:

(i) Essential oils, for use in flavourings, fragrances, etc;

(ii) Fibres and cellulosics;

(iii) Firewood;

(iv) Gums and resins, for use as adhesives, but including those which may be used in foodstuffs;

(v) Latexes—for use as substitutes for Hevea rubber and as sources of hydrocarbon fuels;

(vi) Oilseeds—non-food uses, i.e. technical oils used in surface coatings for lubrication, etc;

(vii) Pesticides;

(viii) Pharmaceuticals—particularly as a source of established drugs or their precursors;

(ix) Tanning materials;

(x) Waxes.

Generally food and forage uses have been excluded although such uses are occasionally mentioned where it seems appropriate to do so. In addition, although firewood continues to be the most important source of fuel for cooking and heating in most Third World countries and its collection in sufficient quantities one of the most pressing daily problems in arid areas and one of the major reasons for their devegetation, little emphasis has been accorded to firewood sources in this report as it was known that a detailed compilation by the National Academy of Sciences in the USA was being undertaken. The compilation was published (National Academy of Sciences, 1980) and those species mentioned therein, but which had not been included in the preliminary draft of this report, have been added, but without comment and denoted by the suffix f.

The headings used in the tables are largely self-explanatory but the following comments may be appropriate. In the first column the botanical nomenclature used follows closely the Index Kewensis and its Supplements and only the more common vernacular names are given. Information given under columns three and four, Potential and Constraints can be considered as positive or negative attributes applicable to each listed species and its possible exploitation in the future. Where a large number of species have certain properties in common, for example the Euphorbias, Opuntias and Yuccas, their common aspects have been drawn together in the form of general notes rather than repeated under each individual entry.

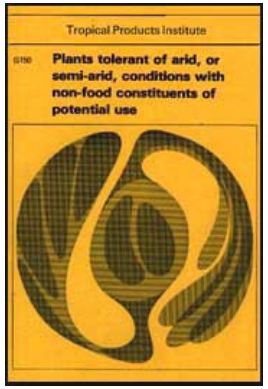
In all entries only a few key references have been quoted in an attempt to keep the numbers manageable. Nevertheless, the reference list which constitutes the second section of the report should prove a valuable bibliography for the many technolgists, scientists and economists who are interested in developing the plant resources of the arid and semi-arid regions.

The report should be regarded as a working document rather than a final definitive work and it is hoped that it will be of value in the following ways:

(i) as a convenient assemblage of data on each of the species listed;

(ii) as a means of identifying gaps in knowledge and hence indicating the possible direction for new research;

(iii) as a basic document from which it may be possible for scientists, technologists, agriculturalists and economists to select a proportion, say 1 in 10, of the species listed as being worth exploring further.

Section 1: List of plants tolerant of arid or semi-arid conditions with non-food constituents of potential use

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
1. *Acacia decurrens* (Wendl.) Willd. (Wattle) Australia, S. and E. Africa	Ten-year old trees yield 20–25 kg of bark, a widely used tanning material. [One variety (var. *mollis;* = *A. mearnsii*) is one of the three major commercial sources of vegetable tanning material]. Wood used for paper pulp.	Bark contains 35% tannins.	Natural tanning materials generally facing severe competition from synthetic tannins.	Duisberg and Hay, 1971 Isenberg, 1956 Kidder and Finney, 1950
2. *Acacia nilotica* Delile; syn. *A. arabica* (Lam.) Willd. ex Del. *[f] (Babul) Indigenous to SE. Pakistan (Sind), the Deccan (India), tropical Africa; also found Arabian Peninsula, Natal, Egypt.	Source of a water-soluble gum similar to gum arabic. In India used for timber, tanning material, fodder.	Gum exudes from wounds in the bark, yielding from about 100–800 g per tree per year. It is a galactoaraban which on hydrolysis yields l-arabinose and d-galactose. Bark contains about 12% tannins, seeds 12–19%. Extract of bark showns CNS activity.	Gum slightly inferior to genuine gum arabic (*see* entry no. 3). Tanning material produces a dark leather with a tendency to crack.	Anderson, 1977 Ayensu, 1979 Chopra *et al.*, 1960 C.S.I.R. India, 1948 George, 1977
3. *Acacia senegal* (L.) Willd. [f] (Kumut) Subtropical arid and semi-arid regions from Delhi westwards to W. Africa; abundant in Sudan, Senegal.	Principal commercial source of gum arabic; widely used in the food, pharmaceutical, confectionery and paper industries. Seeds relished as a vegetable in India; leaves, etc. used as fodder. Second largest cash crop in the Sudan, the world's leading producer.	Withstands drought and high temperatures; yield of gum increases with aridity. Gum almost odourless with a bland taste, high in galactans. Almost completely soluble in an equal weight of water, to give a translucent, viscous, slightly acid solution. Roots of tree protect soil from erosion.	Faces competition from babul gum (*see* entry no. 2), guar, locust bean, tragacanth, agar and modified starch gums. Competitive position in the Sudan partly dependent upon cheap labour. Tapping the tree said to be an unpleasant task.	Adamson and Bell, 1974 Anon, 1979a Chaudhri and Saleem, 1962 CSIR India, 1948 Sen and Bansal, 1979 Tewari, 1979 Wickens in Davis, 1978a
4. *Achillea fragrantissima* (Forssk.) Schultz Bip. N. Africa, Middle East.		Possible source of an essential oil: leaves contain 0.83% (w/v; fresh-wt. basis) of a pale yellow, aromatic oil, containing α-pinene, d-myrcene, sabinene, l-linalool, l-terpineol, eugenol, carvacrol, ethyl n-amyl ketone, n-hex-3-en-1-ol and the corresponding acetate *cis*-hex-3-en-1-yl acetate (used in fragrances in USA).	*Cis*-hex-3-en-1-yl acetate can be prepared synthetically.	Opdyke, 1975 Shalaby and Richter, 1964 Zaitschek, 1953

* Several other *Acacia* species are also found growing wild in N. Africa and are tapped for gum, which is used to adulterate true gum arabic. The species include: *A. glaucophylla* A. Rich., *A. abyssinica* Benth., *A. albida* Delile, *A. seyal* Delile, *A. stenococarpa* A. Rich., and *A. ehrenbergiana* Hayne (*A. albida* Delile recently planted extensively in Chad where it is said to have 'greatly benefitted the rural economy' (Brenan in Davis 1978a)). *Acacia* spp. can also be used as a source of firewood (e.g. in addition to entries 2 and 3, the National Academy of Sciences 1980 list (see Introduction) mentions *A. brachystachya* Benth, *A. cambagei* R. T. Bak., *A. cyclops* A. Cunn. ex G. Don, *A. saligna* (Labill.) H. Wendl., *A seyal* Del., *A. tortilis* (Forssk.) Hayne) and charcoal (and for browse) and, being leguminous, fix nitrogen.

[f] denotes a potential firewood source (see Introduction)

List of plants tolerant of arid or semi-arid - Part 1

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
5. *Achillea santolina* L. Middle East, particularly the Libyan Desert.	Used by the Bedouins medicinally.	Possible source of an essential oil: air-dried flower heads yield 0.95–1.02% yellowish-green, aromatic oil, containing azulene-forming compounds. Santolin and santolinol isolated from flower heads.		Haddad *et al.*, 1960 Khafagy and Fatatry, 1969 Khafagy and Fatatry, 1970 Zaitschek, 1953
6. *Adhatoda vasica* Nees [f] [For *Agathosma* sp., *see* entry no. 57]				
7. *Agave americana* L.* (Century plant) Native to deserts of SW. USA and Mexico, but now found in India, Africa and the Middle East.	Sap fermented to produce the alcholic beverage, pulque.	Juice of mature plants contains sucrose, glucose and mannitol. Possible source of sapogenins: leaves from Texan plants contain 0.04–0.30% hecogenin, Indian 0.065%. Other sapogenins isolated from the leaves include gentrogenin, chlorogenin (?), rockogenin (?). Possible source of paper pulp.	Plants normally 8–10 years old before being used for pulque production in Mexico. †	Blunden *et al.*, 1978 Duisberg and Hay, 1971 Isenberg, 1956 Marker *et al.*, 1943 Sanchez-Marroquín and Hope, 1953 Singh and Pereira, 1964 Wilkomirski *et al.*, 1975
8. *Agave atrovirens* Karw. (Maguey) Native to Mexico where it thrives in the semi-arid severely eroded lands of the central region.	Used to produce the alcoholic beverage mezcal (2 m litres p.a. in 1960) by cooking the centre portion then fermenting; fibre said to be produced as a by-product.	In Mexico, Patrona de Maguey (National Maguey Commission) established to sponsor research on cultivation, crop improvement and utilisation of the products. Said to contain diosgenin (queried by Blunden *et al.*, 1978); and apparently, vitamin B_{12} – an essential and relatively rare vitamin.	†	Ayensu, 1979 Duisberg and Hay, 1971 Hernandez, 1970 Sanchez-Marroquín and Hope, 1953
9. *Agave atrovirens* Karw. var. *salmiana* (Otto ex Salm-Dyck) Trelease; syn. *A. salmiana* Otto ex Salm-Dyck Mexico	Source of alcohol: utilised extensively for production of the beverage pulque.	Production increasing in Mexico, where establishment of nurseries has permitted some selection of stocks. R and D being carried out on technical aspects of processing and handling pulque. Leaves contain hecogenin, its 4-dehydro-derivative, and gentrogenin.	†	Blunden *et al.*, 1978 Hernandez, 1970

[f] denotes a potential firewood source (*see* Introduction)

* The *Agave* genus includes a number of species native to arid/semi-arid regions but only the more important are listed. The sapogenin content of many other *Agave* spp. has also been recorded by Blunden *et al.*, 1978, 1980 (but mainly on plants grown under temperate conditions).

† One of the main constraints to the utilisation of all *Agave* spp. here listed is finding a species which both produces a good-quality fibre at a reasonable rate and an economic concentration of hecogenin (free of tigogenin contamination), or other sapogenin which can be used as a steroid precursor (i.e. diosgenin, smilagenin or sarsasapogenin), for extraction from the wastes (cf. Correll *et al.*, 1955, p. 360 and Coppen, 1979).

List of plants tolerant of arid or semi-arid - Part 2

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
10. *Agave fourcroydes* Lem. (Henequen, Yucatan sisal) Wide range of adaptation in Mexico, where in 1970 there were 200,000 ha. Also grown in Cuba, Honduras, Nicaragua. Grows in almost-arid to sub-humid areas.	Source of a leaf fibre similar to sisal which is used mainly for agricultural twines but also for cordage, upholstery-padding, floor-coverings. Waste from cordage used for paper. Important crop in Mexico where fibre production in 1975 was 139,000 tonnes.	Leaves contain 3–4% fibres, each plant yielding about 2 kg dry decorticated fibre. The leaf waste contains 2% wax (of m.p. 91–92°C), hecogenin (trace up to 0.4%), tigogenin (trace up to 0.1%), diosgenin and gentrogenin. Waste also a possible source of alcohol by fermentation. Considerable research done on by-products in 1940s.	Fibre production only starts when plants are 5–7 years old (but lasts for about 15 years). Need to reorganise and modernise the processing industry and to develop new products. Convenient and economic method of removing the unwanted tigogenin from the hecogenin/tigogenin mixture needed. †	Blunden *et al.*, 1978 Cruse, 1959 Duisberg and Hay, 1971 FAO, 1976a Gentry, 1972 Hernandez, 1970 Isenberg, 1956 Johnson, 1977 Kirby, 1963 Mesa and Villanueva, 1948 Mier and Teran, 1957 Monroe *et al.*, 1955
11. *Agave lechuguilla* Torr. (Ixtle, Tampico fibre, tula, Mexican fibre) Wild plant of the arid limestone mesas and hillsides of Mexico and SE. Arizona, W. Texas and S. New Mexico.	Leaves utilised for fibres used for sacking, upholstery tow, brushes and cordage but particularly good as brush-making fibre as fibres are stiff and easily bleached. Broken fibres used for pasteboard. Source of sapogenins. Stem, root fragments and leaf debris (from fibre extraction) used as a soap substitute in Mexico; stem also used as a fish poison and as roofing material.	Fibres 20–45 cm in length, ultimate fibres 0.4–2.2 mm. Leaves yield about 1% smilagenin on a dry wt. basis along with diosgenin, tigogenin, gentrogenin. Roots yield 1.0% sapogenins (20% gitogenin, 80% smilagenin), green fruit 3.7% hecogenin, and seed 1.5% sapogenins (70% hecogenin + 30% manogenin). Contains a pigment thought to be hypercin, or a very similar compound.	Attempts to industrialise crop for fibre in the USA failed in 1950s. Mexican production has shown a downward trend, due to competition from synthetics, and the industry is dependent upon cheap labour. Unpleasant to handle, juice liable to burn skin. Attempts to develop mechanical decortication have had little success (however the fibre still has considerable local (bartering) importance for the rural poor of N. Central Mexico – and some is still exported). Regarded as an unwanted weed in parts of Texas. Plant takes 8–10 years to reach maturity then flowers and dies. †	Bender, 1963 Benson and Darrow, 1944 Blunden *et al.*, 1978 Cruse, 1959 Cruse, 1973 Duisberg, 1952a Duisberg and Hay, 1971 Hernandez, 1970 Johnson, 1977 Kirby, 1963 Pennington, 1958 Sheldon, 1980 Wall and Fenske, 1961 Wall *et al.*, 1962
12. *Agave mescal* K. Koch Cultivated in Jalisco, Mexico.	Used to produce tequila and allied alcoholic beverages.	Possible source of sapogenins and fibre.	†	Cruse, 1959

† *See* footnote † to entry no. 7.

List of plants tolerant of arid or semi-arid - Part 3

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
13. *Agave palmeri* Engelm. (Palmer agave, mescal, century plant) Widely distributed in SE. Arizona, SW. New Mexico and the Sonora desert (California/SW. Arizona).	Leaf fibre has been used locally (for ropes). Centre stem after baking is used for food and also to produce alcohol (*see* entry no. 8).	Species might have possibilities as a source of fibre and alcohol (for use as a fuel or a feedstock for chemicals).	Plants are not abundant and rate of growth is slow, so harvesting likely to be costly; in contrast to some other *Agave* spp., little or no sapogenins reported in the leaves.†	Bahre and Bradbury, 1980 Benson and Darrow, 1944 Gentry, 1972
14. *Agave promontorii* Trelease SW. USA, Mexico.		Possible source of fibre and sapogenins: sapogenin content reported as: 0.2–0.7% hecogenin, 0.1% tigogenin and trace of manogenin. Has been suggested that it could be developed as a dual-purpose (fibre/sapogenins) crop in Mexico, in place of *A. fourcroydes* and *A. zapupe*.	†	Correll *et al.*, 1955 Wall *et al.*, 1954
15. *Agave schottii* Engelm. (Schott agave, amole, soso) Abundant in S. Arizona, New Mexico, the Sonora desert (California/SW. Arizona) and Mexico.	Used in Mexico as a soap substitute and fish poison.	Possible source of sapogenins: seeds contain 1.7% hecogenin; leaves 0.6–1.2% chlorogenin (?) and 0.3% tigogenin (?) (also (?) smilagenin and gitogenin).	†	Benson and Darrow, 1944 Gentry, 1972 Pennington, 1958 Wall and Fenske, 1961 Wall *et al.*, 1955
16. *Agave sisalana* Perrine ex Engelm. Drummond & Prain (Sisal) Originated in Mexico, but now grown commercially in E. Africa, Brazil, Haiti, Venezuela, etc.	Source of the most important natural hard fibre – sisal (has high breaking strength and low extensibility); used for twine cordage, sack making, upholstery padding, carpets, handicrafts, particle board, paper pulp, carbonised fibre, etc. Wastes from fibre extraction used as a source of hecogenin (for steroid production) and a wax can also be obtained.	Hecogenin content of the leaves varies with site and age of the plants (0.6–1.3%). Tigogenin, neotigogenin, sisalagenin, gloriogenin, diosgenin, gentrogenin, and yamogenin also detected in leaves. Hybrids developed in E. Africa for improved fibre production (but have a lower hecogenin content).	The plant requires irrigation for maximum fibre yields when grown in arid or semi-arid areas – then yield of fibre is about 3.5–4%. Competition from synthetics, particularly polypropylene for baler twine, very serious; is a need to develop new outlets for the fibre. †	Blunden *et al.*, 1974 Blunden *et al.*, 1975 Cruse, 1959 Cruse, 1973 Duisberg and Hay, 1971 Evenari and Koller, 1956 Isenberg, 1956 Lock, 1969 Spensley, 1956 TPI, 1975
17. *Agave sobria* Brandegee var. *roseana* (Trelease) I. M. Johnstone; syn. *A. roseana* Trelease Mexico		Possible source of hecogenin: 2.5% reported in leaves – the highest found (by 1955) in any *Agave* species.	†	Correll *et al.*, 1955

List of plants tolerant of arid or semi-arid - Part 4

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
18. *Agave tequilana* Weber* (Mescal, chino azul) Mexico.	Used to produce (in the same way as mezcal, *see* entry no. 8) the alcoholic beverage tequila; fibre can be produced as a by-product.	Analysis of centre part of plant utilised for production of tequila; water, 60–70%; fibre, 11–12.5%; polysaccharides (mainly inulin), 14.3–24.1%; sugars, 1.0–1.5%; ash, 2.4–3.9%. Fibre softer and finer that that from *A. fourcroydes*. Production of tequila has increased in recent years. Also contains diosgenin and other sapogenins (and ? vitamin B_{12}; *see* entry no. 8).	†	Ayensu, 1979 Duisberg, 1952b Duisberg and Hay, 1971 Sanchez-Marroquín and Hope, 1953
19. *Agave vera-cruz* Mill.; syn. *A. lurida* Ait. (East Indian agave) Probably a native of Mexico, but naturalised in Asia, particularly India.	Source of fibre, fructose, sapogenins, paper pulp, alcohol. Pilot-plant scale production of fructose from the stems developed in India giving yield of about 10% from stems; i.e. about 8.75 tonnes of fructose syrup per hectare.	Leaves yield 1.5–2.5% coarse fibre. Stem rich in polyfructosans. Leaves contain 0.1% hecogenin and 0.01% 9 (11)-dehydro-hecogenin; tigogenin also present.	†	Cruse, 1959 Gedeon and Kincl, 1953 Krishna and Lakshminarayana, 1954 Srinivasan *et al.*, 1954 Subba Rao and Shyama Sundar, 1974
20. *Agave vilmoriniana* Berger Mexico.	Traditionally used as a soap substitute.	Green leaves contain 1%, or less, sapogenins (smilagenin 80%), mature leaves (7–8 years) 3–4.5% sapogenins. Considered to be a promising economic source of smilagenin; but not utilised commercially (1971).	†	Bender, 1963 Gentry, 1972 Wall *et al.*, 1957
21. *Agave zapupe* Trelease Mexico.	Used as a minor source of henequen-like fibre in Mexico.	Leaves contain hecogenin, tigogenin, gentrogenin.	†	Blunden *et al.*, 1978 Correll *et al.*, 1955 Cruse, 1959
22. *Ajuga iva* (L.) Schreb. (Herb ivy, musky bugle) Egypt, S. Europe.		Ecdysterone (0.012%, after purification), a related C_{28} compound (0.11%), and a small quantity of cyasterone (all insect-moulting hormones) isolated from plant extract. Crude extract from plant said to have anti-malarial activity also.		Drar, 1954 Ikan and Ravid, 1971 Khafagy *et al.*, 1979
23. *Albizia lebbeck* (L.) Benth. f				
24. *Aloe* spp. (Aloes) A genus of about 180 species of xerophytic plants, most being indigenous to E. and S. Africa.	When leaves of many species are cut, a juice exudes (known as 'aloes') which is used as a purgative and externally, to aid healing.	Juice contains varying amounts of aloin, a mixture of anthraquinone glycosides; barbaloin is the principal constituent. Entry nos. 25, 26 and 27 are the official aloe species. Further species have been used in traditional medicine.	Use of both crude aloes and aloin as purgatives now discouraged due to their irritant action.	Cheney, 1970 Chopra *et al.*, 1960 Hodge, 1953 Martindale, 1977

* In addition to *A. tequilana* other agaves of the mescal group used to some extent for the production of mescal are: *A. pseudotequilana* Trelease, *A. palmaris* Trelease, and *A. pes-mulae* Trelease.

† *See* footnote † to entry no. 7.

f denotes a potential firewood source (*see* Introduction)

List of plants tolerant of arid or semi-arid - Part 5

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
25. *Aloe ferox* Miller (Cape aloes) S. Africa.	Sole source of 'Cape aloes'.	Aloin content of juice about 10%.	*See* entry no. 26; in addition extraction procedure is very primitive. Severe drought adversely effects yield of aloes. Lower aloin content than *A. vera*.	Cheney, 1970 Chopra *et al.*, 1960 Hodge, 1953
26. *Aloe perryi* Baker (Socotrine- or Zanzibar-aloes) Found on Socotra (Indian Ocean), in E. Africa and the Arabian peninsula.	Source of 'Socotrine aloes' of commerce.	Aloin content of juice a little less than 30%. Socotrine aloes reported to be milder and less irritating than other drug aloes.	Thorny plants, which makes their harvesting unpleasant; low demand for the products and poor financial return; and aloes' effectiveness as a burn treatment (other than as a simple protective coating) has been disputed.	Chopra *et al.*, 1960 Hodge, 1953
27. *Aloe vera* (L.) Burm. f.; syn. *A. barbadensis* Miller, *A. vulgaris* Lam. (Barbados-, Curaçao- or West Indian-aloes) Thought to have originated in the Mediterranean area, but now widespread in Africa, S. Asia and the more arid areas of the Caribbean.	The main commercial source of aloes, most of which is produced in the West Indies ('Curaçao-aloes'). The mucilage remaining after collecting the juice can be used to make a gel ('Aloe-gel') which is incorporated in certain ointments for treating burns and in cosmetics.	Aloin content of juice up to about 30%. The mucilage has repeatedly been investigated for antibiotic activity, but the results have been equivocal and the subject of dispute.	As for *A. perryi*	Anon, 1970a Ayensu, 1979 Cheney, 1970 Chopra *et al.*, 1960 Cruse, 1973 Fly and Kiem, 1963 Hodge, 1953 Leung, 1977 Morton, 1961 Winters *et al.*, 1981
28. *Ammi majus* L. (Bishop's weed, Amee) Indigenous to Egypt, Mediterranean and Ethiopia; also found in India and S. USA.	Drug plant; source of xanthotoxin, a furocoumarin (psoralen) which is a photo-sensitising compound used in suntan lotions and to treat leucoderma (skin depigmentation).	Fully mature fruits contain 0.4% xanthotoxin, (8-methoxy-psoralen), immature green 1.0%. Imperatorin, which can be converted to xanthotoxin, and bergapten (5-methoxy-psoralen and with similar properties to xanthotoxin), also present in fruits. Yield of fruits in India about 1,375 kg/ha. Other psoralens recently detected in the seeds. Such compounds have been used in conjunction with UV irradiation to treat psoriasis (an intractable skin ailment).	The crop requires irrigation when grown in Jammu, India (hot, fairly dry climate: around 500 mm/year) and on the other hand is sensitive to waterlogging following storms. Fruit set is irregular so hand-picking is essential. Psoralens can be synthesised. Their medicinal use, either internal or external, can cause serious side effects.	Anon, 1981 Bradu and Atal, 1970 Bridges and Strauss, 1980 Chopra *et al.*, 1960 Ivie, 1978 Martindale, 1977 Singh, 1963 Stevenson *et al.*, 1981

List of plants tolerant of arid or semi-arid - Part 6

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
29. *Ammi visnaga* (L.) Lam.; syn. *Daucus visnaga* L. (Khella, tooth pick) Indigenous to Mediterranean area. Cultivated in India.	Used in traditional Arab medicine. Now used as a coronary vasodilator and antispasmodic, the major active principle being khellin (5, 8-dimethoxy -2-methyl (4', 5', 6, 7) furanochromone) which is extracted from the seeds and used to treat angina pectoris and also asthma. It is said (cf. Mosig) to be 'non-toxic' (but *see* Martindale).	Fruits contain 1% khellin, 0.1% visnagin (8-desmethoxy-khellin) and 0.3% khellol glycoside. Also contains an aromatic essential oil. Minor constituents accompanying the khellin (visnadine etc.) also have vasodilatory activity.	For angina pectoris, khellin is not so effective as nitroglycerine and in addition, khellin can now be obtained by synthesis.	Anon, 1951b Chopra *et al.*, 1960 Fairbairn, 1953 Gattefossé, 1952 Martindale, 1977 Mosig, 1964 Quimby, 1953 Singh, 1963
30. *Amsonia hirtella* Standl. USA – Arizona, S. California, Carolina.		Can yield 2–5% natural rubber and was investigated as a source of rubber during World War II (when supplies of a *Hevea* rubber were cut off from Malaysia). Recently investigated as a source of petroleum-like feedstock.		Buehrer and Benson, 1945 Krochmal *et al.*, 1954 McLaughlin and Hoffmann, 1982
31. *Anabasis aphylla* L. (Itsegek) Russian steppes from Caspian Sea east to Turkestan; and Syrian deserts.	Source of alkaloids, especially anabasine whose sulphate derivative has been used as an insecticide (mainly in S. Russia).	Contains up to 12% alkaloids, the most important being anabasine, chemically related to nicotine. Other alkaloids present are aphyllidine and aphylline. Methyl-anabasine, a derivative of anabasine, is reported to have an invigorating effect on respiration centres.	Alkaloid content varies with stage of growth (most in new shoots) and soils. Anabasine has always been of only minor commerical importance and has now largely been superseded by more up to date insecticides.	Chopra *et al.*, 1960 Holman, 1940 Martin and Worthing, 1977 Paris and Dillemann, 1960 Petrov, 1972
32. *Anabasis haussknechtii* Bunge S. Russia, Iran, Israel.	Source of alkaloids, crude extract has been used as an insecticide in S. Russia.	Leaves contain the alkaloid anabasine.	*See A. aphylla*	Evenari and Koller, 1956 Zaitschek, 1953
33. *Androcymbium gramineum* (Car.) McBridge (Lofout) Occurs in Sahara oases.		Seeds yield 3.7 g/kg colchicine, bulbs 2.9 g/kg. World demand for colchicine estimated to be about 7 tonnes p.a. (1960), mainly obtained from the autumn crocus *Colchicum autumnale* L. Attempts have been made to spread lofout over a wider area with a view to utilizing it as a source of colchicine.		Paris and Dillemann, 1960 Perrot, 1936

List of plants tolerant of arid or semi-arid - Part 7

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
34. *Anthemis cotula* L. (Mayweed, stinking chamomile, dog fennel) N. and S. America, Australia, Europe.	Dried flowers and leaves reported to be effective against fleas, bed bugs and flies.		In practice, synthetic pesticides generally used, even at local level, for the purposes mentioned.	Krochmal *et al.*, 1954
35. *Apocynum cannabinum* L. (Dog-bane, Indian hemp) USA and S. Canada	Rhizomes used in traditional medicine as a cardiac stimulant and diuretic. Plant extract used traditionally to treat warts. Bark has been used for cordage fibre and whole stem for textile fibre.	Rhizomes contain the cardiotonic steroid glycosides apocannoside and cymarin (0.15–0.17%), both glycosides of the steroid strophanthidin. Seeds contain 23% oil and 29% protein. Fatty acids: non-conjugd. diene* (as C_{18}), 53%; non-conjugd. triene † (as C_{18}), 10%; monoene (as oleic), 30%; saturated, 2%. Extracts from rhizomes reported to have similar but slightly inferior cardiotonic action to digitalin; and an alcoholic extract reported to have a significant inhibiting action, also ascribed to the presence of the above glycosides, against human carcinoma of the nasopharynx (as tested in cell culture). Potential oilseed.		Anon, 1966a Caldwell, 1966 Dodge, 1897 Earle *et al.*, 1960b Golab *et al.*, 1959 Krochmal *et al.*, 1954 Kupchan *et al.*, 1964 Martindale, 1977 Trabert, 1960 Zaitseva and Feofilaktov, 1950
36. *Apodanthera undulata* Gray (a cucurbit – *see* entry no. 95) (Melonloco) Native to SW. USA and Mexico.	Minor oilseed.	Seed contains about 30% oil; iod. val. 160 (semi-drying); fatty acid composition: palmitic, 13%; stearic, 4%; oleic, 11%; linoleic, 42%; linolenic, trace; punicic (9, 11, 13-octadecatrienoic acid), 30%. Of interest because of the high punicic acid content. Has large root containing ∿ 23% starch; iodine affinity value, 5.01 §; gelatinization temperature (64–67°) similar to other cucurbit starches; granules have av. diam. of 17 μm and resemble tapioca starch in form.		Bemis *et al.*, 1967b Berry *et al.*, 1978a Krochmal *et al.*, 1954
37. *Argania spinosa* (L.) Skeels (Argan tree) Morocco; Sahara region.	Seeds used for making oil which is said to be used for cooking. Husks and fruit used for cattle food. Trunk yields a gum. Timber used for construction.	Seeds contain 60.4% oil, 19.4% protein. Oil similar to olive oil but with higher linoleic acid content; no problems in refining. Contains 0.5% sterols, mainly β-sitosterol and stigmasterol (both Δ^5).		Huyghebaert and Hendrickx, 1974 Jones and Barclay, 1972 Usher, 1974

* e.g. linoleic acid

† e.g. linolenic acid

§ A measure of the amylose content of the starch (if <5, it is relatively low as compared with the other major component, amylopectin – as is typical for root/tuber starches: Berry *et al.*, 1978a; Radley, 1968).

List of plants tolerant of arid or semi-arid - Part 8

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
38. *Argemone mexicana* L. (Mexican poppy) Originated in Mexico, but is now widely distributed in the drier parts of the tropics.	Utilised in traditional medicine. Seeds contain a semi-drying oil, utilised as a lubricant in India, for paint manufacture in the USA, and to make soap.	Seeds yield 22–40% oil; sap. val., 188; iod. val., 120; acid val., 3.5; unsap matter, 1.1%. Fatty acids: palmitic, 8%; stearic, 5%; palmitoleic, 2%; oleic, 26%; linoleic, 52%; linolenic, 3%; 'oxy-acids' (found to be a mixture of hydroxy-, epoxy-, and in-chain keto-fatty acids) 4%. Owing to presence of alkaloids (e.g. sanguinarine), oil is narcotic. Oil sometimes used as substitute for, or adulterant of, mustard or linseed oils. Has been suggested for drier areas of W. Africa, because it is quick-maturing. Whole-plant extract shows anti-viral activity.	Regarded as a noxious weed in some areas notably India. The toxic nature of the oil makes it unwise to recommend it for even non-edible purposes in view of possible misuse. Its more polar constituents settle out on standing.	Ayensu, 1979 Bhusan, 1959 Chopra *et al.*, 1960 Coursey, 1964 Gunstone *et al.*, 1977 Mani and Lakshminarayana, 1972
39. *Artemisia absinthium* L. (Wormwood, absinthe) N. Asia, Afghanistan westwards to the Atlantic. Naturalised in N. America.	Source of essential oil, formerly the major flavour constituent of absinthe (liqueur) and vermouth (aperitif); also said to have a tonic and stimulating effect on the digestion if given in small amounts.	Essential oil content of the plant, 0.3%; the chief constituent being thujone. Bitter principles are absinthin and anabsinthin, dimeric guaianolides (C_{30} H_{40} O_6); 5-hydroxy-3, 3', 4', 6, 7-pentamethoxy flavone also reported present. The seed oil (33% w/w) has a high epoxy-fatty acid content (23%), of possible industrial (plastics) use. Lignans, which sometimes show medicinal activity, found in roots (of specimen growing in temperate region).	Thujone and absinthin can cause delirium and hallucinations and so its use as a flavouring agent in now prohibited. Epoxy-fatty acids possibly toxic.	Ayensu, 1979 Beauhaire *et al.*, 1980 Chopra *et al.*, 1960 CSIR India, 1948 Earle *et al.*, 1960c Greger and Hofer, 1980 Herout *et al.*, 1956 Martindale, 1977 Novotný *et al.*, 1960 Tunmann and Isaac, 1957
40. *Artemisia cina* Berg (Levant wormseed) Native to Russia east of the Caspian Sea (Turkestan) and Iran. Has been grown experimentally in many other areas.	Dried flower heads utilised as a source of the anthelmintic drug santonin.	Santonin content varies considerably; can reach 4–5%, but with the commercial product normally 2.0–2.5%. Highest just prior to the opening of the flower buds.	Commercial production confined largely to Turkestan. Requires cheap labour for hand-picking and sorting. Harvesting normally done over a period of only 2 weeks. Requires hot, dry summer, but moisture-retentive, fertile soils. Content of active constituent varies widely (*see* column 3). Attempts at commercial production outside area of origin have met with little success. Care required in use of santonin — can cause bad side-effects and even death.	Chopra *et al.*, 1960 CSIR India, 1948 Malik and Dubash, 1979 Martindale, 1977 Paris and Dillemann, 1960 Smith, 1950

List of plants tolerant of arid or semi-arid - Part 9

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
41. *Artemisia herba-alba* Asso (Desert wormwood, Barbary santonica) N. Africa, Middle East, Iran, Afghanistan.	Utilised as a source of santonin, and of essential oil. Marketed as 'Barbary santonica' which is used locally as a medicine and as a perfumery material.	Dried flowering branches reported to have santonin content 0.99%. Stigmasterol, β-sitosterol, germacranolides, flavones, and thymol also reported. Essential oil content 0.3–1% (thujone main constituent); exhibits anti-bacterial activity - ascribed to the santolina alcohol, an unsat C_{10} alcohol, therein.	See previous entry concerning santonin's toxicity.	Chopra *et al.*, 1960 Drar, 1954 Khafagy *et al.*, 1971 Malik and Dubash, 1979 Paris and Dillemann, 1960 Segal *et al.*, 1963 Yashphe *et al.*, 1979 Zalkow *et al.*, 1980
42 *Artemisia inculta* Del. var. *laxiflora* (Boiss) Tačkh Sinai desert.		Plants yield 1.6% essential oil, thujone being the main constituent.		Drar, 1954
43. *Artemisia judaica* L. (Sheeh, Judean wormwood) Egypt, Arabian desert.	Utilised in traditional medicine (against worms), as an insecticide and as a condiment. Traded locally: e.g. dried leaves sold in Egypt to make a medicinal tea and in Sudan sold as a condiment.	High content of tannins in flowers; sterols and triterpenes, piperitone and derivatives, monoterpenes, etc. isolated from whole plant.	Although the plant is used in the treatment of tape-worms, santonin (the expected active constituent: *see* entry no. 40) is said to be often absent from this particular species.	Osborn, 1968 Uphof, 1968 Tawfik *et al.*, 1978 Zalkow *et al.*, 1980
44. *Artemisia ludoviciana* Nutt. subsp *mexicana* (Willd.) Keck; syn. *A. mexicana* Willd. (Mexican mugwort, estafiate) SW. USA, Mexico.	Used in traditional medicine, particularly as an anthelmintic. Source of an essential oil.	Anthelmintic compound, estafiatin, identified as a sesquiterpenic epoxylactone of the guaiane series. Following compounds identified in the essential oil: (-) - α -phellandrene; (+) -limonene; (-) -β-phellandrene; (-) -camphor; ( ) -borneol; thymol; carvacrol; eugenol.		Manjarrez and Medina, 1964 Sánchez-Viesca and Romo, 1963 Uphof, 1968

List of plants tolerant of arid or semi-arid - Part 10

Name(s)/Distribution	Current/past uses	Potential	Constraints	
45. *Artemisia maritima* L.*; syn. *A. brevifolia* Roy. (Santonica, sea wormwood) Europe to Mongolia particularly NW. India and Pakistan.	Principal commerical source of santonin; also can be used as source of an essential oil.	Improved strains have santonin contents up to 4.25%. Wild plants to be of commercial value should have santonin content of 1–2%. In addition, β-santonin (also anthelmintic but weaker than santonin itself) and a bitter principle artemisan also present. Essential oil content, 0.32% (air-dried material); main constituents being cineole, 21–34%; α-pinene, 13–16%; camphor, 12–15%; thujone, 10–12%. Possibility of extracting santonin with the essential oil as a by-product has been studied.	In late 1950s, production in Pakistan was some 1000 tonnes dried plant material p.a. In order to remain competitive, there is a need to develop improved high-yielding strains and more economical methods of harvesting, and to extract the santonin locally. *See* entry no. 40 re santonin's toxicity.	Chaudhri, 1955 Chopra *et al.*, 1960 CSIR India, 1948 Malik and Dubash, 1979 Nigam and Rao, 1967 Qazilbash, 1942 Qazilbash, 1954 Qazilbash, 1960
46. *Artemisia monosperma* Delile Sahara, Egypt, Saudi Arabia.	Used medicinally in Egypt, especially as an anthelmintic. Also possible source of essential oil.	A santonin-like compound, with strong toxic effect on the worm *Ascaris*, isolated. Hence the suggestion it be used as a substitute for the santonin-containing *Artemisia* spp. (e.g. entries 40, 41 etc.) Its use as an anti-spasmodic in the treatment of colic or conditions associated with hypertension also mooted. Essential oil insecticidal; contains furoartemone, a furan compound. Whole plant contains various coumarins etc. The plant said to be particularly good for stabilising sand.		Evenari and Koller, 1956 Hammouda *et al.*, 1978 Sharaf *et al.*, 1959a, b Zaitschek, 1953
47. *Artemisia tridentata* Nutt. (Black or common sagebrush) SW. USA.	Used in traditional medicine, as a source of pollen extracts, of essential oil, and also as a fodder plant.	Plant material high in fat, 10.5%; protein, 11.2%; carbohydrate, 26.3%. Yield of essential oil varies from 0.7% to 3%, the major constituents being α-pinene, cineole, 'α-terpenes', d-camphor, artemisol, and a monoterpenoid ether ($C_{10}H_{16}O$). Also a number of sesquiterpene lactones isolated from the plant material.	Although used as a fodder plant, it is sometimes poisonous to sheep and horses. Even cultivated specimens show wide variation in e.g. essential oil content.	Buttkus and Bose, 1977 Durham, 1951 Kinney and Sugihara, 1943 Kinney *et al.*, 1941 Krochmal and Krochmal, 1973 Sampson and Malmsten, 1935 Shafizadeh *et al.*, 1971 Welch and McArthur in Davis, 1978c

* There is considerable variation in the santonin content of *A. maritima* and some confusion regarding the nomenclature. Some authorities distinguish the typical xerophytic artemisia in the desert of Kurram, which has a high santonin content, as a separate species *A. kurramensis* Qazilbash.

List of plants tolerant of arid or semi-arid - Part 11

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
48. *Arundo donax* L. (Bamboo reed, Provence cane, carrizo) Native to Mediterranean, but now widespread in sub-tropics.	Source of musical reeds, matting, industrial cellulose and used in basketry; rhizomes used medicinally.	Analysis of culms: cellulose, 40–58%; pentosans, 18–34%; lignin, 9–23%; ash, 2–7%. Pharmacologically active indole-3-alkylamine bases, including bufotenidine and dehydrobufotenine (narcotics), isolated from rhizomes; with triterpenes and sterols from leaves. Research on its possibilities as a source of paper pulp has been carried out in a number of countries.	Synthetic materials replacing reeds in musical instruments.	Chaudhuri and Ghosal, 1970 Duisberg and Hay, 1971 Dutta and Ghosal, 1967 Ghosal *et al.*, 1969 Ghosal *et al.*, 1972 Matzke, 1969 Perdue, 1958
49. *Asclepias erosa* Torr. (Milkweed, hierba lechosa) Mexico, SW. USA.		Rubber content of leaves 2.5–13%. Average when grown under cultivation, 5.5%. Was investigated in 1930s and early 1940s as a possible source of natural rubber in the USA in the event of a shortfall of *Hevea* rubber (but apparently no positive outcome). Recently investigated with *A. subulata* as a source of petroleum-like feedstock. The seeds of *Asclepias* spp. usually also contain ~15–20% of a semi-drying oil similar, but inferior, to linseed oil – and potentially with similar outlets. Most *Asclepias* spp. can also be used as a source of paper-making material.	Use as a source of rubber presumably not viable except perhaps in times of severe *Hevea* shortfall.	Buchanan *et al.*, 1978 a, b Krochmal *et al.*, 1954 McLaughlin and Hoffmann, 1982 Whiting, 1943
50. *Asclepias subulata* Decaisne (Desert milkweed) SW. USA, Mexico.	Source of rubber.	Rubber content varies from 0.5 to 6.0% in wild plants, with most of it in the new growth; mean 2.8%; under cultivation, 5% in 3- and 4-year old plants. Highest during the dormant period. Can harvest every 3 years by allowing regrowth to take place. Said in the mid-1920s to be the most promising native US plant for rubber production there in the event of shortages of *Hevea* rubber. In addition, 28.5% of bleached good quality paper has been obtained experimentally. Most *Asclepias* spp. also yield a seed oil (*see* entry no. 49) and some, including *A. subulata*, an oil-like fuel (*see* entry no. 144); a trial planting of a 'milkweed' (? an *Asclepias* sp.; or possibly entry no. 144) has recently been reported.	X-ray photographs of typical samples of the rubber do not show the crystal structure characteristic of *Hevea* rubber, implying that it would be of little commercial value. Possibility of two sub-species one more xerophytic (with smaller, woody plants) and seems that the yield of rubber may be less from this type. Plant material must be stored in the dark after harvesting otherwise rubber content decreases.	Beckett and Stitt, 1935 Buchanan *et al.*, 1978 a, b Buehrer and Benson, 1945 Calvin, 1978 McLaughlin and Hoffmann, 1982 Whiting, 1943

List of plants tolerant of arid or semi-arid - Part 12

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
51. *Asphodelus aestivus* Brot.; syn. *A. microcarpus* Salzm. et Viv. Mediterranean.	Tubers used in traditional medicine and as a source of gum.	Dry tubers contain 55–65% total sugars and pilot-scale experiments have shown that 21.5–25 litres of alcohol can be obtained per 100 kg dry tubers. Hence a possible commercial source of alcohol (fuel and possible feedstock for manufacture of chemicals). Tubers also contain 2.7% mucilage (glucose, galactose and arabinose), β-sitosterol-β-D-glucoside, and stachydrine; seeds contain 14.8% 'fixed' (fatty) oil containing β-sitosterol and β-amyrin. Possible oilseed.		Drar, 1954 Fell *et al.*, 1968 Ferrari, 1949; 1950 Hammouda *et al.*, 1971 Hammouda *et al.*, 1972 Kampouris and Thomopoulos, 1971 Rizk and Hammouda, 1970
52. *Astragalus gummifer* Lab.† (Tragacanth, astragal, milk vetch) Turkey, Iraq, Iran, Syria, Greece.	One of the earliest gums utilised by man. Now used as a thickener and stabiliser in foods, in cosmetics, in confectionery manufacture, in pharmaceutical preparations and in textile manufacture.	The gum is formed by the transformation of the cells of the pith and medullary rays into a mucilaginous material. Two forms – ribbon, which is preferred, and flakes. The gum is a complex mixture of polysaccharides containing D-galacturonic acid, galactose, L-fucose, D-xylose, L-arabinose; 30–40% of the gum (namely, the fraction known as tragacanthin, an arabinogalactan) is soluble in water, while the remainder forms an insoluble gel known as bassorin or tragacanthic acid. Plant leguminous, hence enriches soil.	Collected from wild shrubs (though commercial cultivation has been considered in Iran) and is dependent upon cheap labour. Quality and yield affected by climate. Life span about 5 years and can only be tapped alternate years. Faces competition from Karaya gum and locust bean gum.	Anon, 1979a Aspinall and Baillie, 1963a, b Barber, 1951 Gentry, 1957 Howes, 1949 Lees, 1973 Stauffer and Andon, 1975 Uphof, 1968
53. *Avicennia officinalis* L.; syn. *A. tomentosa* Jacq. (White mangrove) Salt marshes of India and Middle East, Burma coast, Malayan Peninsula, and islands to the Philippines and parts of S. China.	Various parts used in traditional medicine.	Wood contains 54.7% cellulose and is a possible source of paper pulp. Aerial parts have been found to contain lupenone, lupeol, betulinic and ursolic acids (all triterpenes) and β-sitosterol. Suggested worth investigating as a source of gum in Egypt.	The wood chips badly and produces a pulp which is not easily bleached.	CSIR India, 1948 Drar, 1954 Subramanian and Vedantham, 1974

† Principal species used as a source of gum tragacanth; others include *A. adscendens* Bois S., *A. brachycentrus* Fisch., *A. cerasocrenus* Bunge, *A. kurdicus* Bois S., and *A. microcephalus* Willd.

List of plants tolerant of arid or semi-arid - Part 13

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
54. *Azadirachta indica* A. Juss.[f]; syn. *Melia azadirachta* L. (Neem, margosa, bead tree, Indian lilac) Native of India; now also found in drier regions of Africa.	Fruits yield an oil used in the manufacture of soap. Bark, leaves and fruit used in traditional Indian medicine and as an insecticide. Extracts of bark recently used in tooth-pastes, etc. Timber has been used for furniture, construction and fuel when nothing better available. Exudate from bark used as a gum. Sweet exudate obtained from upper branches utilized as a drink, 'neem toddy'. Shells from seeds used as fuel.	Seed kernels yield 50–60% oil: sap. val., 195–204: iod. val, 68–75; unsap. matter, 0.7–1.7%; fatty acid composition: myristic, 0.1%; palmitic, 16%; stearic 18%; arachidic, 2%; behenic, 0.5%; lignoceric, 0.2%; oleic, 53%; linoleic, 10%. Oil contains bitter principles (2%, mainly nimbidin) and foul-smelling sulphur compounds. Nimbidin and related compounds, present in seeds, bark and leaves, have medicinal activity. Azadirachtin recently isolated from the tree and found to have strong insecticidal properties. Grows rapidly. Can be raised successfully as an intercrop. Thrives on poor dry soil.	Much research needed; such as on the plant's agronomy, on methods of oil extraction, refining and deodorization, and on the use of the oil as a possible replacement for palm or coconut oils in soap manufacture; further investigation of the therapeutic principles, and of the insecticidal and anti-feedant compounds, also required. Domestication said to be difficult; successfully introduced into Haiiti. Frost-sensitive.	Coursey, 1964 CSIR India, 1948 Davis, 1978b Godin and Spensley, 1971 Ketkar, 1976 Lewis and Elvin-Lewis, 1983 Radwanski, 1977 a, b, c, d Radwanski and Wickens, 1981 Thompson and Anderson, 1978 Watson, 1928 Williams, 1966
55. *Baccharis sarothroides* A. Gray (Desert broom) California and the Mojave desert (Arizona).	Sometimes grown as an ornamental shrub (certain other members of the genus, growing in Arizona, are used medicinally).	Seeds contain 31.3% oil and 23.8% protein; a potential oilseed.	Certain other members of the genus, growing in Arizona, are toxic to livestock.	Benson and Darrow, 1944 Jones and Barclay, 1972 Duncan *et al.*, 1957
56. *Balanites aegyptiaca* (L.) Delile; syn. *Ximenia aegyptiaca* L.*. (Desert date, betu, zachum, heglig, thorn tree, Egyptian balsam, lalob tree) Thought to have originated in the Nile Valley but now widely distributed in Africa and Asia as far as Burma.	Seed kernel of fruit yields an oil, mainly used for soap. Fruit edible and used for production of alcoholic beverages, and as a cleaning agent. Wood is used for general carpentry work. Roots and bark are sometimes used medicinally (purgative, anthelmintic); bark is source of a strong fibre.	Kernels consist of about 10–12% of the whole fruit, and contain 40–60% oil and 1% sapogenins. Oil is bland, yellow, tasteless; composition variable. Sap. val., 195–204;; iod. val., 88–103; fatty acid composition: palmitic, 19–24%; stearic, 5–14%; oleic, 27–50%; linoleic, 20–40%; hydroxy-dienoic acids also reported. Protein of kernel reported to be high in lysine. Major sapogenin is yamogenin (same outlets, as a steroid precursor, as diosgenin). Fruit pulp contains 40% reducing sugars and about 1% sapogenins (yamogenin and diosgenin). Various groups have investigated the possibility of utlising the seed as a source of oil and commercially useful sapogenins; an attempt has been made to develop a multi-purpose process to utilize the pericarp and seed for production of sapogenins, oil and oilcake.	The plant grows erratically and is thorny. The principal obstacles to commercial exploitation have been the problems of removing the sticky pericarp, of decorticating the nuts, and obtaining adequate, regular supplies. *See* comments under entry no 111 concerning use of diosgenin as a steroid precursor.	Anon, 1961b Ayensu, 1979 Chantegrel *et al.*, 1963 Coursey, 1964 Drar, 1954 Earle *et al.*, 1960b Hardman, 1969 Hardman and Sofowora, 1970, 1971, 1972 Heintz *et al.*, 1965 Misra *et al.*, 1975 Morris *et al.*, 1960 Paroda, 1979 Uphof, 1968 Williams, 1966

* *Balanites roxburghii* (considered a separate sp. by e.g. Uphof, 1968 but a synonym for *B. aegyptiaca* by e.g. Hardman, 1969) also grows extensively in arid zones and contains 0.9–1.4% diosgenin (Paroda 1979; Misra *et al.*, 1975)

[f] denotes a potential firewood source (*see* Introduction)

List of plants tolerant of arid or semi-arid - Part 14

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
57. *Barosma betulina* (Berg) Bartl. and Wendl. f.* (Buchu) SW. Cape Province, S. Africa.	Leaves are the drug buchu, used as a diuretic, stomach tonic, etc. Source of an essential oil used in artificial fruit flavours particularly blackcurrant, the oil being very expensive and in demand in the USA.	Leaves contain 2–3% essentail oil; brownish-yellow, partly crystalline at 20°C. Crystals (buchu camphor) are a monoterpene (C_{10}) diosphenol. Other constituents include limonene, menthene, L-pulegone. Recently the presence of stereoisomers of 8-mercapto-p-menthan-3-one, plus 120 other constituents reported.	Cultivated on a very limited scale in S. Africa, but seed germination difficult, and the products mostly still obtained from wild plants; plants harvested when 4–5 years old. May yield poorly in true arid zone: plants need well-drained slopes with 400–700 mm (16–28 inches) rainfall p.a. Supplies of the essential oil short in early 1970s but this because interest in the crop had been declining.	Anon, 1974a Blommaert, 1972 Fluck *et al.*, 1961 Gentry, 1961 Kaiser *et al.*, 1975 Klein and Rojahn, 1968 Martindale, 1977
58. *Brassica juncea* (L.) Czern. (Indian or brown mustard; leaf mustard) Probably originated in the drier parts of N. and C. Africa, N. China and SE. Asia. Now found in many parts of Africa, Asia, Europe and America.	Used as a source of edible oil, particularly in Asia; also used as a condiment (increasingly so of late) and medicinally. Leaves used as vegetable. Many different races are cultivated.	Seed contains 30–42% fixed (fatty) oil, plus varying amounts, up to 2.9%, of volatile oil and about 28% protein. Fixed oil has sap. val., 170–176; iod. val., 106–114. Fatty acid composition: erucic, 18–49%; oleic, 7–22%; linoleic, 12–24%; linolenic, 10–15%; saturated acids, 5%. Volatile oil contains allyl isothiocyanate and related compounds, including crotonyl isothiocyante. Integrated process has been developed for production of oil, protein meal and the pungent factor – allyl isothiocyanate.	May not grow well in truly arid areas: currently is mostly grown as a rain-fed oilseed crop in SE. Asia and supplementary irrigation is often used. Use as an edible oil would be restricted by the high content of erucic acid (health risk).	Mustakas *et al.*, 1965a Naqvi and Haq, 1964 Ohlson, 1972 Singh, 1958 Vaughan and Hemingway, 1959 Uphof, 1968
59. *Bromelia serra* Griseb** (Chaguar morado) S. America, especially Argentina and Brazil.	Perennial herb. Source of k(c)araguata fibre, used locally for sacks, and cordage. Was exploited during World War II as a jute substitute.	Possible source of paper pulp.		Anon, 1941 Ercilla, 1948 Ercilla, 1949
60. *Brongniartia alamosana* Rydb. SW. USA, Mexico.		Seeds contain 34% oil, 27% protein. Sap. val. of oil, 166; iod. val. 129. Fatty acids: (as C_{18}) non-conjugated triene, 23%; non-conjugated diene, 15%; conjugated, 3%; monoene (as oleic), 27%. Hence a possible oilseed.		Earle *et al.*, 1962 Jones and Barclay, 1972

* Two other closely related species *B. crenulata* (L.) Hook (oval buchu) and *B. serratifolia* (Curt.) Willd. (long buchu) are also utilized to a limited extent as a source of buchu. Recently transferred to the genus *Agathosma*, thus *B. betulina* has become *A. betulina* Berg. Pillars and *B. serratifolia* has been merged with *B. crenulata* to become *A. crenulata* (L.) Pillans.

** Four other closely related species are also used for fibre (sometimes also known as karaguata); these are *B. balansae* Mez, *B. fastuosa* Lindl., *B. hieronymi* Mez and *B. laciniosa* Mart. ex Schutt. f.

List of plants tolerant of arid or semi-arid - Part 15

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
61. *Bulnesia retamo* Griseb. (Cera mimbi, broom wax) Dry areas of western Argentina.	Source of wax used in polishes (e.g. said to be 'excellent' for shoe polishes), in dyes for leather, printers' ink, pharmaceuticals.	Composition of wax: hydrocarbons, 19.8%; free fatty acids, 33.8%; free alcohols, 7.9%; wax esters, 38.5%. Of the fatty acids around 70% were saturated; 11% hydroxy-acids; 19% unidentified; and 0.4% 'resinous' acids. Potential production of the wax ('Retamo wax' or 'Cera mimbi') in Argentina in late 1950s reported to be of the order of 1,300 tonnes p.a. Used locally and could have possibilities as a substitute for carnauba, candelilla and ouricuri waxes.	Probably local use only: poor market for such waxes.	Lina *et al.*, 1958 Tinto and Pardo, 1957
62. *Bulnesia sarmienti* Lor. ex Griseb. (Pau or palo santo; Paraguay lignum) Paraguay, Argentina.	A source of the essential oil known as guaiac wood oil, used in perfumery (particularly in soap manufacture) and to make guaiac wood acetate, also used in perfumery. Oil sometimes also used to adulterate Bulgarian and Turkish rose oils. Timber used for fences, construction, etc. Rosin used locally to glaze china, etc.	Timber chippings steam-distilled yield 2.7–3.0% of oil with a pleasant, soft, mellow, rose-like odour. sp. gr. (at 30°C), 0.967–0.974; optical rotation, -3° to -8°; n_D (at 20°C), 1.502–1.507; acid no., 0–1.5; ester no., 0–7.5 (98–159 after acetylation); guaiol content, 42–72%. Production in Paraguay in 1973, 75–100 tonnes p.a., exported mainly to the USA. Demand reported to be steady and supplies sufficient to meet it. Attempts have been made to extract the rosin as a by-product in Argentina and to develop its use by the soap and paint industries.		Anon, 1973a Guenther, 1952 Lella and Rique, 1955 Levi-Strauss, 1952
63. *Bursera microphylla* A. Gray; syn. *Elaphrium jorullensis* Kunth (Torote blanco tree, elephant tree, copal) SW. Arizona and NW. Mexico (Baja – California; Sonora).	Bark used as a source of dye and for tanning in Mexico; exudate hardens to form a copal used as incense.	Tree characteristic of very arid areas; has recently attracted attention as a possible source of drugs for cancer treatment. Anti-tumour agents isolated and identified as the (closely-related) lignans deoxypodophyllo-toxin and 3–(3, 4, -methylenedioxy benzyl)–4–(3′, 4′, 5′ -trimethoxybenzyl) – tetrahydrofuran (burseran). β-sitosterol also reported. Essential oil present in twigs, leaves and fruit; and consists of 80% terpenes (largely α- and β- phellandrenes and tetrahydrocuminic acid) and 9% sesquiterpenes and oxygenated compounds. Fruits also contain 5% of soft yellow wax, m.p. 57°C.		Benson and Darrow, 1944 Bianchi *et al.*, 1968 Bradley and Haagen-Smit, 1951 Cole *et al.*, 1969 Duisberg and Hay, 1971 Uphof, 1968
[For *Cactus* spp., see *Opuntia*]				
64. *Caesalpinia gilliesii* Wall. ex Hook. (Bird of paradise) Native of Chile and Argentina but now also established in SE. Arizona and S. New Mexico.		A proteinaceous substance with promising anti-tumour activity isolated from the seeds.		Benson and Darrow, 1944 Duisberg and Hay, 1971 Perdue and Hartwell, 1969 Ulubelen *et al.*, 1967

List of plants tolerant of arid or semi-arid - Part 16

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
65. *Cajanus cajan* (L.)[f]				
66. *Calotropis procera* (Ait.) R.Br. (Akra, alarka, ushar, auricula tree, akund; fruits – apple of sodom) Drier areas of Asia, particularly India, and Africa (especially Libya); has also been introduced into Australia and NE. Brazil.	Seeds source of akund floss, used for upholstery stuffing; seeds also contain a semi-drying oil. Bast (inner-bark) fibres extracted in India and used for rope. Source of latex used for tanning and dyeing. Latex, root bark and leaves used medicinally in India and Africa. Wood used as source of charcoal. Leaves produce merissa, a native beer in W. Africa. Latex removes hair from hides, and stems are used for making huts.	Fibre length of floss 30–40 mm, diameter 0.04 mm; cellulose content 49%. Seeds contain: protein 34%, oil 17–30% (of which unsaturated fatty acids, 69%); pectin 1.2%; also various glycosides. Calotropain, a proteolytic enzyme similar to bromelain and with anthelmintic properties, isolated from the latex. Cardiac glycosides uscharin ($C_{31}H_{41}NO_8S$), voruscharin ($C_{31}H_{43}NO_8S$), uscharidin ($C_{29}H_{38}O_9$), calotropin ($C_{29}H_{40}O_9$), calotoxin ($C_{29}H_{40}O_{10}$), and calactin ($C_{29}H_{40}O_9$) isolated from the latex. Uscharin more poisonous than strychnine. Benzoyllineolone and benzoyliso-lineolone isolated from the bark. Process for preparation of uscharin and uscharidin has been patented. Suggested as a possible oilseed crop, also a fibre crop in Egypt. Attempts have been made to improve the extraction of bark fibre on a cottage-industry scale in India (by Central Arid Zone Research Institute): the fibre used to be spun into a very fine cloth there. Plant easily established in areas of soil erosion: dominant species along Jeddah–Mecca road. Scope for increased fibre production, especially in India (where there are many unharvested trees). Under investigation as a source of hydrocarbons.	Plant regarded as a noxious weed in Australia and Brazil. Fibre soon becomes waterlogged, does not stand rough usage, and has low tenacity. Low annual yield of fibre per plant and gathering of pods said to cause eye damage. Demand for the fibre fell in the 1950s and still indifferent though with the recently increased interest in kapok, which it resembles (but is inferior to), akund could follow suit perhaps.	Anon, 1964 Ayensu, 1979 Batanouny, 1979 Boehringer Sohn, 1939 Chandler *et al.*, 1968 Crout *et al.*, 1963 Crout *et al.*, 1964 CSIR India, 1950 Drar, 1954 Erdman and Erdman, 1981 Garg and Atal, 1963 Kirby, 1963 Maheshwari and Tandon, 1959 Meadly, 1971 Paroda, 1979 Rajagopalan *et al.*, 1955 Santa Rosa, 1949 Santa Rosa, 1960 Siddiqui, 1960 Somaliland Department of Agriculture, 1930 Tewari, 1979 Uphof, 1968
67. *Capparis fascicularis* DC. var. *fascicularis;* syn. *C. rothii* Oliv. Sudan.		Possible oilseed; oil content of kernels 41%; sap. val., 190; iod. val., 71; fatty acid composition: linoleic, 22%; oleic, 38%; palmitic, 16%; stearic, 24%. High oil content could justify development for use as a source of lighting oil or to make soap.		Grindley, 1954 Sen Gupta and Chakrabarty, 1964a
68. *Capparis ovata* Desf. Middle East, W. Asia, N. Africa.		Possible oilseed; seeds contain approximately: oil 31%, protein 24%. Egyptian plant material found to contain 1% rutin (a glycoside of quercetin and said to be of value in controlling certain haemorrhages).	Modern pharmacopeias tend to question rutin's efficacy: *see* entry no 208.	Ahmed *et al.*, 1972 Hammouda *et al.*, 1975 Jones and Barclay, 1972

[f] denotes a potential firewood source (*see* Introduction)

List of plants tolerant of arid or semi-arid - Part 17

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
69. *Capparis spinosa* L. (Capers, abaar, kabar, lassaf) India, Middle East, N. Africa, Europe, Australia.	Pickled flower buds are commercial European capers used as a condiment. Bark used medicinally in the Middle East.	Flower buds contain rutin (0.5%: *see* under *C. ovata* for use), rutic acid, pentosans, a volatile substance with a garlic odour, and saponins. Seeds yield 34–36% pale yellow oil containing a high percentage of unsaturated fatty acids of the C_{18} series (e.g. oleic, linoleic). Bark also contains rutic acid and a volatile substance with a garlic odour. Possible source of cardioactive alkaloids. Extract said to combat liver damage.		Ahmed *et al.*, 1972 Ayensu, 1979 Chopra *et al.*, 1960 Evenari and Koller, 1956 Hammouda *et al.*, 1975 Seidemann, 1970 Sen Gupta and Chakrabarty, 1964a
70. *Carthamus oxyacantha* Bieb. (Poli, kantiari, wild safflower) Grows wild in NW. India and Pakistan, and extends westwards to the Caucasus.	In areas where it occurs in abundance, oil is extracted from the seeds and used to make soap, in varnishes, etc. Thus, poli oil (obtained by cold expression) is used as a luminant, as food, in a hair oil, and for waterproofing. Roghum oil (obtained by dry hot process) is used in waxcloth, for greasing ropes and leather, for cementing glass, etc. Flowers used in indigenous Chinese medicine.	Seed contains about 28% oil, similar to safflower oil; sap. val., 195; iod. val., 112.8; acetyl val., 2.98; acid val., 1.34; unsap. matter, 0.42%. Fatty acids: myristic, 0.66%; palmitic, 3.1%; stearic, 3.6%; oleic, 55.8%; linoleic 36.8%. Although generally treated as a noxious weed it has been suggested that the crop has possibilities as an oilseed for arid areas.	A thorny and pernicious weed which is said to exhaust the soil.	CSIR India, 1950 Deshpande, 1952 Gardener, 1982 Maheshwari, 1963 Uphof, 1968
71. *Carthamus tinctorius* L. (Safflower, false saffron) Long been cultivated in China, SE. Asian sub-continent, Middle East and N. Africa. Successfully introduced into the USA, Mexico, Australia, E. Africa, etc.	Originally grown as a dyestuff but is now utilised as a source of a drying oil similar to linseed which industrially is unequalled as a rapid even-drying, non-yellowing oil, suitable for the production of alkyd resins and in the manufacture of paints. Also widely used as an edible oil which is of particular value due to its high percentage of unsaturated fatty acids. Flowers sometimes used as a source of a natural red dye, carthamin, which is used in cosmetics, foodstuffs, etc.	Seed contains about 26–37% oil, some improved types up to 48%; protein 12–22%; hulls 45–48%, thin-hulled types 14–18%. Characteristics of oil: acid val., 0.4–10; sap. val., 186–194; iod. val., 130–150. Wide diversity in fatty acid composition; average: linoleic, 68–80%; oleic, 10–20%; saturated acids, mostly palmitic and stearic, 6–12%. However, there are significant deviations and it is possible to produce, by breeding, oil with the proportions of oleic and linoleic reversed. Carthamin content of dried flowers, 0.3–0.6%. Considerable research on crop improvement has been carried out in the USA, Mexico and India.	Although the plant is drought resistant, it does require adequate moisture to thrive; namely approximately 300 mm p.a. rain (or its equivalent in irrigation). Has been grown successfully in the Negev desert. Subject to diseases and pests in many areas. Hand-harvesting difficult, but combine is successful in the USA.	Beech, 1969 Claasen, 1950 Evenari *et al.*, 1971 Hodge, 1955 Knowles, 1955 Knowles, 1965 Knowles, 1967 Knowles, 1968 Knowles and Mutwakil, 1963 Selim, 1977 TPI, 1975 Williams, 1966

List of plants tolerant of arid or semi-arid - Part 18

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
72. *Carum bulbocastanum* Koch (Black caraway, black zira, earthnut) Arid hills of W. Pakistan, Afghanistan and Kashmir.	Seeds used as a carminative in indigenous medicine or as a spice. Starchy tubers eaten as a vegetable or in salads.	Has been suggested as a remunerative crop for the higher waste arid lands in Pakistan and India. Fruit yields 2% essential oil, containing 18% aldehydes.	The plant will survive on dry (< 150 mm) summers but to thrive it requires cold (even snowy) winters and is usually only found at above 2,000 m (6,600 ft). Takes 4 years to flower from sowing seed (but then provides fresh growth from its tuber annually).	Bhartiya, 1967 Chaudhri, 1953 CSIR India, 1950 Singh, 1973 Uphof, 1968
73. *Cassia angustifolia* Vahl;* syn. *C. medicinalis* Bisch. (Tinnevelly or Indian senna) Grows wild in E. Africa, Sudan, Arabian Peninsula and the Kutch region of India. Cultivated in the Tinnevelly district in southern India as a dry-land, or semi-irrigated, crop.	The fruit or leaves of the plant, often as an aqueous extract, are used as a purgative drug which is widely used, particularly in the UK, the USA, and West Germany.	Fruit, or 'pods', and leaves contain 1.2—2.5% of sennosides A and B, plus smaller quantities of allied compounds such as sennosides C and D (all being glycosides based on the 2-substituted-4, 5-dihydroxyanthraquinones rhein and aloe-emodin, or the corresponding dianthrones). A valuable drug in the treatment of habitual constipation. Yields in Tinnevelly 335–780 kg/ha leaves, 85—170 kg/ha pods. Considered to be very drought resistant and to have potential for cultivation in India and Pakistan. Development of dry, granular extractions has stimulated demand for the crude drug.	Adequate supply of cheap labour needed for handpicking and sorting. Sennoside content of plant varies during maturation and important to harvest at right stage for worthwhile yield — for pod, when immature; for leaf, when plant is flowering; also to dry at $\leq 40^{\circ}C$ to avoid degradation of the active constituents.	Anon, 1959b Chopra *et al.*, 1956 Chopra *et al.*, 1960 Fairbairn and Shrestha, 1967 Gupta, 1971 Gupta, 1974 Khorana and Sanghavi, 1964 Lemli and Cuveele, 1978 Pharmaceutical Society of Great Britain, 1973 Schmid and Angliker, 1965 Seaforth, 1962 Selvaraj and Chander, 1978
74. *Cassia italica* (Mill.) Lam. ex F. W. Andr.; syn. *C. obovata* Collad., *C. obtusa* Roxb. (Dog, Italian, Tripoli, Senegal or Jamaican senna) Grows wild in Egypt, Sudan, S. and C. Sahara down to Upper Senegal, Chad and Niger, through SW. Asia to India.	Utilized locally as a purgative drug; recognised in the French Pharmacopoeia.	1.1—3.8% anthraquinones (of the type described in entry no. 73) reported present in the leaves, including rhein and aloe-emodin (*see* entry no. 73) sennidins (non-glycoside versions of the sennosides) and a trace of chrysophanol (chemically related to rhein). Similar constituents present in the pods, although only traces of the anthraquinone constituents. Considered as a cheap substitute for Alexandrian or Tinnevelly senna and sometimes used to adulterate these sennas.		Chopra *et al.*, 1960 Paris and Dillemann, 1960 Saber *et al.*, 1962 Seaforth, 1962
75. *Cassia leptocarpa* Benth. SW. USA, Mexico, S. America.		Possible source of gum (and of sennosides? *See* entry no. 73))	Said to be a need for a critical study of the plant as a potential source of gum.	Bender, 1963

* Some authorities consider *C. angustifolia* to be so similar to *C. senna* as to be treated as the same species, but the trade continues to differentiate between them.

List of plants tolerant of arid or semi-arid - Part 19

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
76. *Cassia senna* L.;* syn. *C. acutifolia* Del. (Alexandrian senna) Indigenous to the Sudan, but found growing wild in other parts of Africa. Cultivated to a limited extent in the Sudan, Egypt and India	A purgative drug which is widely used, particularly in the USA, the UK and West Germany: *see* entry no. 73.	Commercial pods contain 2.5–4.5% sennosides A and B, plus a number of other anthraquinone glycosides based on rhein or aloe-emodin. Plant easy to grow. Development of dry granular extractions has stimulated demand for the crude drug: *see* entry no. 73.	*See* entry no. 73.	Anon, 1959b Chopra *et al.*, 1960 Crellin *et al.*, 1961 Fairbairn *et al.*, 1958 Lemli and Cuveele, 1978 Paris and Dillemann, 1960 Pharmaceutical Society of Great Britain, 1973 Seaforth, 1962 Selvaraj and Chander, 1978
77. *Cassia siamea*†				
78. *Ceratonia siliqua* L. (Locust bean, carob, St. John's bread) Widely distributed in Turkey, Syria, and around the Mediterranean. Successfully introduced into S. America, California, Mexico, S. Africa, India and Australia.	Endosperm of seed used as a source (yield 35% based on seeds taken) of gum (known as 'locust bean' or 'locust kernel gum' 'tragasol' or 'gum tragon') used by the food, confectionery, pharmaceutical, paper, textile, leather industries, etc. Whole pods used for food, animal feed, as a source of sugars (especially 'cane sugar' — i.e. sucrose), alcohol and beverages, and as a substrate for citric acid production; also used medicinally and as a substitute for cocoa, coffee and chocolate. The wood is a source of natural dye used in textile manufacture in Argentina and is used to make carts and furniture.	The bean consists, by weight, of 5–20% seed, 80–95% pod. Composition of both vary widely. Typical values for pod: carbohydrates, 50–70% (much of which usually present as sucrose and allied sugars) along with ∿10% fibre, 5–8% protein, 2% fat, 10% moisture, 2–3% ash. Seed endosperm typically consists of ∿80–85% of a galactose-mannose (in ratio ∿1:5) polysaccharide (whence the gum) plus 3–4% pentosans, 6% protein, 3% fibre, 1% ash, 5% moisture. Sugar content of pod (or of whole bean) similar to, sometimes exceeds, that of sugar cane or beet. Tannin content of ripe pods ∿1.4%, mainly as gallic acid. Good demand for gum: a 2% aqueous soln. is semi-solid (1% in presence of borax). Process developed recently for production of fungal protein for animal feeding from waste pod shells. Successfully introduced into the Negev, where development of cultivars which shed their fruit on maturity is being investigated.	A drought-resistant evergreen but requires some irrigation if grown in areas with annual rainfall below about 300 mm. The gum is in competition with (but in some aspects superior to) guar, gum arabic, etc. Simple water extraction of the pod-sugars reported to be difficult: alcohol or similar solvent required. Meal from pods reported to depress growth of monogastric animals.	Alumot and Nachtomi, 1962 Anon, 1962b Anon, 1974e Anon, 1976a Anon, 1979a Binder *et al.*, 1959 Charalambous, 1966 Coit, 1951 Davies, 1970 Evenari *et al.*, 1971 Griffiths, 1949 Imrie, 1973 Josyln *et al.*, 1968 Leo, 1960 Loo, 1969 Macris, 1975 Mitrakos, 1968 Primo *et al.*, 1964 Sekeri-Pataryas *et al.*, 1973 Singh, 1961 Storey, 1955 Uphof, 1968

*Some authorities consider *C. angustifolia* to be so similar to *C. senna* as to be treated as the same species, but the trade continues to differentiate between them.

† denotes a potential firewood source (*see* Introduction)

List of plants tolerant of arid or semi-arid - Part 20

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
79. *Chamaecrista leptadenia* (Greenm.) Cockerell; syn. *Cassia leptadenia* Greenm. Northern Sierra Madre area of Mexico and adjacent USA.		Possible source of gum (and of sennosides? *see* entry no. 73)	Said to be a need for a critical study of the plant as a potential source of gum.	Bender, 1963
80. *Chilopsis linearis* (Cav.) Sweet; syn. *C. saligna* D. Don (Desert willow) SW. USA.	Wood used for fence posts, branches for making baskets; flowers, medicinally for coughs and as a stimulant in cardiac diseases.	Seed contains: 20–35% protein; 32–33% oil; sap. val., 183; iod. val., 142. Approximate fatty acid composition: saturated fatty acids, 5%; trans-10-trans-12-octadecadienoic, 12%; trans-9-trans-12-octadecadienoic, 15%; trans-9-trans-11-cis-13-octadecatrienoic, 25%; linoleic, 25%; undetermined, 18%. Investigated by American workers as a possible industrial oilseed in early 1960s. Flowers of possible interest – to perfumery trade.		Benson and Darrow, 1944 Chisholm and Hopkins, 1963 Earle *et al.*, 1960b Hopkins and Chisholm, 1962 Jones and Barclay, 1972 Maurer, 1964 Uphof, 1968
81. *Chrozophora plicata* (Vahl) A. Juss. ex Spreng. (Akasa; terba) India; Africa (especially N. Sudan)	Seed capsules source of bluish-purple dye like litmus. Seeds and leaves used locally as a purgative.	Seeds contain 39% of an oil (which resembles cottonseed oil). Iod. val., 112; sap. equiv., 294; f.f.a. (as oleic), 2.2%; unsap. matter, 0.9%. Fatty acid composition: linoleic, 52%; oleic, 25%; palmitoleic, ~0.2%; stearic, 13%; palmitic, 9%; arachidic, 0.6%; myristic, 0.2%. Possible oilseed suitable for soapmaking.	At present only grows wild and doubtful if available in commercially exploitable quantities. Plant also contains a poisonous principle which could handicap harvesting. Seeds very small and so collection may be difficult.	Barker *et al.*, 1950 CSIR India, 1950 Uphof, 1968
82. *Chrysanthemoides monilifera* (L.) T. Norl; syn. *Osteospermum moniliferum* L. Southern Africa		Seeds contain 49% oil with iod. val. 146 and containing, by u.v., 38% conjugated triene and 2% conjugated diene (dimorphecolic?) acids. Investigated in early 1960s as a possible industrial oilseed.	Only grows wild.	Earle *et al.*, 1964 Jones and Barclay, 1972

List of plants tolerant of arid or semi-arid - Part 21

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
83. *Citrullus colocynthis* (L.) Schrad. (Colocynth, bitter apple) Drier parts of Africa, Mediterranean, Turkey, SE. Asian sub-continent.	Commercial source of the drug 'colocynth', being the dried unripe fruit pulp; a powerfull purgative. Seeds contain brownish-yellow, bitter oil. Roots used in traditional medicine, as a purgative. Oil is used to make soap.	Fruits consist of 70% pulpy mesocarp, 5% seeds. Juice reported to contain an anticoagulant. Glycoside content of fruits: 0.22%; α-elaterin 2-D-glucopyranoside and its aglycone (cucurbitacin E*) have been detected in all parts of the plant; curcurbitacins B, I and L (both free and glycosidal forms) in stems, leaves and fruits, highest in fruits. Seeds yield 16–20% oil, characteristics and composition of which vary according to environment. Indian oil: sap. val., 297.4; iod. val., 124.6; unsap. matter, 1.6%. Fatty acid composition: linoleic, 59.2%; linolenic, 1.6%; oleic, 21.1%; arachidic, 1.9%; stearic, 6.6%; palmitic, 9.6%. Algerian oil: linoleic, 65%; oleic, 17.2%; hexadecenoic, 1.2%; tetradecenoic, 0.9%; stearic, 5.6% palmitic, 8.9%; myristic, 1.2%. Seeds source of protein. Anti-cancer activity of α-elaterin investigated in late 1950s. Possibility of developing the plant as a source of semi-drying linoleic-rich oil suggested. Yield of seed estimated to be about 6,700 kg/ha. Ripe fruit pulp possible source of pectin. Plant is useful as a sand binder and is very drought resistant.	Only a limited demand for colocynth nowadays: has been mainly superseded by less drastic and less toxic purgatives; and α-elaterin has not apparently fulfilled its earlier promise (absent from 'very variable'. Oil is inedible due to its purgative action and bitterness†.	Abu-Nasr and Potts, 1953 Boyko, 1954 Chawan and Sen in Davis, 1978c Darwish-Sayed *et al.*, 1973 Darwish-Sayed *et al.*, 1974 Drar, 1954 El Khadem and Abdel Rahman, 1962 Evenaria and Koller, 1956 Faust *et al.*, 1958 Gitter *et al.*, 1961 Lavie *et al.*, 1964 Martindale, 1977 Misra *et al.*, 1962 Paroda in Davis, 1978c Pillai *et al.*, 1957 Sen and Bansal, 1979 Sen Gupta and Chakrabarty, 1964b Tewari, 1979 Zaitschek, 1953
[*Cnidoscolus* spp. – see under syn. *Jatropha* spp.]				
84. *Colchicum ritchii* R. Br. Middle East.		Potential source of the drug colchicine (used in particular to counter gout). Flowers contain six times as much colchicine as bulbs. Colchicine content of Israeli bulbs reported to be satisfactory, that of Egyptian to be very low. Possibility of breeding improved high-yielding strains and growing in beds to facilitate harvesting has been suggested.		Boyko, 1954 Drar, 1954 Martindale, 1977 Zaitschek, 1953
85. *Colophospermum mopane*[f]				
86. *Conocarpus lancifolius* Engl. (Damas, hodeti) Somalia; introduced into Kenya, Sudan, N. Yemen, S. Yemen.	Quick-growing tree used for firewood, boat and house building; is grown in dry river beds.	Suitable for making charcoal. Not affected by soil salinity. Reaches height of 50–60 ft (15–18 m) in 10–12 years, giving long straight poles. Wood is light but hard-grained.	Seeds must not be covered and must be watered copiously for 4–5 months.	Howes, 1951

* The cucurbitacins are bitter, highly oxygenated molecules based on the triterpenoid skeleton, usually C_{30} or C_{32} with 7–9 oxygen atoms and isolated from various Cucurbitaceae.
† *Citrullus lanatus* (Thunb.) Mansf., also an AZ plant, contains in contrast an *edible* oil (Paroda, 1979).
[f] denotes potential firewood source (*see* Introduction)

List of plants tolerant of arid or semi-arid - Part 22

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation date
87. *Copernicia australis* Becc. (Caranday) Native of NE. Brazil and Chaco side of Rio Paraguay in Paraguay.	Timber utilized locally for construction; leaf straw for hats; fibre for ropes, etc.	Potential source of hard wax. Thus the leaves yield about 4 g each of clean wax, similar to carnauba (*see* entry no. 88); m.p., 82°C; acid val., 2.7; sap. val., 64.9; iod. val., 10.5; unsaps., 54%. Elementary fibres 1.5—3.5 mm long; 10—40μm thick. Wood yields 35% cellulose. Possible source of paper pulp. Fruit yields (55%) a non-drying oil.	Possibilities of exploiting wild palms as a source of hard wax was considered in 1940—1950s but handicapped by a shortage of labour for harvesting and processing and also (for floor polishes) by increasing competition from synthetic materials. Also competes to some degree with carnauba wax and candelilla was (*see* entry nos. 88 and 127). A semi-arid rather than arid plant.	Anon, 1954a Bertuzzi *et al.*, 1939 Markley, 1955 Medeiros Trancoso, 1945 Medeiros Trancoso, 1948
88. *Copernicia cerifera* (Arr. Cam.) Mart. (Carnauba) Native of NE. Brazil.	Source of hard high-quality wax, used in floor and other polishes, carbon paper, leather finishing, inks, gramophone records, lubricants, cosmetics, etc. Also used locally as a source of fibre. Pulp of fruit ground into flour for local use. Nuts used as a source of oil.	Leaves yield about 5—15 g of wax each (yield increases with drought). M.p., 85°C; acid val., 4; iod. val., 10.1—13.5; sap. val., 78—80; hydrocarbons, 0.3—1%; long-chain aliphatic esters, 38—40%; monohydric alcohols, 10—12%; ω-hydroxy-aliphatic esters, 12—14%; p-methoxycinnamic aliphatic diesters, 5—7%; p-hydroxycinnamic aliphatic diesters, 20—30%; an uncombined triterpene diol, 0.4%; uncombined acids, etc., 5—7%. R and D in Brazil has led to increased yield of wax and a whiter product with increased oil retention. Possible new use of the improved product is as a time release agent for insecticides, fungicides and fertilizers. Current developments include the possible use of leaf fibre for paper making and of waste pulp for livestock food.	Wax is obtained from wild palms. Suffered severe competition in late 1950s until early 1970s from polymer-based floor polishes, etc, but shortage of styrene monomer led to increased demand in 1970s. However, worldwide there is currently (1979) an over-production of carnauba with stockpiling occurring in e.g. Brazil. Attempts to develop cultivation in other areas have met with little success. Possibility of decrease in supplies as land is cleared in Brazil to grow other crops such as maize, castor and cashew.	Anon, 1953 Anon, 1954b Anon, 1973b Anon, 1976b Barnes *et al.*, 1965 Santa Rosa, 1970 Sweet, 1973 Taube, 1952 Vandenberg and Wilder, 1970 Vollmuth and Baldini, 1973 Walters *et al.*, 1979

List of plants tolerant of arid or semi-arid - Part 23

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation date
89. *Cordeauxia edulis* Hemsl. (Yeheb, yebb, jeheb, geeb, geheb) Somalia and S. Ethiopia. Introduced into Tanzania and Kenya.	A leguminous desert shrub whose fruit pods yield edible seeds, which form the staple diet of the region's nomads, and a magenta pigment used locally to dye textiles. The leaves are used as a tea substitute.	The seeds contain 24% sugars, 37% of other carbohydrate, 13% protein, 11% fat, 3% ash and 9% moisture. Another analysis confirms the high carbohydrate, low protein and low fat contents. The seeds are considered to have high nutritive value, are low in anti-nutritional factors but also low in methionine. The oil is intermediate in type between liquid oils and solid fats, tastes less pleasant than olive oil but could be used for soaps; the meal could be used for extraction of sugars and the residue for fodder or manure. Nuts a possible coffee substitute. Fruits ripen completely within 5–6 days. The chemistry of the dye, a quinone, has been examined and its chemical structure deduced.	Attempts to grow outside natural habitat have not succeeded. Requires rain for normal fruiting. Plant is never found in pure stands. Pressure from overgrazing (by goats and camels) and from heavy use by nomads said to be threatening the plant with extinction. Seedlings grow only slowly, at least until the extensive and deep root system has been established.	Brilli and Mulas, 1939 Fabriani, 1940 Fehlmann and Niggli, 1965 Greenway, 1941 Lister *et al.*, 1955 Miège and Miège, 1978 Tria and Fabriani, 1940 Uphof, 1968
90. *Crambe abyssinica* Hochst. ex. R.E. Fries (Crambe; Abyssinian-kale, -cabbage or -mustard) Found growing wild in the Ethiopian foothills and N. African plains. Successfully introduced into a number of countries including the USA, USSR, Canada, Kenya, Venezuela and N. Nigeria.	Gives an oil (similar to rapeseed oil) used for soap, in margarine, and in manufacture of lubricants. Good natural source of erucic acid which on ozonolysis yields brassylic ($HOOC(CH_2)_{11}COOH$) and pelargonic acids ($CH_3(CH_2)_7COOH$) used variously in the manufacture of polyesters, alkyd resins, plasticizers, synthetic fibres, rubber additives, etc. In the USA, residual meal is used for animal feed after removal of thioglucosides by e.g. treatment with ammonia and is considered to be one of their most promising new industrial crops with much recent R and D activity.	Hull comprises 25%, or more, of seed weight. Crude protein content of dehulled seed 22–37%; oil content 36–54%. Oil has sap. val., 169; iod. val., 94; f.f.a, 0.4%; unsap. matter, 0.6–1.0%. Fatty acid composition: erucic, 58–61%; oleic, 20–21%; linoleic, 6–9%; linolenic, 3–6%; palmitic, 2–3%; eicosenoic, 3–4%; behenic, 1–1.5%; stearic, hexadecenoic, and docosadienoic, all < 1%. Possibility of using the oil to produce, by hydrogenation, a wax with properties similar to those of sperm whale oil is currently being investigated in the USA. Residual meal contains 46–58% crude protein but also 8–10% thioglucosides (principally epiprogoitrin, a growth inhibitor), and a bitter-tasting alkaloid, sinapine (0.46%). Suggested cool-season crop for India.	Relatively drought resistant but requires moisture during flower and seed development. Requires relatively cool growing conditions (15–20°C). In semi-arid areas seed yields increased by irrigation; average 2,000 kg/ha in cool semi-arid regions. Traditional oilseed processing methods have proved expensive in the USA – need for further research; also on new methods of treating the meal to remove the thioglucosides and to improve palatability for animal feeding (*see* left): maximum utilization of the meal is essential for economic processing.	Anon, 1966b Anon, 1974c Asthana, 1972 Austin and Wolff, 1968 Baker *et al.*, 1975 Chang *et al.*, 1975 Cornelius and Simmons, 1969 Duisberg and Hay, 1971 Earle *et al.*, 1965 Godin and Spensley, 1971 Kirk *et al.*, 1966, 1971 Mustakas *et al.*, 1965b, 1968, 1976 Nieschlag *et al.*, 1977 Princen, 1982 Spencer *et al.*, 1974

List of plants tolerant of arid or semi-arid - Part 24

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation date
91. *Crocus sativus* L. (Saffron) Originated in eastern Mediterranean, Turkey, Iran. Now spread to N. of SE. Asian sub-continent, Spain, China, etc.	Flower stigmas source of yellow dyestuff and food flavouring. Used in indigenous Indian medicine.	Typical composition of commercial saffron: moisture, 15.6%; protein, 12.4%; starch and sugars, 13.4%; other N-free extractives (carbohydrate), 43.6%; crude fibre, 4.5%; ash, 4.3%; essential oil, 0.6%; 'fixed' (fatty) oil, 5.6%. Chief pigment a yellowish-red carotenoid-glycoside, crocin; other carotenoids present include lycopene, α-carotene, β-carotene, zeaxanthin and crocetin. One part saffron will colour 100,000 parts water. Yield in India of dried flower stigmas 2.5—3.0 kg/ha. The corms of the plant regenerate for 10 years or so before needing to be renewed.	Very drought resistant in the dormant stage, but yield benefits from moisture prior to flowering in autumn. Studies have not revealed any constituents of therapeutic value. High value crop but requires supply of cheap seasonal labour for harvesting, which is very labour-intensive. Product often adulterated.	Dhingra *et al.*, 1975 Ingram, 1969 Madan *et al.*, 1966
92. *Cryptostegia grandiflora* (Roxb.) R. Br. (Madagascar rubber vine) Indigenous to India, but found wild in arid and semi-arid areas of SE. Asian sub-continent. Introduced into Mexico, SW. USA and Australia.	Source of a natural rubber.	Latex content varies with season, soil, age of plant and tissue; normally highest in the leaves: average 4%, improved hybrids 8.6%. Solids in latex: rubber, 57.1%; resins associated with rubber, 7.2%. Rubber comparable in quality to that of *Hevea*. Seeds contain 10.8% semi-drying oil, 4.7% rubber and 17.5% resin. Crop considered to have potential in arid areas of India as an oilseed, source of fibre and anti-erosion crop. Five cardenolides, some of which showed anti-tumour activity and including a new natural product (16-propionylgitoxigenin), recently detected in plant extract.	Investigated thoroughly during World War II as a source of natural rubber, but yield too low and cost of collection too high for it to compete successfully with *Hevea* rubber.	Anon, 1944a Buchanan *et al.*, 1978a Cruse, 1949 CSIR India, 1950 Doskotch *et al.*, 1972 Polhamus *et al.*, 1934 Polhamus, 1962 Siddiqi and Mathur, 1946 Stewart *et al.*, 1948
93. *Cucumis prophetarum* L. (Wild cucumber, Mandera cucumber) Arid parts of Africa, Arabian Peninsula, SE. Asian sub-continent.	Fruit pulp used as a purgative and emetic in indigenous medicine.	Seeds constitute 5.2% by weight of fruit; oil content, 28.4%; sap. val., 186.8; iod. val., 133.0; acid val., 11.6; unsap. matter, 1.4%; saturated fatty acids, 10.6%. Protein content of meal after oil extraction, 25.6%. Cucurbitacins B, C, D and Q1 (*see* footnote* to entry no. 83) isolated from fruits and also a sterol, pro-pheterosterol. Has been suggested as a potential oilseed for arid lands.	A bitter resinous substance, myriocarpin, which produces nausea and is toxic to animals, is also reported present in the fruit pulp.	Aslam *et al.*, 1965 Boyko, 1954 CSIR India, 1950 Khan and Zehra, 1975

List of plants tolerant of arid or semi-arid - Part 25

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation date
94. *Cucurbita digitata* A. Gray USA – Arizona, New Mexico, Texas.	Seed used as a foodstuff by the American Indians.	Seeds contain about 21% protein and 27% of a drying oil which is similar to linseed oil: iod. val., 139.2; fatty acid composition: palmitic, 10%; stearic, 5%; oleic, 24%; linoleic, 43%; conjugated triene (? punicic) acid, 18%. Seeds rich in phytin (a sugar phosphate). Roots contain about 49% starch; iodine affinity value* 4.42; diameter of starch grains 3–17μm, average 9μm; gelatinisation temperature 65.5–68.0°C. Yields of seed from wild plants have been estimated at 550–3,300 kg/ha (from very limited observations). Has been suggested as a potential oilseed (? and starch source) for desert areas: it is a perennial which thrives in hot arid conditions.		Bemis *et al.*, 1967a Berry *et al.*, 1975 Bolley *et al.*, 1950 Cruse, 1949 Curtis, 1946 Duisberg, 1952b Krochmal *et al.*, 1954 Jacks *et al.*, 1972
95. *Cucurbita foetidissima* Kunth (Buffalo gourd, chilicote, mock orange) SW. USA, Mexico; much more widespread than *C. digitata* and *C. palmata*.	For many years, American Indians have used the seeds for food and the fruit pulp and vine as soap substitutes. The vine winter die-back has been used as fodder.	Fruit – 44% seeds, 56% pulp; crude protein content of pulp, 30.1%; fibre, 27.7%; ash, 14.2%. Seed: moisture, 4.9%; crude protein, 31.3%; crude fibre, 25.6%; oil, 30.4% (which has iod. val. 133.6 and fatty-acid composition: palmitic, 11%; stearic, 1%; oleic, 50%; linoleic, 38%; but negligible triene -in contrast to entries nos. 94 and 96). Seed consists of 30% hull, 64% embryo. Embryo: moisture, 4.5%; crude protein, 37.5%; fibre, 6.9%; ash, 4.2%; oil, 48% (which has – sap. val., 191.8; iod. val., 136.1; unsap. matter, 1.53%; f.f.a. (as oleic), 2.0%. Fatty acid composition: linoleic, 61.0%; oleic, 23.1%; palmitic, 9.3%; stearic, 4.2%; linolenic, 1.5%; myristic 0.2%). Seed rich in phytin (*see* above). Fresh roots: moisture, 67–69%; starch, 15–17%; granules similar to those of cassava starch, iodine affinity value* 4.07; diameter 2–17μm, average 6μm; gelatinisation temperature 57.0–60.5°C. All parts of the plant, except seeds, contain cucurbitacins (bitter triterpenoid glycosides†). Alcoholic extract of root has oxytocic action (aids childbirth). Potential value as an arid zone crop recognised for past 30 years, both as an oilseed (protein and oil from seeds) and root crop (huge tubers as source of industrial starch).	Currently research is being carried on in Arizona, Mexico, Lebanon, India and Iran: need for increased input on breeding, cultural practices, etc. Potential seed yield estimated at 3,000 kg/ha, break-even point in the USA estimated at 2,000 kg/ha. Need to dehull seed; high fibre content restricts use of hulls, or whole seed meal, for animal feed. The seed oil is difficult to bleach and this could restrict its use. The effect may be due to weathering of fruit before harvesting, and drying under shelter might improve colour. Protein is low in sulphur-containing amino acids and lysine. The starch has to be extracted with brine to avoid bitters.	Bemis *et al.*, 1967a, 1975, 1978 a, b, 1979 a, b Berry *et al.*, 1975, 1976, 1978b Bolley *et al.*, 1950 Brooks in Davis, 1978b Curtis, 1946 Duisberg, 1952a, 1952b Ferguson, 1955 Jacks *et al.*, 1972 National Academy of Sciences, 1975 Shahani *et al.*, 1951 Smith *et al.*, 1959 Uphof, 1968

* For significance, *see* entry no. 36.
† cf. footnote* to entry no. 83.

List of plants tolerant of arid or semi-arid - Part 26

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation date
96. *Cucurbita palmata* S. Watson (Coyote melon) USA — California.		Seed contains about 24% protein and 27% of a drying oil with, like entry no. 94, some similarities to linseed oil: iod. val., 139.2; unsap. matter, 1.6%; average fatty acid composition: palmitic, 8%; stearic, 4%; oleic, 25%; linoleic, 40%; linolenic, 6%; conjugd. triene (? punicic) acid, 17%. A potential AZ oilseed (and ? source of starch from tubers).	Rather restricted in distribution compared with *C. digitata* and *C. foetidissima*.	Bemis *et al.*, 1967a Bolley *et al.*, 1950 Cruse, 1949 Curtis, 1946 Duisberg, 1952a Krochmal *et al.*, 1954 Jacks *et al.*, 1972
97. *Cyamopsis tetragonoloba* (L.) Taub. (Guar, cluster bean) Probably originated in Indian subcontinent but now widely distributed in tropics and sub-tropics.	A legume whose seeds are a source of gum used in the food, paper, textile and pharmaceutical industries, and as a flocculant and filterant in the refining of mineral ores, etc. Residue left after extraction of gum utilised as an animal fodder. (Seed themselves sometimes so used but this represents a waste of the gum). Seeds used for preparation of protein-enriched foods, and immature seed pods eaten as a vegetable. Used as appetite depressant, to help treat diabetes, and in cosmetics.	Seed consist of: hull, 14—16%; endosperm, 38—45%, cotyledons, 40—46%. Endosperm contains 68—70% of a polysaccharide, galactomannan gum (commercial guar), with approximate composition: moisture, 12%; protein, 5%; gum, 80%; fibre, 1.4%; fat 0.7%; ash 0.9%. It is composed D-galactopyranose and D-mannopyranose units, has high viscosity at low concentrations and can function over a wide pH range. Demand for guar gum has shown a considerable increase in recent years. India and Pakistan main producers (the former exports ~ 40,000 tonnes, value $20m, p.a.); USA principal import market, although crop is being developed in SW. USA. Possible new use for guar is in diabetic diets. Thought that yield could be improved by genetic improvement and by better field management.	Can be grown successfully in arid areas but needs a little supplementary irrigation. Competes with locust bean gum, gum arabic and tragacanth (*see* entry nos. 78, 3 and 52).	Anon, 1974b, d Anon, 1979a Bhatti and Sial, 1971 Hymowitz and Matlock, 1963 Kay, 1979 Paroda, 1979 Poats, 1960 Uphof, 1968 Whistler, 1982 Whistler and Hymowitz, 1979
98. *Cymbopogon coloratus* (Nees) Stapf; syn. *Andropogon coloratus* Nees (Pillu grass) India — Tinnevelly district as far as the Anamalai hills, and in Karnatik (Madras).	Highly aromatic, xerophytic plant which yields an essential oil used locally for perfuming soaps.	Yield of oil, obtained by steam distillation, 0.35%, sp. gr. (at 15°C), 0.911—0.920; optical rotation, − 7° 43′ to − 10° 42′. Composition (old data): geraniol (partly as the acetate) variously put at 15—33%; terpene aldehydes (mainly citronellal), 34—50%; and hydrocarbons (? mainly limonene), 7%.	The oil resembles lemongrass oil but is considered to be 'inferior' to it.	Choudhury, 1961 CSIR India, 1950

List of plants tolerant of arid or semi-arid - Part 27

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
99. *Cymbopogon jwarancusa* (Jones) Schult; syn. *Andropogon iwarancusa* Jones (Khavi grass) SE. Asian sub-continent; especially abundant in the desert areas of the Punjab.	As source of an essential oil suitable for perfuming soaps. Used as cattle fodder in times of drought.	Yield of oil, by steam distillation, 0.4–1.0%; sp. gr. (at 15° C), 0.920; acid no., 5.6; ester no., 21.0; ester no. after acetylation, 117.8; total alcohols, 34.0%. The oil, which has been suggested as a possible substitute for palmarosa oil (next entry), is reported to contain up to 24% *d*-Δ^4-carene, and up to 80% piperitone (readily convertible into thymol, a mild antiseptic). Also reported present, an alcohol with rose-like odour and a sesquiterpene alcohol with b.p. at 31 mm Hg vacuum of 176–177° C. Roots contain 0.4–0.9% volatile oils; also resins and bitter principles.	Carene is a skin irritant and this could restrict the usefulness of the essential oil in perfumery. Wide variation in oil composition.	Bradu *et al.*, 1977 Choudhury, 1961 CSIR India, 1950 Guenther, 1950 Hussain and Hassan, 1958
100. *Cymbopogon martinii* (Roxb.) Stapf var. *motia**; syn. *Andropogon martinii* Roxb. var. *motia*. (Palmarosa grass, rusa grass) India, especially the central/southern areas such as the Deccan plateau. Also Brazil, Paraguay, Angola, Indonesia.	A perennial grass which on steam distillation yields the 'palmarosa oil' of commerce, traditionally produced from wild stands in India for export (95 tonnes p.a. late 1960s) to USA and Europe for use in perfumery (gives rose-like odour, e.g. to quality soaps) or as a source of geraniol.	Top two-thirds or so of the plant cut for use (regenerates for several years) and after brief drying yields up to 1% oil, dry basis, provided care is taken with the distillation. Sp. gr., 0.874–0.889; ester value ~35; main consituent (~90%) is geraniol, partly as acetate/caproate. Most of the oil is in the leaves. The plant size and the oil yield per plant vary widely in natural stands, and also to some extent in γ-ray produced mutants – so giving the possibility of commercial development of higher-yielding strains.	Plant needs light well-drained soil and although said to survive hot, fairly dry climates, some claim that 800 mm rain p.a., or equivalent irrigation, is desirable for good yield. In the wild, the plant grows in scattered patches and collection/distillation tend to be *ad hoc*/rudimentary. More recently grown in plantations (especially Indonesia).	Anon, 1972 Choudhury, 1961 CSIR India, 1950 Dutta and Sahoo, 1977 Guenther, 1950 Gupta, 1969 Gupta, 1972 Paroda, 1979 Virmani *et al.*, 1967
101. *Cymbopogon proximus* (Hochst. ex A. Rich.) Stapf; syn. *C. schoenanthus* (L.) Spreng, subsp. *proximus* (Hochst. ex A. Rich.) Maire & Weiler, *Andropogon proximus* Hochst. ex A. Rich. (Mahareb, halfa bar) Upper Egypt, Sudan, Ethiopia, N. Nigeria, Ghana and Guinea.	The air-dried leaves and stems are highly valued in indigenous medicine in Egypt and Sudan as an antispasmodic drug (the antispasmodic principle is now known to be a saturated dicyclic sesquiterpenoid diol, proximadiol, $C_{15}H_{28}O_2$).	Considered to have potential as an essential-oil crop, the oil being suitable for the perfumery trade and as a raw material for preparation of menthol. Yield and composition of oil varies widely according to habitat and maturity. Yield of up to 6.8%, fresh wt. basis, claimed for leaves gathered immediately after flowering (optimum). Main components: piperitone (*see* entry no. 99), 22–88%; elemol, 0.4–39%; and β-eudesemol (both sesquiterpenes), 2–20%. Pipertone content reported to increase with aridity.	Unusually wide variability in oil yield and composition could be a disadvantage for large-scale exploitation.	Abdel-Moneim *et al.*, 1969 Banthorpe *et al.*, 1976 Drar, 1954 Guenther, 1950 Radwan, 1975 Rovesti, 1971

* *C. martinii* (syn. *A. martinii*) var. *sofia* requires a moister, and shady, habitat and yields an oil, gingergrass oil, with commercially less desirable characteristics than palmarosa oil.

List of plants tolerant of arid or semi-arid - Part 28

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
102. *Cymbopogon schoenanthus* (L.) Spreng. subsp. *schoenanthus* syn. *Andropogon schoenanthus* L. (Camel grass) Widely distributed in arid areas of N. Africa, Arabian Peninsula, Iran and SE. Asian sub-continent.	Used locally as a perfume and diuretic.	The dried gass yields about 1% of oil on steam distillation; sp. gr. (at 15°C), 0.905. Reported to contain 3–10% phenols, 10–30% aldehydes and some phellandrene (hence the elemioil-like odour). A typical desert plant; has been suggested as being worthy of further investigation.		Guenther, 1950 Paris and Dillemann, 1960
103. *Dasylirion wheeleri* S. Wats. ex Rothr. (Sotol) USA (Sonora desert and Texas), Mexico	As source of alcohol (e.g. was so utilised in Texas during World War II).	Seeds yield 26% protein and 22% oil (which has iod. val., 146; sap. val., 182; and fatty acid composition: C_{18} non-conjugated diene (e.g. linoleic), 73%; monoene (e.g. oleic), 14%; saturated, 8%). Possible source of a 'fixed' (fatty) oil, fairly high in unsaturated acids. Fibre suitable for cordage.		Anon, 1945 Earle *et al.*, 1960b Gentry, 1972
104. *Datura inoxia* Mill.*; syn. *D. meteloides* DC. ex Dunal (Black datura) Native of Mexico, but now widespread especially in SE. Asian sub-continent and Egyptian deserts.	Source of the alkaloid hyoscine (scopolamine) used in surgery and childbirth and to prevent travel sickness, etc. Commercial supplies of the drug consist of dried leaves and flowers; hyoscine content, 0.25–0.55%.	Alkaloid content varies according to season and location, normally highest in seeds (up to 0.45%). Seeds also contain 14% protein and 19.6% 'fixed' (fatty) oil. Thrives on wastelands and has been suggested as a possible drug plant for cultivation on wastelands in India, Pakistan and Egypt.	Limited demand only in international trade (but *see* entry no. 105). Hyoscine can now be obtained synthetically. All parts of the plant are narcotic (? harvesting problems).	Arnon, 1972 Chopra *et al.*, 1960 Orar, 1954 International Trade Centre, 1974 Jones and Earle, 1966
105. *Datura metel* L. (White datura, thorn apple†) Native of tropical Asia and possibly Africa; now widely distributed in drier parts of the tropics and sub-tropics.	Source of the alkaloid hyoscine (scopolamine: *see* previous entry), the dried leaves and flower heads being the normal commercial form (hyoscine content should be 0.25–0.55%); also used in traditional medicine. Plant is understood to be grown commercially in Spain and Egypt.	Alkaloid content varies according to location, season and part of plant. Seeds contain 13–14% protein and 16–19% oil (which has iod. val., 104–119; sap. val., 179–188; and fatty acid composition: linoleic, 52%; oleic, 32%; palmitic, 13%; stearic, 3%). Very similar to *D. inoxia* (*see* entry no. 104). Has been suggested as a possible crop for the Negev desert and SE. Asian sub-continent.	Similar problems apply as to entry no. 104, which see. Considerable variation in hyoscine content reported in Indian samples.	Burkhill, 1935 Earle *et al.*, 1960b Earle *et al.*, 1962 Evenari *et al.*, 1971 Grindley, 1954 International Trade Centre, 1974 Karnick and Saxena, 1970 a, b Martindale, 1977 Shah and Khanna, 1963 Shah and Khanna, 1964 Shah and Khanna, 1965

* Sometimes referred to in the literature as *D. metel* var. *fastuosa*.

† Used for both *D. metel* and *D. stramonium*.

List of plants tolerant of arid or semi-arid - Part 29

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
106. *Datura stramonium* L. (Devil's apple, Jamestown weed, stramonium, thorn apple†) Thought to have originated around the Caspian Sea; now found in a wide range of habitats in Europe, Africa America and Asia.	Source of the drug stramonium, similar to belladonna, and used as a narcotic and anti-spasmodic; widely used to treat asthma. Commercial form of the drug consists of the dried leaves and flower heads; alkaloid content should be 0.25–0.5%, and consists mainly of hyoscyamine ($C_{17}H_{23}O_3N$; m.p., 108° C). Also used as a source of the alkaloid atropine.	Seeds contain 0.1–0.3% alkaloids; also 18% protein, 16–27% oil (with sap. val., 189.5; iod. val., 130.5; fatty acid composition: linoleic, 61%; oleic, 23.5%; palmitic, 11.5%; stearic, 4%). Suggested as a possible crop for Egyptian deserts. Attempts have been made to develop the crop in India and Pakistan. Experimentally, yields in India average 1,100–1,700 kg/ha of leaves and 770 kg/ha seed. Use of nitrogenous fertilisers favours alkaloid formation. Stramonium is listed in many pharmacopoeias.	Attempts to grow stramonium in USA during World War II were not very successful, because of harvesting difficulties. May need nitrogen input for acceptable alkaloid yield: see left. Must be used carefully – toxic side-effects. Competition from synthetic anti-spasmodics.	Chopra *et al.*, 1956 Chopra *et al.*, 1960 Crooks, 1949 Drar, 1954 Grindley, 1954 Jones and Earle, 1966 Khan and Hussain, 1960 Martindale, 1977 Wahid and Kazmi, 1960
(*Daucus visnaga* L. – synonym for *Ammi visnaga*, which see)				
107. *Dimorphotheca cuneata* DC. Native of S. Africa.		Seeds contain (hull-free basis) 38–41% protein, 32% oil – which has iod. val., 137; conjugated acids in oil: diene (dimorphecolic acid), 69%; triene, 3%. Dimorphecolic acid (9-hydroxy -10, 12-*trans-trans*-octadecadienoic acid) contains multiple reactive groupings, similar to the ricinoleic acid in castor oil. Hence a possible industrial oilseed and source of dimorphecolic acid (used in the manufacture of plastics, paints, lubricants, surfactants, etc.). The oil is reported to be similar to tung oil and produces comparable phenolic resins. Thus with other members of the genus *Dimorphotheca*, *D. cuneata* has been investigated as a possible oilseed in the USA. Found to be a drought-resistant shrub, which is fairly resistant to frost, and 90% of its seeds mature over 20 days (so mechanical harvesting is feasible). Its seeds do not shatter as easily as those of *D. sinauta* (*see* next entry). Estimated average yield 1,700 kg/ha.	In the USA found to be susceptible to disease (but despite this considered a promising crop).	Barclay and Earle, 1965 Duisberg and Hay, 1971 Earle *et al.*, 1964 Jones and Barclay, 1972 Rheineck and Sobol, 1963 Willingham and White, 1973

† Used for both *D. metel* and *D. stramonium*

List of plants tolerant of arid or semi-arid - Part 30

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
108. *Dimorphotheca sinuata* DC; syn. *D. auranthiaca* DC. (Cape marigold) Native of S. Africa; but now found widely in the USA too.	Widely used in the USA as an ornamental.	Seeds contain (hull-free basis) 34–38% protein; 28–38% oil (with sap. val., 177; iod. val., 124; fatty acid composition: dimorphecolic, 66%; linoleic, 14%; oleic, 10% palmitic, 4–5%; stearic, 4–5%; miscellaneous acids, 5%). Potential source of a drying oil similar to tung oil, and a source of dimorphecolic acid: *see* previous entry. It is the most extensively researched of the *Dimorphotheca* spp. Adapted to a summer-dry regimen after seedling establishment; moisture requirements are low. Composition of meal after oil extraction: protein, 58.7%; ether extract, 22.9%; ash, 8.5%; fibre, 4.6%; N-free extract, 25.3%. Methionine and lysine limiting amino acids.	Fruit is a wafer-thin achene; shattering and maturity over a prolonged season are both problems. Also trouble with pests and diseases. Presence of lipolytic enzyme in crushed seed necessitates prompt extraction to produce oil of low f.f.a. content. Considerable agronomic research, especially breeding and selection, required; yields vary considerably, but can reach about 900 kg/ha.	Barclay and Earle, 1965 Binder *et al.*, 1964 Duisberg and Hay, 1971 Earle *et al.*, 1960c Earle *et al.*, 1964 Etten *et al.*, 1961 Jones and Wolff, 1960a Jones and Wolff, 1960b Knowles *et al.*, 1964 Knowles *et al.*, 1965 Rheineck and Sobol, 1963 Smith *et al.*, 1960 Willingham and White, 1973
109. *Dimorphotheca zeyheri* Sond. Native of S. Africa, especially around the Cape.		Seeds contain (hull-free basis) 42% protein and 36% oil – which has iod. val., 130; conjugated acids: diene (dimorphecolic), 43%; triene, 2%. Hence a possible industrial oilseed and source of dimorphecolic acid (*see* entry no. 107).	Mainly restricted to semi-arid summer-rainfall areas.	Barclay and Earle, 1965 Earle *et al.*, 1964
110. *Dioscorea elephantipes* (L'Her.) Engl. (formerly *Testudinaria elephantipes*). (Elephant's foot; Hottentot bread; yams (various *D.* species)) S. Africa, especially rocky semi-desert areas of the Cape.	Source of sapogenins, particularly diosgenin (precursors for steroid drugs). One of the first sources of diosgenin to be exploited.	Yields large tubers, which can weigh up to 350 kg or more, having a diosgenin content of up to 4.5%.	Grows too slowly to be cultivated commercially. Natural supplies in danger of exhaustion due to over-exploitation. Other *Dioscorea* spp. and other natural sources being exploited. The diosgenin is extracted in the country of origin, notably Mexico. *See* also next entry.	Albans, 1956 Coursey, 1967 Dyer, 1955 International Trade Centre, 1974 Martin, 1969 Martin, 1972

List of plants tolerant of arid or semi-arid - Part 31

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
111. *Dioscorea sylvatica* Eckl. (formerly *Testudinaria sylvatica* (Eckl.) Kunth) S. Africa, particularly the Transvaal around Lydenburg.	Source of sapogenins, particularly diosgenin (precursors for steroid drugs). One of the first sources of diosgenin to be exploited.	Yields large tubers, which can have a diosgenin content of up to 6%.	Natural supplies are now protected to help prevent over-exploitation; but other *Discorea* spp. are now being exploited, some of which are being cultivated and therefore yielding more certain supplies. In addition, sapogenins are also being obtained from other sources, e.g. *Agave* spp. (which have the advantage of yielding a fibre as well: *see* entries 7–21); and the world demand for most natural sapogenins is nowadays threatened by the spread of 'synthetic' (microbiologically derived) steroids (although there may still be a small demand for the naturally obtained sapogenins locally in developing countries from small firms lacking the technology for making 'synthetics').	Albans, 1956 Asolkar *et al.*, 1979 Blunden *et al.*, 1971, 1975 Coppen, 1980 Coursey, 1967 Dyer, 1955 International Trade Centre, 1974 Martin, 1969 Martin, 1972
112. *Duboisia hopwoodii* F. v. Meull. (Pitur.) Endemic to Australia – SW. Queensland, S. and C. Australia, and the drier parts of W. Australia.		Possible use crude as a natural insecticide or as a source of nicotine. Thus the leaves and twigs contain nicotine and/or nor-nicotine up to about 5%. Samples from W. Australia and SW. Queensland usually contain nicotine, those from S. and C. Australia, nor-nicotine.	Possibility of exploiting natural stands, and cultivating the trees, as a natural source of nicotine for use in insecticides was investigated in the 1940s: when it was concluded that other sources of nicotine were likely to be more economic. In addition, use of nicotine, a poison, nowadays discouraged.	Chopra *et al.*, 1960 Barnard, 1952 Bowen, 1944

List of plants tolerant of arid or semi-arid - Part 32

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
113. *Duboisia leichhartii* F. v. Meull. (Corkwood tree) Endemic to Australia.	A drug plant which is used as a source of tropane alkaloids, particularly hyoscyamine (from which atropine can be made). The plant is very drought resistant and is now being grown commercially in Australia to supplement supplies from natural stands — and also to supplement supplies of drug material from the closely related, but not drought resistant, species *D. myoporoides* R. Br.	Leaves contain on average about 3% total alkaloids consisting mainly of hyoscyamine but hyoscine, butropine and valtropine are also present. Plant is very drought resistant.	When tried experimentally in India, the seeds did not germinate. Competes with Egyptian henbane (*Hyoscyamus muticus* — entry no 176).	Barnard, 1952 Berens, 1953 Carr, 1974 Chopra *et al.*, 1956 Griffin *et al.*, 1975 Rosenblum and Taylor, 1954
114. *Emblica officinalis* Gaertn. [f]				
115. *Ephedra alata* Decne.* C. and S. USSR, Arabian and Sahara deserts.		Green twigs possible source of the alkaloids ephedrine and pseudoephedrine (the latter being an isomer of the former and with essentially similar properties: *see* next entry). Thus samples of Moroccan twigs reported to contain up to 1% pseudoephedrine (but Egyptian plants 50% less).	Not considered to be of value, except for local use. As noted left, alkaloid content rather low and varies widely with location.	Abdel-Wahab *et al.*, 1960 Paris and Dillemann, 1960 Reader, 1951
116. *Ephedra equisetina* Bunge (Horsetail ephedra, mupen or murtse ma-huang), Mountain deserts and semi-deserts of Asia (especially China).	Green twigs source of the alkaloid ephedrine, a vasoconstrictor with adrenaline-like stimulant and also decongestant activity; used in the treatment of asthma, bronchitis, renal colic, etc. Wild plants used extensively in Chinese medicine.	Total alkaloid content of up to 3% has been reported but average is 1.8% (1.6% ephedrine and 0.2% pseudoephedrine). Alkaloid content increases from spring to autumn and varies with altitude. Was cultivated successfully on an experimental scale during the late 1930s.	Alkaloid content varies with season and altitude (*see* left). In addition, like all natural sources of ephedrine (e.g. entry nos. 117, 119, 120) this species is facing increasing competition from synthetic material and more efficacious drugs, and the outlook is not promising.	Chopra *et al.*, 1960 Hu, 1969 Paris and Dillemann, 1960 Reader, 1951

* Various *Ephedra* spp. are widely distributed throughout the warm, dry regions of the world, but only those containing significant quantities of ephedrine or pseudoephedrine (*see* entry no. 115) are listed.
[f] denotes a potential firewood source (*see* Introduction)

List of plants tolerant of arid or semi-arid - Part 33

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
117. *Ephedra gerardiana* Wall. ex Stapf; syn. *E. vulgaris* Hook f. non. A. Rich. Endemic to the more arid, mountainous areas of the northern SE. Asian sub-continent, particularly Baluchistan (SW. Pakistan). Normally found at altitudes of between 2,000 and 4,200 m.	One of the principal commercial sources of natural ephedrine (*see* entry no. 116). Thus is grown commercially in Baluchistan and processed at Quetta. Consumption of crude drug in 1960s estimated at about 1,000 tonnes p.a. when Pakistan was the principal commercial supplier of natural ephedrine.	Total alkaloid content of dried green twigs is 1.0–2.5% (highest in the autumn) of which 60–70% is normally ephedrine and the rest pseudoephedrine. Waste obtained after commercial extraction of the alkaloids found to contain 36% fatty acids, including stearic and palmitic, a high molecular weight alcohol ($C_{24-28}H_{48-58}O$) and about 3% sterol ($?C_{27}H_{46}O$). R and D has been undertaken to find a use for this waste material and its use as an emulsion for waterproofing hardboard and as a source of tannin, has been suggested. The plant has been successfully cultivated experimentally in Australia and Kenya.	Plant is only found at high altitudes (*see* column 1) and alkaloid content adversely affected by rain. Future outlook not promising due to increasing competition from synthetic ephedrine, *see* entry no. 116, although may continue to be of local importance.	Ali and Ahmad, 1968 Chaudhri, 1957 Chopra *et al.*, 1960 Chumbalov and Taraskina, 1961 Duisberg and Hay, 1971 Paris and Dillemann, 1960 Reader, 1951 Siddiqui and Hahn, 1959 Wright, 1960
118. *Ephedra intermedia* Schrenk & C. A. Mey. (Chung ma-huang) Sandy desert areas of N. Asia, generally at an altitude of 1,500–2,000 m, but in very arid areas of Pakistan can occur at 2,700 m.	Dried green twigs contain alkaloids (mainly pseudoephedrine). Used in Chinese medicine – and sometimes also to adulterate commercial supplies of *E. gerardiana*.	Indian samples of dried green twigs reported to contain 2.3% alkaloids of which 1.8% was pseudoephedrine and 0.4% ephedrine; but Pakistan samples reported to have total alkaloid content of 1.5% or less.	Plant is only found at certain altitudes and both alkaloids can be obtained synthetically (*see* entry no. 116).	Chaudhri, 1957 Chopra *et al.*, 1960 Hu, 1969 Paris and Dillemann, 1960 Reader, 1951
119. *Ephedra major* Host; syn. *E. nebrodensis* Tineo ex Guss. Northern SE. Asian sub-continent, Spain.	Closely resembles *E. gerardiana* and some authorities do not differentiate between the two. Used as a commercial source of natural ephedrine (*see* entry no. 116).	Indian samples of dried twigs reported to contain 2.8% total alkaloids, of which 1.9% was ephedrine.	Same constraints as noted for entry no. 116.	Chaudhri, 1957 Chopra *et al.*, 1960 Paris and Dillemann, 1960 Reader, 1951
120. *Ephedra sinica* Stapf (Tsaopen ma-huang) Native of the drier areas of China.	The principal Chinese species of *Ephedra*. Used as a commercial source of natural ephedrine (*see* entry no. 116).	Average total alkaloid content of green dry twigs, 1.3%; ephedrine, 1.1%. In 1930s, the Chinese plants were an important commercial source of ephedrine in international trade, but superseded by supplies from Pakistan. Alkaloid content highest in the autumn.	Outlook not promising: *see* entry no. 116.	Chopra *et al.*, 1960 Duisberg and Hay, 1971 Hu, 1969 Paris and Dillemann, 1960 Reader, 1951

List of plants tolerant of arid or semi-arid - Part 34

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
121. *Eucalyptus dumosa* A. Cunn. ex Schae* (Bull mallee†) Native of Australia (NSW, Victoria and S. Australia).	The higher-cineole specimens have been used occasionally as a source of medicinal eucalyptus oil, an essential oil used in pharmaceutical products.	Yield of oil from foliage about 1%. Composition: cineole‡ (33—44%, usually but occasionally up to 66%) along with D-α-pinene, aldehydes, and sesquiterpenes. Has been suggested as a possible *Eucalyptus* species for arid lands. Multipurpose — also a possible source of fuel and, through its flowers, of honey (regarding tannins, *see* footnote *)	Eucalypts tend to denude surrounding ground of moisture (and store it in the roots where it can be used as a source of water). Nowadays only those eucalypt oils with at least 70% (e.g. next entry) cineole used as medicinal oil.	Paris and Dillemann, 1960 Penfold and Morrison, 1950 Penfold and Willis, 1954 Penfold and Willis, 1961
122. *Eucalyptus fruticetorum* F. Muell; syn. *E. polybractea* R. T. Baker (Blue mallee†) Native of Australia (W. NSW and the mallee district of Victoria).	Source of medicinal eucalyptus oil. Australian production in 1968 reported to be about 50 tonnes but supplies likely to diminish unless plantations are established or natural stands upgraded. The principal 'mallee' eucalypt; in late 1950s it provided over one-third of Australia's eucalyptus oil.	Yield of oil from foliage 1.5—2.5%, depending upon season and age of tree. Composition of oil: cineole‡ 77—85%, plus *p*-cymene, cuminal, 4-isopropyl salicylaldehyde (all three being C_{10} aromatics), L-α-phellandrene, phellandral, cryptone, piperitone (related monoterpenes). Also, as for entry no. 121, a possible source of fuel and of honey (regarding tannins, *see* footnote *).	*See* entry no. 121 *re* water use.	Guenther, 1968 Penfold and Morrison, 1950 Penfold and Willis, 1954 Penfold and Willis, 1961
123. *Eucalyptus oleosa* F. Muell. Australia (NSW, Victoria, S. and W. Australia).	Source of medicinal eucalyptus oil. Foliage usually distilled in admixture with other mallees.	Yield of oil 0.9—2.0% (average 1.4%). Cineole content 54—80%, average, 64%. Also, as for entry no. 121, a possible source of fuel and of honey (for tannins, *see* footnote *). Has been suggested as a possible *Eucalyptus* species for arid lands, as it is very drought-resistant.	*See* entry no. 121.	Paris and Dillemann, 1960 Penfold and Willis, 1954

* In addition to those *Eucalyptus* species listed, *E. cneorifolia* DC. and *E. viridis* R T Baker, are also exploited on a very small scale (the latter is also mentioned by Paroda, 1979, as being an Indian AZ plant which yields an essential oil). Most also contain 10—20% tannins, sometimes more, in wood and bark but the arid-tolerant spp. are generally too small, too scattered and too low in tannins to make exploitation, except locally, worthwhile (Penfold and Willis, 1961). Several (*E. camaldulensis* Dehnh., *E. citriodora* Hook, *E. gomphocephala* A.DC., *E. microtheca* F. Muell., *E. occidentalis* Endl.) have been identified as potential firewood sources (National Academy of Sciences, 1980: *see* Introduction).

† Dwarf, stunted eucalypts known as 'mallees' occur in low rainfall areas of Australia.

‡ Strictly 1,8-cineole (a monoterpene, $C_{10}H_{18}O$, containing an ether ring) — to distinguish from 1,4-etc. isomers.

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Name(s)/Distribution	Current/past uses	Potential‡	Constraints	Citation data
124. *Eucarya spicata* Sprague & Summerh. (Australian sandalwood) Native of arid areas of W. and S. Australia.	Source of sandalwood oil, used mainly in perfumery; formerly used medicinally.	Yield of oil from butts and roots, 1.4–2.6%. More than 90% of oil consists of sesquiterpenes (calculated as $C_{15}H_{24}O$); α-santalol chief constituent.	Oil considered to be inferior to 'East Indian' (from *Santalum album*, S. India) sandalwood oil. Production understood to be declining owing to over-exploitation.	Guenther, 1952 Penfold and Willis, 1954 Walker, 1966
125. *Euphorbia abyssinica* J. F. Gmel*; syn. *E. erythraeae* N. E. Br. Sudan.		Seeds yield 33% of a drying oil, similar to linseed oil with sap. val., 190; iod. val., 177.7–179.2; unsap. matter, 1.8%; and fatty acid composition: linolenic, 53.4%; linoleic, 17.9%; palmitic, 13.8%; oleic, 9.2%; stearic, 5.2%; arachidic, 0.4%; myristic, 0.1%. Analysis of latex obtained by tapping: rubber, 9.0%; resin, 65%; insoluble matter, 11%. Potential oilseed: harvesting of the seed would be relatively easy if cultivated on a large scale; and the oil may then provide an alternative to linseed oil as the drying-oil constituent of paints, varnishes, 'linoleum' etc. The plant could also perhaps be used as a source of rubber.	*	Barker *et al.*, 1950 Henry and Grindley, 1944 Sudan, Report of the Government Analyst, 1942
126. *Euphorbia antiquorum* L. (Triangular spurge †) SW. Asia, India.	Despite its irritant nature, the plant is widely used in indigenous medicine, both internally (e.g. as a purgative and against gout) and externally (e.g. the latex is used on warts and to kill maggots). The latex is also used as a fish poison.	A saline extract of the stem has anti-bacterial action. Latex contains 4.0–6.4% rubber. Following compounds (all triterpenes) isolated; from the stems – taraxerol, friedelan-3α- and 3β-ols and taraxerone; from the latex – β-amyrin, cycloartenol, euphol and α-euphorbol; (but *see* also footnote*); from the roots – taraxerol.	Latex very irritant*.	Anjaneyulu *et al.*, 1967 Anjaneyulu and Ramachandra Rao, 1971 Chopra *et al.*, 1960 CSIR India, 1952 Sen Gupta and Ghosh, 1964

* The *Euphorbia* is a very large genus (over 200 species) of lacticiferous herbs, shrubs and small trees which are drought resistant and found in the arid and semi-arid regions. Most have the disadvantage, which acts as a major general constraint on their utilisation, that the latex which exudes from the leaves or stems on cutting contains substances [identified as esters of the tetracyclic diterpenes phorbol, ingenol and allied compounds (Evans and Soper, 1978; Hecker, 1977; Upadhyay *et al.*, 1976) occasionally varying with the plant's location (Fürstenberger and Hecker, 1977; Kinghorn, 1979) which are powerful skin irritants causing severe inflammation, particularly to the eyes, and which also act as cocarcinogens (i.e. accentuate the cancer-causing activity of any true carcinogen(s) present). Those species listed here whose latex has been shown to have irritant activity in a standard test include entry nos. 125, 126, 132, 133, 144, 146, 150, 151, 155, 157, (all very active, especially nos. 150 and151) and nos. 145 and 152 (moderate); nos. 129 and 141 showed little activity and the remainder were not included in the study (by Kinghorn and Evans, 1975). Not surprisingly, consumption of various parts of *Euphorbia* sp. has on occasion caused illness, and sometimes death, in both animals and humans (Watt and Breyer-Brandwijk, 1962). The 'euphorbium' and 'euphorbone' derived from latex (or resin) are not chemical entities but mixtures: cf. McDonald *et al.*, 1949.

† *Euphorbia* spp. in general are often known locally as spurge or devil's milk.

‡ Despite the comments under*, certain phorbol derivatives of the kind found in *Euphorbia* spp. show anti-cancer activity (Kupchan, 1976; Ogura *et al.*, 1978; *see* also under entry no. 151).

List of plants tolerant of arid or semi-arid - Part 36

Name(s)/Distribution	Current/past uses	Potential	Constraints*	Citation data
127. *Euphorbia antisyphilitica* Zucc.; syn. *E. cerifera* Alcocer (Candelilla, jumete) USA – SW. Texas, S. New Mexico, Arizona, California; and N. Mexico.	Commercial source of candelilla wax, used extensively to harden other waxes, as a substitute for carnauba wax and has similar industrial uses, e.g. in polishes, moulding and adhesive compounds, chewing gum, lubricants, plastics, cosmetics, explosives, insulators etc.	The (leafless) stems contain 2.5–5% wax – with m.p. 66–71°C; sap. val., 47–64; acid val., 12.3–20.6; iod. val., 19–44; on the basis of 67% unsaponifiable matter, the composition appears to be about: esters of hydroxylated acids, 33–35% (primarily sitosterol combined with dihydroxymyricin-oleic acid); lactone, 5–6% (hydroxy-myricino-lactone); free acids, 9–10%; hydrocarbons, 50–53% (hentriacontane, tritriacontane). The wax said to have a 'valuable industrial potential', especially if the plant could be domesticated and improved wax-extraction procedures devised (said to appear easier to mechanise harvesting and production of this wax than carnauba, its main competitor). With industrialised processing, the waste might be used for paper pulp. Latex reported to contain a proteolytic enzyme, euphorbain.	Considerable R and D effort needed to develop commercial cultivation and improve processing: with current primitive processing techniques extraction rate of wax is only about 2%. Extraction process requires an adequate supply of water. Like carnauba wax, suffering from competition from synthetic waxes. Production from natural stands is declining in Mexico, the major producer. Attempts to cultivate the plant outside its native habitats have mainly been unsuccessful and cultivated plants said to yield less wax than wild strands.	Castaneda *et al.*, 1943 Daugherty *et al.*, 1953 Duisberg, 1952a, b Duisberg and Hay, 1971 Hernandez, 1970 Hodge and Sineath, 1956 Kroner, 1951 McNair, 1954 National Academy of Sciences, 1975 Paroda, 1979 US Government, 1957
128. *Euphorbia atoto* Forst.f. syn. *E. dulcis* Blanco Tropical Asia, especially SE. Asian subcontinent.	Latex used in indigenous medicine, as an emmenagogue and abortifacient.	An alkaloid, (+)-9-aza-1-methylbicyclo (3:3:1) nonan-3-one, isolated.		Beecham *et al.*, 1967 Hart *et al.*, 1967 Uphof, 1968
129. *Euphorbia balsamifera* Ait. (Balsam spurge) W. Africa, Canary Islands.	Used in indigenous medicine, particularly in veterinary medicine for the treatment of horses. Commonly grown for hedging. Latex investigated in 1940s as a source of rubber.	Latex yields 15–28% coagulum, which consists of 84% resin, 12% rubber and 4% insoluble material. Latex also contains traces of an irritant, cocarcinogenic compound, 12-deoxyphorbol. Germanicol, germanicone, lupeol, lupenone, β-amyrin, cycloartenol, dihydroagnosterol and cycloartanone also reported in latex. The rubber could be used as a plasticizer for rubber mixtures; coagulum itself also of interest.	Rubber very inferior to *Hevea* rubber. Irritant compounds a serious handicap to the exploitation of the tree;* also its prickly nature.	Calvin, 1978 Compagnon, 1943 Dalziel, 1948 Evans and Kinghorn, 1975 Gonzalez *et al.*, 1976 Le Bras, 1943

*For general points concerning the *Euphorbia* spp., *see* footnote* on p.39.

List of plants tolerant of arid or semi-arid - Part 37

Name(s)/Distribution	Current/past uses	Potential	Constraints*	Citation data
130. *Euphorbia calycina* NE. Br. (*See* also under *E. candelabrum*) Sudan.	Ripe fruit contains small seeds, which yield 'fixed' (fatty) oil. Tapping of tree yields resinous latex, reported to be used as an insecticide in E. Africa.	Fruit contains 14–16% seeds, oil content, 21–25%. Oil has sap. val., 189; iod. val. 189–192; fatty acid composition: linolenic, 60–66%; linoleic, 9–12%; oleic, 2–19%; palmitic, 11%; stearic, 12%. Latex contains rubber, 7.3–11.3%: resin, 61.9%; insoluble matter, 26.7–29.9%. Examined during World War II as possible source of natural rubber. The oil is even more unsaturated than linseed oil and so may have potential as a drying oil for paint etc: properties approximate those of conophor oil (from *Tetracarpidium conophorum*, West Africa).	Sparsely distributed; would have to be cultivated systematically in order to produce oil in quantities sufficient for commercial exploitation.	Barker *et al.*, 1950 Henry and Grindley, 1944 Sudan, Report of the Government Analyst, 1942 Vanderplank, 1945
131. *Euphorbia calyculata* Kunth (Chupire (n)) Mexico.	Exploited as a minor source of natural rubber in early 1900s.	Latex yields 21% of good-quality rubber.		Uphof, 1968
132. *Euphorbia candelabrum* Trem. ex Kotschy; syn. *E. calycina* NE. Br. Africa, especially Eritrea and the Sudan.	A tree up to 50 ft (16 m) in height. Plant extracts sometimes used in indigenous medicine.	Fruit contains 14% seeds, oil content, 21%. Sap. val., 189; linolenic acid, 42.5%; linoleic, 37.5%; oleic, 12.5%; saturated acids, 7.5%. Latex contains 50% rubber, around 14% gum and some wax. Investigated during World War II as a possible oilseed; also considered a possible source of natural rubber.	*	Dale and Greenway, 1961 Kokwaro, 1976 Polhamus, 1962 Sudan, Report of the Government Analyst, 1942 Watt and Breyer-Brandwijk, 1962
133. *Euphorbia desmondi* Keay & Milne-Redhead W. Africa.	Grown for fencing; latex used locally as a fish poison.		Latex contains about 1% ingenol, a cocarcinogenic irritant*.	Evans and Kinghorn, 1973 Evans and Kinghorn, 1975 Kinghorn and Evans, 1974
134. *Euphorbia dracunculoides* Lam. (Haunchee, titlee) SE. Asian sub-continent, tropical Africa.	Source of the indigenous drug 'sudab' – which is used medicinally.	A glycoalkaloid, euphorbine, reported in the stalk and leaves. Euphorbol (a triterpene), sucrose and a flavone-glycoside, kaempferol, also isolated from the stalks and leaves. Seeds contain 0.28% phenolic substance (m.p. 258° C), kangiol; also 25–28% yellowish-brown oil with sap. val., 200; iod. val., 172.6; acid val., 26.3; unsap. matter, 2.65%; and fatty acid composition: oleic, 30.5%; linoleic, 23.5%; linolenic, 8.6% behenic, 0.6%; arachidic,, 5.3%; stearic, 15.3%; palmitic, 7.1%; myristic, 0.3%. Hence a potential drying oil for use in paints etc.	Considerable variation in the reported oil constants. Unsaturation barely high enough for reliable use as linseed oil substitute (needs an iodine value of at least 175 to 180).	CSIR, India, 1952 Pal and Dutta, 1969 Singh and Singh, 1959 Singh and Srivastava, 1966 Singh *et al.*, 1968

* For general points concerning the *Euphorbia* spp., *see* footnote* on p. 39.

List of plants tolerant of arid or semi-arid - Part 38

Name(s)/Distribution	Current/past uses	Potential	Constraints*	Citation data
135. *Euphorbia echinus* Hook. f. & Coss. N. Africa, SW. Africa (Namib desert).		Rubber content of latex reported to be 2.67%; resin content 18.8%. Hence a possible source of rubber.	Rubber content probably too low for economical extraction.	Audy, 1942 Ruiz and French, 1948
136. *Euphorbia fiha* Dec. (Fiha) Madagascar.	Minor source of rubber; used locally for preparation of varnish and as a source of wax (obtained from the leaves).			Decary, 1946 Decary, 1962
137. *Euphorbia fulva* Stapf; syn. *E. elastica* Alt. & Rose (Palo amarillo, palo colorado, palo cucaracha, papelillo) Mexico.	Exploited as a minor source of rubber in early 1900s and during World War II.	Trees can be tapped for their latex three times a year for about 10 years. Rubber content of latex, 18–20%, resin up to 40%. Oil content of seeds, 30%, suitable for soap manufacture (and perhaps as a drying oil); residual oil cake high in protein.	Latex very irritant, especially to the eyes. Rubber difficult to extract because of high resin content of latex.	Uphof, 1945 Zinser, 1941
138. *Euphorbia gregaria* Marloth SW. Africa.		Possible oilseed (seeds contain 42% oil) and source of poor-quality rubber.		Mensier, 1957 Watt and Breyer-Brandwijk, 1962
139. *Euphorbia gymnoclada* Boiss. Brazil.	Source of balata (a gutta-percha-like plastic material obtained on drying the latex obtained from the wood). The wood is also extensively used for firewood.	Balata reported to have 17% gutta content. Has been suggested that the fibrous residue remaining after removing the latex from the wood could be used as a source of paper pulp.	The balata obtained is of poor quality (normal commercial material has 50%, and sometimes up to 80%, gutta).	Mors and Rizzini, 1966
140. *Euphorbia heterophylla* L. (Painted spurge, catalina) Mexico.	Said to be used in indigenous medicine as an antidote to the irritation caused by other *Euphorbia* spp.; but shows acute toxicity in substantial quantities.	Seeds contain 25% protein and 37% oil; this has sap. val., 188, iod. val., 200, and fatty acid composition: linolenic, 55%; linoleic, 22%; oleic, 10%; saturated acids, 8%. Hence a possible source of drying oil (iod. val. well over the 175–180 threshold: *see* entry no. 134).	Lysine the limiting amino acid in the oilcake.	Earle *et al.*, 1960b Etten van *et al.*, 1961 Watt and Breyer-Brandwijk, 1962

* For general points concerning the *Euphorbia* spp., *see* footnote * on p. 39.

List of plants tolerant of arid or semi-arid - Part 39

Name(s)/Distribution	Current/past uses	Potential	Constraints*	Citation data
141. *Euphorbia hirta* L.; syn. *E. pilulifera* auct. non L. (Spurge, betsim, merina, snakeweed herb, Indian wolf's milk) Probably originated in Africa but now widely distributed (particularly in Australia, E. Asia, Brazil and Mexico).	Used in indigenous medicine in Africa and India. Contains an anti-spasmodic principle and has been used widely for the treatment of asthma and bronchitis. Has a galactogenic action. Used also for dysentery.	An approximate analysis of plant material reported as: fat, 1.0%, sterols, 0.4%; resins, 2.6%; reducing sugars, 1.7%. Presence of L inositol, quercitol (sugars), quercitrin (flavone), taraxerone, taraxerol, α- and β- amyrin, friedelin, campesterol, stigmasterol, sitosterol (common plant triterpenes and sterols), hentriacontane and succinic, fumaric and ellagic acids has been reported. Further investigation of the therapeutic action considered to be worthwhile; non-irritant extracts with wide therapeutic activity said to have been prepared.	Plant yields very little latex.	Ayensu, 1979 Blanc and De Saqui-Sannes, 1972 Caldwell, 1966 Chopra *et al.*, 1960 Gupta and Garg, 1965 Gupta and Garg, 1966a Hallett and Parks, 1951 a, b Hallett and Parks, 1953 Kinghorn and Evans, 1975 Rakoto-Ratsimamanga *et al.*, 1968 Steinmetz, 1964
142. *Euphorbia intisy* Drake (Intisy, herotra) Madagascar; introduced experimentally into USA during late 1920s.	Source of rubber.	Rubber is of high quality – best of the *Euphorbia* spp. Heavily exploited during the rubber boom in early 1900s (plants almost exterminated). Reported that it can be grown easily from seed.	Some doubt concerning the age at which the plant can be tapped for rubber.	Anon, 1930c Decary, 1962 Polhamus, 1962
143. *Euphorbia lagascae* Spreng. Native to arid region of SE. Spain: introduced successfully into the USA (Arizona and California), S. America.	Grown as a winter annual in the USA.	Seeds contain: protein, 21–26%; oil, 42–50% – which has sap val., 188; iod. val., 91.7–92.7; unsap. matter, 0.71%; vernolic acid (*cis*–12, 13-epoxy-*cis*-9-octadecenoic), 58–62%. Potential industrial oilseed: source of vernolic acid (used in plastic formulations, protective coatings, etc.).	Disease and nematodes are a problem in US operation. Seed yield 950 kg/ha or less. Need to develop strains with better seed retention. Steam heat necessary to inactivate enzymes, during oil extraction.	Kleiman *et al.*, 1965 Krewson and Scott, 1966 Scott and Krewson, 1966 White and Wolf, 1968 White *et al.*, 1971

* For general points concerning the *Euphorbia* spp., *see* footnote * on p. 39.

List of plants tolerant of arid or semi-arid - Part 40

Name(s)/Distribution	Current/past uses	Potential	Constraints*	Citation data
144. *Euphorbia lathyris* L. (Gopher plant, caper spurge, oily milkweed, myrtle spurge, and petrol tree (also used for *E. tirucalli*)) Asia, Europe, USA (especially N. California).	Long cultivated in China for medicinal purposes and as a fish poison.	A potential industrial oilseed (occurs as a biennial weed in the USA). Experiments indicate seed yields of 1,700–2,000 kg/ha attainable. Seeds contain: protein, 14–17%; oil, 48–50%. The latter has sap. val., 197; iod. val., 82–89 and fatty acid composition: oleic, 84.3–90.0%; linoleic, 2.3–7.0%; saturated acids, 5.7–7.7%. Oil strongly purgative and so unsuitable for edible purposes, but produces a high-grade soap. A number of compounds (e.g. 6, 20-epoxylathyrol, and the bicoumarin, euphorbetin) have been isolated from the oil. In addition, ingenol 3-hexadecanoate and 3-tetradeconoate, which have co-carcinogenic activity*, have been isolated from the oil and from the plant latex. Leaves and flowers contain 18% resins and 0.15–0.26% of a rubber-like material. Seed hulls can be used for preparation of furfural. It has been suggested that by cultivating as an annual and harvesting the whole plant (mechanically), the equivalent of around 15 barrels crude fuel oil/ha p.a. could be obtained – even using non-improved wild seed. Under trial in Israel yield of 68.7g/m^2/yr of hexane-extractables obtained from leaves and stem.	Needs a period of cold to flower. In the USSR germination has been found to be uneven, but improved lines capable of being harvested mechanically have been developed. Oilcake too toxic for use as animal feed. Said (in 1977) to be many unsolved problems especially as regards extraction of the latex (? by crushing or by solvents) for fuel.	Adolf and Hecker, 1971 Adolf and Hecker, 1975 Adolf *et al.*, 1970 Anon, 1977b Aronson and Zur, 1982 Buchanan *et al.*, 1978b Calvin, 1978 De Parceveaux and Allirand, 1977 Dublyanskaya, 1937 Dutta *et al.*, 1972 Gardener, 1982 Grynberg *et al.*, 1962 Johnson and Hinman, 1980 Kester, 1949 Kleiman *et al.*, 1965 Narayanan *et al.*, 1971 Schroeder *et al.*, 1979 Tyutunnikov *et al.*, 1935 Wang and Huffman, 1981 Zechmeister *et al.*, 1970a and b
145. *Euphorbia neriifolia* L.; syn. *E. ligularia* Roxb., *E. pentagona* Blanco Tropical Asia, especially SE. Asian sub-continent.	Latex and leaf extract used in indigenous medicine. Leaves sometimes used as a fish poison.	Latex contains 0.2–2.6% rubber. Euphol, nerifoliol, friedlan-3β and 3α-ols, taraxerol, and glut-5(10)-en-1-one (all triterpenes) reported in plant tissue.	Latex reported to cause dermatitis, etc.*.	Anjaneyulu and Ramachandra Row, 1965 Anjaneyulu *et al.*, 1973 Chopra *et al.*, 1960 CSIR India, 1952 Nageswara Rao and Ramachandra Row, 1966 Watt and Breyer-Brandwijk, 1962
146. *Euphorbia nivulia* Buch. Ham. Dry rocky areas of SE. Asian sub-continent; also reported in Burma and dry forests of Peru.	Latex, leaf extract and root bark all used in indigenous medicine.	Latex contains about 1% rubber. Bark is suitable for making composite cork boards, hardboard, etc.	Latex is reported to cause dermatitis, etc*. An aqueous alcohol extract of the aerial parts medicinally inactive in a wide range of tests.	Ayensu, 1979 Chopra *et al.*, 1960 CSIR India, 1952 Narayanamurti, 1952 Narayanamurti and Singh, 1954

* For general points concerning the *Euphorbia* spp., *see* footnote* on p. 39.

List of plants tolerant of arid or semi-arid - Part 41

Name(s)/Distribution	Current/past uses	Potential	Constraints*	Citation data
147. *Euphorbia officinarum* L. (Gum thistle) N. Africa.	A source of gum euphorbium used mainly as a vesicant in veterinary medicine. Plant investigated as a possible source of rubber in 1940s.	Chief constituents of the gum, or coagulum, are resin, wax, lignin, bassorin, salts of malic acid and a volatile oil.	Very irritant: workers require protection from the dust when collecting and packing the gum.	Grieve, 1976
148. *Euphorbia phosphorea* Martius (Candomble, cipo cunanam, cipo de breu) Brazil (Bahia and Piaui).	Source of a wax resin. At one time plant powder used locally for domestic lighting, as a substitute for kerosene and for soap manufacture. Latex has been used in the manufacture of chewing gum; and resin was utilised during World War II.	The wax resin could probably be used in the preparation of varnishes, based on drying oils, and adhesives. It has the following characteristics: acid val., 41.3; sap. val., 100.7; softening point, 91—92°C; m.p., 134—141°C. Lupeol, lupenone taraxerone, taraxerol acetate and olean—13(18)-en-3-one (triterpenes) have been reported in the plant.	At one time latex was exported to the USA, but ceased because of high cost of extraction. Resin examined in early 1950s, but considered to have a very limited commercial potential. Latex causes dermatitis.	Carrazzoni, 1966 Rosenthal, 1954
149. *Euphorbia pirahazo* Jum. Madagascar.		At one time exploited as a source of rubber which was reported to be of good quality.	Plant now very rare owing to over-exploitation.	Perrier de la Bathie, 1949 Polhamus, 1962 Uphof, 1968
150. *Euphorbia poisonii* Pax (Candle plant, Tinya) W. Africa.	Latex used in indigenous medicine, and as a counter-irritant drug; also as an insecticide and fish poison.	Four chemically related diterpene toxins have been isolated from the latex: a 12-deoxy-4β-hydroxphorbol and its 20-acetate, resiniferatoxin (*see* next entry) and tinyatoxin, the last two compounds being the most potent toxins so far obtained from the Euphorbiaceae.	Latex can cause skin lesions and inflammation of the mucous membranes; and chronic exposure is reported to cause blindness.*	Dalziel, 1948 Evans and Kinghorn, 1975 Evans and Schmidt, 1976 Hecker, 1977 Schmidt and Evans, 1975 Schmidt and Evans, 1977

*For general points concerning the *Euphorbia* spp., *see* footnote* on p.39.

List of plants tolerant of arid or semi-arid - Part 42

Name(s)/Distribution	Current/past uses	Potential	Constraints*	Citation data
151. *Euphorbia resinifera* Berg. (Euphorbium) N. Africa, especially Morocco.	Dried latex is a source of the commercial drug euphorbium – used, mainly in veterinary medicine, as a counter-irritant drug.	Latex contains 33–36% solids, of which 6–8% rubber, 40–51% resins, 28–30% waxes, 11% water-soluble compounds (pectin and protein, 4.6–7%). Latex also reported to contain: phorbic acid (a water-soluble C8-acid), euphol, euphorbol, taraxol, resiniferol, (all triterpenes), an irritant diterpene ester, resiniferatoxin. Latex investigated during 1940s as a possible source of rubber. (–)-quinic acid, D(+)-α-hydroxyglutaric acid, myoinositol, L(–)-inositol and probably vanillic acid have been reported in crude euphorbium. Certain fractions in the resin have shown promising anti-tumour activity.	Workers collecting the crude coagulated latex have to be protected because it is so acrid. Certain fractions in the resin are reported to be carcinogenic. For utilisation as a source of rubber, it was found essential to remove all the resin and to purify if one is to obtain a satisfactory, durable rubber. The prickly nature of the plant and the vesicant properties of the latex* are a considerable handicap to its commercial exploitation.	Audy, 1942 Bernatek *et al.*, 1963 Boe *et al.*, 1969 Chopra *et al.*, 1960 Compagnon and Ziller, 1942 Dupont *et al.*, 1947 Dupont *et al.*, 1951 Dupont *et al.*, 1953 Hecker, 1977 Hergenhahn *et al.*, 1975 Kopaczewski, 1946 a, b Lavie *et al.*, 1963 Le Bras, 1942
152. *Euphorbia royleana* Boiss. (Thor) SE. Asian sub-continent.	Used in indigenous medicine as an anthelmintic and cathartic; also used as a fish poison.	Fresh latex has a rich sweet odour. Reported to consist of 64–80.5% water and water-soluble compounds and 1.0–5.4% rubber. Euphol, cycloeucalenol, sitosterol, taraxerol, epitaraxerol, glut-5-en-3β-ol (all triterpenes), ellagic acid and 3, 4-benzocoumarins reported present in the latex. Taraxerol also present in stem tissue and ellagic acid in the flowers.	Latex is reported to cause dermatitis and to be injurious to the eyes.* Plant extracts irritant.	Anjaneyulu *et al.*, 1974 Ayensu, 1979 Chopra *et al.*, 1960 CSIR India, 1952 Ghosal *et al.*, 1976 Nazir *et al.*, 1965 Nazir *et al.*, 1966 Sengupta and Ghosh, 1965 Sharma *et al.*, 1964b
153. *Euphorbia thi* Schweinf. Tropical Africa, especially in the Sudan and Somalia.		Latex contains 6.8% rubber and 61.2% resins. Plant investigated during World War II as a source of rubber.		Sudan, Report of the Government Analyst, 1942
154. *Euphorbia thymifolia* L. Widely distributed in the tropics, especially Asia.	Used in Indian indigenous medicine for treatment of asthma, bronchitis, skin diseases, etc. The essential oil present is used as an insecticide and vermifuge and in medicinal soaps.	Taraxerol, tirucallol (triterpenes), a C_{30} wax alcohol (myricyl alcohol) and hentriacontane identified in plant extract. Presence of antimicrobial alkaloids has been reported. Stem and leaves contain free fumaric acid and 5, 7, 4'-trihydroxyflavone-7-glycoside. Essential oil has a pungent odour and irritating taste; its constituents include carvacrol, limonene, various sesquiterpenes and salicylic acid.		CSIR India, 1952 Gupta and Garg, 1965 Gupta and Garg, 1966b Jabbar and Khan, 1964

*For general points concerning the *Euphorbia* spp., *see* footnote* on p.39.

List of plants tolerant of arid or semi-arid - Part 43

Name(s)/Distribution	Current/past uses	Potential	Constraints*	Citation data
155. *Euphorbia tirucalli* L.; syn. *E. scoparia* NE. Br. (Milk bush, Indian tree spurge, petrol tree [also used for *E. lathyris*], potato gum tree, finger euphorbia) Native of Africa, but now widespread in the drier parts of the tropics, especially in the SE. Asian sub-continent.	Shrub or tree grows to 20 ft (6 m). Commonly grown as a hedge plant (partly because the irritant latex acts as a deterrent). Latex, roots and branches used in indigenous (mainly external) medicine in Africa and Asia, and as a fish poison. Attempts made to utilise the latex as a commercial source of rubber in South Africa during rubber boom of early 1900s and World War II, and (during World War II) to utilise the resin present in the latex.	Chemical composition of latex varies according to origin and to some extent whether fresh or dried. Analysis of S. African latex: moisture, 51.3%; rubber, 8.3%; resins; 30.4%; impurities, 4.0%; ash, 6.0%. Rubber, which is stable to paling and aging, has lower tensile and higher elongation values than *Hevea* rubber. Resin has acid val., 3.5–9.5; sap. val., 41–47; m.p., 51–60°C. In addition to the irritant deoxyphorbols (and/or analogues), latex contains euphol, taraxasterol and tirucallol (triterpenes). Stems contain hentriacontane, hentriacontanol (waxes), β-sitosterol, taraxerol (triterpenes), kaempferol (flavone), ellagic acid (a phenol) and its 3, 3-dimethoxy derivative. Plant has been suggested as a source of papermaking material mixed with bagasse and sisal; and is currently being investigated as a possible source of fuel† (e.g. by OALS, Arizona (Davis, 1978a) and by Calvin) – in this case, in contrast to *E. lathyris* (q.v.), by tapping the mature tree. Plant and extracts said to show insect-deterrent activity.	Latex is a potent co-carcinogen (*see* footnote* for definition), very irritant to mucous membranes and difficult to handle, which handicaps any commercial exploitation*. High cost of harvesting and difficulty of extracting the rubber, because of the high resin content of the latex, made exploitation in S. Africa uneconomic. The rubber manufactured from the latex is said to be of low grade and the resin to be unsuitable for making varnish as it lacks durability. Many problems with obtaining a fuel (*see* entry no. 144).	Anon, 1942c Anon, 1943b Anon, 1944b Anon, 1977b Calvin, 1978 Chopra *et al.*, 1960 De Parcevaux and Allirand, 1977 Dutta and Karimullah, 1944 Furstenberger and Hecker, 1977 Gopalachari and Siddiqui, 1949a, b Gupta and Mahadevan, 1967 Haines and Warren, 1949 Karimullah and Gopalachari, 1949 Kinghorn, 1979 Kopaczewski, 1947 Martin, 1944 McDonald *et al.*, 1949 Seelkopf *et al.*, 1959 Vanderplank, 1945 Wang and Huffman, 1981 Watt and Breyer-Brandwijk, 1962
156. *Euphorbia trigona* Haw. (said to be synonymous with *E. neriifolia* (q.v.); Watt and Breyer-Brandwijk, 1962) SE. Asia.	Leaves and latex used in indigenous medicine.	Latex contains resin, malic acid and rubber (1.5%). Vegetative parts are reported to contain hydrocyanic acid.	The latex is acrid and vesicant (*see* comment left *re* HCN content).	Badhwar *et al.*, 1946 Burkhill, 1935 CSIR India, 1952
157. *Euphorbia unispina* NE. Br. (Candle plant) W. Africa.	Latex used in indigenous medicine as a counter-irritant drug and as a fish poison. Often grown as a hedge plant (*see* entry no. 155) and other *Euphorbia* entries).		Latex is very irritant to skin due to the presence of aliphatic esters of 12-deoxyphorbol, especially resiniferatoxin.*	Evans and Kinghorn, 1975 Hecker, 1977 Hergenhahn *et al.*, 1975 Schmidt and Evans, 1977

*For general points concerning the *Euphorbia* spp., *see* footnote* on p.39.

†*see Asclepias* spp.

List of plants tolerant of arid or semi-arid - Part 44

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
158. *Fallugia paradoxa* (D. Don) Endl.; syn. *F. acuminata* (Woot.) Cockerell (Apache plume) SW. USA, Mexico.	Forage crop and as a shrub for controlling erosion (said to be excellent for this).	Seed contains: protein 30.6%; oil 36.8%. Hence a possible oilseed.		Benson and Darrow, 1944 Deitschman *et al.*, 1974 Jones and Barclay, 1972
159. *Ferula alliacea* Boiss.* (Hing) E. Iran.	One of the principal sources of the gum-resin known as 'asafoetida', used medicinally (as a carminative and expectorant) and as a flavour and condiment. It is obtained as an exudate by slicing the upper part of the root and is marketed in three forms: teas, mass and paste.	Chief constituents of asafoetida are: resin, 40—64%; gum, 25%; essential oil, 10—17%; ash, 1.5—10%; plus traces of umbelliferone. Resin appears to consist of asaresinotannol both free and combined with ferulic acid. Gum is mainly a mixture of polysaccharides (D-galactose, L-arabinose, L-rhamnose and glucuronic acid). The presence of two unidentified pinenes, isobutyl propenyl disulphide (mainly responsible for the characteristic odour), and various other disulphides has been reported.	Commercial samples of asafoetida are frequently adulterated with cheaper gums, starch and cereal flours; very unpleasant to take and many medicinal alternatives.	Arnon, 1972 Chopra *et al.*, 1960 CSIR India, 1956 Guenther, 1950 Jones and Thomas, 1961 Kazmi, 1951 Martindale, 1977 Raghavan *et al.*, 1974 Shivashankar *et al.*, 1972
160. *Ferula assa-foetida* L. (Hing) India (Punjab, Kashmir), Iran, W. Afghanistan.	A source of the gum-resin, asafoetida: *see* entry no. 159.	*See* entry no. 159. This species has been suggested as a suitable crop for cultivation in the arid wastelands of Pakistan.	*See* entry no. 159.	Chaudri, 1955 and references under entry no. 159
161. *Ferula foetida* Regel (Hingra) S. Turkey, Iran, Afghanistan.	One of the principal sources of the gum-resin asafoetida.	*See* entry no. 159.	*See* entry no. 159.	*See* entry no. 159

*About 60 species are widely distributed in C. Asia, Europe and N. Africa; in addition to those listed, the N. African species *F. communis* L. and *F. tingitana* L. (syn. *F. sancta* Boiss.) are of minor commercial importance as a source of 'ammoniac of Morocco' (used medicinally) and various other species, e.g. *F. narthex* Boiss. and *F. persica* Willd., are sometimes used in Asia as a source of asafoetida (*see* entry no. 159).

List of plants tolerant of arid or semi-arid - Part 45

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
162. *Ferula galbaniflua* Boiss. & Buhse.[†] (Galbanum) Iran	Source of an oleo-gum resin, galbanum, used medicinally (as an expectorant), as a flavouring, and also in perfumery. It is obtained, like asafoetida (*see* entry no. 159), by incising the stem or root. Two types are available commercially – Levant, or soft, galbanum, and Persian, or hard, galbanum. Reported to be of some importance in the French perfumery industry.	Gum resin composition typically: resin, 50–70%; gum, 20%; essential oils, 25%; ash, up to 8%; moisture, 1–10%. Resin consists of umbelliferone (free and combined), galbanic acid (a coumarin carboxylic acid) and two isomeric lactones. D-α-pinene, β-pinene (ca. 55%), myrcene, cadinene, camphene, β-ocimene, 3-carene and α-carene and α-cadinol reported in the essential oil, plus a group of eight pyrazines, including 2-methoxy-3-sec-butyl pyrazine (≤ 0.05%) found to be responsible for the oil's characteristic aromatic odour. Fruit also contains 2.35% of an essential oil, approximate composition D-β-pinene, 30%; DL-α- and D-α-pinenes, 40%; D-limonene, 1.5%.	Rarely used medicinally nowadays (except locally).	Arnon, 1972 Borisov *et al.*, 1973 Bramwell *et al.*, 1969 Burrell *et al.*, 1970 Chrétien-Bessière *et al.*, 1967 CSIR India, 1956 Guenther, 1950 Martindale, 1977 Naves, 1967 Naves, 1969 Shivashankar *et al.*, 1972 Teisseire, 1965
163. *Ferula suaveolens* Aitch & Hemsl. (Muskroot) C. Asia.	Dried roots used medicinally by, and to some extent as, a source of an essential oil ('oil of sumbul').	Root contains 9% of a gum resin and 0.2–1.37% of an essential oil with a musk-like odour (and so could have applications for many perfumes).	Despite its apparently desirable odour, the oil has never attained commercial importance (possibly because the musk odour is only 'faint').	CSIR India, 1956 Guenther, 1950 Shivashankar *et al.*, 1972
164. *Ferula sumbul* (Kauffm.) Hook. f. (Muskroot) C. Asia.	As for previous entry, the two species being used interchangeably.	As for previous entry.	As for previous entry.	*See* previous entry
165. *Fouquieria splendens* Engelm. (Ocotillo, ocote, candlewood shrub, coachwhip, devil's walking stick) SW. USA (particularly the Sonora desert); Mexico.	Wax resin from stems reported to be used for a belt dressing and earlier for rubber. Plant extract used medicinally by Apache Indians. Stems used for fencing and construction. Flowers are edible.	A triterpene, ocotillol ($C_{30}H_{52}O_3$), m.p. 198–200°C, and with an unusual (cyclic ether) side-chain structure, has been isolated from the waxy resin; also two new triterpenes, fouquierol and isofouquierol.		Anon, 1916 Benson and Darrow, 1944 Burgess, 1966 Butruille and Dominguez, 1974 Halls and Warnhoff, 1963 Krochmal *et al.*, 1954 Warnhoff and Halls, 1965

[†] *F. ceratophylla* Regel & Schmalhausen, from Turkestan, and *F. rubricaulis* Boiss, from N. Iran, are also sometimes used to a limited extent as a source of galbanum.

List of plants tolerant of arid or semi-arid - Part 46

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
166. *Garcia nutans* Rohr (Piñocillo) Mexico, Venezuela.		Seed contains about 41% oil, kernel, 53–56%. Oil has sap. val., 189.2–192.4; iod. val., 176.8–177.8; acid val., 1.1; fatty acid composition: elaeostearic (conjugd triene; C_{18}), 85–91%; oleic, about 10%; trace linoleic. Hence a possible drying oil (similar to tung oil) and investigated as such during 1940s.	At the time of the investigations in 1940s, natural supplies were estimated at less than 10 tonnes p.a. and experimental plantings were made in the USA to assess its usefulness but there has apparently been no follow-up.	Cruse, 1949 Gardner and Westgate, 1943 Lundell, 1945 Lynch, 1944 Madrazo and Sierra, 1954 Westgate, 1944
167. *Glycyrrhiza glabra* L.* (Liquorice, licorice) Mediterranean, Asia Minor; has been introduced successfully into SE. Asian sub-continent.	Extract of dried roots widely used in medicine, particularly as an expectorant. Also used as a flavouring, especially for tobacco in the USA, as a sweetener and in confectionery. More recently used as a source of glycyrrhet(in)ic acid used in the treatment of Addison's disease and in the preparation of anti-inflammatory agents for the treatment of gastric ulcers. Chief producers of liquorice root are: Spain, France, Greece, Italy, Iran, Iraq, Turkey, Lebanon, Israel and USSR. Principal producers of solid extract are: USA, France, Italy, Turkey and Israel.	Principal constituents of roots: glycyrrhizin, 2–14%; glucose, up to 3.8%; sucrose, 2.4–6.5%; starch, 30% asparagine, 2–4%; essential oil, 0.03–0.35%. Glycyrrhizin is the potassium salt of a triterpenoid saponin, glycyrrhinic acid, the parent aglycone of which is glycyrrhetic acid. In addition, several minor constituents have recently been identified – including various other (related) triterpenes, various flavonoids (flavones such as formononetin, liquiritigenin, liquiritin; isoflavones such as glyzarin; and two chalcones) and a coumarin, liqcoumarin. To what, if any, extent these substances contribute to the medicinal effect of crude root extracts is unknown. Spent pulp left after extraction can be utilised for the production of a foam stabiliser, foaming agents, alcohol, insulation boards, etc.	Demand is mainly for extract and is fairly static. Establishment of extraction plants involves a relatively high capital outlay. The plant is not a complete xerophyte (but Drar considered that it would be valuable to study it under desert conditions). Value in ulcer treatment disputed.	Bhardwaj *et al.*, 1976a Bhardwaj *et al.*, 1976b Bhardwaj *et al.*, 1977 Chopra *et al.*, 1960 CSIR India, 1956 Drar, 1955 Elgamal *et al.*, 1965 Elgamal *et al.*, 1972 Elgamal *et al.*, 1975 Hulle *et al.*, 1971 International Trade Centre, 1974 Isenberg, 1956 Larkworthy *et al.*, 1977 Masters, 1972 Paris and Dillemann, 1960 Saitoh and Shibata, 1975
168. *Grindelia squarrosa* (Pursh) Dunal (Curly cup gum weed, resin weed, tarweed) Western N. America from Saskatchewan to Mexico, particularly along dry river beds.	Decoction of flowers and leaves at one time used as an anti-spasmodic and stomachic.	Contains a sterol glucoside ('grindelol') and an alkaloid, grindeline; also many diterpenes and flavonoids. Seeds contain protein, 14%; oil, 20% (with iod. val., 138, sap. val., 186). A possible oilseed.	It has been suggested that there needs to be a revaluation of the chemotherapeutic properties of *Grindelia* spp.	Ayensu, 1979 Cheney, 1962 Earle *et al.*, 1960b Krochmal *et al.*, 1954 Krochmal and Krochmal, 1973

* There are several sub-species, of which the most xerophile is *G. glabra* var. *violacea* Boiss., Persian liquorice.

List of plants tolerant of arid or semi-arid - Part 47

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
169. *Gynandropsis gynandra* (L.) Briq.; syn. *G. pentaphylla* DC (Cat's whiskers) Tropics generally (especially India, S. China and W. Africa).	Seeds used as an anthelmintic. Leaves used as a pot-herb and for flavouring and in traditional medicine.	Seeds contain 17–22% of a greenish oil, with faint mustard odour. Sap. val., 194: iod. val., 114–122; unsap. matter, 2–3.5%. Approx. fatty acid content (pre-g.l.c.): linoleic, 54%; linolenic, 2%; oleic, 15%; palmitic, 18%; stearic, 8%; arachidic, 2%; myristic, trace. A possible oilseed: in particular the oil considered to have potential for soap manufacture. β-D-glucoside of β-sitosterol and free β-sitosterol (triterpene), hexacosanol (a wax alcohol, $C_{26}H_{54}O$) and kaempferol (a flavone; $C_{15}H_{10}O_6$) also isolated from the seeds. An unsaturated lactone ($?C_{17}H_{14}O_7$), said to be cause of medicinal activity, reported early on but not confirmed on reinvestigation.	Collection of seeds (for oil) said to be a problem. High acid value of stored oil sample may indicate a strong lipolytic factor in the seed. Plant, which is an annual, reported to be poisonous to poultry and sheep in Australia. Bruised leaves tend to be vesicant.	CSIR India, 1956 Gupta *et al.*, 1968 Sen Gupta and Chakrabarty, 1957 Sen Gupta and Chakrabarty, 1964a Uphof, 1968
170. *Gypsophila rokejeka* Delile (White or Levantinian soap root) Middle East.	Used in the preparation of halava (a confection typically made from sesame seeds and honey).	Plant contains up to 16% saponins. Suggested worth investigation as a source of sapogenins (precursors of steroidal drugs).	Present-day market for steroidal sapogenins is indifferent.	Coppen, 1980 Zaitschek, 1953
171. *Haloxylon* spp. (Saksaul, saxaul (for various tree species), ghada tree) Mediterranean region, USSR, Algeria, Syria, Afghanistan, Iran.	Trees and shrubs in desert regions whose timber is used as a fuel.* In addition *H. schweinfurthii* Aschers. ex Aschers. & Schweinf., is source of a manna, and the gum is consumed by Bedouins; the wood is used for carpentry, and the tree planted as a sand-binder. Ash of *H. ammodendron* Bunge is used in Kazakstan for control of mange in sheep; and *H. persicum* Bunge ex Boiss & Buhse provides camel fodder and grows in areas with 25 mm (1 in.) rainfall annually.	Anabasine (a nicotine-like compound) found as the major alkaloid in *H. persicum* and nicotine the minor alkaloid (both powerful insect poisons). Total alkaloid content, 5.4% on dry basis. Eight alkaloids, including halosine of known (C_{10}) structure, have been found in *H. salicornicum* Bunge ex Boiss. *H. aphyllum* (Minkw.) Iljon can provide both cattle fodder and fuel; and desert reclamation/cultural experiments are being conducted in the USSR. Haloxylon wood is equal to coal in calorific value and is already used as a basic fuel of the desert people in C. Asia.	*H. ammodendron* only grows very slowly and the wood is extremely hard. The alkaloids are of little medicinal value. Anabasine and nicotine avoided nowadays wherever alternatives are available.	Babayev, 1978 Habib *et al.*, 1974 Lagereva, 1947 Linnard, 1960 Michel *et al.*, 1969 Paris and Dillemann, 1960 Rivière, 1931 Sandberg *et al.*, 1960 Uphof, 1968 Zohary, 1940a, b

* *H. aphyllum* and *H. persicum* considered potential firewood species by the National Academy of Sciences, 1980.

List of plants tolerant of arid or semi-arid - Part 48

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
172. *Hancornia speciosa* Gomes (Mangabeira, mangaba) NE. Brazil.	Was exploited commercially for rubber in early 1900s and during World War II, and even now used locally as a source of second-class rubber; fruits used for juices, sherberts and ice cream.	Rubber content of latex, 25–40%; high in resins (10–13%).	Low yields of latex, often trees can be tapped only once a year. Soft rubber deteriorates on storage; need to improve processing.	Mors and Rizzini, 1966 Polhamus, 1962 Santa Rosa, 1960 Schery, 1949
173. *Haplophyton cimicidium* A.DC* (Cockroach plant) Mexico from Guaymas, Sonora southeastward, and Guatemala.	Traditionally used to poison cockroaches, lice, flies, etc.	Contains a series of indole alkaloids mainly of the eburnamine and aspidospermine (5 and 6-rings respectively) types such as: haplophytine ($C_{37}H_{40}N_4O_7$: up to 0.03%), cimicidine ($C_{23}H_{28}N_2O_5$), haplocine ($C_{22}H_{28}N_2O_3$), haplocidine ($C_{21}H_{26}N_2O_3$), and cimicine ($C_{23}H_{26}N_2O_4$). Some are structurally similar to the anti-tumour vinca alkaloids and so may have interesting pharmacological activity. Potential insecticide; effective against fruit-flies.	Insecticidal activity varies, probably according to growing conditions. Cheap production would be necessary to compete against synthetics.	Benson and Darrow, 1944 Caldwell, 1966 Cava *et al.*, 1963a, b Plummer, 1938 Roark, 1947 Rogers *et al.*, 1952 Snyder *et al.*, 1954a, b Yates *et al.*, 1973
174. *Heliopsis longipes* (A. Gray) S. F. Blake (Chilcuague, chilcuan) Mexico.	Extract of roots employed in the preparation of insecticides for local use.	Roots contain about 1% of an amide, N-isobutyl-2, 6, 8-decatrienoamide, which has a similar paralysing action and toxicity to houseflies as the pyrethrins. Originally, sample examined by USDA was designated *Erigeron affinis* DC and considered to be a promising natural insecticide.	Distribution restricted: cultivation would be necessary to supply commercial quantities.	Acree *et al.*, 1945a, b Jacobson *et al.*, 1947 Little, 1948 McGovran *et al.*, 1947 Roark, 1947
175. *Hyoscyamus albus* L. (White henbane) Grows wild in Mediterranean countries, particularly Egypt.	Drug plant; source of the alkaloid hyoscyamine (*see* entry no. 176).	All plant parts contain alkaloids, principally hyoscyamine plus some hyoscine. Alkaloid content varies: roots, 0.1–0.3%; leaves, 0.06–0.56%; stems, 0.07–0.13%; flowers 0.13%; fruits, 0.06%; seeds, 0.04%. The plant is used in some countries as a substitute for the official drug henbane, *see* entry no. 176.	Similar constraints to those noted under entry no. 176: competition from synthetic substitutes and from other natural sources. Also low (? and erratic) alkaloid content.	Chopra *et al.*, 1960 Khafagy *et al.*, 1965

* A closely related species *H. crooksii* L. Benson, the Arizona cockroach plant (found in the desert areas of Arizona, New Mexico, Texas and Mexico) has been suggested as an effective insecticide, but does not appear to have been investigated.

List of plants tolerant of arid or semi-arid - Part 49

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
176. *Hyoscyamus muticus* L. (Egyptian henbane) Indigenous to Egypt, but now extends eastwards to Pakistan (Punjab and Sind).	Drug plant; commercial source of the alkaloids hyoscyamine and hyoscine — these being, respectively, an optical isomer of atropine with similar, and important, pharmacological activity and its epoxide derivative. Both are used widely in various medicinal preparations — as 'calming' agents in, for example, travel sickness pills, in eye ointments etc.	Commercial samples normally contain 0.6–1% total alkaloids, of which 90% is hyoscyamine. Alkaloid content highest in leaves, up to 1.4%; (seed, 0.9—1.3%; stems, 0.6%). In the Negev desert plants with a total alkaloid content of 2.5% have been obtained experimentally. Other constituents are hyoscine, traces of atropine and tetramethyl-diamino-butane. The seeds also have medical properties but are rarely used — the dried leaves (and flowers) normally being the parts used for drug preparations.	At one time wild plants in Egyptian deserts were exploited on such a large scale that natural supplies were endangered. Attempts to cultivate have not been very successful and have been handicapped by declining demand, partly because of synthetic substitutes and the availability of other natural products: eg the closely related species *H. niger* L. and *Duboisia* spp. (*see* entry no. 113). In addition cultivated plants were found to have a lower alkaloid content that those growing wild (though aridity reported to increase alkaloid content). Was (? and still is) considered to be a promising crop for the Negev and arid areas of Pakistan and India; however experimental plantings in India yielded plant material with a low alkaloid content.	Ahmed and Fahmy, 1951 Chaudhri and Saleem, 1962 Chopra *et al.*, 1956 Chopra *et al.*, 1960 CSIR India, 1959 Drar, 1954 Duisberg and Hay, 1971 Evenari *et al.*, 1971 Martindale, 1977 Mital and Saxena, 1977 Paris and Dillemann, 1960 Saber and Balbaa, 1954 Zaitschek, 1953
177. *Hyphaene thebaica* (L.) Mart (Egyptian doum palm, ginger bread palm) Native of Egypt, but widely distributed in more arid parts of W and E. Africa; also found in SE. Asian sub-continent.	Fruit kernel formerly utilised as a source of vegetable ivory, used for the manufacture of buttons. Now used in local crafts. Fruit and roots used in indigenous medicine. Leaf and root fibre used locally for ropes; leaf also used for thatching, baskets, etc. Fruits and immature kernels are also used for various edible products. Timber used for construction.	Kernel contains 6–10% of an edible oil; sap. val., 225—249; iod. val., 28—33; unsap. matter 1.9%; f.f.a. content, 1.3—1.6%; fatty acid composition: caprylic, 0.7—1.3%; capric, 2.8—7.0%; lauric, 31.8—38.4%; myristic, 14.8—19.9%; palmitic, 7.1—13.8%; stearic, 1.4—4.8% (C_8—C_{18} saturated acids); and oleic, 24.8%; linoleic, 0.7%. Fibre properties: wt. per unit length (tex), 10.4; breaking stress (g/tex), 35; extension to break, 4.8%. Length of ultimate fibres, 1.7—1.9 mm, diameter, 13 μm; cell wall thickness, 4.5 μm. Possible source of paper pulp.	Oil content too low for exploitation as an oilseed. Now only used to a very limited extent for the manufacture of speciality buttons and craft articles. Although good quality paper is obtained from the leaf pulp, yield is poor. Wood gives inferior quality pulp. Extraction of the fibre is difficult and laborious and there is a need to develop more efficient decortication methods. Has been suggested as a useful tree for the Sahara but requires underground water near the surface.	Coursey, 1964 CSIR India, 1959 Drar, 1954 Giffard, 1966 Laws and Jarman, 1962 Osborn, 1968 Rajagopal and Achaya, 1961

List of plants tolerant of arid or semi-arid - Part 50

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
178. *Hyssopus officinalis* L. (Hyssop) Native of Mediterranean region and temperate Asia; has been naturalised in the USA.	Source of an essential oil used medicinally, for perfumery, and as a flavouring (particularly for liqueurs).	Yield of essential oil from dried leaves and flowering tops about 0.8%. About 50% of this ('hyssop') oil consists of the (C_{10}) pinane derivative L-pinocamphone; other compounds present include α- and β-pinenes, l-pinocampheol, and a series of minor mono- and sesquiterpenes. Seeds contain: protein, 27%; oil, 29.4% and hence a possible oilseed crop. Has been recommended as an anti-erosion crop, particularly in semi-arid mountainous regions.	The essential oil is relatively expensive and is sometimes adulterated with lavender or rosemary oils. Possible climatic constraints (*see* 'Distribution').	CSIR India, 1959 Guenther, 1949 Jones and Barclay, 1972 Joulain and Ragault, 1976 Katz, 1950 Paris and Dillemann, 1960 Sharma *et al.*, 1963 Tucakov, 1960
179. *Isomeris arborea* Nutt. (Burro fat) SW. USA.		Seeds contain: 37--40.6% protein; 42—45% oil; sap. val., 189; iod. val., 107. Hence possible oilseed?	No *non*-food uses actually recorded (in references available).	Benson and Darrow, 1944 Earle *et al.*, 1960b Jones and Barclay, 1972
180. *Jatropha cardiophylla* (Torr.) Muell. Arg. (Limber bush) SW. USA (Arizona, Sonora desert), Mexico.	Reddish root juice, at one time used as a tanning material or a dye. Said to be used medicinally in Mexico.	Roots contain over 5% tannic acid on a dry basis. Stems are reported to contain 3% rubber.		Benson and Darrow, 1944 Hall and Long, 1921
181. *Jatropha cinerea* (Ortega) Muell. Arg. (Lomboi, ashy jatropha) SW. USA (Sonora desert), Mexico.	Said to be used medicinally in Mexico.	Seeds contain: protein 28.1%; oil, 50.9%. Oil has sap. val., 188; iod. val., 105; fatty acid composition: linoleic, 6.3%; oleic, 65.2%; saturateds, 15%. Possible oilseed.		Bachstez and Ripoll Gomez, 1954 Benson and Darrow, 1944 Reis Altschul, 1973
182. *Jatropha cuneata* Wiggins & Rollins; syn. *J. spathulata* (Ortega) Muell. Arg. (Sangre de drago) SW. USA, Mexico.	Stems used for making baskets and whips. Bark used for tanning and as a source of red dye. Used medicinally in Mexico.	Presence of alkaloids reported (? possible medicinal value).		Benson and Darrow, 1944 Dominguez *et al.*, 1960 Uphof, 1968

List of plants tolerant of arid or semi-arid - Part 51

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
183. *Jatropha curcas* L. (Physic nut, purging nut, pig nut, Barbados nut) Shrub which is very widely distributed throughout the tropics (grown commercially in the Cape Verde Islands and in Madagascar).	Used medicinally (purgative) in many parts of the tropics. Source of a semi-drying oil, used for a variety of purposes, e.g. soap manufacture, medicinally, as an illuminant, textile lubricant and, after chlorination, as a plasticiser. Detoxified oil cake has been used as a protein nutrient source in production of antibiotics by microbial fermentation. Oilcake also used for production of synthetic fibres.	Kernel forms 60–80% of seed weight and yields about 18% protein, 46–60% oil. Oil has sap. val., 188–196; iod. val., 93–107; unsap. matter 0.4–1.1%; fatty acid composition: oleic, 37–63%; linoleic, 19–40%; palmitic, 12–17%; stearic, 5–6%; arachidic, 0.3%; myristic, 0.5%. Suggested use is as a motor oil in diesel engines (and if purified and refined, for edible purposes?) β-D-glucoside of β-sitosterol has been isolated from the seed, stem and bark. β-amyrin, taraxerol and β-sitosterol (triterpenes) present in stem bark. Leaves contain stigmasterol, β-sitosterol, and another triterpene alcohol. Plant also exudes an acrid latex containing 14.6% resin. The bark also contains tannins (37% dry basis), a wax (a mixture of 'melissyl' (myristyl C_{14}) alcohol and myristyl myristate), and a dark blue dye. Has been suggested as a suitable crop for the arid and semi-arid areas of NE. Brazil, not only as a oilseed, but also as an anti-erosion and soil improving crop. In some areas the seed is used to adulterate castor seeds. An alcohol extract of the aerial parts shows anti-tumour activity.	The seeds (and the crude oil) contain a toxic principle, curcasine, which produces skin lesions on mice — and so may present handling problems; and the latex is said to be 'acrid'.	Coursey, 1964 CSIR India, 1959 El Kiey *et al.*, 1966a Godin and Spensley, 1971 Hufford and Oguntimein, 1978 Khafagy *et al.*, 1977 Mensier and Loury, 1950 Mitra *et al.*, 1970 Santa Rosa, 1949 Santa Rosa, 1960 Stirpe *et al.*, 1975 Vyas and Desai, 1952 Williams, 1966
184. *Jatropha macrorhiza* Benth. Arizona, Mexico.	Used by the Mexicans as a purgative.	Plant root extract found to have tumour-inhibitory action and recently two anti-tumour agents have been isolated: jatropham (5-hydroxy-4-methyl-3-pyrrolin-2-one) and a diterpene, jatrophatrione ($C_{20}H_{26}O_3$).		Reis Altschul, 1973 Torrance *et al.*, 1976 Torrance *et al.*, 1977 Wiedhopf *et al.*, 1973
185. *Jatropha phyllacantha* Muell. Arg.; syn. *Cnidoscolus phyllacanthus* Muell.–Arg. Pax & Hoffm. (Favela, favelera) NE. Brazil.	Source of edible oil, suitable for use as a salad oil and for soap manufacture. Oilcake suitable for animal feeding and for enriching cassava flour. Bark and roots used for animal feed in times of drought. Wood used for fuel.	Seeds contain about 25% protein; 30–37% light yellow edible oil, sap. val., 195; iod. val., 109; saturated fatty acids, 27%; unsaturated, 72%. Residual oilcake has a protein content of about 26%. Exudes a latex which contains a combustible resin.	Shrub covered with large prickles exuding an irritant juice, which can cause harvesting problems. At one time considered to have a potential as an industrial crop in NE. Brazil but handicapped by harvesting problems (but the potential could be improved by exploiting a recently claimed 'non-spiny' variety).	De Parcevaux and Allirand, 1977 Dodsworth Machado *et al.*, 1950 Mors and Rizzini, 1966 Santa Rosa, 1949 Santa Rosa, 1959 Santa Rosa, 1960

List of plants tolerant of arid or semi-arid - Part 52

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
186. *Juncus acutus* L.* Europe, Mediterranean, Israel, on the sandy dunes of the coastal plain.		A tussocky, low rush. Approximate composition of stems (oven-dry material): cellulose, 47.3%; pentosans (possible raw material for furans and allied chemicals), 22.4%; lignin, 20.0%; ash, 5.4%. Fibres are fine with an average length of 1.11 mm. Seeds contain an oil (? edible) and are rich in organic acids, sugars and amino acids. Considered to be a potential papermaking material in Israel. Pulp would be suitable for writing paper (grade index 75%). Plant is very suitable for stabilization and fixing of sand dunes and absorbs salt from brackish soils.	Adequate growth may require N/P (fertiliser) supplementation; oil not yet tested for toxicity.	Lewin, 1953 Zahran *et al.*, 1979
187. *Juncus maritimus* Lam. N. Central Africa and SE. Asian sub-continent areas where there is brackish underground water.		Approximate composition of stems (oven-dry material): cellulose, 48.0%; pentosans, 23.7%; lignin, 18.65%; ash, 6.65%. Average fibre length, 1.46 mm; width, 12µm. Experimentally, a yield of 34—39% bleached pulp obtained, intermediate between esparto and straw pulps. Considered to be a potential source of paper pulp in Israel. Attempts made to develop cultivation in the Negev; is particularly suitable for saline soils.		Bloch *et al.*, 1954 Evenari and Koller, 1956 Lewin, 1953

* Similar remarks apply to *J. rigidus* Desf. — which on balance appears from the 1979 reports to be preferable to *J. acutus*.

List of plants tolerant of arid or semi-arid - Part 53

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
188. *Larrea divaricata* Cav.*† (Creosote bush, jarilla) In the Gran Chaco desert of Argentina (and also in similar areas of Chile, Bolivia, Peru).	Leaves and twigs have a resinous coating from which nordihydroguaiaretic acid (NDGA), a phenolic lignan (i.e. substituted dibenzylethane) used as an antioxidant in foods, cosmetics and pharmaceuticals, may be extracted. Plant extracts used in indigenous medicine in Mexico; found to have antimicrobial and tumour-inhibiting properties.	Dried leaves contain 14.0% crude protein; 18% ether extract (fats); 44% 'N-free extract' (mainly carbohydrates); 16–21% total phenolics (NDGA content, 8–9%); in addition the related lignans dihydroguaiaretic acid, norisoguaiacin (and its 3'-demethoxy derivative) have been isolated; and these compounds have anti-tumour activity. Leaves high in protein and could be used for production of animal feed. Possibility of integral utilisation of *Larrea* spp. investigated in Argentina. *See* also footnote†	From 1943 for about 25 years, utilised as a commercial source of NDGA (used as an antioxidant) but recently an improved synthetic method has been developed for the production of NDGA so that the future for the natural product is less promising. Also the use of NDGA in general, at least in foods, has recently been curtailed following toxicity studies which have led to its removal from the US Food and Drug Adminstration's GRAS ('generally recognised as safe') list; similar restrictions also apply in the EC. Commercial utilisation of the shrub for the production of an animal feedingstuff considered not economic, unless other products (e.g. NDGA or resins) are also obtained.	Bender, 1963 Blaizot and Cuvier, 1949 Duisberg, 1952a, b, c Duisberg and Hay, 1971 Gisvold and Thaker, 1974 Grice *et al.*, 1968 Horn and Gisvold, 1945 Krochmal *et al.*, 1954 Mabry *et al.*, 1977 Mizrahi, 1967 Oliveto, 1972 Paris and Dillemann, 1960 Parker, 1980 Waller and Gisvold, 1945
189. *Larrea tridentata* (Sessé & Moc. ex DC.) Colville† (Creosote bush, hediondilla, hideonado) SW. USA, N. Mexico.	The most common desert shrub in SW. USA. Utilised as source of NDGA *as per* the previous entry, and as a source of resin for varnish manufacture in 1940s.	Fresh, machine-threshed leaves reported to have a NDGA content of 1.31–1.84%. Also contain 0.54% of a dark-orange hard wax, m.p. 73.5°C. Fungicides can be made from the phenols (lignans) present in resin; and resin itself is fungistatic (fungicidal at high concentrations) and is also amoebicidal. Residual plant material could be used as fodder or for other conventional cellulose use. Subject of recent (1978) international conference at Centro de Investigación Quimica Aplicada (CIQA), Salthillo, Mexico ('Larrea: a vast resource of the American deserts') and a book (Mabry *et al.*). *See* also footnote†.	*See* previous entry. The 1979 authors note that it is 'a very aggressive shrub' which can be 'a major pest' since it invades, and overwhelms, any adjoining grassland; and that NDGA shows toxic effects.	Cruse, 1949 Fernandez *et al.*, 1979 Kurtz, 1958 Mabry *et al.*, 1977 Page, 1955 Paris and Dilleman, 1960 Tipton and McWilliams, 1979

* In addition, in the Gran Chaco desert *L. divaricata* forms associations with *L. cuneifolia* Cav. and *L. nitida* Cav.

† *L. divaricata* and *L. tridentata* are very closely related; in fact, some authorities do not consider that there are two distinct species while others (*see* e.g. Lloyd, 1979) consider the N. American creosote bush to be solely *L. tridentata* and the other *Larrea* species to be restricted to S. America. The comments are allocated to *L. divaricata* and *L. tridentata* as by the original authors, but can probably be combined. The leaves of all *Larrea* species contain, in addition to NDGA and its derivatives, a series (Mabry *et al.*, 1977) of flavonoid glycosides, terpenes (α-pinene, camphor, *etc.*), paraffinic hydrocarbons (and derived ketones), wax esters, and triterpene glycosides — some of which may be of use (? or could be used *in toto* as a fuel).

List of plants tolerant of arid or semi-arid - Part 54

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
190. *Leptadenia pyrotechnica* (Forssk.) Decne. syn. *L. spartium* Wight (Markh) Africa – particularly N. Nigeria, Sudan, Egypt and Mauritania; SE. Asian sub-continent.	Utilised for fodder and thatching; roots are sometimes eaten as a vegetable.	Plant has been suggested as being worth further investigation, e.g. as a possible source of fibre for rope and as a papermaking material.	Fibre reported to be difficult to extract.	Drar, 1954 CSIR India, 1962
191. *Lesquerella fenderli* (A. Gray) S. Wats.* (Fendler bladder pod) Indigenous to SW. USA and N. Mexico.		Seeds contain: protein, 20.6–22.5%; oil, 19.8–28.1%. Oil has iod. val., 105–108 and contains 57% lesquerolic acid (14-hydroxy-11-*cis*-eicosenoic (C_{20}) acid). Oilcake contains 34% protein, high in lysine. Hence considered to have potential as an industrial oilseed, similar to castor, and giving a versatile industrial oil rich in hydroxyacids and also a nutritious oilcake suitable for animal feed. Occurs as a winter annual in semi-arid areas of the USA and has received considerable R and D. Has been grown experimentally in Israel. A polymorphic species so selection could provide a high-yielding plant adapted to mechanical harvesting.	In Israeli experiments, germination rate was low (but plant breeding may help). Inactivation of lipolytic enzymes essential during extraction to obtain an oil with low f.f.a. content.	Barclay *et al.*, 1962 Duisberg and Hay, 1971 Gentry and Barclay, 1962 Knowles *et al.*, 1964 Mikolajczak *et al.*, 1962 Miller *et al.*, 1962 Princen, 1979 Princen, 1982 Sharir and Gelmond, 1971

*About 72 species are found growing wild as spring annuals or perennials in SW. USA and Mexico, with seeds containing 11–39% oil with a hydroxy acid content of 45–74%; and of these *L. fenderli* appears to be a species with potential as an annual, cool semi-arid, industrial oilseed crop.

List of plants tolerant of arid or semi-arid - Part 55

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
192. *Leucaena leucocephala* (Lam.) (Leucaena, ipil-ipil, horse tamarind, lead tree) Native to Mexico, but now widely distributed throughout the tropics.	A very quick-growing leguminous tree. Utilised mainly for forage, but wood can be used for fuel or making charcoal and for paper pulp, fibreboard etc. Pods and seeds sometimes used as a foodstuff. Seeds used for decorative purposes in craft work. Various parts of plant used in indigenous medicine, and as a source of dye. Also grown as an anti-erosion crop, ornamentally and for soil improvement, etc. Leaves provide a good green manure.	Protein content of foliage of high nutritional quality: amino-acids present in well-balanced proportions, similar to alfalfa. Considered to have potential as a versatile legume crop for non-acid soils in semi-arid and savannah areas. The leaves also have a high carotenoid content and can replace alfalfa or synthetic cartenoids in poultry feeds (to colour the egg yolks) although antioxidant may need to be added for prolonged storage. Wood is high in holocellulose (72%); pulp yield, 50–52% (comparable to other fast-growing hardwoods). Fibres have average length, 1.20 mm; diameter, 0.025 mm. Seeds contain 25% of a water-soluble gum (similar to gum arabic, guar, or carob bean) and 9% oil and is a potentially useful source of both. The oil has sap. val., 185; iod. val., 110; unsap. matter, 4.7%; fatty acid composition: linoleic, 54.3%; oleic, 23.6%; palmitic, 12.7%; stearic, 5.0%; behenic 3.6%; lignoceric (C_{24} saturated), 0.7%. Leucaena wood has high calorific value and its charcoal has 70% heating value of fuel oil. Coupled with high growth rate, should make good source of firewood. Philippines considering growing it in plantations as an energy source: 1 m barrels oil equivalent from 12,000 ha p.a.	Excessive amounts of pods/seeds or leaves in the diet, or forage (especially of non-ruminants), results in ill health (goitre) due to the presence of a toxic amino-acid (mimosine: 3.5%, dry wt. basis, of the protein). Need for considerable R and D to develop improved (especially low-mimosine) strains. Also there is the complication of there being three types — Hawaii (bushy), Salvador (tall), Peru (much foliage) — with character-istics appropriate to different uses (firewood, energy plantations, and forage respectively); and the Hawaiian can become an aggressive weed difficult to control under ideal con-ditions. However all types show a tendency to grow vigorously only at below about 500 m (or 1,000 m near the equator). Needs a reasonably heavy soil: poor growth on sandy, stony or shallow soils. Seedlings prone to grasshopper and termite attack. Use as a building material hampered by the wood's tendency to insect attack. Plant failed to provide protection against, specifically, soil erosion in gullies (Malawi). Its possible use as a com-mercial source of gum said to require further study.	Anon, 1977c Brewbaker and Hutton, 1979 CSIR India, 1962 FAO, 1976b Farooq and Siddiqui, 1954 National Academy of Sciences, 1977a USAID, 1978 Yabes, 1977

List of plants tolerant of arid or semi-arid - Part 56

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
193. *Licania rigida* Benth. (Oiticica) Indigenous to NE. Brazil.	A long-living (100 yrs) tree of up to 30 m high producing up to 2 tonnes p.a. seed which yields a drying oil similar to tung oil (an excellent drying oil in considerable demand for the manufacture of paints, varnishes, etc.) and used in the production of paints, enamels, varnishes, plasticizers, linoleum, etc.: an AZ equivalent of (and substitute for) tung oil.	Seed consists of 60–75% kernel containing 55–63% of a viscous, semi-solid oil with various uses but an unpleasant flavour and odour. Exports from Brazil about 9,000 tonnes p.a. in early, 1960s. Sap val., 186–195; iod. val., 139–185; unsap. matter 0.5–1%; saturated fatty acids 10–11%; oleic 4–6%; other unsaturated acids are mainly the C_{18} conjugated triene acids, α-licanic and an isomer of elaeostearic (coulpicic). Possibility of utilising oil-cake as a source of tannins or for the production of furfural has been investigated in Brazil; it contains 11.8% pentosans.	Supplies of the oil reported to be decreasing, partly because of variability of yields and cost of labour required for harvesting from wild trees. Need to develop plantation production is recognised (and some research being done). Conservation measures have been taken in Brazil and export of seed has been prohibited to prevent introduction elsewhere. Oil inferior to tung as regards colour (darker: can only be used for dark-coloured paints), drying rate and water resistance – but oiticica succeeds where tung (which needs 750–1,000 mm p.a. rainfall) will not. Oilcake not suitable for animal feed because of its purgative action.	Francois, 1952 Godin and Spensley, 1971 Kehren, 1963 Markley, 1957 Mensier, 1957 Santa Rosa, 1949 Williams, 1966
194. *Limnanthes alba* Hartw. ex Benth. (Meadowfoam) A winter annual, native to coastal areas of N. California and S. Oregon.		Seeds contain: protein, 20%; oil, 27%. The oil has iod. val., 94 and 95% of its fatty acids have more than 18 carbon atoms, major component acid (61%) being cis-5-eicosenoic (C_{20}). Could possibly be used as an industrial oil for the production of waxes, lubricants, detergents and plasticizers. Fully hydrogenated, a wax with a hardness approaching carnauba or candelilla is obtained. Genus considered to have potential for development as a source of an oil-wax similar to that obtained from jojoba. *L.alba* considered to be agronomically superior to other species and the most xerophytic; but all species have a mechanism of protective dormancy when temperatures are high.	All species require moisture, and soil temperatures of 16°C or less, for germination. Considerable R and D required on selection and breeding and also on utilisation of oil. Seeds contain (cf. rapeseed) thioglucosidic precursors of volatile isothiocyanates and a small amount of an oxazolidinethione-like compound (2.7 mg/g in the resulting meal).	Brown *et al.*, 1979 Devine and Johnson, 1978 Duisberg and Hay, 1971 Gentry and Miller, 1965 Higgins *et al.*, 1971 Miller *et al.*, 1964 Toy and Willingham, 1966 White and Wolff, 1968

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
195. *Lophocereus schottii* (Engelm.) Britton and Rose; syn. *Cereus schottii* Engelm. (Senita cactus, cina, cabesa de viejo) S. Arizona/N. Mexico (especially Sonora desert) and Baja California.		Total alkaloid content of 3.7% reported, mainly concentrated in the green epidermis. Alkaloids pilocereine and piloceredine plus smaller quantities of lophocerine have been isolated. Hence a possible source of these (tetrahydroisoquinoline) alkaloids – which may be of value as anti-malarial drugs. Five sterols also reported present.		Cruse, 1959 Djerassi *et al.*, 1953 Djerassi *et al.*, 1958 Kircher, 1969
196. *Lygeum spartum* ex. L. Loefl. (Albardine, esparto grass*) N. Africa (especially Tunisia), S. Spain; also found in Mexico	Source of paper pulp suitable for manufacture of writing, wrapping and kraft papers. Can also be used for cordage and sacking.	Fibres: length, 1.3–4.5 mm; diameter, 0.010–0.027 mm. Composition: ash, 6–8%; lignin, 17–19%; pentosans, 27–32%; cellulose, 50–54%; α-cellulose, 33–38%. Yield of screened pulp, 47.6–51.6%. The paper has a high bulk capacity and dimensional stability toward moisture changes. A rapid continuous pulping process has been developed for the exploitation of the grass in Tunisia. Considered to have possibilities for development in Egypt.		Bergada Girona *et al.*, 1951 Clark, 1965 Cunningham *et al.*, 1970 Drar, 1954 McGovern and Grant, 1962
197. *Lygos raetam* (Forssk.) Heywood; syn. *Retama raetam* (Forssk.) Webb & Benth., *Genista raetam* Forssk. (R'tem, retem, retenshrub) E. Mediterranean (especially Sinai peninsula)	A typical desert shrub; sheep eat small fruits. Wood is source of excellent charcoal (widely used by desert tribes); herb used as abortifacient, purgative and vermifuge.	The seeds contain 4.5% semi-drying oil (sap. val., 188; iod. val., 125) the unsaturated fatty acids being oleic, (47%), linoleic (27%), and linolenic, (3%), plus 8% conjugated-diene acids. The saturated fatty acids (14%) include palmitic, stearic, arachidic, behenic and, probably, lignoceric acids. The unsaponifiable fraction (4.5%), contains 75% β-sitosterol. The mucilage from the defatted seeds contains (by acid hydrolysis), 19% D-galactose and 78% D-mannose. Alkaloids in the seeds include thermospine, d-sparteine, retamine, anagyrine, sophoramine and sophochrysine (all C_{15} tetracyclic compounds) and cytisine (C_{11} tricyclic). Has been considered as a source of cellulose and fibre.		Ahmed and Rizk, 1963 Boyko, 1954 Uphof, 1968

*More usually used for the grass *Stipa tenacissima* L. which is very similar; frequently no differentiation is made by the paper industry; *see* entry no. 265.

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
198. *Manihot dichotoma* Ule (Manicoba de jequie; tequie manicoba) Indigenous to NE. Brazil but not so widespread as *M. glaziovii*. The species has been introduced successfully into Asia, notably India, and Hawaii.	Source of good quality rubber. Roots contain starch and are used as a foodstuff in times of famine.	Latex reported to have a rubber content of 25–50%. In Brazil, the latex is extracted by a series of zig-zag cuts and spontaneous coagulation occurs. The trees were exploited as a commercial source of rubber during the early 1900s and during World War II – and still considered to have this potential in Brazil. Seed kernels contain about 48% oil, which has sap. val., 187.7; acid val., 1.6; iod. val., 144.4; unsap. matter 0.78% – and is a potential semi-drying oil.	Yield of latex rather low as compared with *Hevea*.	Burkhill, 1935 CSIR India, 1962 Polhamus, 1962 Santa Rosa, 1949 Santa Rosa, 1960 Schery, 1949
199. *Manihot glaziovii* Muell-Arg. (Ceara or manicoba rubber) Indigenous to NE. Brazil; has been introduced successfully into Africa, (notably Tanzania), Asia and Hawaii.	Source of rubber. It is the most widely known and exploited of the rubber *Manihot* spp. and is reported to be resistant to prolonged drought. Seeds utilised to a limited extent in Brazil as a source of drying oil (manioc oil) used in paint and varnish manufacture and in the manufacture of dyes.	Latex contains 3–12% resin. Analysis of coagulum: rubber, 92%; resin, 4.3%; insoluble material, 3.2% Latex coagulates spontaneously; acid treatment of wound reported to delay coagulation and to increase latex flow. Yield in Brazil about 100 g latex per tree per tapping; in Tanzania about 220–330 g/tree/year. Is considered to have potential in Brazil. Seed kernel contains 25–45% oil which has sap. val. 188–193; iod. val., 135–142; acid val. 0.6–1.7; unsap. matter 0.5–0.9%.	Horny bark makes tapping difficult and resin content is rather high. Cannot be tapped continuously and, compared with *Hevea*, latex yield is low.	Borget, 1952 Burkhill, 1935 Coursey, 1964 CSIR India, 1962 Marsland, n.d. Polhamus, 1962 Santa Rosa, 1949 Santa Rosa, 1960 Schery, 1949 Williams, 1966
200. *Manihot heptaphylla* Ule (San Francisco manicoba) Indigenous to NE. Brazil.	A minor source of rubber	Roots are tapped for a latex similar to that obtained from *M. glaziovii*.	Mortality among trees is high and this species is now of minor importance in Brazil.	Polhamus, 1962 Santa Rosa, 1960 Schery, 1949
201. *Manihot piauhiensis* Ule (Piauhy rubber) Indigenous to NE. Brazil; has been introduced into India.	Source of rubber.	Latex obtained by tapping roots which is similar to that obtained from *M. glaziovii*. Seed kernels contain about 48% oil which has sap. val., 188; acid val., 1.6; iod. val., 144; unsap. matter, 0.78% – and is a potential semi-drying oil.	Mortality among trees is high and this species is now of minor importance in Brazil.	CSIR India, 1962 Polhamus, 1962 Santa Rosa, 1960 Schery, 1949
202. *Martynia parviflora* Woot.† (Devil's claw) Texas, New Mexico.		Seeds contain: protein, 24%; oil, 35–36% – which has sap. val., 197; iod. val., 122. Seeds a possible source of oil, similar to cottonseed or sunflower seed oil.		Duisberg, 1952a, b Krochmal *et al.*, 1954

† *See* also entry no. 236

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Name (s)/Distribution	Current/past uses	Potential	Constraints	Citation data
203. *Moringa oleifera* Lam.; syn. *M. pterygosperma* Gaertn. (Drumstick or horse radish tree) Reported to be indigenous to India, but now widespread in many of the drier parts of the tropics, especially W. Africa and the WI.	Source of light edible oil (ben or behenen oil) used mainly as a lubricant (including, to a minor extent, commercially as a substitute for sperm whale oil for lubricating fine machinery, e.g. watches). Also used in the preparation of cosmetics and perfumes. Oilcake used as a fertilizer but unsuitable for animal feed due to presence of an alkaloid. Tender pods esteemed as a vegetable. All parts of the tree used in Indian indigenous medicine. Stem exudes a gum, used medicinally and in calico printing.	Seed composition varies according to origin. Indian seed: shell, 23–30%; kernel, 70–74%. Kernel contains protein, 38.4%; oil, 34.7%; oil has sap. val., 182.2; iod. val., 64.2; acid val., 3.5; unsap. matter, 3.05%; Fatty acid composition: palmitic, 9.3%; stearic, 7.4; behenic, 8.6; oleic, 65.7%. Oilcake contains 58.9% crude protein but has a bitter taste. Roots and bark contain 0.1% alkaloids (moringine and moringinine). Roots contain the alkaloid spirochine and also an antibiotic principle, pterygospermin ($C_{22}H_{18}N_2O_2S_2$). Stem gum is a neutral polyuronide consisting of arabinose, galactose, glycuronic acid and traces of methylpentose. Analysis of wood: ash, 3.2%; pentosans, 17.6%; lignin, 26.4%; cellulose, 62.4%. Fibres average length, 1.14 mm, diameter, 28 μm. Wood considered suitable for making paper pulp and of a grade suitable for the manufacture of writing and printing papers.	Considerable scope for improvement and need for research on its medicinal uses.	Burkhill, 1935 Coursey, 1964 CSIR India, 1962 Guha *et al;* 1968 Guha and Negi, 1965 Ingle and Bhide, 1954 Ingle and Bhide, 1962 Kurup and Narasimha Rao 1950 Ramachandran *et al.*, 1980 Siddiqui and Khan, 1968 Subba Rao *et al.*, 1953
204. *Moringa peregrina* (Forssk.) fiori; syn. *M. aptera* (Forssk.) Gaertn., *M. arabica* (Lam.) Pers (Egyptian ben-oil tree or ban tree) Egypt, Sudan, Ethiopia (Eritrea), Syria, S. Arabia.	Source of a light edible oil used locally for cooking, as a lubricant, and in the preparation of cosmetics and perfumes. Oilcake used as a fertilizer.	Seeds consists of 48% kernel which has an oil content of 52%. Oil has sap. val., 188.2; iod. val., 71.2; acid val., 0.5; unsap. matter, 0.5%; and is very similar to ben oil (*see* previous entry). Oilcake has a bitter flavour and contains: protein 48.6%; carbohydrate, 28%; fat, 2.6%; ash, 5.5%; fibre, 6.6%; plus saponins.	Oilcake unsuitable for use as an animal feedingstuff due to its bitterness.	Anon, 1930b Drar, 1954 Osborn, 1968
205. *Mundulea sericea* (Willd.) A. Chev.; syn. *M. suberosa* Benth. Tropical Asia, especially SE. Asian sub-continent; Africa, especially Sahel and Sudan to Natal.	Seeds and bark used as a fish poison (grown for this purpose by farmers in the Sahel) and an insecticide. In India attempts have been made to isolate strains with a high insecticidal activity.	Rotenone (a powerful contact insecticide and fish poison) content of E. African bark reported to vary from 0 to 1.1%; elsewhere up to 2% (constituents vary greatly according to origin and strain). Indian bark samples reported to contain munetone (a substituted bis-dimethylchromene, $C_{26}H_{24}O_5$)*, which is also highly toxic to fish. Indian and African samples also contain the closely related ($+H_2O$) compound, mundulone*. Seeds contain also an allied compound ($C_{25}H_{24}O_6$) which is toxic to fish. Alcoholic extracts of fruits and leaves reported to have antimicrobial activity.	Variability of nature and quantity of insecticidal constituents.	CSIR India, 1962 Dutta, 1955 Dutta, 1956 Dutta, 1959 Ghosh and Dutta, 1962 Narayana and Rangaswami, 1955 Nickell, 1959 Spickett 1955 Spoon, 1962

*For (revised) structures, see C. S. Barnes, J. L. Occolowitz, N. L. Dutta, P. M. Nair, P. S. Phadke and K. Venkataraman, *Tetrahedron Letters*, 1963(5), 281–288.

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
206. *Nanophyton erinaceum* (Pallas) Bunge. Asia.	Extract of the piperidine derivatives present is used in the treatment of hypertension.	Overground parts of the shrub contain up to 0.1% 2, 6—dimethyl-piperidine and 1, 2, 6—trimethyl-piperidine.		Kuzovkov and Men'shikov, 1951 Petrov, 1972
207. *Neoglaziovia variegata* (Arr. Cam.) Mez (Caroa) NE. Brazil.	Source of fibre, now used mainly for cordage, mats and braided articles. Residue pulp reported to be used for papermaking, and also for textiles in mixture with cotton – used as weft yarn.	Grows in dry, poor soils. Leaves yield 12—14% fibre; reported to be stronger than jute and finer than sisal. Composition of waste pulp: cellulose, 58.9%; lignin, 12.7%. Was exploited during 1940s and early 1950s, when crop received some agronomic research input and also research on fibre extraction methods to give an improved fibre. Annual production in 1960s estimated at 4,000 tonnes.	Harvesting and fibre extraction said to be problematic.	Anon, 1950 Anon, 1954c Kirby, 1963 Mors and Rizzini, 1966 Santa Rosa, 1949
208. *Nicotiana glauca* R. C. Grah (Tree tobacco, masseyss) Asia, Middle East, Argentine, SW. USA	Contains two substances which are/have been in commercial use – anabesine [an alkaloid (*see* entry no. 31) used as an insecticide] and rutin (a glycoside of the flavone quercetin).	Total alkaloid content of the leaves of Argentinian plants 1.1% (mainly anabasine); US plants' average anabasine content is 0.84%. Egyptian plants have anabasine contents of: leaves, 1.09%; fruits, 1.16%; and a rutin content which at maximum (before flowering or at fruiting) reaches 1.6%. Investigated as a potential insecticidal crop in the USA during 1940s. Plant considered to have commercial potential as a source of anabasine and rutin in Egypt in 1960s. Leaves of hybrid *N. rustica* x *N. glauca* reported to contain as much as 6.6% anabasine.	Rutin was once considered to have vitamin activity (part of the so-called vitamin P complex) and was used pharmaceutically to correct various apparent vitamin-deficiency symptoms; but its value in this respect is now largely discounted.	Barilari, 1957/58 Feinstein *et al.*, 1951 Khafagy and Metwally, 1968a Khafagy and Metwally, 1968b Krochmal *et al.*, 1954 Martindale, 1977 Roark, 1947
209. *Nolina microcarpa* S. Wats. (Bear grass) SW. USA Mexico. [For *Nopalea* sp., *see* entry no. 211]	Has been used as a source of fibre suitable for brushes, baskets, etc. Also of value as a range-conservation plant.	Each plant yields about 14—34 kg of green leaves – and these contain on average 48% crude fibre and 43% protein. Exploited commercially as a fibre source during World War II.	Fibre has rather low tensile strength.	Bender, 1963 Benson and Darrow, 1944 Botkin, 1945 Cruse, 1949 Duisberg, 1952a Duisberg, 1952b Duisberg and Hay, 1971 Krochmal *et al.*, 1954

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
210. *Opuntia* spp. (Cacti often known, whatever the species, as prickly pear; also as nopal or tuna) Arid and sub-arid regions of N., C. and S. America; naturalised in Australia, Hawaii, Asia, Mediterranean, Africa.	Used mainly for animal fodder and edible fruit production. Minor outlets which have been tried out or mooted include: as a source of adhesives, cellulose, drugs, essential oils, gums and resins, enzymes, insecticide, latex (rubber substitute), seed oil. Various parts of plant used in Indian medicine.	Some species are hardy and frost-resistant. Twenty nine species have been examined as potential oilseeds; composition of oil varies with species — examples follow. Industrial (fuel) alcohol can sometimes be obtained from the fruits: heating the must with bisulphite said to give the best results. Alkaloids isolated from Italian spp., one an anti-diabetic factor. In the USA, 2 tonnes flowers collected annually for perfume production. The plants can be grown from seeds or by vegetative reproduction.	Some species can spread rapidly and become uncontrollable weeds.	Cruse, 1949 Cruse, 1959 Cruse, 1973 CSIR India, 1966 Duisberg, 1952a, b Fernandez, 1954 Lercker *et al.*, 1976 Lotti and Averna, 1968 Pantanelli, 1920 Reti, 1950 Reti, 1954
211. *Opuntia cochinillifera* (L.) Mill.; syn. *Nopalea cochinillifera* (L.) Salm-Dyck (Nopal) Indigenous to Mexico but now widespread in the tropics.	Cultivated as host plant for the cochineal insect from which the deep red dye is obtained (at one time Mexico was a major producer but synthetic dyes virtually eliminated this trade). The mucilage (*see* entry no. 215) used locally as anti-inflammatory agent. Fruits edible. Trial cultivation (as forage crop) in Mozambique and Venezuela.	Indications of a renewed interest in cochineal, at least as a food colorant (due to the introduction of more stringent food-additive regulations). A pectin-like mucilage (gum), considered to have commercial potential as such, has been isolated in 0.48% yield (of fresh whole plant) and analysed by acid hydrolysis; arabinose, galactose, xylose, rhamnose are the main sugars present.	Found to be susceptible to a virus (Cactus virus X) in Venezuela	Anon. 1959a Baranyovits, 1978 Lloyd, 1980 Mindt *et al.*, 1975 Myre, 1974 Uphof, 1968
212. *Opuntia cylindrica* DC. Peru.		Contains the hallucinogenic alkaloid mescaline (0.9% w/w of the whole dried plant).		Elferink, 1974 Turner and Heyman, 1960
213. *Opuntia dillenii* (Gawler); syn. *Cactus indicus* Roxb. (Prickly pear) C. America, naturalised in India.	Popular hedging plant since spiny and easily propagated; of local medicinal use and, after burning off spines, as cattle fodder.	Thrives in the poorest and driest of soils. The fruits (5.6% moisture, 41.9% carbohydrates, 32% fibre, 3.6% fat, 6.2% albuminoids, 10.6% ash) contain 8% fermentable sugar and could be a useful source of industrial (or fuel) alcohol. The plant will also yield a (poor quality) paper pulp and gum. Glycosides of flavonoids isorhamnetin and quercetin extracted from the flowers.		CSIR India, 1966 Nair and Subramanian, 1961
214. *Opuntia elatior* Mill.; syn. *O. nigracans* Par. ex Foerst. (Prickly pear) S. America, naturalised in India (especially in W.).	As for *O. dillenii*, above.	The fruits contain (dry wt. basis) 58.1% carbohydrates, 13.5% fibre, 3.3% fat, 6.4% albuminoids (and ash etc.). Structure of opuntiol shown to be 6-hydroxymethyl-4-methoxy-α-pyrone.		CSIR India, 1966 Ganguly *et al.*, 1965

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
215. *Opuntia ficus-indica* (L.) Mill (Prickly pear, Indian fig, Sardinia cactus, tuna de castilla, Barbary fig) Indigenous to C.S. America but widely naturalised.	Cultivated mainly for the fruit. A gum can be obtained from various parts of the plant (by extracting with water and straining) and is used as an adhesive, (including mixed with pesticides, in a USDA-developed cotton pesticide formulation), and in cosmetics; main constituents, galactose and arabinose. A spineless species so can be, and is, used direct as fodder.	Fruit flesh contains (dry wt. basis) 58% carbohydrate – from which industrial (fuel) alcohol can be obtained by fermentation – and a yellow betaxanthin-type pigment, indicaxanthin (also betanin – violet). The fruit juice contains 0.04% vitamin C and reportedly a trace of carotene (?). The seeds give 6% semi-drying oil (iod. val., 125) and a 'nutritious' oilcake which can be used as a fodder (12% protein, 5% fat, 11% fibre, 21% ash, 14% moisture, rest carbohydrate, etc). Leaves contain 0.3% triterpenes and sterols (including sapogenins). A high yield of almost pure, white cellulose (76–81% α-cellulose) can be obtained (apparently from the whole plant.)	Alcohol fermentation said to proceed only slowly.	Amin *et al.*, 1970/71 Anon, 1934 Cruse, 1949 Cruse, 1973 CSIR India, 1966 Deplano, 1932 Fernandez, 1954 Krochmal *et al.*, 1954 Minale *et al.*, 1965 Mukerji and Ting, 1968a Mukerji and Ting, 1968b Piatelli *et al.*, 1964 Tawfik *et al.*, 1978 Uphof, 1968
216. *Opuntia fulgida* Engelm.; syn. *O. cholla* Weber (Cholla) Mexico, S. USA.	Gum used in Mexico as size and cloth stiffener; stem used in craft products.	Gum exudate consists of L-arabinose (6 parts), D-xylose (2 parts), D-galactose (3 parts), D-galacturonic acid (1 part). Resembles other plant gums. Acid hydrolysis of gum yields glucose (and other reducing sugars) and pentosans. Gum is soluble in aqueous ammonia or alkali.		Belani, 1934 Brown *et al.*, 1949 Duisberg, 1952a Duisberg, 1952b Uphof, 1968
217. *Opuntia megacantha* Salm-Dyck Mexico.	Apart from use of the fruits as food and as a constituent of a fermented beverage, the stem juice is boiled with tallow to make candles and used locally as an anti-inflammatory agent.	A gum reported to be obtainable (*see* previous *Opuntia* entries).		Churms *et al.*, 1973 Uphof, 1968
218. *Opuntia vulgaris* Mill. (Prickly pear, Barbary fig) Indigenous in S. America. Widely distributed in Mediterranean, Madagascar, etc.	Yields a gum (*see* entry No. 215) which has been used with Bordeaux mixture and arsenates as an adhesive in insecticide sprays: 1 lb of the mucilage from which it is derived yields enough gum for 25 gallons of spray (i.e. 1 kg to 250 litres). Has also been put to several of the other uses listed under entry no. 210.	Four triterpenes isolated from (whole) plant: friedelin, friedelan-3α-ol, taraxerol and taraxerone. A flavonoid glycoside can be extracted from the dried flowers in 2% yield and has rutin-like (*see* entry no. 208) and also anti-diarrhoea activity. Alkaloids containing β-phenylethylamine skeleton present. Fresh stalks yield, on water extraction, 0.7% of a pectate said to have anti-haemorrhage activity. Seed contains 8% oil, sp. gr. 0.918, iod. val., 103. Main constituents of the gum are arabinose and galactose.	Very susceptible to attack by *Dactylopius indicus*, a common cochineal insect (in India).	Chatterjee *et al.*, 1976 CSIR India, 1966 Paris, 1951 Reti, 1950

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
219. *Osteospermum* spp. S. Africa, St. Helena.		Small annuals to shrubby perennials. Seed oil of 14 species (not all AZ species) surveyed and found to contain 2—48% conjugd. trienoic acids and up to 60% dimorphecolic acid. (For its structure and possible industrial uses (in plastics, paints, etc: cf. castor oil), *see* entry no. 107).	No species at present suitable for modern cultivation methods but variability in range suggests possiblility of developing suitable lines (spp. of the Blaxium section of the genus considered to have the best prospects; *O. ecklonis, O. caulescens* and *O. jucundum* merit attention).	Barclay and Earle, 1965 Earle *et al.*, 1964
220. *Osteospermum muricatum* E. Mey. ex DC. S and E. Africa, Arabia.		Oil content of seed, 6—11%, protein, 11—12%. A perennial bush with good achene production and which is drought-resistant and adaptable to semi-arid regions.	The achenes are situated below the crown of the shrub.	Barclay and Earle, 1965 Jones and Earle, 1966
221. *Osteospermum sinuatum* (DC.) Norlindh S. Africa.		Oil content of seed, 39—42.6%; protein, 41.9—44%. The oil has iod. val., 140 and contains 32% conjugd. trienes (by U.V.) and 2% dimorphecolic acid (*see* entry no. 107).		Earle *et al.*, 1964 Jones and Barclay, 1972
222. *Osyris* spp. (E. African sandalwoods) Mediterranean; Africa to India.	Leaves of E. African spp. used as source of sandalwood oil. *O. abyssinica* Hochst. ex A. Rich. a source of tanning material. Little known of botanical origin of E. African sandalwoods. Some spp. used as timber.	Seed oil has similar composition to those of other Santalaceae [and interesting in that they provide one of the few known sources of acetylenic fatty acids (*see* next entry) whose reactivity may have industrial potential (cf. uses of acids such as dimorphecolic: entry no. 107)].		Guenther, 1952 Guenther, 1968 Mensier, 1957
223. *Osyris alba* L. (Gardrobe, poets' cassia) Mediterranean (common in S. France).		A shrub. Seeds contain 36% oil, 11% protein. Oil has iod. val., 117 and major component is an acetylenic acid — probably ximenynic (11-en-9-yn-C_{18}), 57%; also oleic, 32%; linoleic, 2%; linolenic, 2%; stearic, 3%. Various parts of plant analysed for phenolics and flavonoids and the following identified: para-hydroxy-benzoic, isoferulic, proto-catechic and para-coumaric acids; also 'rutoside' (rutin: *see* entry no. 208).	Semi-parasite.	Jones and Barclay, 1972 Mikolajczak *et al.*, 1963

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
224. *Parkinsonia aculeata* L.[f]				
225. *Parthenium argentatum* A. Gray (Guayale) Indigenous in Mexico and Texas (especially the Chihuahuan Desert of SW. Texas and N. Mexico).	Nil currently (experimental plots only — in Israel, Arizona and California), but was cultivated in USA during World War II as part of emergency programme to overcome shortage of natural *Hevea* rubber at that time, and wild stands were processed for rubber on a large scale in Mexico from 1905 to *circa* 1925. Was used for making vehicle tyres and many other commercial rubber products.	A frost-tolerant [15° F(−10° C) a safe minimum for mature plants] shrub whose roots penetrate 20 ft (6 m) in arid areas and which will live 30+ years. Contains a latex dispersed throughout much of the plant except the leaves (including one-third in the roots) and which yields a high-quality rubber; yield ∿ 10% of total plant dry wt. usually, but over 20% found in some strains. Can be harvested mechanically — either the whole plant or the top is mown off and the stump allowed to regrow. Extraction of the rubber is straightforward.* A disadvantage of the pre-1946 rubber was that the resin that remained in it reduced its quality; but since then a method of washing this out with e.g. acetone has been discovered and this gives a product which is virtually indistinguishable in all properties (tensile strength, chemical composition, etc.) from *Hevea* rubber — and better for most applications than synthetic rubber. On a small scale, retting (spontaneous microbial action on stored wet shrub material) can be used instead of acetone-washing. Yields of 1.3–1.7 tonnes/ha p.a. of rubber recorded from mature cultivated (but partially irrigated) guayule, and although much slower production during drought, the rubber still slowly accumulates and does not deteriorate even if the shrubs are not harvested for some years. Demand for natural rubber (which for certain applications, especially alone or blended in tyres, cannot be replaced by synthetics) predicted to continue rising during 1980s at 5% or more p.a. and to outstrip likely supplies of *Hevea* rubber, thereby possibly allowing guayale to return as a major commercial source — and a source derived from areas with a far less amenable environment than *Hevea* needs. Many possible guayale by-products. Thus the shrubs also yield many, though small, seeds which may have oil and protein potential. Also, for each tonne of rubber won, around 2 tonnes wood fibre (bagasse), 0.5 tonnes resins, 1 tonne leaves are left. The	Restricted to well-drained non-acid soils and needs 250–380 mm rain p.a. for worthwhile growth — which for good rubber yields must include a definite dry period in the winter to stress the plant. Doubtful whether it would survive the long hot dry summers of e.g. the Sahel. Seeds must be pre-treated, with hypochlorite, to remove natural inhibitors; and the seedlings (best raised in a nursery) grow slowly, need frequent irrigation until established (but avoid waterlogging which encourages fungal attack), and are easily overwhelmed by weeds which must be controlled manually, mechanically or by herbicides. Rubber content of wild stands very variable (but this should be countered, when cultivated, by breeding). Latex distributed in single cells not ducts so cannot be tapped and the whole plant, or its aerial parts, must be harvested. Both forms of harvesting (digging up or mowing) have disadvantages in arid areas: the first leaves the soil bare and prone to erosion and with the second the plant	Anderson, 1982 Archer, 1979 Buchanan *et al.*, 1978a, b Calvin, 1978 Campos, 1975 Chechelnitzky, 1975 CONACYT, 1978 Cruse, 1949 Duisberg, 1952a, b Duisberg and Hay, 1971 Feustel and Clark, 1950/51 Forti, 1975 Hammond and Polhamus, 1965 Hanson *et al.*, 1979 Hendrickson and Rees, 1962 International Rubber Study Group, 1978 Johnson 1977 Johnson and Hinman, 1980 Laguinge, 1951/2 Lipinsky, 1978 McGinnies, 1975 McGinnies in Davis, 1978a McGinnies and Haase, 1975 Mears and Larson, 1982 Meeks *et al.*, 1951 National Academy of Sciences, 1977b Rodriguez *et al.*, 1981 Schechter, 1975 Vietmeyer, 1979 Weihe *et al.*, 1979

* Shrubs dipped in hot water (to coagulate the rubber and remove unwanted leaves and root soil), milled/pulped in presence of caustic soda solution, the crude rubber allowed to separate (by rising to the surface), collected, washed, extracted with warm acetone to remove resin and dried by passing through a screw press and then hot air drier.

[f] denotes a potential firewood source (*see* Introduction)

List of plants tolerant of arid or semi-arid - Part 65

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
Parthenium argentatum (*contd*)		fibre may yield pulp adequate at least for lower quality paper or cardboard. The resins comprise 10–15% of the plant dry matter and consist of C_{10}, C_{15}, C_{20} terpenes (including diterpene acids), glycerides, hydrocarbon polymers — variously of potential use as paper sizing and as turpentine substitutes; in addition, a high yield of the cinnamate ester of partheniol [a bi-cyclic (5+7–membered rings) sesquiterpene] has been recovered and may prove to be a useful intermediate in chemical synthesis. The leaves yield (2.5% dry wt.) a hard white wax with a m.p. (76° C) even higher than carnauba. Steam distillation of leaves and/or resin yields a volatile oil containing the above-mentioned terpenes (including the pinenes, limonene, etc.) and having a spicy odour. The dried plant burns fiercely due to its high hydrocarbon content and may prove to be a useful energy source — either locally as such or, on a larger scale, by initial conversion into a substitute liquid fuel. It is browsed in the wild and it may be of use as forage, as a windbreak, or to check erosion. Guayule is considered sufficiently important to warrant a regular international conference (Consejo Nacional de Ciencia y Tecnologia (CONACYT) 1978). It is very amenable to hybridisation with other *P.* species (*incanum*, *stramonium*, etc: *see* next entry) and it was said in 1977, that such exports may be the key to its future exploitation.	tends to desiccate and not regrow. Unlike *Hevea*, contains no natural anti-oxidant and so must be processed fairly quickly after harvesting. Processing requires supplies of water and, except as indicated under 'Potential', a deresinating solvent. Raising seedlings and planting out needs much labour. Research needed on quality control of the rubber and on by-product uses, though much already being done by e.g. CIQA (Saltillo), US tyre manufacturers, etc. Possible health hazard in the cultivation and processing of guayule due to the presence of allergenic terpenes.	
226. *Parthenium incanum* HBK. (Mariola) Arizona, Texas.		A low shrub growing at 2,500–5,000 ft (800–1,600 m) in same areas as guayule but more abundant than guayule itself; also appears to have a less restricted range than guayule. Contains only a small percentage of rubber (less than 1% of benzene extract obtained; another result gave rubber content of whole plant, 0.28%); but often hybridises in the wild with guayule and has been deliberately hybridised in plant breeding experiments designed to increase the size of the resulting shrub above that normal for guayule itself.	Of little value itself as a source of rubber.	Hall and Long, 1921 Hanson *et al.*, 1979 Polhamus, 1957

List of plants tolerant of arid or semi-arid - Part 66

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
227. *Pectis papposa* Harv. & Gray (Foetid marigold, chinchweed) SW. USA Mexico.	A bushy plant growing from sea-level to 4,000 ft (1,300 m) and used by American Indians for perfume, as a dye and for flavouring food. Has been cultivated experimentally.	The essential oil of the leaves has a pleasant lemon fragrance. Plant yields 7.5 tonnes/ha of green wt. (irrigated fields) and 0.40—0.60% of oil, on green basis, is obtained by steam distillation (1% on dry wt. basis). The seeds have a spicy flavour and are produced abundantly, 170 kg/ha. Approximate composition of oil: terpenes, 25%; aldehydes, 50%; ketones, 25%. Of the constituents pinocarvone is 20%, carvone, 5%, and a terpene hydrocarbon (probably β-pinene), 25%. Cuminaldehyde (*p*-isopropylbenzaldehyde) content the same as in cumin oil, 47.0%.	Fresh seed has low germinating power (but after storage, germinates well). Control of weeds a problem.	Bradley and Haagen-Smit, 1949 Duisberg, 1952b Krochmal *et al.*, 1954
228. *Pedilanthus pavonis* (Klotzsch & Garcke) Boiss. (Candelilla plant) Mexico, Texas.	A minor source of a candelilla wax (which however is chiefly obtained from *Euphorbia antisyphilitica*: entry no. 127). Wild plants are collected for their coating of wax, which is used for making candles and as a substitute for carnauba and beeswax in many industrial products. The exploitation has been destructive to the wild stands. The wax is extracted by heating the waxy stalks in boiling water, most extraction plants being in Mexico and in Texas.	Contains 3.5—5% wax. Domestic production said to be worth consideration. Is stated to have emetic, purgative and emmenagogue properties.	Experimental work on cultural techniques, processing and economics desirable.	American Wax Importers and Refiners Association, 1971 Duisberg, 1952b Duisberg and Hay, 1971 Hodge and Sineath, 1956 Krochmal *et al.*, 1954 Uphof, 1968 Wastler *et al.*, 1953

List of plants tolerant of arid or semi-arid - Part 67

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
229. *Peganum harmala* L. (Harmel, harmal, harmala, Syrian rue, wild rue, hermal, harmara, hurmur, isbendlahouri) Mediterranean area, C. and SE. Asia.	A shrub common in dry waste places. In India and Pakistan, the dried seeds (known as 'harmal') are sold as an anthelminthic, narcotic, stimulant, febrifuge, diuretic, abortifacient, and for treatment of asthma. Is also used in the form of a powder of the dried roots. Harmine, from the seeds or roots, has been used against encephalitis and Parkinson's disease. Roots are used in the USSR for treating rheumatism and seeds burnt as a fumigant. The seeds yield (12–14%) a semi-drying oil known as zit-el-harmel, used locally medicinally and for making soap. The seeds (or fruits) are used as a source of a red dye, 'Turkey red' (used in Turkey for dyeing tarbooshes, which are a kind of hat).	On dry wt. basis, ripe seeds contain 3.8–5.8% alkaloids; the fruit, 4.4%; twigs, wood and leaves, 1.0–1.3%; bark, 2.2%; and roots, over 3%. These consist of three indole alkaloids (the 'harman alkaloids': harmine; its dihydro-derivative, harmaline; harmalol) and a group of quinazoline alkaloids (vasicine (peganine), etc). Much work on the biosynthesis of several of these reported during the 1960s and 1970s, and so-called 'harmidine' identified as harmaline. The harman alkaloids have a similar action to quinine and potentiate the effect of small doses of amphetamine; in addition to current usage, they are also said to be lethal to moulds, bacteria and internal parasites, and have been suggested as algae- and protozoa-controlling agents, coronary dilators and, in vapour form, as insecticides (ineffective by contact). Harmine can act as an acid/base fluorescent indicator in analysis. Vasicine causes broncho-dilation (? use as expectorant). The seed oil is said to be non-toxic when fed to rats and has been suggested as a component of salad and cooking oils and for the industrial production of alkyd resins. It has iod. value, 120 and fatty acid composition (approximate): oleic, 40%; linoleic, 38%; other unsats., 2%; palmitic and stearic, 20%; and contains ∿5% unsaps. (β-sitosterol and paraffinic hydrocarbons). Leaves said to contain 80 mg/100g vitamin C. A new amino-acid, pegaline ($C_6H_{11}O_3N$), has also been reported present.	The seeds are toxic due to alkaloid content and the plant is thought to have led to the death of browsing animals on occasion (but is generally rejected as unpalatable); as with many alkaloids their use as a drug needs careful dose control (can cause tremors, CNS depression, failing respiration, etc.).	Chatterjee and Ganguly, 1968 CSIR India, 1966 Gröger and Mothes, 1960 Hassan, 1967 Hocking, 1966 Ikram and Islam, 1963 Indian Standard, 1958 Javed *et al.*, 1972 Khasimov *et al.*, 1969 Koretskaya and Utkin, 1958 Kutlu and Amal, 1967 Liljegren, 1971 Mensier, 1957 Nadkarni, 1954a Paul *et al.*, 1960 Robinson, 1965 Schipper and Volk, 1960 Schmitt and Schmitt, 1964 Siddiqui, 1962a, b Siddiqui and Kemal, 1964 Uphof, 1968 Zetler *et al.*, 1972
230. *Periploca laevigata* Ait.; syn. *P. angustifolia* Labill. Mediterranean region; Canaries. Grown widely in Egypt.		A small shrub, laticiferous. The oily material obtained (1.14% yield by solvent extraction of the whole dried shrub), contains 53% unsap. matter and 46% fatty acids (which include oleic, linoleic, linolenic, myristic, palmitic, stearic, arachidic, behenic and lignoceric). Unsap. fraction contains β-sitosterol, campesterol and stigmasterol (the usual plant sterols). Aerial parts contain carbohydrates, tannins, cardiac glycosides, unsaturated sterols, flavonoids, oxidases (but no alkaloids or volatile oils).		Ahmed *et al.*, 1969

List of plants tolerant of arid or semi-arid - Part 68

Name(s)/Distribution	Current/pass uses	Potential	Constraints	Citation data
231. *Physochlaina praealta* Miers. (Laltang) N. India.	An erect perennial herb which grows wild, and abundantly, in the high dry valleys of N. India (e.g. Ladakh). The seeds are used locally as a vermifuge.	Leaves of wild plants contain 1% or more alkaloids — mainly hyoscyamine; but experimental cultivated plants at 5,000 ft (1,500 m) were stunted and contained only 0.2% alkaloids in the first year and 0.7% in the second. Being a perennial plant, the leaves can be harvested repeatedly (for sun-drying when they are either powdered and used as such — giving a belladonna-like pupil-dilating effect — or used for extracting the hyoscyamine (which in turn can be converted into the drug atropine)). The roots also contain alkaloids — around 0.6% w/w.	Natural habitat 9,000—11,000 ft (2,700—3,300 m) altitude; full height not attained at 5,000 ft (1,500 m) and cultivated plants apparently contain less hyoscyamine than wild. Prefers a humus-rich soil. High collection and transport costs from the high remote arid areas where it grows satisfactorily make its exploitation uneconomic. The leaves are narcotic to man and some animals (but are used as fodder for others).	Arnon, 1972 Chopra *et al.*, 1960 CSIR India, 1969 Handa *et al.*, 1951 Kapoor *et al.*, 1953 Sarin *et al.*, 1963
232. *Pimpinella anisum* L.; syn. *Anisum vulgare* Gaertn., *A. officinarum* Moench. (Anise plant, aniseed, sweet cumin) Greece, Egypt. Widely cultivated in Europe, Asia, N. America.	An annual herb 30—60 cm high. Whole fruits are distilled to produce essential oil which is used widely in flavouring, liqueurs, mouth washes and as anise milk. The oil is also used externally as a mild insecticide and fungicide. Seeds used medicinally as an aromatic stimulant, etc. Distillation residues have some food value and can serve as stockfeed.	Under favourable conditions yields 400—600 lb seeds/acre (450—700 kg/ha). These give, ideally after crushing, on steam distillation, 1.5—6% (usually 2—3%) essential oil — known as anise oil. This contains 80—90% anethole (methyl ether of *p*-propenylphenol), methyl-chavicol (its *p*-allyl isomer), and traces of various terpenes. The seeds also contain ∿10% moisture, 18% protein, 12—25% fibre, 6—10% ash, 25% carbohydrate, and (by ether extraction after steam distillation removal of the essential oil) up to 25% greenish oil containing 1—2% unsap. matter and with sp. gr., 0.923—0.930; sap. val., 178—188; iod. val., 102—106; fatty acid composition: oleic, 56%; petroselinic (the Δ^6 isomer of oleic (Δ^9) and convertible into the possibly useful intermediate 6, 7—dihydroxystearic acid), 24%; linoleic, 17%; palmitic, 3%. It has been suggested (1963) that the essential and fatty oils could be extracted simultaneously. Pharmacology and veterinary usages have been described.	An annual plant having a long vegetative period which necessitates sowing earlier than other crops. Progressive ripening of fruits presents harvesting problems. Although classified as a desert plant by Arnon, it requires periodic irrigation or rainfall in growing season, is susceptible to extreme climatic conditions and is difficult to mature in hot, dry regions. Susceptible to attack by the insect *Systole albipennis*. The anise oil of commerce is frequently adulterated with the cheaper, and inferior (harsher odour), oil derived from *Illicium verum* (known as 'star anise oil'). Anise oil slowly deteriorates on prolonged exposure to air and light (? due to oxidation/polymerisation) and similarly leaves a residue on evaporation in an open dish.	Anon, 1961a Anon, 1962c Arnon, 1972 Ayensu, 1979 CSIR India, 1969 Dublyanskaya, 1964 Guenther, 1950 Mensier, 1957 Rakoto-Ratsimamanga *et al.*, 1969 Topalov *et al.*, 1963 Uphof, 1968

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
233. *Pinus halepensis* Miller[f]				
234. *Pithecellobium dulce* (Roxb.) Benth.[f]				
235. *Plantago ovata* Forssk.; syn. *P. decumbens* (Spogel plantain, ispaghula) Mediterranean, SE. Asia.	The dried seeds are known as ispaghula or isubgol. The seeds have a mucilaginous husk, which can be separated out by crushing the seeds and then sieving, which swells (to a gel of 25–50 times the volume) on mixing with water. The mucilage is the active principle for the main current use of this plant, namely of the husk or whole seeds, as a gentle laxative and emollient, both in local Indian medicine and exported (especially to the USA). In 1976–77, 4,770 tonnes of husk exported from India. The mucilage is also used as a stabilizer in ice-cream manufacture, in cosmetics, as a thickening agent, in printing and, after treatment with caustic soda solution, as an agar-agar substitute.	The gel-forming properties of the mucilage are superior to those of many other gums - - and hence is a potential replacement for these. It consists of a mixture of polysaccharides containing mainly xylose, arabinose and galacturonic acid units. The seeds also contain a yellow semi-drying oil (5%) with sap. val., 182; iod. val., 116, 2% unsap. matter (including β-sitosterol); fatty acid composition: oleic, 37%; linoleic, 48%; palmitic, 4%; stearic, 7%; lignoceric (C_{24} sat.); 1% (the high acetyl val. reported, 37.7, implies a significant % mono/di-glycerides and/or undetected hydroxy-acids present).	Naturally an ephemeral but is cultivated in India and Pakistan (when it needs occasional rain or irrigation to germinate and develop). The fruits must be harvested by hand (ideally in early morning when slightly damp) as the plants have weak stems and also shed their seeds readily. Does not do well in very hot conditions.	Arnon, 1972 Chandler, 1954 CSIR India, 1969 Maheshwari and Tandon, 1959 Martindale, 1977 Mithal and Bhutiani, 1969 Mithal and Zacharias, 1971 Modi *et al.*, 1974 Paroda, 1979 Uphof, 1968
236. *Proboscidea parviflora* (Woot.) Woot. & Standl.; (probably syn. with *Martynia parviflora* Woot.) (Devil's claw) Native of SW. USA deserts.	Herbaceous oilseed plant; grows wild in SW. USA deserts up to 4,000 ft (1,200 m) or higher, but is also cultivated in Indian reservations. Fibre used in basketry.	Potential of 1,000 kg oil/ha. The oil (36% of seed wt.) has a high linoleic content: overall has a similar degree of unsaturation to safflower oil – hence should make a good drying oil. Stiff-stalked lines with an erect habit have been bred. A recent study concludes that domesticated it could be developed into a valuable oilseed for arid lands.		Berry *et al.*, 1981 Krochmal *et al.*, 1954 Nabhan *et al.* in Davis, 1978c New Mexico Agricultural Experiment Station, 1954

[f] denotes a potential firewood source (*see* Introduction)

List of plants tolerant of arid or semi-arid - Part 70

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
237. *Prosopis alba* Griseb.[f]				
238. *Prosopis chilensis* (Mol.) Stuntz[f]				
239. *Prosopis cineraria* (L.) Druce[f]; syn. *P. spicigera* L. (Musquit bean, screw bean, Jandi, Khejri) Iran, India, Afghanistan.	A small tree of up to around 12 m in height. Pods used in various foods (such as curries) especially by desert dwellers. Gum, which exudes from cut stems, is eaten and marketed, like that from several *Prosopis* spp., as 'mesquite gum'. In many areas, the branches are cut off annually and used for fuel: the wood is said to be excellent for this and also to give a high-quality charcoal. The ash is a rich source of potash. The wood is also occasionally used for wagons, implements, furniture, etc. (but there are constraints on its use outdoors). The leaves are regularly lopped for use as fodder and are also composted. A fibre, sarmdal, is sometimes made from the bark. The plant is used in Indian medicine for rheumatism etc.	Grows well in India even where rainfall is only 100 mm p.a. and will regenerate via suckers in such areas (seeds need more moisture). The gum is similar to gum acacia and can be used as a substitute though it has the slightly inferior HLB value* of 9.3–9.4. Acid hydrolysis yields the sugars arabinose, galactose and rhamnose and a uronic acid. Ethanol extraction of the heartwood yields 0.5% material containing 26% sugars (sucrose, glucose, fructose, arabinose and mannose), a large amount of tannin, several flavones, and 0.5% β-sitosterol. Patulitrin has been isolated from the flowers and a mixture of C_{50-60} wax esters (of possible interest), the usual plant sterols (β-sito-, stigma-, campe-) and a piperidine alkaloid (spicigerine) from the leaves, and various flavones from the seeds.	The timber is not very durable and is susceptible to insect attack. It has (1967) no large-scale commercial use.	Bhardwaj *et al.*, 1980 CSIR India, 1969 Jewers *et al.*, 1976 Kaul and Ganguly, 1962 Khasgiwal *et al.*, 1969 Khasgiwal *et al.*, 1970 Sarwar *et al.*, 1967 Sharma *et al.*, 1964*a* Tewari, 1979 Uphof, 1968 Wadhwani, 1953

* The Hydrophile-Lipophile Balance – a measure of the effectiveness of an emulsifying agent as when used e.g. in pharmaceutical preparations; acacia gum gives a value of 11.87 (W. L. Guess, *J. Pharm. Sci.*, 1961, *50*, 238).

[f] denotes a potential firewood source (*see* Introduction)

List of plants tolerant of arid or semi-arid - Part 71

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
240. *Prosopis juliflora* (SW) DC.[f] (sometimes recorded as *P. glandulosa* Torr. and by some authors as *P. chilensis* var. *glandulosa*) (Torr.) Standley (Mesquite) Tropical America, Africa (naturalised in Egypt), and parts of Asia.	Small (up to 10m) thorny tree which is a prolific seed bearer (90 kg/tree at 10 years). Its bark exudes a gum ('mesquite gum') which is edible and is used in the manufacture of mucilages and confectionery and as an emulsifying agent. The bark is also used for tanning. The timber is used for fuel, fence posts (resistant to rotting) and occasionally for conversion into charcoal. The wood flour has been used as an extender for phenolformaldehyde plastics. The ripe pods are used locally as food and more widely as fodder (dry wt. analysis – fibre, 30%; digestible protein, 6.9%; carbohydrate, 50%; fat, 5%; ash, 5%) as are the leaves (air-dried have protein, 26%; fibre, 25%; moisture, 7%). The flowers yield nectar and honey. Leaf extracts used medicinally locally.	Method of providing cover for bare arid land (providing it can be kept under control), and, being leguminous, increases soil nitrogen content (by 2–2.5 times). Acid hydrolysis of the gum, a water-soluble polysaccharide, yields mainly arabinose, which can be easily separated so making a useful source of this sugar, plus some galactose and glucouronic acid. The fruits contain the flavonoid patulitrin and free sugars (glucose and sucrose). Could be a useful multi-purpose plant: in addition to the established uses (left) and indicated previously, it has been suggested that the timber could be used for the production (by acid hydrolysis -- as used on cellulose wastes) of alcohol (for fuel) or acetic acid, of single cell protein for use in feeds (by aerobic fermentation), to make fibreboard, as a paper-making material, and finally of producer gas by dry distillation. Most parts of the tree contain tannins: 0.9% in the dry wood, 3.0–8.4% in the bark and 6–7% in the roots. The seeds contain (dry wt.) 6.6% oil and 39.9% protein, but negligible tannin.	An aggressive, rapidly spreading (especially where animals browse it and spread the seed in their droppings) weed; has overwhelmed large areas of grassland in e.g. Mexico. Attempts frequently made to eradicate it in various arid areas. Is partially controlled by heavy browsing but is little affected by insect pests being generally resistant to them. Extensive root system strips surrounding ground of its available moisture. Intensive use in fodder for cattle leads to malnutrition in them. The gum is considered inferior to gum arabic (*see* entry no. 3). Tannin contents considered unworthy of exploiting (1960 ref.).	Arnon, 1972 Aykroyd and Doughty, 1964 Brookbank, 1975 Cruse, 1959 Cruse, 1973 CSIR India, 1969 Cuneen and Smith, 1948 Duisberg, 1952a, b Felker, 1979 Gianinetto *et al.*, 1975 Gowda and Ramaswamy, 1960 Graziano *et al.*, 1971 Guha *et al.*, 1970 Jones and Earle, 1966 Krochmal *et al.*, 1954 Laundrie, 1958 Marshall, 1947 Morton, 1963 Parker in Davis, 1978c Parker and Martin, 1952 Ratle *et al.*, 1966 Smith, 1951 Thayer, 1979 Uphof, 1968 Wassel *et al.*, 1972 Whitford *et al.*, 1978 Wright in Davis, 1978c
241. *Prosopis pallida* (Willd.) HBK[f]				
242. *Prosopis tamarugo* f. Phil.[f]				

[f] denotes a potential firewood source (*see* Introduction)

List of plants tolerant of arid or semi-arid - Part 72

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
243. *Pyrethrum santolinoides* DC.; syn. *Tanacetum sinaicum* Delile ex DC. Israel (and to the south thereof).		'High' (but unspecified) essential oil content; has been under investigation in Israel.	No recent references found, suggesting earlier promise not fulfilled.	Zaitschek, 1953
244. *Rhamnus catharticus* L. (Common buckthorn, purging buckthorn) Europe, Asia, N. Africa.	Shrub or small tree; wood used for making small wooden articles by lathe; berries used as source of a purgative (e.g. in the tinctus known as Sirupus Rhami catharticae) and of a dye known as sap green.	Seeds (which have wt./1,000 of 13.1g) contain 20% protein and 25% of a drying oil which is greenish with an unpleasant taste and which has sp.gr., 0.919; sap. val. 185; iod. val. 160; fatty acid content: linoleic, 35%; linolenic, 25–30%; oleic, 20–30%; sats. 10%. Seeds also contain kaempferol, a yellow flavone responsible for their colour; berries contain the closely related flavone, rhamnetin. Purgative action due to anthraquinone derivs. (emodin etc.)	Tends to prefer relatively well-watered areas. Remarks made under entry no. 73 (senna) probably also applicable here.	Ayensu, 1979 Earle *et al.*, 1960b Jones and Barclay, 1972 Mensier, 1957 Oesch and Perkin, 1914 Paris and Dillemann, 1960 Uphof, 1968
245. *Rheum emodi* Wall. ex Meissn. (Indian rhubarb, Himalayan rhubarb) N. India.	A herb 2–3 m high. The rhizomes and roots have purgative action (due to the presence of senna-like compounds) and are astringent – and are used in Indian medicine.	The rhizomes and roots contain a mixture of substituted anthraquinones and their glycosides (such as emodin and its derivatives, the sennosides, etc.), which are responsible for the purgative action, and phenolics (gallic acid etc.), the cause of the astringency. Steam distillation of roots yields 0.05% essential oil whose characteristic odour is due to eugenol. The rhizome also contains a little tannin, and 5–6% water-soluble mucilage.	The plant is 'drought-resistant' but is restricted in nature to the slopes of the Himalayas between 3,000 and 5,000 m (though has been cultivated lower down) and is barely within the scope of this compilation. The plants have to be 6–7 years old before the rhizome is collected.	CSIR India, 1972 Mukerji, 1943 Nadkarni, 1954b Youngken, 1946

List of plants tolerant of arid or semi-arid - Part 73

Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
246. *Ricinodendron rautanenii* Schinz. (Manketti, mongongo) Angola, Botswana, Zambia, Mozambique.	A tree 10–16 m in height, the fruit and nut of which are important in the diet of Kalahari-desert bushmen. The seed oil can be expelled by pressure. The fruits are also distilled to make alcohol.	Grows well in 'Kalahari sand', especially along the crests of sandy ridges, where rainfall is 150–600 mm p.a. (but 200 mm is adequate and it can 'withstand long droughts'). The tree bears fruit after 25 years and can be propagated either from the kernel or vegetatively. The kernel, which is edible and is 9% by wt. of the fruit, has high fat (57.3 g/100 g) and protein content (28.8 g/100 g). A mature (female) tree yields up to 950 fruits. The seed oil is pale yellow and is semi-drying: a solvent-extracted sample had (1967): density (at 20° C), 0.960; sap. val., 193; iod. val., 156; fatty acid composition: sat. acids, 13%; linolenic, 3%; linoleic, 44%; oleic, 17%; elaeostearic (C_{18} containing a conjugd. triene unit), 23% (confirmed by u.v. spectrum). The oil when fresh is said to be edible and to have a pleasant taste. Its relatively high unsaturation may make it of some use in the manufacture of paints and varnishes. The oil-cake contains 60% protein. The wood is soft and light, a substitute for balsa, and can be used for matches and insulating boxes. Paper-making experiments show generally good mechanical properties. Board-making experiments have also been conducted.	Restricted in nature (though could presumably be cultivated in similar areas) to sub-tropical latitudes of S. Africa and sandy well-drained oils. Tolerant of semi-arid rather than arid regimes. The wood is too light-weight for building. The nut-shell is very hard to crack (requires an initial roasting). Only 35% of the whole fruit is edible (26% flesh, 9% kernel) the remainder being shell and skin. The seed oil is not likely to find general acceptance as an edible oil on a commercial scale as its high elaeostearic acid content will lead to its rapid deterioration (by polymerisation of the triene function) on storage or heating. At the same time its occurrence in greater preponderance in *R. heudelotii* seed oil (~ 50%) and in tung oil (70–80%) means that *R. rautanenii* is hardly likely to be a viable source of this potentially interesting fatty acid.	Adrian *et al.*, 1955 Anon, 1951c Anon, 1959c Biesele *et al.*, 1979 Chisholm and Hopkins, 1966 Chittenden *et al.*, 1960 Lee, 1973 Mensier, 1957 Petroff *et al.*, 1967 Xabregas and Teixeira, 1952 Xabregas *et al.*, 1967 Xabregas, 1957 Uphof, 1968
247. *Ricinus communis L.* (Castor oil plant, palma Christi) Widely in tropical (and some sub-tropical) regions.	Very variable shrubby plant 1–8 m in height. Cultivated on a very large scale in Brazil, India, etc.; total production around 800,000 tonnes seed p.a. worldwide. Oil content of seed, 40–50%. The oil is almost pure (around 90%) ricinoleic acid triglyceride and is a major industrial product being both used as such	Said to be one of the few crops in India which will grow economically on poor gravelly soils. The oil is unusual in being almost entirely one chemical species (hence no separation problems) from which almost pure ricinoleic acid can be obtained on hydrolysis. This acid has several functional groups and so has high potential as the raw material for the production of various chemical compounds. Some are already in use on a large scale (*see* left) but others could follow. Pyrolysis of castor oil said to produce a useful pyrethrum synergist.	Said to prefer fertile, deep, well-drained soils and rainfall of 400–500 mm in 6 months followed by dry periods but there are many forms (? sub-species) which vary in water requirements. However, has poor tolerance to salt and is sensitive to frost. The various severely toxic constituents of the seed, which remain in the	Anon, 1942b Anon, 1943a Arnon, 1972 CSIR India, 1972 Duisberg and Hay, 1971 Godin and Spensley, 1971 Hinkson *et al.*, 1972 Jones and Earle, 1966 Layton, 1977 Macfarlane, 1975 Mensier, 1957

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
Ricinus communis (contd)	(medicinally, as a purgative, and industrially, in lubricants, brake fluids, cosmetics, and in the production of crumb rubbers and speciality soaps) and as a raw material for the manufacture of: a) Sebacic and undecylenic acids, used in making synthetic resins and fibres (nylon). b) Dehydrated castor oil (DCO), made by acid-catalysed dehydration, with a higher iod. val., (110) than castor oil itself (85) and hence a valuable semi-drying oil; used widely in the manufacture of paints and varnishes. c) Turkey red oil, made by treatment with cold sulphuric acid, widely used in the textile industry. d) Hydrogenated castor oil — used as a substitute for carnauba wax and in the formulation of greases, etc. The oil cake is used as a fertiliser (castor pomace). Stems used as fuel, in building and as source of cellulose for manufacture of cardboard, newsprint etc. Leaves used as feed for silkworms in India.		cake on expelling the oil, prevent the cake's use as a feed (though research on heat and/or chemical detoxification, is continuing). The 1940s suggestion that castor may be a useful agricultural pesticide has faded with the introduction of modern synthetic pesticides.	Paris and Dillemann, 1960 Perrot and Gentil, 1921 Rao, 1970 Rautou, 1958 Roark, 1947 Uphof, 1968 US Report to Congress, 1957 Weiss, 1971 Williams, 1966

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
248. *Rosmarinus officinalis* L. (Rosemary) Mediterranean region.	A perennial herb (of up to 2 m in height), which grows wild on the dry rocky hills in the Mediterranean region and is cultivated in e.g. N. Africa and Spain. The herb is widely used in flavouring foods (and teas) and the derived essential oil is used in perfumery, in soaps, in cosmetics and to some extent medicinally and in liniments.	The leaves and upper parts of the plant yield, on steam distillation, 1—2% volatile oil (oil of rosemary), which contains varying amounts of α-pinene, 'verbenone' (the 4-keto deriv. of α-pinene), camphor, borneol and 'eucalyptol' (1, 8-cineole). The leaves also contain as a major constituent, (0.7%), carnosic acid, a diterpene carboxylic acid which contains an aromatic (catechol) ring and which as a result has antioxidant activity. The leaves also contain several triterpenes and a flavone (but the alleged alkaloid rosmaricine, also reported in the leaves, has been shown to be an artefact).	Composition of the volatile (essential) oil very variable with geographical origin (and to some extent season): e.g. samples from Corsica and Algeria have been reported (1973) to contain (by g.l.c.): 26–34%, 22—37%. 2—8%, trace—6%, and trace, respectively, of the five terpenes noted left — whereas samples from Tunisia gave corresponding figures of: 9—13%, trace—6%, 8—24%. 7—8%, and 35—50% (part of the variation seen in commercial oils may well be due to non-standardised production methods having been used — a problem in its own right which would need resolving before this oil could become commercial).	Abdel Haafez *et al.*, 1966 Brieskorn and Domling, 1969 Brieskorn and Michel, 1968 Brieskorn and Zweyrohn, 1970 Butterfield and Pickthall, 1958 CSIR India, 1972 Granger *et al.*, 1970 Granger *et al.*, 1973 Ostric-Matijasevic, 1963 Uphof, 1968 Wenkert *et al.*, 1965
249. *Rumex hymenosepalus* Torr. (Canaigre, raiz del India, wild rhubarb, American red ginseng) SW. USA, Mexico.	A perennial herb with tuberous roots which contain 'over 25%' tannin (improved strains yield '35—42%'); the roots are used by the local American Indians as a source of tanning agent (and the extracted tannin was exported to Europe in the late 19th century); also as a source of a yellow dye used for dyeing wool; and medicinally. Leaf-stalks sometimes used for pies instead of rhubarb; leaves eaten as greens. Occasionally cultivated.	Can be grown as an annual crop for use as a source of tanning agent; adaptable to mechanical propagation and harvesting; the tannin is said to have excellent properties and the plant to be one of the most promising potential sources of tannins in the USA. Yield: 1,000 lbs tannin/acre (1,140 kg/ha) and 'promising' for sole leather; and may find use as a viscosity regulator for oil well drilling. Chrysophanic acid and physcion, both 1,8-dihydroxyanthraquinone derivatives, isolated (1.2% and 0.3% respectively dry wt.) from the tubers (in 1955 — and despite conflicting reports, the related compound emodin since confirmed present). In addition crude isolates showing anti-tumour activity have been isolated from the roots and tubers (flavonoid derivatives). The roots also contain 20—30% starch and 9—13% sugars and the possibility of fermenting these constituents to alcohol, for fuel use, has also been mooted.	Was research in the USA in 1950s on breeding for higher yields and on better processing methods, but this has not resulted in notable development as yet. To obtain the yields quoted, the plant may need some irrigation. Judged (in 1959) that commercial development of the plant for tanning material was not practical at the market prices then current. Despite vernacular name, no ginseng-like components detected.	Arnon, 1972 Buchalter, 1969 Buchalter and Cole, 1967 Cole and Buchalter, 1965 Duisberg, 1952a Griffin *et al.*, 1959 Hillis, 1955 Johnston, 1979 Krochmal *et al.*, 1954 Lui and Staba, 1980 Uphof, 1968 US Report to Congress, 1957

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
250. *Salsola arbuscula* Pallas; syn. *S. richteri* Karel ex Moq. Maritime and salt steppes of the USSR, Iran.	Plant is mentioned for its medicinal properties in the pharmacopoeia of the USSR. Grows extensively in semi-shifting sands.	Contains a group of isoquinoline alkaloids — salsoline, salsolidine and salsamine — said to be capable of reducing blood pressure and similar in composition to those of Cactaceae. The plant is also useful for reinforcing shifting sands for their subsequent afforestation. As with the following entry, the plant accumulates high concentrations of salts and its ash could therefore be used as a source of these.	The alkaloids' medicinal properties may be of local use but are by no means unique — and all three have since been obtained by synthesis. Not listed in British Pharmacopoeia nor in Martindale.	Kametani and Okawara, 1977 Martindale, 1977 Paris and Dillemann, 1960 Petrov, 1972 Proskurnina, 1958 Rossiiski, 1945 Teitel *et al.*, 1974 Zaitschek, 1953
251. *Salsola kali* L. var. *ruthenica* (Iljin) Soó; syn. *S. pestifera* A. Nels., *S. tenuifolia* Tausch (Russian thistle, tumbleweed, prickly saltwort, glasswort) Widespread in drier areas of S. USSR and W. USA.	A salt-tolerant, drought-resistant fleshy plant, the young shoots of which are occasionally used as a vegetable or in salad. Major use has been as a forage during times of scarcity of more usual grazing (e.g. in the 1930s drought of W. USA).	Good silage can be prepared from salsola, which is equivalent to alfalfa in protein and fat content and superior in carbohydrate: fibre ratio. Will yield 6 tonnes dry matter/ ha p.a. with 240 mm rain and no fertilizer. Plant has very high salts content (especially potassium, ash contains up to 30% K_2O) and will reduce salinity of the soil in which it is growing. The sun-dried plant material has a heat content of ∿15 megajoules/kg and, it has been suggested, would make a useful fuel for local use (domestic heating/cooking or local small-scale industries) after pelletising or pyrolysis to a crude liquid hydrocarbon fuel.	A pest of agriculture in N. America where it is an aggressive and invasive weed of the arid/semi-arid western states (especially on over-grazed or abandoned land). Has not been tried as a cultivated forage crop partly for this reason (in addition is prickly when dry, possibly making it unacceptable — except in times of scarcity). May be problem with high oxalic acid levels.	CSIR India, 1972 Donaldson and Goering, 1940 Fowler and Hagerman, 1979 'JS', 1980 Meinel *et al.*, 1980 UN, 1977 Uphof, 1968 Willis and Shaw, 1973
252. *Salvadora persica* L.* (Salt bush, mustard tree, toothbrush tree) Middle East, tropical Africa, India, Sri Lanka.	A salt-tolerant shrub to small tree which coppices well (for sticks and fuel) and is used to make shelter belts. Shoots eaten as salad and used as camel fodder. Fruits and the root bark are locally used medicinally and the seed fat is used for candles. The ash from the plant is high in salts, the crude solid being known as kegr.	Seeds contain 35—45% oil with sap. val., 245—247; iod. val. around 6 (only). Unsap. fraction, 0.9%; sp. gr. (at 15° C), 0.8669. The oil tends to have a disagreeable odour but this vanishes on purification; it is inedible — due to the presence of various substituted dibenzylureas — but its fatty acid composition (lauric, 20%; myristic, 55%; palmitic, 20%; oleic, 5%) is excellent for making soaps and it makes a good substitute for coconut oil and is a potential industrial substitute. The roots contain β-sitosterol, *m*-methoxybenzoic acid, unidentified alkaloids and a substituted urea. The wood from the plant is white, easy to work and takes a good polish.	The plant is prone to attack by various beetle larvae and fungi. The root bark is acrid and vesicant. The wood makes a poor fuel.	Ayensu, 1979 Coursey, 1964 CSIR India, 1972 Khan *et al.*, 1972 Mensier, 1957 Ray *et al.*, 1975 Uphof, 1968 Sen and Bansal, 1979 Sen and Chawan, 1969

* The closely similar shrub (CSIR India, 1972) *Salvadora oleoides* also has oil-yielding seeds (45%) containing substituted ureas; again the fat makes a good soap and is a potential industrial substitute for coconut oil in this respect. The oilcake (30% protein, dry wt. basis) is used commercially for feed.

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
253. *Salvia officinalis* L. (Common sage, garden sage) Mediterranean region (but cultivated widely on small scale as a herb).	Small shrub cultivated as kitchen herb used for flavouring foods: essential oil used in medicine (e.g. as a vermifuge against ascaris) and flavouring, and also in perfumes, deodorants and insecticides. Leaves used as infusion — 'sage tea' (which is also said to have various medicinal, especially soothing, properties). Leaves also used in 'green cheese'. Dried leaves used as carminative, etc.	Can be grown from seeds or cuttings, but seeds do not germinate well. Produces better quality flavour components on clay-loam soil; adapted to cotton-growing regions of S. USA. Herb also contains pentosans, a bitter principle resembling marrubiin, resins, tannins (3—7% in the leaves, depending on origin), etc. The resin is low in ash (1.5%), soluble in alcohol (and various other organic solvents), and is rich in catechol-like (antioxidant) components. Essential oil yield is 2.6% of dried wt. of leaf, and consists mainly of thujone (45—50%: the higher the better, being the major determinant of the oil's quality), linalyl acetate (10—15%), α and β-pinenes (total 5—10%), and borneol and camphor (7—8% each). Leaves also contain carnosic acid, which is an antioxidant (*see* entry no. 248). The sterol (β-sitosterol) and triterpene (ursolic and oleanolic acids) content increases with plant maturity and is highest in leaves (0.25%, 0.13%, 0.08% dry wt. respectively). The leaves also contain a group of eight flavones (partly free and partly as glycosides based on genkwanin). The seeds contain a drying oil; fatty acid composition: oleic, 14%; linoleic, 29%; linolenic, 35%; sats., 12%.	Gave good quality essential oil when grown at Jammu in N. plains of India but quality said to suffer when plant is grown in particularly hot and dry climates.	Arnon, 1972 Brieskorn and Biechele, 1971 Brieskorn and Dömling, 1969 CSIR India, 1972 Duquesnois, 1972 Hanson and Hocking, 1957 Murko *et al.*, 1974 Nicholas, 1961 Uphof, 1968 Walther, 1958
254. *Sarcobatus vermiculatus* (Hook.) Torr. (Greasewood bush, common or Mexican greasewood, chico) SW. USA and adjacent areas of Mexico.	Nordihydroguaiaretic acid — an effective antioxidant for butter and fats — used to be extracted from leaves and twigs on a large scale for incorporation in foods.	Possible source of shellac.	Use of NDGA as an antioxidant in foods has recently been curtailed following toxicity studies: *see* entry no. 188. The foliage is high in oxalates so although it is sometimes used as a feed in semi-arid areas, undesirable to use to excess.	Clawson, 1934 Colton, 1943 Cruse, 1949 Fleming *et al.*, 1928 Sampson and Malmsten, 1935 Uphof, 1968

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
255. *Scaevola plumieri* (L.) Vahl Along tropical coastlines and beaches.	A wild shrub found in arid lands (and presumably also salt-tolerant). Pith is squeezed flat to make rice paper. Other *Scaevola* spp. (e.g. *S. serucea* Vahl, syn. *S. koenigii* Vahl: CSIR India, 1972; Uphof, 1968) yield a hard wood which is resistant to salt water and is used in boat building.	Seed contains 66.7% oil, 19.2% protein.		Jones and Barclay, 1972 Willis and Shaw, 1973
256. *Scorzonera tau-saghyz* Lips. and Bosse (Black root, sweet root) On the Kara-Tau plateau of S. USSR.	Grown in the USSR as a source of rubber (which is in the root). The plant is perennial and may continue storing rubber for many years.	The plant can be cultivated in very different climates — easily propagated by seed or root cuttings. Sometimes up to 40% w/w of rubber can be obtained from the roots (probably the highest concentration in any plant) and it is usually of excellent quality.	Found at elevations of 500—1,100 m, with a short summer and where annual rainfall is 350 mm (but coupled with a long cold winter: the plant may need more water in a uniformly hot climate). Difficult to establish. Entire plant must be ploughed up since nearly all the rubber is in the roots, very little is in the aerial parts. Plant may take up to 5 years to accumulate maximum rubber content — much longer than its nearest competitor (*Taraxacum koksaghyz*: which see) but which however has a lower maximal rubber content.	Anon, 1932 Arnon, 1972 Kosurukow, 1935 Polhamus, 1962 Uphof, 1968

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
257. *Sesamum indicum* L.; syn. *Sesamum orientale* L. (Sesame, bene, benniseed, gingili (gingelly), simsim) Widely distributed in tropical and sub-tropical areas.	The seeds are used in bread and confectionery. However, the major outlet is as the source of a high-quality, colourless, unsaturated oil used as a cooking or salad oil and in shortenings. (It is also added to other oils to prevent their oxidative deterioration.) But it also has various non-food uses based on the combination of it being a free-running oil and yet reasonably stable to oxidation, due to the presence of the natural antioxidant, sesamol (3, 4-methylenedioxy-phenol); e.g. as a solvent for fat-soluble medicaments for injection, in the preparation of ointments and cosmetics, as a base for perfumes, to oil tanned hides, and to make soap. The oil also contains (0.5–1.0% and 0.3–0.5% w/w respectively) sesamin and sesamolin (both C_{20} compounds related to sesamol) which act as synergists to (i.e. boost the activity of) the insecticides pyrethrum and rotenone. The oilcake is used as cattle feed or fertilizer.	Seed yields range from 80 kg/ha to 750 kg/ha (and to 2,000 kg/ha with modern cultural practices including irrigation). Oil content, 40–58%. The oil is stable due to the antioxidant constituent. The oil-extraction rate varies from 35–50% oil according to method. Fatty acid composition: palmitic, 7–9%; stearic, 4–5%; oleic, 37–50%; linoleic, 37–47%; sp. gr. (at 25° C), 0.918–0.926; refractive index, 1.472–1.474; iod. val., 104–118; sap. val., 187–193; unsap. matter, 1.5–2.5% (of which sterols, 0.3–0.5%).	Not suitable for altitudes above 1,250 m. Intolerant of acid soils. Seeds germinate slowly (rate can be accelerated by growth substances); temperature of 25–27° C best for rapid germination and for the plant's subsequent development. Plant requires 200–800 mm rain p.a. (400 mm said to be adequate for dry-land farming in the Mediterranean region). If grown in desert areas, may require some irrigation during the growing season. Sensitive to frosts. Dehiscent varieties present harvesting problems. Subject to attack by various pests and diseases. A dry period is required for ripening but temperatures above 40° C harmful. The oil's stability may be seriously reduced (due to the removal of the sesamol) by purification procedures such as steam distillation or deodorisation (sesamol volatile). Sesamin and sesamolin have largely been replaced as synergists by the semi-synthetic analogue, piperonyl butoxide.	Arnon, 1972 Beroza, 1954 CSIR India, 1972 El Baradi, 1972 Godin and Spensley, 1971 Lyon, 1972 Paroda, 1979 Tribe, 1967 Weiss, 1971 Williams, 1966

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
258. *Simmondsia chinensis* (Link) Schneider; syn. *S. californica* Nutt. (Jojoba, goat nut, pignut). SW. USA and adjacent areas of N. Mexico, especially the Sonora Desert.	Traditionally, the local Indians have hand-harvested wild stands to make various beverages, etc. from the seeds and to express the oil for medicinal uses.	A shrub commonly 0.5–2 m in height, but occasionally 3 m, which grows wild on dry, gravelly, well-drained slopes, from sea level to 1,200 m; tolerates air temperatures of up to 45°C and, when mature, tolerates frosts to -9°C. Has a system of deep tap roots and can survive, and apparently even produce some seed, on 100 mm rain p.a. (though run-off may concentrate this; generally needs more for reliable seed production) and survives complete drought for up to a year by leaf-shedding. Lives for 100+ years; salt-tolerant (so can use salty irrigation water to help establish plantations) and suffers from no severe pests in the areas so far tried. The seed yields (50%), by normal mechanical expression, an almost colourless, odourless oil with f.p., 10–7°C; b.p. (under N_2), 398°C; smoke p., 195°C; iod. val., 82; sp. gr., (at 25°C) 0.863. It is unchanged by prolonged heating and requires no refining before use. It is unusual – possibly unique – for a seed oil in that it is not a glyceride 'fat' but a liquid wax consisting almost entirely (97%) of a mixture of wax esters (esters of long-chain fatty acids and similar alcohols), the major constituent fatty acids, all monounsaturated, being: C_{18} (i.e. oleic), 10%; C_{20}, 71%; C_{22}, 14%; C_{24}, 1%; and the alcohols, also monounsaturated: C_{20}, 44%; C_{22}, 45%; C_{24}, 9%. Jojoba oil thus closely resembles the industrially important product sperm whale oil (in detail, it is more homogeneous, of higher molecular weight and lacks sperm whale oil's glyceride content – and, advantageously, its fishy odour), whose use has recently been partly or completely banned by various governments as a conservation measure. This has led to widespread interest in jojoba with extensive literature, and a biennial international conference and periodical (*Jojoba Happenings*, University of Arizona) devoted entirely to it. Extensive research seems to indicate that jojoba oil could replace sperm whale oil in many of its uses – especially in lubricants, either as such or after sulphurisation, where its stability to heat and chemical degradation, and its metal-wetting capacity, enables it to be used at high temperatures and very high pressures. It may also be able to replace, at least in part, the sperm whale oil traditionally used to oil and soften leathers. The many other uses mooted for it once, or if,	Requires 400–500 mm rain p.a. for a worthwhile crop; must be mainly winter/spring rain (claims of good yields on much less probably due to run-off effects). Even then, yield very variable in wild stands and still too low to be viable even when cultivated; and although plant selection/breeding experiments are proceeding, still too early to be sure that a reliable and sufficient (say 2.5 tonnes oil/ha from mature (>8-year) plants) yield can be obtained. With wild plants, yield continues to rise as moisture input is increased from the 400/500 mm level to 1,300 mm (which implies the need for irrigation or the construction of run-off catchment hollows). Tendency for the current experimental plantations barely to be in even the semi-arid category. Jojoba is naturally dioecious (separate male and female plants) with wind pollination, so that plantation workers must be able to recognise the male seedlings and insert them thinly and evenly throughout the otherwise female plantation (typically at 1 in 10), wasting the rest (current plant-selection work may eventually remove this difficulty). Five year wait from planting seedling to worthwhile seed production	Anon, 1979b Anon, 1980a Anon, 1980b Aronson and Zur, 1982 Bell *et al.*, 1977 Brooks, 1978 Clarke and Yermanos, 1980 Devine and Johnson, 1978 Elliger *et al.*, 1975 Fink and Ehrler, 1979 Foster and Wright, 1980 Geigert *et al.*, 1980 Hogan, 1979 Johnson, 1977 Letan, 1975 Miwa *et al.*, 1974 National Academy of Sciences, 1975 Prabhudesai and Viswanathan, 1978 Princen, 1979 Schechter in Davis, 1978a Sherbrooke, 1978 Simpson and Miwa, 1977 Spener, 1979 Walters *et al.*, 1979 Wisniak, 1977 Yermanos, 1978 Yermanos *et al.*, 1979

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
Simmondsia chinensis (*contd*)		it becomes commercially available, include use as a source of the rubbery material known as a 'factice' (used in the manufacture of linoleum, printing ink, paints and varnishes), of long-chain unsaturated fatty acids and alcohols (which could be derivatised at the double bond to make plasticisers, etc.), as an inert solvent for orally administered drugs, as an antifoam agent in antibiotic manufacture, in cosmetics, etc. On hydrogenation, jojoba oil gives a solid (m.p. 67°C), hard white wax (almost as hard as carnauba) for which many traditional uses could be envisaged — such as in polishes, carbon paper, smokeless candles, etc. It is also fully miscible with polyethylene to which it imparts additional, and possibly useful, hardness. The oilcake contains 30/35% protein but also an appetite-depressant, simmondsin. This led to starvation of trial animals fed it at a level greater than 10% in a mixed feed (though desert rodents eat the whole seeds with no apparent ill effect — perhaps through adaptation). However, a method of detoxifying by prolonged treatment with ammonia has been reported.	and a further 3—4 years until a steady commercial level is reached. Shrubs damaged by temperatures below -9°C (seedlings, -4°C). Considered that except in regions where very cheap labour available for hand-harvesting, mechanical harvesting will be necessary and no method of so doing has yet been devised; tendency for rodents to take fallen seeds so may need to harvest continuously as they ripen. Total market for the oil likely to remain relatively small and specialist, mainly as a sperm whale oil subsitute and in the cosmetic and pharmaceutical industries. The demand for the wax is likely to be small as there is a surplus of carnauba, etc. waxes (which, in addition, do not need hydrogenation first). Current demand for sperm whale oil is much down on the mid-1960s figure of 150,000 tonnes p.a. and could be satisfied, at 2.5 tonnes oil/ha, by only 10,000 ha of mature jojoba (though more, in the event of its other suggested uses leading to a substantial demand). Also, *Limanthes alba* and *Moringa oleifera* (entry nos. 194 and 203) may compete as partial sperm whale oil substitutes; and, more likely, substitutes manufactured from common glyceride oils (by hydrolysis,	

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
Simmondisia chinensis (*contd*)			reduction of half the acids to alcohols, and coupling) may become established before jojoba oil can be produced in commercial quantities. The oilcake-detoxification procedure so far reported requires a 30-day contact time to be effective, and coupled with the cost of the ammonia, is likely to make the material uncompetitive, except where there is little alternative. Introduction into other arid regions restricted by soil type and the need for winter/spring rains; browsing animals (and local insects) would be a problem at the seedling stage; an area in western Saudi Arabia has been mooted. The effect of differing daylight lengths on growth, simmondsin content, etc. currently being studied.	
259. *Smirnowia turkestana* Bunge USSR. Widespread in C. Asia.	Grows to 1 m in height; used in treatment of hypertension and relieving blood vessel spasms.	Two alkaloids of unknown structure (smirnovinine and spherophysine) isolated.		Petrov, 1972 Ryabinin and Il'ina, 1951
260. *Solanum carolinense* L. (Carolina horse nettle) N. America	Air-dried ripe fruits used as sedative and anti-spasmodic.	Steroid alkaloids (solasodine etc.) found; also (from the roots) solamine (an aliphatic base), the insecticide anabasine, and a carbamate with a structure resembling some of the synthetic carbamate insecticides.	Anabasine of minor importance: *see* entry no. 31.	Arnon, 1972 Evans and Somanabandhu, 1977 Uphof, 1968

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
261. *Solanum incanum* L.; syn. *S. melongena* L. var. *incanum* (L.) Kuntze (Asind) E. Africa, SE. Asia.	A woody herb. Fruit and leaves used widely as drugs in e.g. Kenya, both topically and orally (*see* 'Constraints' for the danger of so doing); seeds are used for curdling milk. Root used as horse medicine.	The plant is easy to cultivate, yielding 60–70 fruits per plant and can replace *S. khasianum* as a source of glycoalkaloids. Alkaloids found in all parts of plant but mostly in the fruits, especially solasodine and its glycoside derivative, solasonine. Diosgenin and yamogenin (optical isomers, at C_{25}) also present. These four compounds can all be converted by acid treatment into precursors for the steroid industry: *see* next entry. A high-alkaloid content race occurs in S. India.	Fruit found to contain dimethylnitrosamine, a potent carcinogen. Market for steroid precursors of the kind mentioned here is now poor: *see* entry no. 111. In addition, several of the species even in this compilation also yield steroid precursors (e.g. entries 111, 170, 262).	Ali *et al.*, 1967 Ammal and Viswanathan, 1974 Baquar and Tasnif, 1967 Coppen, 1980 CSIR India, 1972 Du Plessis *et al.*, 1969 Schoental, 1969 Segal *et al.*, 1977
262. *Solanum surattense* Burm. f.; syn. *S. xanthocarpum* Schard. & Wendl. Widely in the tropics of the Old World.	Used medicinally in Hindu India against fever and chest complaints; seeds used as an expectorant.	Fruit contains 20.7% w/w seeds, and seeds 19% semi-drying oil containing 43% oleic, 36% linoleic, 5% palmitic and 10% stearic acids; and with sp. gr. (at 27° C) 0.924; sap. val., 182; iod. val., 124; unsap. fraction, 1–1.5%. Fruits contain 1.1% steriodal alkaloids of the solasodine (*see* previous entry) type*; also diosgenin. Relatively large amounts of β-sitosterol also thought to be present. Carpesterol, an unusual and potentially useful C_{30} sterol with C=O at C_6, C=C at C_7–C_8, –OH at C_{22}, and present as a C_3– benzoate, isolated. Various coumarins and quercetin (flavone) also isolated. Whole-plant extract shows anti-viral and anti-tumour activity.	Demand for steroid precursors poor: *see* previous entry for the species. Little demand for the coumarins also present – hence steroids industry will not benefit in reducing manufacturing costs by exploiting other constituents.	Arnon, 1972 Ayensu, 1979 Beisler and Sato, 1971 Bhatnagar *et al.*, 1961 Dubey and Gupta, 1978 Gupta and Dutt, 1936 Heble *et al.*, 1968 Mensier, 1957 Paul *et al.*, 1958 Tupkari *et al.*, 1972 Uphof, 1968
263. *Solidago canadensis* L. (Canada goldenrod) Eastern N. America and the W. deserts; also in India (as an ornamental).	A perennial herb: the seeds were eaten by the local Indian tribes. An emergency food plant, and source of oil – goldenrod oil.	The whole plant contains about 4% latex (other *Solidago* spp. have occasionally been proposed as an emergency source of rubber). Steam distillation of the aerial parts yields 0.6% of a pale yellow fragrant oil, Canadian goldenrod oil, consisting mainly of terpenes. The aerial parts also contain a series of flavones (rutin, campherol, quercitin and isorhamnetin) and a flavone glycoside, isoquercitrin. Roots contain the multi-functional (furan ring, conjudg. ene-one, –OH) diterpene solidagenone (1.2%) and two related spiro-ethers (total 2%); also a series of terpenes (β-caryophyllene *etc:* according to i.r.), hydrocarbon waxes and myricyl alcohol (a C_{30} wax alcohol). The seeds yield 30% of a semi-drying oil with iod. val. 140, and containing 62% linoleic and 32% oleic acids plus 3% of a keto- and 2% of a hydroxy-acid. Extracts of leaves (and less so, flowers) show hypotensive activity.	Rutin was once considered to have vitamin activity but this is now largely discounted: *see* entry no. 208.	Anthonsen *et al.*, 1969 Batyuk and Kol'tsova, 1968, 1969 Buehrer and Benson, 1945 CSIR India, 1972 Earle *et al.*, 1960b Krepinsky and Herout, 1962 Krochmal *et al.*, 1954 Racz *et al.*, 1979

* Such compounds are common in *Solanum* spp. and e.g. the fruits of *S. indicum*, a forest shrub (and so non-arid tolerant?) from the hotter parts of India (CSIR India, 1972), contain 1.8% of these compounds, but the same constraints apply (although as compared with obtaining steroid precursors from slow-growing *Dioscorea* tubers, solanum fruits appear quickly).

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
264. *Stillingia sylvatica* L. (Queen's delight, queen's root, yaw root) N. America (e.g. in the SW. deserts).	A herbaceous perennial; grows best in dry sandy soils; up to 1–1.5 m tall. Dried root has been used medicinally — as an emetic, cathartic, laxative, duiretic and 'tonic' (was mentioned in US Pharmacopoeia and is noted in the Merck Index of chemicals and drugs for 1976).	Seed contain 30–33% light yellow oil; sp. gr., (at 25°C) 0.926; r.i., 1.4833; sap. val., 189; iod. val., 190; acetyl val., 37.5; unsap. fraction about 0.75%. Approximate fatty acid composition: oleic, 18%; linoleic, 25%; linolenic, 48% (remainder are saturateds). Should make a good drying oil suitable for paints and varnishes, and allied products requiring such. The oil dries in 4–6 h when spread out in the air. Root contains an acrid resin (sylvacrol), an acrid oil, a glucoside, 3–4% of volatile oil, and 10–12% tannin.	Member of the Euphorbiaceae and so handling may be hazardous (*see* footnote to entry no. 126): the root resin is known to be toxic and very irritant.	Adolf and Hecker, 1980 Anon, 1930a Batterson and Potts, 1951 Krochmal *et al.*, 1954 Mensier, 1957 Uphof, 1968
265. *Stipa tenacissima* L.*; syn. *Macrochloa tenacissima* (L.) Kunth (Esparto grass, alfa grass, halfa grass) N. Africa.	A perennial grass which takes 12 years to mature. An important source of paper-making material in the Mediterranean region; also used for ropes, sails, mats, etc. Some is exported for pulp. Cattle graze on natural populations. The wax which can also be obtained is used in carbon paper, polishes and leather finishes.	Grows wild in near-desert areas (rainfall 150 mm/year). Green plant yields 40–42% cellulose. The pulp is suitable for printing, writing and wrapping papers. Research programme in Tunisia for improvement of quality and development of simple harvesting machines. Esparto wax occurs as a coating on the grass and is released as a by-product during paper manufacture; yield up to 5%; a hard, brittle, non-tacky brownish wax, m.p. 78°C, which on melting then solidifying gives a very smooth surface. It contains 65–70% of the hydrocarbon $C_{31}H_{64}$, has an acid value of around 30; sap. val., 63–69; iod. val., 8–16. It is a good substitute for carnauba wax — and superior in the sense that it contracts less on solidifying and gives softer films. About 500 tons of pure wax per annum were being produced by an Italian firm in the early 1940s. There is a patent for production of activated carbon from the residue resulting from the alkali digestion. Residue from wax purification forms excellent filler for moulded plastics.	Organic solvents (expensive/inflammable) required to extract and purify the wax. Generally poor market for waxes (*see* comments under entry no. 258) though may possibly fulfil a local need. Not so readily miscible with fatty and other oils as carnauba. Plant breeding experiments, by seed or vegetatively, have not been encouraging.	Anon, 1942a Anon, 1951a Anon, 1978 Arnon, 1972 Bennett, 1975 Bui-Xuan-Nhuan, 1971 Farnell, 1934 Isenberg, 1956 Soler and Guzman, 1954 Uphof, 1968 Winkler, 1968

* *See* also *Lygeum spartum*

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
266. *Styrax officinalis* L. (Officinal styrax, styrax tree) S. Europe, Asia Minor (Turkey, Greece, Cyprus, Crete).	A small shrub; the resin (storax) is used in pharmacy, cosmetics, perfumery, etc. and as a source of incense. Seed powder is used as an insecticide, in fish baits and as a fish poison.	Grows up to an altitude of 700 m. Produces 1–6 kg (small to large bushes) fruits; oil content of seed, 50%, protein, 16.5%. The oil is viscous, slightly yellow, tasteless; can be used in soap; its low iodine value (72) prevents use in dye industry. Fatty acid composition: oleic, 51.5%; linolenic, 26.6%; palmitic, 11.6%; Δ^9-eicosenoic (C_{20}), 7.1%; stearic etc. 2%; leaf extract showed (weak) anti-tumour activity: analysis showed presence of paraffinic (waxy) hydrocarbons, derived long-chain ketones and alcohols, and β-sitosterol. A saponin with exceptionally strong foaming action and haemolytic activity isolated from pericarp. A series of glycosides isolated from seeds which yield, on acid hydrolysis, the substituted benzofuran egonol and related compounds.		Diapoulis, 1952 Jones and Barclay, 1972 Segal *et al.*, 1964 Segal *et al.*, 1967 Ulubelen, 1976 Ulubelen and Gören, 1973 Vardar and Oflas, 1973
267. *Tamarix gallica* L.* (Tamarisk, salt cedar, French tamarisk) Mediterranean region, introduced into the SW. USA.	A shrub or small tree; in wadis and other areas likely to contain residual moisture.	The wood has been suggested as a source of fuel, fence posts, wood pulp and to make furniture. Plant contains active principle which combats liver damage. *Tamarix* spp. noted as potential firewood sources by the National Academy of Sciences (1980).	Has a relatively large water requirement and has extensive tap roots to supply it, but in so doing denudes the immediate area of moisture to the detriment of other plants. A pest in areas where some form of irrigation is practised, as it colonises, and draws water from, irrigation channels and stream beds.	Arnon, 1972 Ayensu, 1979 Benson and Darrow, 1944 Duisberg, 1952a, b Duisberg and Hay, 1971

* A very similar plant, salt-tolerant and 'able to flourish with scanty rainfall and extremes of temperature', occurs in India and used also to be described as *T. gallica;* but more recently has been considered a distinct species – *T. troupii* or *T. indica* (CSIR India, 1976a); it contains the phenol ellagic acid (0.1% in the roots) and is used widely in local medicine, for making wooden implements, thatching and firewood (ibid; Israili *et al.*, 1965).

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
268. *Taraxacum kok-saghyz* Rodin (Kok-saghyz, Russian dandelion) On the Kara-Tau plateau of S. USSR.	Planted in the USSR during World War II, and in the USA from seed supplied by the USSR, as a source of latex (in roots); planting since discontinued in the USA. A perennial herb.	Experimental work in Sweden and Spain on high-yielding strains were successful; yield of 130 lb of rubber/acre (150 kg/ha) obtained. As compared with its nearest competitor, (*see* entry no. 256), kok-saghyz is easier to establish and produces a worthwhile crop of rubber in a single season (but *see* right). Average rubber content of roots, 6%. Does not generally require a high concentration of fertilizers in peat soil.	Adapted to a short summer growing season; found at high altitudes where there is a high diurnal variation in temperature. Seeds require high moisture soil content for germination (and pre-treatment, according to trials in Australia). Soils rich in organic matter give best production. Produces a relatively low (especially as compared with entry no. 256) concentration of rubber. The rubber is in the roots so the entire plant has to be harvested.	Anon, 1944a Arnon, 1972 Garkavyi, 1935 Polhamus, 1962
269. *Tecoma stans* (L.) Juss; syn. *Stenolobium stans* Seem, *Bignonia stans* L., *Tecoma mollis* Kunth (Yellow elder, trumpet bush, yellow bells) N. and S. America, Cuba, Mexico naturalised in India and W. Africa.	Shrub or small tree; grown as a hedge plant. In India grows wild in waste, dry places. The roots are used in Mexico for making beer and also medicinally (to control diabetes).	The plant contains almost 4% latex. The roots are considered a powerful diuretic, vermifuge, tonic. Seeds have a bitter taste (alkaloids) and contain (23%) an oil with iod. val., 209 (hence a potential drying oil); fatty acid composition: palmitic, 6%; stearic, 3%; C_{18} with one C=C (? oleic), 7%; with two (? linoleic), 24%; with three (? linolenic), 41%; with four (a new and unusual structure with C=C at positions 3, 9, 12, 15), 19%. The plant was early shown to contain triterpenes, hydrocarbons, resins and alkaloids. Of these, the latter now known to consist of a series of six or more C_{11} (pyrindane) alkaloids based on the skytanthine skeleton, the major one being tecomine (tecomanine). Tecomine shows high hypoglycaemic activity (and low toxicity) in experimental animals, so confirming the plant's traditional use as an anti-diabetes drug by the Mexican Indians. An indole oxidase (enzyme) has been isolated from the leaves; the dried fruits contain 0.06% sterols of which half is β-sitosterol. The flower petals contain (126 p.p.m. fresh wt.) a mixture of β-carotene (pro-vitamin A) and zeaxanthin, 1:6.	Tecomine is unstable to air (especially at alkaline pH) making its clinical use possibly difficult (though this is countered by anti-oxidants). It is not mentioned as a recognised drug in Martindale's pharmacopoeia. The carotene is present in too small a concentration to be really useful (and its identity was not proven unequivocally).	Bianco *et al.*, 1980 CSIR India, 1976a Dickinson and Jones, 1969 Hammouda *et al.*, 1963 Hammouda and Khalfallah, 1971 Hammouda and Le Men, 1963 Hammouda and Motawi, 1959 Hopkins and Chisholm, 1965 Jones *et al.*, 1963 Jones *et al.*, 1971 Krochmal *et al.*, 1954 Maheshwari and Banerjee, 1970 Martindale, 1977 Nair and Vaidyanathan, 1964 Taha, 1954 Uphof, 1968

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
270. *Tephrosia vogelii* Hook f. (Fish poison bean) Tropical Africa; naturalised in India.	Shrub 2—4 m high; can thrive on very poor soils. Grown as a green manure and used to stupefy fish (still edible) and as an insecticide.	Seeds contain 13% oil: sap. val., 163; iod. val., 103. Seeds have high content of N material and no sugars. Main interest is the rotenoid content of the plant (rotenone and analogues — powerful natural insecticides, which are less toxic to warm-blooded animals than the synthetic organo-chlorine compounds like DDT and BHC), concentrated in the leaves; content, 2—3% (dry wt. basis) in improved strains in fresh leaves; although this is only ½-⅓ that in the traditional rotenone sources (viz. *Derris* and *Lonchocarpus* sp. roots), the latter only yield after 2—3 years and one needs to harvest the whole plant, whereas *T. vogelii* leaves can be gathered, if sufficient moisture, 6 months after sowing seed. Best yield obtained (∿ 140 kg/ha) by gathering leaves just before the plant flowers. Although essentially an annual, it will regrow for a 2nd year's crop. Of all *Tephrosia* spp., *vogelii* contains the most rotenoids.	Main doubt is to what extent this plant is truly arid (or even semi-arid)-tolerant. Frequent irrigation was found to be necessary for young plants growing in experimental plots in the Indian plains (possibly less necessary for the 2nd year's growth). Rotenoid content varies widely in wild stands (some indications that content higher in relatively dry areas). Extraction method important: extensive pre-drying results in loss of rotenoids. Best to heat fresh leaves in acetone, this being better than the Soxhlet-extraction equivalent. Seeds need pre-treatment for good germination. Labour costs of raising annuals relatively high. Is susceptible to damage by browsing animals. The plant has become a difficult-to-control weed in parts of India.	Barnes and Freyre, 1966a, b Barnes and Freyre, 1967 Barnes and Freyre, 1969 CSIR India, 1976a Gaskins *et al.*, 1972 Hagemann *et al.*, 1972 Kapur *et al.*, 1972 Martin and Cabanillas, 1970 Mensier, 1957 Tucakov, 1965 Uphof, 1968 White and Wolff, 1968
[For *Testudinaria* spp., see under *Dioscorea* spp.].				
271. *Thymelaea hirsuta* (L.) Endl; syn. *Passerina hirsuta* L., *Daphne gnidium* L. (Sparrow-wort, gnidium, spurge flax, mitnan) Mediterranean area (Egypt, Libya, etc.)	A shrub which grows abundantly in the Mediterranean coastal strip and desert. Crushed roots used in Sardinia to stupefy fish, powdered bark as an abortive. Leaf is an anthelmintic, the powder a remedy for dermatitis, and the bark is used in treatment of wounds.	Bark is a source of a strong fibre; possible use for textiles requires investigation. Described as a new paper-making source giving a high-quality pulp. Leaves contain 0.1% of a crystalline reducing phenol, 'thymelol' (since shown to be a substituted coumarin, daphnoretin) and also a catechol-tannin. The lipids in the leaves consist of 3% fatty acids esters (64% sat. C_{14}—C_{20} acids and 18% oleic, 11% linoleic, 7% linolenic) and 1% unsap. material [paraffinic waxes (C_{27}—C_{31}) and wax alcohols (C_{22}—C_{28})] and also β-sitosterol (plus a little campesterol). The plant also contains an essential oil and a kaempferol glycoside (tiliroside).	Poisonous to browsing animals (cattle and camels).	Boyko, 1954 Ismail, 1978 Lewin, 1953 National Paper Co. (and University of Tanta), Egypt; in Davis, 1978c Rizk *et al.*, 1974 Saleh *et al.*, 1963 Saleh and Sarg, 1965 Uphof, 1968

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
272. *Thymus capitatus* (L.) Hoffm. & Link; syn. *Coridothymus capitatus* (L.) Reichb. f. (Conehead thyme, thyme of Sicily, origanum) Mediterranean area.	A shrub which grows in arid and calcareous soils. Steam distillation of the aerial parts of the plant yields (1.5%) an essential oil which has many medicinal uses both externally and internally (in digestive complaints etc.) and is anti-septic. The oil is also used for scenting soaps and both oil and dried plant are used for flavouring foods (*see* following entry).	Constituents of the essential oil are cymene and 75–80% of carvacrol. Carvacrol can be used for production of carvomenthol esters which are used in cosmetics.	Composition of oil varies with locality.	Drar, 1954 Duisberg and Hay, 1971 Fayaud and Rivera, 1954 Rovesti, 1961 Rovesti, 1970 Uphof, 1968
273. *Thymus vulgaris* L. (Common thyme, garden thyme) Mediterranean area (e.g. Algeria, S. Spain, Morocco).	Steam distillation of the aerial parts of the plant yields 1–2% essential oil, a commercial product (from e.g. S. Spain) used widely in medicine as an antiseptic and disinfectant both externally and in oral preparations. Mentioned in various pharmacopoeias for its medicinal uses such as in mouth washes; also as an antispasmodic, a carminative and in cough linctus. Also used for scenting soap and as a food flavouring (the dried plants themselves are also used for this).	Composition of 'thyme oil' varies somewhat with the species used (not always *T. vulgaris*) but is usually rich in phenols (typically 50–60%), especially thymol and carvacrol. The seeds yield (37%) an oil with iod. val., 208 and fatty acid composition: oleic, 18%; linoleic, 13%; linolenic, 62%; sats., 3%. Hence potentially a very good drying oil. The plant also contains various triterpenes and flavones and the leaves are a good source of thiamine (vitamin B_1).	Plants become woody and have to be replanted after 3–4 years. Composition of oil varies, depending on altitude at which plant is grown.	CSIR India, 1976a Duisberg and Hay, 1971 Earle *et al.*, 1960a Guenther, 1949 Keuning, 1952 Martindale, 1977

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
274. *Trigonella foenum-graecum* L. (Fenugreek, metha, helba) Mediterranean (including N. Africa), India, Ethiopia and China.	An annual herb, cultivated N. Africa and India (as a winter crop). The leaves of the plant are used as a vegetable and as a livestock feed (e.g. in N. India where it is considered superior to, and more drought resistant than, several other fodder legumes). The seeds are used as a food, spice and condiment and also medicinally, as a demulcent and emollient, and in poultices. The essential oil is used in perfumery. Seed extract is used as a flavouring for ice-cream etc. and powdered seed as a dye.	A leguminous plant so should help soil fertility. Seeds contain 28 - 39% crude protein, 6–8% fatty oil, 0.02% essential oil, a galactomannan mucilage (gum), the alkaloid trigonelline (a nicotinic acid derivative) and ∿ 1% diosgenin (and traces of other sapogenins). The leaves also contain the latter compounds and the plant has been seriously considered as a source of sapogenins for the steroid industry (grows faster, and easier to harvest than *Dioscorea* tubers). The fatty oil has iod. val., 115; sap. val., 180 and contains 17% sat. (C_{16}–C_{22}) fatty acids, 35% oleic, 34% linoleic and 14% linolenic. The mucilage is said to be as good as, or superior to, guar (*see* entry no. 97) and alginic acid as, respectively, a paper-size and swelling agent in pharmaceutical preparations.	Doubtful whether can be considered truly semi-arid tolerant: responds vigorously to irrigation and said to grow best with 20–60 ins (500–1,500 mm) rain p.a. Use of diosgenin as steroid precursor has limitations – *see* entry no. 111 (though this plant has the advantages of being multi-purpose, providing gum and fodder as well as sapogenins, and quick-growing). The seed oil has an unpleasant odour (but this can be removed by washing with a mixture of methanol and petroleum ether).	Anon, 1956 Blunden *et al.*, 1975 CSIR India, 1976a Flaschenträger and Kalatzis, 1957 Gardener, 1982 Mensier, 1957 Reid and Meier, 1970 Shankaracharya and Natarajan, 1972 Shankaracharya *et al.*, 1973 Singh and Mehra, 1970 UNESCO, 1960 Wells, 1958 Uphof, 1968
275. *Turbina corymbosa* (L.) Raf. syn. *Ipomoea burmanni* Choisy, *I. sidifolia* Choisy, *Rivea corymbosa* (L.) Hall f. (Ololiuqui, piule, yerba de la Virga) Mexico to S. America, cultivated in E. Africa.	A woody vine, used as a source of narcotics from ancient times. Seeds of the plant still used by Mexican Indians as a hallucinogenic drug; sold locally for such purposes.	Analysis of seeds from Cuba: alkaloids 0.045% of fresh weight (some claim up to 0.07% in the kernel); 'lipids', 8% Alkaloids were found in the embryo but not in the seed coat. The ergot alkaloids ergine and isoergine, along with a series of related lysergic acid derivatives, occur variously in the seed, leaf and stem – but not the root. The seeds also contain a CNS-stimulant, turbicoryn (a glucoside), and 8% fatty oil.	Not listed by Arnon (1972) and probably only tolerant of semi-arid conditions. Also only of limited value (ergot alkaloids are available, if needed, from other sources and there is only a low percentage of oil present).	Cook and Keeland, 1962 CSIR India, 1972 Genest and Sahasrabudhe, 1966 Hofmann, 1971 Hofmann and Cerletti, 1961 Marderosian and Youngken, 1966 Taber *et al.*, 1963 Taber and Heacock, 1962 Uphof, 1968
276. *Urginea indica* Kunth (Indian squill) India.	A small bulbous perennial found on the Indian plains and the dry lower slopes of the Himalayas; is cultivated for its medicinal uses. Generally similar properties, actions and uses to *U. maritima*, and also appears in pharmacopoeias.	In place of the alcohol-soluble carbohydrate content in *U. maritima*, this squill's bulb is rich in alcohol-insoluble mucilage which can be used in dilute aqueous solution as an adhesive and for sizing cotton cloth. An alcohol extract of the bulbs shows anti-cancer and hypoglycaemic activity.	Said to prefer ⩾ 500 mm rain p.a. on a sandy soil. Drug hygroscopic (*see* next entry). Has lower glycoside content than *U. maritima* and is only used as a substitute when *U. maritima* is in short supply. Considerable variation in cardiotonic-glycoside content during year.	CSIR India, 1976a Hakim *et al.*, 1976 Martindale, 1977 Patil and Torne, 1980

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
277. *Urginea maritima* (L.) Baker; syn. *U. scilla* Steinh., *Scilla maritima* L. (Squill, sea onion) Mediterranean area, S. Africa.	A bulbous perennial which occurs as two varieties, red and white ('red squill' and 'white squill'). Both contain cardiotonic (heart stimulant) glycosides of the steroid (bufadienolide) type exerting digitalis-like action: the dried sliced bulb of the white variety, with the scales removed, is used clinically as a rapid-acting cardiotonic, diuretic and, particularly, expectorant; it is included in various pharmacopoeias. However, the red variety has additional constituents and shows very marked toxicity towards rats and other rodents (ascribed to the glycoside scilliroside) and is used as a rat poison, not clinically.	Main interest is as a source of cardiotonic glycosides. However, the bulbs (75% water) also contain, on a dry-water basis, 74% carbohydrate, 2.5% fat and 7% protein; ethyl alcohol can be obtained by yeast fermentation of the hydrolysed sliced bulbs, with animal feed and fertilizer as by-products. Anthocyanins (cyanidin and pelargonidin) and various flavonoids (quercetin, kaempferol, etc.) have been isolated from bulbs of the red variety. Can be propagated by seed or vegetatively from bulbs; the latter produces a crop two years earlier. On measuring the comparative potencies of this and Indian squill (*U. indica; see* previous entry) the latter was found to be less potent. Red squill acts as a specific poison to rodents as other, e.g. domestic, animals reject it by vomiting.	The powdered drug is hygroscopic and should be stored in a dry atmosphere. Its clinical use can lead to severe side-effects and digitalis is usually preferred when a cardiotonic is required (major use is as an expectorant). The red variety is very irritant to the skin and must be handled with care.	Abdel Kader *et al.*, 1973 Anon, 1940 Balbaa *et al.*, 1979 Blanchard, 1972 Chevalier, 1953 Crabtree, 1947 Hakim *et al.*, 1976 Karawya *et al.*, 1973 El Kiey *et al.*, 1964 El Kiey *et al.*, 1966b El Kiey *et al.*, 1967 Kubinyi *et al.*, 1971 Martindale, 1977 Pantanelli, 1946 Uphof, 1968 Vega *et al.*, 1969 Vega *et al.*, 1972 Wartburg, 1964 Wartburg, 1966 Wartburg *et al.*, 1968

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
278. *Vernonia anthelmintica* Willd; syn. *Centratherum anthelminticum* Kuntze (Ironweed, Indian ironweed, purple fleabane) India, S. America.	A perennial herb, used in some parts of India for skin diseases, leprosy and as an abortifacient; fruits are used for their anthelmintic activity. Seed is used in stomach-swells of cattle and as carminative for horses.	The seeds contain (26%) an optically active ($[\alpha] -10.7^{\circ}$) oil, iod. val., 102 and with fatty acid composition: vernolic (12, 13-epoxy-octadec-9-enoic), 70/75%; accompanied by oleic, linoleic, and C_{14}—C_{18} sats. Unsaponifiable fraction reported to be 6–7% of oil (high) and to include 10% stigmasterol, no brassicasterol (despite earlier reports) and 70% Δ^7—avenasterol (the 7, 24(28) diene derivative of stigmasterol) and so may make a useful source of this C_{29} unsat. sterol. The main interest is the vernolic acid, by far the major constituent, which is multi-functional as it stands, or after hydrolysis to dihydroxyoleic acid; it is a possible intermediate for the chemical industry. Also big demand for epoxy-oils in plastics industry, for protective coatings, etc. and expensive to synthesise so that this natural source should be very competitive. Tests with PVC show that vernolic acid esters make good plasticisers (better in some respects than the usual synthetics) improving its stability to heat and light; and that the crude oil makes a useful stabiliser (and after epoxidation of the remaining double bonds, plasticiser). The amino-acid content of the seed (18% protein) has been measured.	Harvesting of seed made difficult by tendency to shatter (leading to high seed losses); seed dust contains a toxic bitter principle which necessitates careful handling during harvest and storage (perhaps requiring facemasks).	Asaka *et al.*, 1977 CSIR India, 1950 Earle *et al.*, 1960c Frost and Ward, 1968 Krewson *et al.*, 1966 Krewson and Luddy, 1964 Krewson and Scott, 1964 Mensier, 1957 Princen, 1979 Princen, 1982 Riser *et al.*, 1966 Smith *et al.*, 1959 Tiwari *et al.*, 1968 Trotter *et al.*, 1962 Uphof, 1968 White and Wolff, 1968 Williams, 1966
279. *Willardia mexicana* (S. Wats.) Rose; syn. *Coursetia mexicana* S. Wats. (Nesco, palo piojo) Mexico.	Shurb or tree growing in the Sonora/Chihuahua desert/semi-desert areas of NW. Mexico. Wood used for mining props. Decoction of bark used against parasites on cows and horses.	Seeds contain 26% protein and 34% oil. Oil has iod. val., 137, sap. val., 175; main constituent (50%) probably oleic. Extracts of bark, stems and wood show insecticidal activity; also said to be effective against melonworm. Plant is a legume and so should improve soil fertility.		Bottger and Jacobson, 1950 Earle *et al.*, 1962 Feuell, 1965 Jones and Barclay, 1972 Uphof, 1968

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
280. *Withania somnifera* (L.) Dunal (Ashwagandha (in India)) Mediterranean area, Africa, S. Asia.	Perennial. Seeds used in Sudan to coagulate milk;* Decoction of root and bark used in local medicine since ancient times in, respectively, India (where known as ashwagandha) and parts of southern Africa; is listed, as a sedative, in the Pharmacopoeia of India; leaves used topically to promote healing of ulcers, abscesses, etc.	In India roots for medicinal use were originally obtained from wild stands but more recently a plant earlier assumed to be *W. somnifera* has been cultivated to ensure regular supplies. It grows on soils unsuitable for other crops, requires no irrigation (except rain at sowing time) nor fertilizer. Yield 150 kg (sometimes 300) dried roots/ha. Roots contain many alkaloids (0.1–0.3%; and responsible for the roots' pharmacological activity), along with starch and other carbohydrates, waxes, etc. and also two C_{28} steroids known as withanolides. A large, though variable (*see* Constraints), number of the latter compounds, which are characterised by the presence of a lactone ring in the side chain, occur in the leaves of *W. somnifera* and are thought to be responsible for their healing powers. The most important is withaferin A, of known structure, and readily isolated (0.18% yield; said to be higher in African plants) from the leaves: it shows antibiotic, anti-inflammatory (competes in activity with hydro-cortisone) and anti-tumour activity – and its use has been patented. Its antibiotic activity depends on its unsaturated side-chain lactone and is destroyed by reduction or hydrolysis. Berries have unusually high free amino-acid content (due to presence of a proteolytic enzyme). Plant said to have insecticidal activity.	The main interest is in the roots and so the whole plant has to be harvested and fresh plant raised from seed. Some doubt as to whether Indian wild and cultivated plants have same activity/constituents – or indeed are same species. Also wide variation in constituents of wild stands with geographical location: identifiable 'chemotypes' of the species characterised by their withanolide content and type; complicates possible exploitation. Withaferin A's instability to alkali should be considered in isolation/purification procedures. Typical, and inactive, plant sterols (campesterol etc.) produced in tissue cultures of *W. somnifera* rather than withanolides.	Atal and Schwarting, 1960 Atal and Schwarting, 1961 Bhatnagar *et al.*, 1961 Chakraborti *et al.*, 1974 CSIR India, 1976a Duisberg and Hay, 1971 Fontaine and Erdös, 1976 Glotter *et al.*, 1973 Jacobson, 1975 Kirson *et al.*, 1977 Uphof, 1968 Yu *et al.*, 1974
281. *Xanthium commune* Britt. (*see* also next entry) (Cocklebur) Tropics and subtropics including arid regions (e.g. SW. USA)	Small herbaceous annual; leaves used by American Indians in local medicine.	Solvent extraction of seed yields, depending on solvent used, 4.6–7.5% oil; iod. val. ranging from 44.6–103 and density (at 25°C), 0.894–1.009. Reported that the oil 'can be used in paints and varnishes' (but barely as a drying oil presumably).		Duisberg and Hay, 1971 Krochmal *et al.*, 1954 Tussing and Dunbar, 1935

* Similar (but enhanced) property exhibited by *W. coagulans* ('Indian rennet'), a xerophytic plant from the drier parts of Pakistan and NW. India, ascribed to a coagulating enzyme which is very active; used in India as a substitute for animal rennet to make cheese (CSIR India, 1976a).

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
282. *Xanthium strumarium* L. (Same vernacular name and generally similar to (? syn. with) *X. commune*) (Cocklebur) Native of S America; now widespread in the tropics, naturalised 'in the hotter parts of India'. Cultivated in China.	A coarse annual up to 1.5 m high; young leaves used as a vegetable, mature leaves used as a green manure. Decoction of leaves widely used in various local medicines.	Aerial parts contain various alkaloids and sesquiterpene lactones, some with pharmacological activity. Seeds yield (27% by pressure; 30–41% by solvent) a semidrying oil, resembling sunflower oil, with iod. val., 112–142, fatty acid composition: oleic, 22–37%; linoleic, 52 - 67%; sats., 10–16%; unsap. fraction, 0.37--1.3%. Could make a useful oil for inclusion in paints, varnishes and alkyd resins. Oil also contains relatively high percentage of phosphatides and has been suggested as a source of lecithin. The residual oilcake is rich in N and P and makes a good fertilizer (10% N, 3.5% P_2O_5, dry wt. basis). The fruits are rich in vitamin C (47 mg/100g) and the seeds in iodine.	Seeds and the uncooked (especially young) leaves are toxic, e.g. to browsing animals; similarly the oilcake. Seeds difficult to remove from fruits. Chemical composition varies widely. Tends to become an uncontrollable weed (via burrs catching on wandering animals and on clothing).	CSIR India, 1976b Watt and Breyer-Brandwijk, 1962
283. *Xanthocephalum sarothrae* (Pursh) Shinners, syn. *Gutierrezia sarothrae* (Pursh) Britt. & Rusby (Broomweed, matchweed, snakeweed) SW. USA, Mexico.	Aqueous extract of plant material used in traditional medicine and is sometimes used as a forage for sheep and horses.	Seeds contain protein 32.3%; oil 31.8% (? a possible oilseed). Aqueous extract of plant material found to contain an anti-tumour, proteinaceous substance.	Very aggressive plant in its natural habitat (? difficult to control).	Benson and Darrow, 1944 Jones and Barclay, 1972 Krochmal and Krochmal, 1973 Ulubelen *et al.*, 1965

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
284. *Ximenia americana* L.; syn. *X. spinosa* Salisb. (Wild olive, wild lime, tallow wood, hog plum, spiny plum, tallow nut, beach plum, false sandalwood) Widely in the tropics and sub-tropics including some of the drier areas (Sudan, Deccan peninsula of India, etc.)	A spiny shrub, 4–5 m tall, which grows on very poor land. Yields a good wood, sometimes used as a substitute for sandalwood. Fruits (and seeds) eaten widely and also made into jam and jelly. Seeds boiled with water yield a fat used in S. India as a substitute for ghee; also in some countries has cosmetics uses. The fruits resemble limes, but the juice is sweeter and more insipid; used in S. Africa to make a kind of beer. The seed oil is used to make soap and candles and as a lubricant, but is not competitive with other oils. Wood contains an essential oil and is used for fumigation in Ethiopia. Crushed leaves smell of bitter almonds and are used as flavouring in Indonesia. The bark contains 17% tannin and an insect repellent, and extracts are used as an astringent and disinfectant. The fruits, seeds and roots feature in various local medicines.	The seed has a high (68–75%) oil (fat at normal temperatures) content but when obtained by expelling is yellow, viscous and mucilaginous; cleaner product obtained by solvent extraction. Oil characterised by the presence of unusually long-chain acids (? possible industrial use). Thus petroleum extraction yields (62%) an oil with iod. val., 85 and fatty acid composition: oleic, 49% total (sat. and mono-unsat.) C_{24}-acids, 5%; C_{26}-acids, 7%; C_{28}-acids, 14%; C_{30}, 5.5%; the acetylenic acid ximenynic acid (the acetylenic analogue of oleic with in addn a Δ^{11} C≡C; with alkali, gives the conjugated triene acid), 6%; and its 8-hydroxy deriv., ∿10%. Unsap. fraction, 1.7%. Roots rich in acetylenic fatty acids.	Rubbery material in the oil (especially when expelled) makes it difficult to use; and it is a non-drying oil. Both seed and oil may be toxic in even moderate quantities due to present of a cyanide-producing principle which occurs in varying amounts depending on location, etc. (hence deceptive). The oilcake is unsuitable as a feed – has purgative action. There are richer sources of the principal acetylenic acid (ximenynic) elsewhere: e.g. *Osyris alba*, entry no. 223, has 57%.	Anon, 1935 Anon, 1936 Burkhill, 1935 Coursey, 1964 CSIR Inida, 1976b Earle *et al.*, 1960b Fanshawe, 1948 Freise, 1936 Freise, 1938 Grant and Williams, 1936 Gurney and Francis, 1940 Lighthelm, 1954 Lighthelm and Schwartz, 1950 Mensier, 1957 Mikolajczak *et al.*, 1963 Uphof, 1968 Vaughan, 1970 Williams, 1966 Willis and Shaw, 1973

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
285. *Yuccas — general comments* (The same common, or local, name frequently given to more than one species (e.g. 'soapweed')) Desert and semi-desert areas of SW. USA and N. Mexico.	Yuccas are commonest in sand and gravel soils. Early and present day uses of yuccas in general are locally for food, in beverages and as a crude 'soap' (detergent) (due to the saponins present), for clothing, in construction of dwellings and household articles. Most extensive use is for fibre. Juice used as a base in liquid fertilizers.	A major recurring interest has been the isolation of saponins, and hence sapogenins, as precursors of steroids (of both the cortisone and contraceptive-pill types) from the leaves and/or seeds as by-products to fibre extraction. Another possibility is the extraction of oil and protein from the seeds; and some *Yucca* spp. are said to have a high vitamin C content.	Average wild stand of yuccas too small for large-scale economic exploitation; cultivation would be necessary (even then except when e.g. war cuts off normal fibre supplies not likely to be worthwhile). No area bearing less than 200 kg fresh leaves could be harvested profitably. *Yucca* spp. generally grow very slowly and need at least 3–5 years to produce worthwhile new growth after cutting, and they flower, and set seed, irregularly. Obtaining maximum sapogenin yield may require allowing the endogenous enzymes to act on the glycosides first, at neutral pH, before treating with acid. Demand for sapogenins as steroid precursors (being those given in footnote† to entry no. 7) has waned! *see* entry no. 111.	Anon. 1955a Arnon, 1972 Blunden *et al.*, 1965 Cruse, 1973 Duisberg, 1952a, b Duisberg and Hay, 1971 Hernandez, 1970 Kirby, 1963 Krochmal *et al.*, 1954 Paris and Dillemann, 1960 Webber, 1953
286. *Yucca arizonica* McKelvey† Arizona.		Seeds have one of the highest sapogenin contents recorded — 12% sarsasapogenin (dry wt.) and this can be converted chemically into cortisone.	*	Wall and Fenske, 1961 Webber, 1953
287. *Yucca baccata* Torr.† (Pita, dátil, bayonet yucca, soapweed, banana yucca) S. USA, Mexico.	Woody plant: Fruits are eaten cooked, fresh or dried by Indians and Mexicans; and the fresh flower buds eaten. Fibres used for basketry, mats and various tying purposes. Flowers a possible source of perfume.	Fruits a rich source of sugars. Some of the strongest yucca fibre known comes from this species: said to be comparable with Manila hemp. Seeds fairly high (6.8%) in sarsasapogenin (*see* previous entry).	*	Benson and Darrow, 1944 Duisberg, 1952b Krochmal *et al.*, 1954 Latorre and Latorre, 1977 Uphof, 1968 Wall and Fenske, 1961 Webber, 1953

* *See* (also) constraints noted under first entry on *Yuccas*.
† Concerning varieties and tendency to hybrid formation, *see* Webber, 1953.

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
288. *Yucca brevifolia* Engelm. (Joshua tree, tree yucca, cactus-yucca, yucca-palm) Utah, Arizona, California, Nevada.	A small tree growing in extensive open 'forests' at 1,000–2,000 m. Cattle and sheep eat the flowers (but which, though nutritional, have a soapy taste – due to the saponins). An extract of the plant is used in the production of root and ginger beer, having a great foaming quality, and marketed as 'Brevifoline' (*see* also entry no. 295).	Can be used for newsprint cellulose. Unusually large content of sapogenin (8% tigogenin) in seeds. Wood has small amount of smilagenin. Seeds and dry pods would make good feed materials. Seeds contain 34% oil which is semi-drying (iod. val., 120), edible and may have other uses. Wood possibly valuable in manufacture of vanillin (by oxidation of the 9% lignin therein).	Very low (compared with other *Yucca* spp.) sapogenin content in leaves. For exploitation of the seed sapogenins to be economic (in competition with *Dioscorea*, etc. sources), large quantities of plant material would have to be available and collection costs low*.	Beggs, 1949 Cruse, 1973 Duisberg, 1952b Wall and Fenske, 1961 Webber, 1953 Woodbury *et al.*, 1961
289. *Yucca carnerosana* (Trel.) McKelvey; syn. *Samuela carnerosana* Trelease (Palma samandoca, palm barretta) Mexico, Texas.	Unbranched thick trunk up to 6 m high crowned with a rosette of long narrow leaves; thrives on calcareous soils from valley bottoms to mountain crests (3,000 m). Fibre (ixtle de palma) obtained from the inner leaves of the rosette has properties and uses as for *Agave lecheguilla* (*see* entry no. 11) fibre though less popular since more difficult to work. Can also obtain a kraft (brown) paper from the pulp. Again, residues can be used for soap. Trunk of plant especially useful in constructing walls of buildings and fences.	Plant has relatively long life span for a yucca (50–75 years). The fibre has similar potential to that of *Agave lecheguilla* but is slightly less sought after.	Grows wild at rather low densities – hence collection problems. Although fibre is similar to that of *A. lecheguilla*, the latter is preferred since is cleaner, easier to work and more durable. Similarly, the soap substitute is also inferior. (Despite this still has an important rôle in life of the rural poor of N.C. Mexico).*	Ridaura-Sanz, 1979 Sheldon, 1980 Webber, 1953
290. *Yucca constricta* Texas.		The seed yields (26%) an oil with iod. val., 128, hence a semi-drying oil, containing 63% dienoic (?linoleic) and 24% monoenoic (?oleic) fatty acids.	Agronomic research required before cultivation as economic crop*.	Cruse, 1973 Earle *et al.*, 1960b Webber, 1953

* *See* (also) constraints noted under first entry on yuccas.

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
291. *Yucca elata* Engelm. (Palmella, soapweed, soaptree, beargrass) SW. USA, Mexico.	Small tree. Roots used locally as soap for washing clothes and leaf fibre as cordage and also woven into mats and cloth. On a larger scale, the fibre has been used as a substitute for jute around bales (during World War II, for making mattresses, and to make speciality paper in the USA. The whole plant has been used as an emergency cattle feed during drought (after manual or mechanical chopping up and mixing with e.g. cottonseed meal) with no apparent ill-effects.	Seeds contain (dry wt.) 0.9% sarsasapogenin and 29% of a semi-drying oil, iod. val., 128, fatty acid composition: linoleic (probably), 52%; oleic, 32%; sats., 9%; epoxy-acids, 6%. Leaves contain 40/45% dry wt. fibre of similar strength to sisal and is, with that from *Y. glauca*, usually considered one of the two most commercially attractive yucca fibres. A root extract has been mooted as a possible foaming agent for beverages: *see* entry no. 295.	Very low sapogenin content; epoxy-fatty acids may cause toxicity problems*.	Cruse, 1949 Cruse, 1973 Duisberg, 1952b Earle *et al.*, 1959 Isenberg, 1956 Jones and Conner, 1918 Kirby, 1963 Uphof, 1968 Wall and Fenske, 1961 Webber, 1953
292. *Yucca filamentosa* L. (Common yucca, Eve's thread, Adam's needle) N. America; has been introduced, as an ornamental, to India.	Perennial coarse herb. Fruits eaten by the local Indians. Roots used as a crude soap; macerated leaves as fibre (said to be one of the best yuccas for fibre) and the point as a needle; central spike used as a vegetable as also other parts of shoot. Saponins have been extracted from the roots.		A cellulose-extraction plant established in 1956 was not successful and the original stands of the yucca have been cleared. Problems with large-scale propagation, as required for commercial production, especially with seed propagation (variable seedling characteristics)*.	Cruse, 1949 CSIR India, 1976b Czaja, 1951 Czaja, 1957 Hernandez, 1970 Kirby, 1963 Uphof, 1968
293. *Yucca filifera* Chab. Mexico.	One of the most abundant *Yucca* spp. in Mexico (in alkaline sandy-clay). Leaves are used locally as a roofing material and as a source of fibre for making brushes and paper pulp.	Thrives on 350 mm rain p.a. Seeds rich source of sarsasapogenin (*see* entry no. 286) and contain 20% semi-drying oil (iod. val., 135) which, after epoxidation, can be used as a plasticiser. Field studies in 1956 indicated adequate wild stands to feed a cellulose — extraction plant.	Very slow growth (flowers/seeds only after 30+ years) and lack of information created doubts. Meanwhile stands are being destroyed for agriculture.*	Blunden *et al.*, 1975 Gentry, 1972 Hernandez, 1970 Ridaura-Sanz, 1979

* *See* (also) constraints noted under first entry on yuccas.

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
294. *Yucca glauca* Nutt. (Small soapweed, beargrass, Great Plains yucca) SW. USA, Mexico, Pakistan.	A low shrub which tolerates salt. Roots used locally as a soap for washing clothes (and young stems, the central spike, flowers and seed pods as foods). The leaves have been used on a large scale as a source of fibre for burlap and bagging (40,000 tonnes during World War I), as a jute substitute around bales (also in World War I) and to make a heavy-duty kraft (brown) paper used in construction etc (especially during World War II). Has also been used like *Y. elata* as an emergency cattle feed.	Seed yields (27%) an oil with Iod. val. 142: hence a potentially useful semi-drying oil for use in paints etc; main fatty acid constituent (69%) dienoic (?linoleic) acid. Dried leaves have 40/45% fibre — which has almost the tensile strength of jute. With *elata*, this is one of the two *Yucca* spp. fibres usually considered to have commercial possibilities. Sarsasapogenin (around 1% dry wt.: *see* entry no. 286) with smaller amounts of several other sapogenins isolated from seeds.	Commercial production ceased due to slow plant growth and to difficulties with retting (extracting the fibre)*.	Cruse, 1949 Cruse, 1973 Duisberg, 1952a, b Earle *et al.*, 1960b El-Olemy *et al.*, 1974 Jones and Conner, 1918 Kirby, 1963 Wakil and Khan, 1975 Webber, 1953
295. *Yucca schidigera* Roezl ex Ort.; syn. *Y. mohavensis* Sarg. (Mohave yucca) Arizona, California.	Woody plant: leaves have been used (e.g. during World War I when other fibres were scarce) as a source of fibre — which is similar to that from *Y. baccata* though slightly softer and weaker. A concentrated aqueous extract of the leaves is widely used as a foaming agent for soft drinks in the USA.	A toxicological study of the foaming agent showed no *in vivo* haemolytic activity nor any other adverse effect. Seeds contain 6.6% sarsasopgenin (*see* entry no. 286).	*	Cruse, 1973 Oser, 1966 Uphof, 1968 Wall and Fenske, 1961 Webber, 1953
296. *Yucca schottii* Engelm.; syn. *Y. macrocarpa* Engelm. (Mountain or hoary yucca, sword cactus) Arizona, New Mexico.	1.5–2.0 m tall; grows at 4,000–7,000 ft (1,200–2,100 m) altitude.	Sarsasapogenin content of seeds, 4.9%	*	Wall and Fenske, 1961 Webber, 1953

* *See* (also) constraints noted under first entry on yuccas.

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Name(s)/Distribution	Current/past uses	Potential	Constraints	Citation data
297. *Yucca whipplei* Torr. (several sub-species and varieties known) syn. *Hesperoyucca whipplei* (Torr.) Baker. (Our-Lord's-candle, Chaparral yucca, Quixote yucca) California, Arizona, Mexico.	Leaves used on a small scale as a source of a long white fibre similar in texture to, and nearly as strong as, henequen. Flowers and seed used locally as foods.	Tigogenin content of seeds, 1.9%; leaves contain 1% sapogenin (mainly tigogenin). Seeds have high oil and protein content and leaves abundant cellulose content.	Relatively low sapogenin contents*.	Bender, 1963 Wall and Fenske, 1961 Webber, 1953 Uphof, 1968
298. *Zizyphus obtusilfolia* (Torrey & Gray) A. Gray Texas, Mexico.	A spiny tree, adapted to deserts. Fruits are eaten and have an agreeable taste (slightly 'puckering'). Used by the Mexican Indians.	The seeds contain 21.5% protein and 28.8% oil. Other species of the genus, in other parts of the world, are used as a source of drugs, tanning materials, alkaloids, timbers, dye, fish poison, cattle fodder; *Z. mauritiana* and *Z. spina-christi* mentioned as potential firewood species by the National Academy of Sciences (1980).		Chevalier, 1947 Jones and Barclay, 1972 Latorre and Latorre, 1977

* *See* (also) constraints noted under first entry on yuccas.

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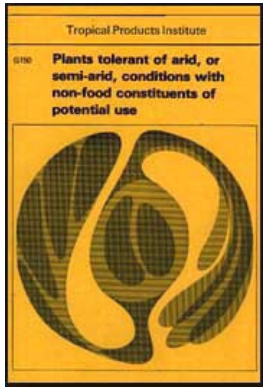

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