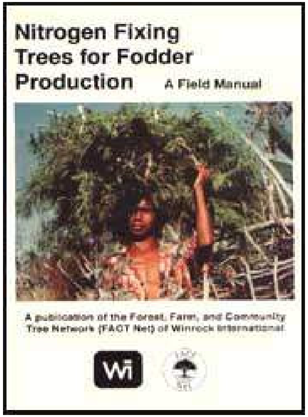
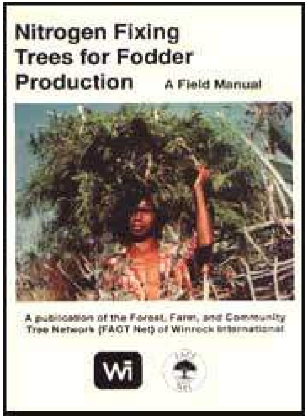


Nitrogen Fixing Trees for Fodder Production - A Field Manual (Winrock, 1996, 125 p.)

trees

[Home]"" """"> [ar].[cn].[de].[en].[es].[fr].[id].[it].[ph].[po].[ru].[sw]



Nitrogen Fixing Trees for Fodder Production - A Field Manual (Winrock, 1996, 125 p.)

editors:
James M. Roshetko

Ross C. Gutteridge

FACT Net,
Winrock International

Roshetko, James M. and Ross C. Gutteridge, editors. 1996. Nitrogen Fixing Trees for Fodder Production: a field manual. Morrilton, Arkansas USA: Forest, Farm, and Community Tree Network (FACT Net), c/o Winrock International.

Published by Winrock International
Forest, Farm, and Community Tree Network (FACT Net)
38 Winrock Drive
Morrilton, Arkansas 72110-9537, USA
Phone: 501-727-5435
Fax: 501 -7275417
Printed by Craftsman Press Limited
487/42 Soi Wattanasilp
Rajprarob Road

Pratunam
Bangkok, Thailand

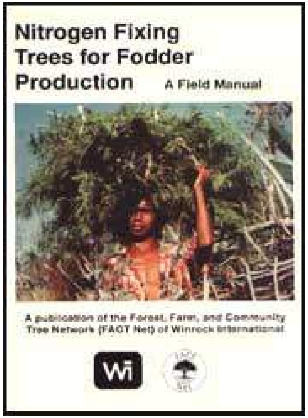
In cooperation with:

- **United States Department of Agriculture, Forest Service - International Forestry (USDA/FS/IF)**
- **Danish International Development Agency (DANIDA) in New Delhi**
- **Indo Swiss Project of Andhra Pradesh (ISPA)**
- **National Bank for Agricultural & Rural Development (NABARD)**
- **BAIF Development Research Foundation**

Cover photo by James M. Roshetko

Home"" """""> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Nitrogen Fixing Trees for Fodder Production - A Field Manual (Winrock, 1996, 125 p.)
Appendices
Seed and inoculant suppliers
Authors



Nitrogen Fixing Trees for Fodder Production - A Field Manual (Winrock, 1996, 125 p.)

Appendices

Seed and inoculant suppliers

This 11st of seed and Inoculant suppliers Is Intended to provide a first reference. Prices may vary depending on the particular Import/ export requirements for each country. They also change frequently. We suggest you contact a supplier and provide a description of your site, a 11st of the species you require, and how you Intend to use the seeds.

The supplier can then send you detailed information about seed and inoculant availability and prices.

Sources are listed alphabetically by country.

Seed
Australian Revegetation Corporation
42 Sarich Court
Osborn Park 6017
Western Australia AUSTRALIA
Phone: (61) 9-446-4377
Fax: (61) 9-446-3444

Australian Tree Seed Centre
CSIRO Division of Forestry
P.O. Box 4008
Queen Victoria Terrace
Canberra, ACT 2600 AUSTRALIA
Phone: (61)6-281-8211
Fax: (61) 6-281-8266

DPI Forestry
Tree Seed Centre

MS 424 Roys Road
Beerwah, Queensland 4519 AUSTRALIA
Phone: (61) 74-94-0362
Fax: (61) 74-94-0068

M.L. Farrar Pty. Ltd.
P.O. Box 1046
Bomaderry, N.S.W. 2541 AUSTRALIA
Phone: (61) 44-217-966
Fax: (61) 44-210-051

Queensland Forest Service
Tree Seed Section
GPO Box 944
Brisbane, Queensland 4001 AUSTRALIA
Phone: (61) 7-234-0104
Fax: (61) 7-221-4713

Top Ends Seeds
P.O. Box 2204
Darwin N.T. 0801 AUSTRALIA
Phone: (61) 89-811-962
Fax: (61) 89-812-717

Banco Latinoamericano de Semillas Forestales
CATIE 7170-137
Turrialba COSTA RICA
Phone: (506) 556-1933
Fax: (506) 556-1533

Danida Forest Seed Centre
Krogerupvej 3A
DK - 3050 Humlebaek DENMARK
Phone: (45) 42-19-05-00
Fax: (45) 49-16-02-58

Banco de Semillas
ESNACIFOR, A.P. No. 2
Siguatepeque HONDURAS
Phone: (504) 73-2011, 73-2018 or 73-2023
Fax: (504) 73-2300 or 73-2565

Centro de Mejoramiento Genetico y Banco de Semillas Forestales
Km 79 Carretera Managua-Leon
Aptdo. 630 Leon NICARAGUA

Phone: (505) 0311-6579 or 0311-5803
Fax: (505) 0311-3711 or 0311-6578

Papua New Guinea Forest Research Institute
P.O. Box 314
Lae, Morobe Province PAPUA NEW GUINEA

International Institute of Rural Reconstruction
Plant Genetic Resources Conservation
Program
Appropriate Technology Unit
Silang, Cavite 4118 PHILIPPINES
Phone: (63) 2-58-2659
Fax: (63) 2-522-2494

Mindanao Baptist Life Center
P.O. Box 80322
8000 Davao City PHILIPPINES
Phone: (63)82-221-1185
Fax: (63) 82-64-617

Rayos Marketing
c/o Jose Rayos

78 Molave St. Project 3
1102 Quezon City PHILIPPINES
Phone: (63) 2-922 0947
Fax: (63) 2-922-4592

The Inland Foreign Trading Company
Block 79A
Indus Road #04-418/420316 SINGAPORE
Phone: (65) 272-2711
Fax: (65) 271-6118

National Tree Seed Programme
P.O. Box 373
Morogoro TANZANIA
Phone: (255) 56-3912 or 56-3093
Fax: (255) 56-3275 or 51-46312

Henry Doubleday Research Association
Ryton Organic Gardens
Ryton-on-Dunsmoref
Coventry CV8 3LG UNITED KINGDOM
Phone: (44) 1203-303-517
Fax: (44)1203-639-229

E-mail: pharris@hdra.demon.co.uk

Agroforester T Tropical Seeds
P.O. Box 428
Holualoa, Hawaii 96725 USA
Phone: (1) 808-324-4427
Fax: (1) 808-324-4129
Email: agroforester@igc.org

ECHO
17430 Durrance Road
North Fort Myers FL 33917-2239 USA
Phone: (1)941-543-3246
Fax: (1) 941-543-5317
E-mail. 74172.370@compuserve.com

Hawaii Agricultural Research Center
99-193 Aiea Heights Drive
Aiea, HI 96701 USA
Phone: (1) 808-487-5561
Fax: (1) 808-486-5020

Lawyer Nursery

950 Highway 200 West
Plains, Montana 59859-9706 USA
Phone: (1)406-826-3881
Fax: (1) 406-826-5700

The New Forests Project
731 Eighth Street, SE
Washington. DC 20003 USA
Phone: (1) 202-547-3800

Rhizobium Inoculants

CSIRO
Cunningham Laboratory
Carmody Road
St Lucia, Queensland 4067 AUSTRALIA
Phone: (61) 7-3377-0209
Fax: (61) 7-3371-3946

Dr Peter Dart
Department of Agriculture
The University of Queensland
Brisbane, Queensland 4072 AUSTRALIA

Phone: (61) 7-3365-2867
Fax: (61) 7-3365-1177

AgroForesterT Tropical Seeds
PO Box 428
Holualoa, Hawaii 96725 USA
Phone: (1) 808-324-4427
Fax: (1) 808-324-4129
Email: agroforester@igc.org

Lipha Tech (Nitrogen Inoculants)
3101 West Custer Avenue
Milwaukee, Wisconsin 53217 USA
Phone: (1)414-462-7600
Fax: (1) 414-462-7186

Nitrogen Fixation in Tropical Agricultural
Legumes (NifTAL) Center
1000 Holomua Road
Paia, Hawaii 96779 USA
Phone: (1)808-579-9568
Fax: (1) 808-579-8516

Mycorrhizae Inoculants

Bioscientific, Inc.
4405 South Litchfield Road
Avondale, AZ 85323 USA
Phone: (1)800872-2461
Fax: (1) 602-925-0506

Plant Health Care, Inc
440 William Pitt Way
Pittsburgh, PA 15238 USA
Phone: (1) 412-826-5488
Fax: (1) 412-826-5445

Premeir Enterprises Ltd.
326 Main Street
Red Hill, PA 18076 USA
Phone: (1) 800-424-2554
Fax: (1) 215-679-6430

Tree of Life Nursery
PO Box 736
San Juan Capistrano, CA 92693 USA

Phone: (1) 714-728-0685
Fax: (1) 714-728-0509

Authors

Dr. M. Raisul Alam
Department of General Animal Science, Bangladesh Agricultural University
Mymensingh 2202, Bangladesh
Phone: (880-91) 5695-97
Fax: (880-02) 8187-60

Mr. Narayan C. Basak
On-farm Research Division, Bangladesh Agricultural Research Institute
Kishoreganj 2300, Bangladesh
Fax: (880-2) 8329-15

Dr. G. Bheemaiah
Department of Forestry, College of Agriculture, Andhra Pradesh Agricultural University
Rajendranagar, Hyderabad 500 030, Andhra Pradesh, India
Phone: (91-40) 245163

Mr. Bire Bino

Highlands Agriculture Experiment Station, Department of Agriculture & Livestock
P. O. Box 384
Kainantu, E. H. P., Papua New Guinea
Phone: (675) 773500
Fax: (675) 773516

Dr. Asim K Biswal
Indo-Swiss Project Orissa
IInd Lane, Brahma Nagar
Berhampur 760 001, Orissa, India
Phone: (91-680) 202389 / 73056
Fax: (91-680) 73271

Dr. J. C. Dagar
Central Soil Salinity Research Institute
Kachhwa Road
Karnal 132 001, India
Phone: (91-184) 20801
Fax: (91-184) 20480

Dr. J. N. Daniel
FACT Net India Program, c/o BAIF Development Research Foundation

Dr. Manibhai Desai Nagar
Warje, Pune 411029, India
Phone: (91-212) 369955 / 365494
Fax: (91-212) 366788

Ms. Mila Gracia A. Ejercito
Heifer Project International
4th Floor, Fresnedi Bldg., National Road, Putatan
Muntinlupa, Metro Manila, Philippines
Fax: (63-2) 818-76-18 / 587-919
Dr. A. S. Gill
National Research Centre for Agroforestry
Jhansi, Uttar Pradesh 284 003, India
Phone: (91-517) 442364
Fax: (91-517) 440833

Prof. H. P. M. Gunasena
Faculty of Agriculture, University of Peradeniya
Peradeniya, Sri Lanka
Phone: (94-8) 88375
Fax: (94-8) 32517

Dr. R. C. Gutteridge

Department of Agriculture, The University of Queensland
Queensland 4072, Australia
Fax: (61-7) 3651188

Mr. Tony Oude Hengel
Indo-Swiss Project Orissa
IInd Lane, Brahma Nagar
Berhampur 760 001, Orissa, India
Phone: (91 680) 202389 / 73056
Fax: (91-680) 73271

Dr. Takashi Kato
Forest Management Division, Forest Products Research Institute,
Forestry Agency
P. O. Box 16, Tsukuba Norin
Kenkyu Danchi, Tsukuba, Ibataki, 305, Japan
Fax: (81-298) 74-3720

Mr. D. Y. Khandale
BAIF Development Research Foundation, Central Research Station
Urulikanchan, Pune 412 202, India

Dr. G. R. Korwar

Central Research Institute for Dryland Agriculture (ICAR)
Saidabad, Hyderabad 500 659, India

Fr. Roland Lesseps, S. J.
Kasisi Agricultural Training Centre
P.O. Box 30652
Lusaka 10101, Zambia
Fax: (260-1) 293763
E-mail: PHENRIOT@UNZA.GN.APC.ORG

Dr. M. de S. Liyanage
Coconut Research Institute
Lunuwila, Sri Lanka
Fax: (94-31) 7195

Mr. P. K. Mutty
Department of Livestock Services
Jalan Veteran
Kupang 6, Timor, NTT, Indonesia
Phone: (62-91) 21558
Fax: (62-91) 33060

Dr. B.W. Norton

Department of Agriculture, The University of Queensland
Queensland 4072, Australia
Fax: (61-7) 3651188

Mr. Soulivanh Novaho
Ministry of Agriculture and Forestry, Department of Livestock and Veterinary Services
Vientiane, Lao PDR
Fax: (856-21) 217-250

Dr. R. T. Paterson
International Centre for Research in Agroforestry, KARI Regional Research Centre
P.O. Box 27, Embu, Kenya
Fax: (254-161) 30064

Dr. N. N. Pathak
Department of Forestry, J. N. Krishi Vishwavidyalaya
Jabalpur 482 004, Madhya Pradesh, India

Dr. P. S. Pathak
Indian Grassland and Fodder Research Institute
Jhansi 284 003, India

Dr. F. B. Patil
Mahatma Phule Krishi Vidyapeeth
Rahuri, Ahmednagar 431 722, India

Dr. A. N. F. Perera
Department of Animal Science, Faculty of Agriculture, University of Peradeniya
Peradeniya, Sri Lanka
Phone: (94-8) 88480 /88239
Fax: (94-8) 32043
E-mail: Congress@Pgra.Pdn.ac.lt

Dr. Sunil Puri
Department of Forestry, Indira Gandhi Agricultural University
Raipur 492 012, Madhya Pradesh, India
Phone: (91-771) 424481
Fax: (91-771) 424532

Mr. James M. Roshetko
Winrock International
38 Winrock Drive
Morrilton, Arkansas 72110, USA
Phone: (1-501) 727-5435

Fax: (1-501) 727-5417
E-mail: JMR@MSrnail.winrock.org.

Dr. R. V. Singh
176 Vasant Vihar I
Dehra Dun 248 006, Uttar Pradesh, India
Phone: (91-135) 683261
Fax: (91-135) 23539

Ms. J. L. Stewart
Oxford Forestry Institute, Department of Plant Sciences,
University of Oxford
South Parks Road
Oxford OX1 3RB, United Kingdom
Fax: (44-865) 275074

Mr. P. S. Takawale
BAIF Development Research Foundation, Central Research Station
Urulikanchan, Pune 412 202, India
Mr. Francis A. Xavier
Agriculture Man Ecology (AME)
368, 4th Cross, J. P. Nagar III Phase
Bangalore 560 078, India

Phone: (91-80) 642303
Fax: (91-80) 6633706 Attn: AME

Selected references

Nitrogen Fixing Trees for Fodder Production

Little, E.L. and F. H. Wadsworth. 1989. Common trees of Puerto Rico and the Virgin Islands. Agricultural Handbook no. 249. Washington DC, USA: USDA Forest Service. 556 p.

National Taiwan University.1965. The leguminosae of Taiwan for pasture and soil improvement. Taipei, Taiwan, Republic of China: National Taiwan University.

Fodder Tree Establishment

Castellano, M.A. and R. Molina. 1989. Mycorrhizae. In: T.D. Landis, R.W. Tinus, S.E. McDonald, and J.P. Barnett, eds. The container tree nursery manual, Volume 5. Washington DC, USA: USDA Forest Service, pp 101-167.

Ferguson, J.J. and S.H. Woodland. 1982. Production of endomycorrhizal inoculum: A. Increase and maintenance of vesicular-arbuscular

mycorrhizal fungi. In: N.C. Schenck, ed. Methods and principles of mycorrhizal research. St. Paul, Minnesota, USA: American Phytopathological Society, pp 47-54.

Keyser, H. 1990. Inoculating tree legume seed and seedlings with rhizobia. Paia, Hawaii, USA: Nitrogen Fixation in Tropical Agricultural Legumes (NifTAL) Center, 2 pp.

Liegel, L.H. and C.R. Venator. 1987. A technical guide for forest nursery management in the Caribbean and Latin America. General Technical Report SO-67. New Orleans, Louisiana, USA: USDA Forest Service, Southern Forest Experiment Station, 156 pp.

Macklin, B., N. Glover, J. Chamberlain, and M. Treacy. 1989. NFTA Cooperative Planting Program establishment guide. Morrilton, Arkansas, USA: Forest, Farm and Community Tree Network (FACT Net), Winrock International, 36 pp.

Malajczuk, N., N. Jones, and C. Neely. Undated. The importance of mycorrhiza to forest trees. Land Resources Series - No. 2. Washington, DC, USA: The World Bank, Asia Technical Department, 10 pp.

Postgate, J.R. 1987. Nitrogen fixation, second edition. The Institute of Biology's studies in biology . London, UK: Edward Arnold LTD, 73 pp.

Shelton, H.M. 1994. Establishment of forage tree legumes. In: R.C. Gutteridge and H.M. Shelton, eds. Forage tree legumes in tropical agriculture. Wallingford, UK: CAB International, 139 pp.

Somasegaran, P and H.J. Hoben. 1985. Methods in legume-rhizobium technology. Paia, Hawaii, USA: Nitrogen Fixation in Tropical Agricultural Legumes (NifTAL) Center, 367 pp.

Fodder Production Systems

D'Mello, J.P.F. and C. Devendra, eds. 1995. Tropical legumes in animal nutrition.Wallingford, UK: CAB International, 338 pp.

Gutteridge, R.C. and H.M. Shelton, eds. 1994. Forage tree legumes in tropical agriculture. Wallingford, UK: CAB International, 389 pp.

IIRR. 1992. Intensive feed garden. In: Agroforestry Technology Information Kit (ATIK); No. 4 Livestock and poultry production. Silang, Cavite, PHILIPPINES: International Institute of Rural Reconstruction (IIRR), pp 10-25.

Le HouŠrou, H.N., ed. 1980. Browse in Africa: the current state of knowledge. Addis Ababa, ETHIOPIA: International Livestock Centre for Africa (ILCA), 491 pp.

Paterson, R.T., G.A. Proverbs and J.M. Keoghan. 1987. The management and use of forage banks. Bridgetown, BARBADOS: Caribbean Agricultural Research and Development Institute (CARDI), 21 pp.

Shelton, H.M. and W.A. St,r, eds. 1991. Forages for plantation crops. ACIAR Proceedings No. 32. Canberra, AUSTRALIA: Australian Centre for International Agricultural Research (ACIAR), 168 pp.

Selecting Species of Nitrogen Fixing Fodder Trees

Briscoe, C.B. 1989. Field trials manual for multipurpose tree species. Multipurpose Tree Species Network Research Series; Manual No. 3. Bangkok, THAILAND: Winrock International, 163 pp.

Burley, J. And P.J. Wood. 1976. A manual on species and provenance research with particular reference to the tropics. Tropical Forestry Paper No. 10. Oxford, UK: Oxford Forestry Institute.

MacDicken, K.G., G.V. Wolf and C.B. Briscoe. 1991. Standard research methods for multipurpose trees and shrubs. Multipurpose Tree Species Network Research Series; Manual No. 5. Bangkok, THAILAND: Winrock International, 92 pp.

Macklin, B., N. Glover, J. Chamberlain, and M. Treacy. 1989. NFTA

Cooperative Planting Program establishment guide. Morrilton, Arkansas, USA: Forest, Farm and Community Tree Network (FACT Net), Winrock International, 36 pp.

Roshetko, J. 1994. Fodder bank establishment and management. Agroforestry for the Pacific Technologies, Fact-sheet 8. Morrilton, Arkansas, USA: Forest, Farm and Community Tree Network (FACT Net), Winrock International, 4 pp.

Webb, D.B., P.J. Wood and J. Smith. 1980. A guide to species selection tropical and subtropical plantations. Tropical Forestry Paper No. 15. Oxford, UK: Oxford Forestry Institute.

Nutritive Value and Animal Production from Fodder Production

Ahn, J.H. 1990. Quality assessment of tropical browse legumes: tannin content and nitrogen degradability. PhD Thesis, The University of Queensland, AUSTRALIA.

Ahn, J.H., B.M. Robertson, R. Elliott, R.C. Gutteridge, and C.W. Ford. 1989. Quality assessment of tropical browse legumes: tannin content and protein degradation. Animal Feed Science and Technology 27:47-156.

Ash, A.J. 1990. The effect of supplementation with leaves from the leguminous trees Sesbania grandiflora, Albizia chinensis and Gliricidia septum on the intake and digestibility of Guinea grass hay by goats. Animal Feed Science and Technology 28:225-232.

Bamualim, A., R.J. Jones, and R.M. Murray. 1980. Nutritive value of tropical browse legumes in the dry season. Proceedings of the Australian Society of Animal Production 13:229232.

Borens, F.M.P. and D.P. Poppi.1990. The nutritive value for ruminants of tagasaste (Chamaecytisus palmensis), a leguminous tree. Animal Feed Science and Technology 28:275292.

Brewbaker, J.L. 1986. Leguminous trees and shrubs for Southeast Asia and the South Pacific. In: G.J. Blair, D.A. Ivory, and T.R. Evans, eds. Forages in Southeast Asian and South Pacific agriculture. ACIAR Proceedings No. 12. Canberra, AUSTRALIA: Australian Centre for International Agricultural Research (ACIAR), pp 43-50.

Carew, B.A.R. 1983. Gliricidia septum as a sole feed for small ruminants. Tropical Grasslands 17:181-184.

Chadhokar, P.A. 1982. Gliricidia maculata: a promising legume fodder plant. World Animal Review 44:36-43.

Devendra, C. 1995. Composition and nutritive value of browse legumes. In: J.P.F. D'Mello, and C. Devendra, eds. Tropical legumes in animal nutrition.. Wallington, UK: CAB International, pp 49-66.

Gohl, B. 1981. Tropical feeds. FAO Animal Production and Health Series No. 12. Rome, ITALY: Food and Agriculture Organization of the United Nations, 529 pp.

Jones, D.I.H. and A.D. Wilson. 1987. Nutritive quality of forage. In: J.B. Hacker and J.H. Ternouth, eds. The nutrition of herbivores. Sydney, AUSTRALIA: Academic Press, pp 65-90.

Lamprey, H.F., D.J. Herlocker and C.R. Field. 1980. Report on the state of knowledge on browse in east Africa in 1980. In: H. N. Le Hourou, ed. Browse in Africa. Addis Abab, ETHIOPIA: International Livestock Centre for Africa (ILCA), pp 33-54.

Le HouŠrou, H.N. 1980. Chemical composition and nutritive value of browse in West Africa. In: H. N. Le HouŠrou, ed. Browse in Africa. Addis Abab, ETHIOPIA: International Livestock Centre for Africa (ILCA), pp 261-290.

Lowry, B.J. 1989. Agronomy and forage quality of Albizia lebbeck in the semi-arid tropics. Tropical Grasslands 23:84-91.

McMeniman, N.P. 1976. Studies on the supplementary feeding of sheep consuming mulga (Acacia aneura) 3. The provision of phosphorus, molasses and urea supplements under pen conditions. Australian Journal of Experimental Agriculture and Animal Husbandry 16:818-822.

Norton, B.W. 1994a. The nutritive value of tree legumes. In: R.C. Gutteridge and H.M. Shelton, eds. 1994. Forage tree legumes in tropical agriculture. Wallingford, UK: CAB International, pp 177-191.

Norton, B.W. 1994b. Anti-nutritive and toxic factors in forage tree legumes. In: R.C. Gutteridge and H.M. Shelton, eds. 1994. Forage tree legumes in tropical agriculture. Wallingford, UK: CAB International, pp 202-215.

Norton, B.W., W. Rohan-Jones, F. Ball, R.A. Leng and R.M. Murray. 1972. Nitrogen metabolism and digestibility studies with Merino sheep given kurrajong (Brachychiton populneum), mulga (Acacia aneura) and native grass (Iseilema spp.). Proceedings of the Australian Society of Animal Production 9:346-351.

Norton, B.W., F.K. Kamau and R. Rosevear.1992. The nutritive value of some tree legumes as supplements and sole feeds for goats. In: C. Reodecha, S. Sangid, and P. Bunyavetchewin, eds. Recent advances in

animal production, Proceedings of the Sixth AAAP Animal Science Congress, 23-28 November 1992. Sukothai Thammathirat Open University, Nonthaburi, Thailand, Volume III, p151.

Robertson, B.M.1988. The nutritive value of five browse legumes fed as supplements to goats offered a basal rice straw diet. MS Thesis, The University of Queensland, AUSTRALIA.

Singh, C., P. Kumar, and A. Rekib. 1980. Note on some aspects of the feeding value of Sesbania aegyptica fodder in goats. Indian Journal of Animal Science 50:1017-1020.

Skerman, P.J., D.J. Cameron and F. Riveros. 1988. Tropical forage legumes, 2nd edition, FAO Plant Production and Protection Series, No. 2, Rome, ITALY: Food and Agriculture Organization of the United Nations, 692 pp.

Soedomo, R., P.M. Ginting, and G.J. Blair.1986. Non-leguminous trees and shrubs as forage for ruminants. In: G.J. Blair, D.A. Ivory, and T.R. Evans, eds. Forages in Southeast Asian and South Pacific agriculture. ACIAR Proceedings No. 12. Canberra, AUSTRALIA: Australian Centre for International Agricultural Research (ACIAR), pp 51-54.

Van Eys, I.E., W.I. Mathius, P. Pongsapan, and W.L. Johnson.1986.

Foliage of the tree legumes gliricidia, leucaena, and sesbania as a supplement to napier grass diets for growing goats. Journal of Agricultural Science (Cambridge) 107: 227-233.

Problems and Constraints of Trees as Fodder Resources

Boa, E.R. and J.M. Lenn'e. 1994. Diseases of nitrogen fixing trees in developing countries: an annotated list. Chatham, UK: Natural Resources Institute (NRI), 82 pp.

Bray, R.A. 1994. The leucaena psyllid. p 283-291. In: R.C. Gutteridge and H.M. Shelton, eds. 1994. Forage tree legumes in tropical agriculture. Wallingfrod, UK: CAB International, 389 pp.

Geiger, C.A., B. Napompeth, and R. Van Den Beldt. 1995. An update on the status of the leucaena psyllid in Southeast Asia. p 125-128. In: H.M. Shelton, C.M. Piggin and J.L. Brewbaker, eds. Leucaena - opportunities and limitations. ACIAR Proceedings No. 57. Canberra, AUSTRALIA: Australian Centre for International Agricultural Research (ACIAR), 241 pp.

Gutteridge, R.C. and H.M. Shelton, eds. 1994. Forage tree legumes in tropical agriculture. Wallingford, UK: CAB International, 389 pp.

Lenn,, J.M. and E.R. Boa.1994. Diseases of tree legumes. p 292-308. In: R.C. Gutteridge and H.M. Shelton, eds. Forage tree legumes in tropical agriculture. Wallingford, UK: CAB International, 389 pp.

Lenn,, J.M. 1992. Diseases of multi-purpose woody legumes in the tropics: a review. Nitrogen Fixing Tree Research Reports 10:13-29.

Walter, G.H. and W.H. Parry. 1994. Insect pests and forage tree legumes: biology and nonchemical control. In: R.C. Gutteridge and H.M. Shelton, eds. Forage tree legumes in tropical agriculture. Wallingford, UK: CAB International, 389 pp.

Werner, J. 1993. Participatory development of agricultural innovations-procedures and methods of on-farm research. Eschborn, GERMANY: Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ).

Species fact sheets: Nitrogen fixing fodder trees

Acacia aneura is known as mulga in its native Australia where it is one of the best known species in the genus. Mulga is the Aboriginal word for a long narrow shield made of acacia wood. It is probably the most important woody forage plant in Australia because it is palatable, abundant and widespread in regions of low rainfall. Its use as an exotic. however. has been restricted by its relatively slow growth rate and its

limited capacity lo regenerate after fire or severe branch lopping.

Acacia aneura, repented with permission. M. Simmons, 1961. Inset map shows natural distribution of mulga in Australia (Turnbul et. al. 1986).

BOTANY: Acacia aneura F. Muell. ex Benth. is one of many thornless acacias endemic to Australia. It occurs as a 10-15 m tall, often single stemmed tree in higher rainfall areas but is a 2-3 m high shrub in dry situations or on very shallow soils. Its form and phyllode morphology are exceptionally variable (Midgley and Gunn 1985). The phyllodes range from short and needle-like to long (20 cm), broad (1 cm) and net. Very fine hairs give the foliage an attractive silvery-gray appearance.

Small yellow flowers form spikes 1.5-2.U cm long. Thin. net membranous pods, 2-5 cm long, usually with an obvious narrow wing along their edge. contain dark brown seeds, each with a small pale aril at the base.

Flowering depends on favorable weather conditions and only late summer powering followed by winter rain leads to seed set (Davies 1976).

ECOLOGY: Mulga is the one of the dominant species in Australian shrub woodlands. Natural populations extend over an area of 1.5 million km chiefly in the arid climates where the annual rainfall is 200-250 mm. Mulga ranges in elevation from sea level to 300 m elevation. In many of the drier parts of its distribution mulga occurs as the only species in groves up to 50 m wide and 400 m long with intergrove areas acting as water catchments to provide substantial run-on water.

In the eastern part of its range in northern New South Wales and Queensland mulga is found in semiarid conditions with a mean annual rainfall of 300-500 mm. It experiences hot summers and cool winters with light frosts. Soils supporting mulga are usually acidic sands or sandy loams, which permit easy filtration of water into the upper horizons, but are usually very low in nitrogen and available phosphorus

(Turnbull 1986). Acacia aneura can live for more than 50 years, it is drought-tolerant, but very fire sensitive (Kube 1987).

PROVENANCE TRIALS: The wide variability in soils and climate together with a high degree of polymorphism suggests that major provenance differences will occur in growth rates and drought and frost tolerance. International provenance trials were initiated in 1984 by FAO and CSIRO Division of Forestry and Forest Products, Canberra (Midgley and Gunn 1985) and trials were established in South Asia, the Middle East. Africa and South America.

WOOD USE: The heartwood of mulga is dark brown with contrasting markings of golden yellow; the sapwood is white. The wood is very hard, heavy (850-llOU kg/m3) and durable in the ground; it turns well and takes a high polish (Boland et al. 1984). Mulga also makes an excellent firewood and charcoal. In Australia the wood has been used extensively for fence posts but a log size rarely exceeding 2 m x 25 cm usually restricts the use of the wood to small turnery items.

FODDER In many parts of Australia mulga forms a significant part of a sheep's diet at all times of the year but without supplementary high quality feed it supplies protein and energy barely sufficient for maintenance of dry-range sheep (Goodchild and McMeniman 1987).

Phyllodcs have a high crude protein level (11-16%), low phosphorus content (0.05-0.12%) and good palatability (Turnbull et al. 1986, Vercoe in Boland, 1987). Excessive grazing may result in the death of mulga.

OTHER USES: Mulga can be used in arid areas to provide shelter and shade, its attractive silvery grey foliage makes it a popular choice for amenity plantings. The Australian Aborigines ground the mulga seed for flour. The seeds have a protein content comparable to dried split peas or peanuts (Caffin et al. 1980). Aborigines also used the resinous phyllodes of desert mulga form as an adhesive resin (Turnbull et al. 1986).

ESTABLISHMENT: For good germination, seed (50,000-110,000/kg) should be scarified by mechanical abrasion or immersed in undiluted sulfuric acid (95% 36N) for 30 minutes and then thoroughly washed in water. Alternatively, immersion in hot water (90§C) for 1 minute will usually break dormancy (Doran and Gunn 1987). Seeds sown in a germination tray are ready for separating into containers within 10 days. The polling mix needs to drain freely but have good moisture holding capacity (Kube 1987).

Nursery growth is slow with seedlings often taking 6-8 months to reach

20 cm tall. When transplanted to the field the seedlings usually require several months without severe moisture stress to survive and in arid areas may need supplementary irrigation. Established seedlings have the ability to survive severe drought. They develop a long tap root and an extensive lateral root system in the top 30 cm of the soil. Acacia aneura needs to be protected from browsing animals while young.

GROWTH: Growth rate is generally slow but is related to moisture conditions. In central Australia planted specimens receiving an average of 370 mm of rainfall a year grew in ten years into multi-stemmed shrubs 3 m tall and 2-4 cm dbh with a crown diameter of 2 m (Kube 1987). Cultivated specimens receiving regular irrigation have reached 10 m tall and 10 cm dbh in 10 years. In trials where rainfall is relatively high, the Charleville, Queensland provenance, a broad phyllode form, has grown more rapidly than provenances from central Australia (Ryan and Bell 1989). Trees with different phyllode forms have been observed to have different growth rates (Fox 1980).

SYMBIOSIS: A. aneura forms nodules with Rhizabium with which it exhibits a degree of specificity (Roughley 1987). Ectomycorrhizal associations have been observed and there is almost certainly VA mycorrhizal symbiosis (Reddell and Warren 1987).

PESTS AND DISEASES: In its natural habitat A. aneura is subject to partial defoliation by a range of insects and root damage by termites. Termite damage was light (4% mortality) to moderate (30% mortality) to two provenances aged 18 months in a trial in Zimbabwe (Mitchell 1989).

WEEDINESS: With its relatively slow growth rate and irregular seeding habits A. aneura is unlikely to become a serious weed.

PRINCIPAL REFERENCES:

Boland, DJ., M.H. Brooker, G.M. Chippendale, N. Hall, B.P.M. Hyland, R.D. Johnston, DA. Kleinig and J.D. Turner. 1984. Forest trees of Australia. 4th Ed. Nelson-CSIRO, Melbourne.

Boland, D.J. (ed). 1987. Trees for the tropics: Growing Australian multipurpose trees and shrubs in developing countries. ACIAR Monograph No. 10. ACIAR, Canberra, Australia.

Caffin. N., R. Bell, G. Nitchie, S. Weston and N. Ho. 1980. Protein and mineral content of several species of Acacia seeds. Mulga Research Centre Annual Rep. No. 3, 1979. W. Australian Inst. of Tech. Bentley, Australia. p. 43-44.

Davies, S.J.J.F. 1976. Studies of the powering season and fruit production of some arid zone shrubs and trees in western Australia. J. of Ecology 64:665-687.

Fox, J.E.D. 1980. Stability in mulga stands in times of drought. in Mulga Research Centre Annual Report, No. 3, 1979. W. Australian Inst. of Tech., Bentley, Australia.

Midgley, SJ. and B.V. Gunn. 1985. Acacia aneura seed collections for international provenance trials. Forest Genetic Resources Information 13:21-29.

Simmons, M. 1981. Acacias of Australia. Thomas Nelson, Melbourne.

Turnbull, J.W. (ed). 1986. Multipurpose Australian trees and shrubs. ACIAR Monograph No. 1. ACIAR Canberra, Australia.

Turnbull, J.W. (ed). 1987. Australian acacias in developing countries. ACIAR Proceedings No. 16. ACIAR. Canberra. Australia.

Acacia holosericea - A Successful for the Dry Tropics

This shrubby acacia is little used in its native Australia, yet it promises to be an outstanding multipurpose tree for the dry tropics. Its excellent

potential for fuel, charcoal, animal fodder, land rehabilitation and as an ornamental is now being realized in Africa and the Indian subcontinent.

BOTANY: A. holosericea A. Cunn. ex G. Don is one of some 850 thornless species of the genus endemic to Australia. It bears large phyllodes, 10-25 cm long and 1.5 to 10 cm broad, usually covered densely with fine hairs, giving the tree attractive silvery foliage. Small bright yellow flowers are aggregated in prominent spikes 3-6 cm long. Narrow, hairless pods, 3-6 cm long, are coiled in dense clusters and contain shiny black seeds, each with a yellow aril at the base. Flowering is heavy and precocious, and abundant crops of mature seeds may be formed within two years of planting. It commonly forms a spreading shrub to 5 m in height with many ascending branches from just above ground level. Occasionally it grows as a small tree up to 8 m in height.

ECOLOGY: Natural populations occur in a wide range of tropical climates. In semi-arid areas mean annual rainfall can be as low as 300 mm, and in these conditions it is confined to seasonally dry stream banks. Throughout much of its natural distribution annual rainfall is 600-1200 mm with most rain concentrated in four months. It does occur, however, in areas where rainfall exceeds 1500 mm (Booth and Jovanovic 1988). Most of the distribution is frost-free, but up to ten frosts each year occur at some inland sites. It occurs on a variety of soil

types, but mainly on shallow, acidic, stony sands and loams of low fertility (Turnbull, et al. 1986).

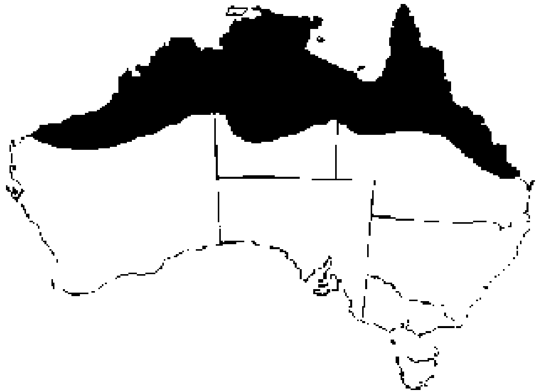
In Senegal tests have shown that the species behaves satisfactorily with rainfall over 500 mm in areas under coastal influences and over 600 mm in continental Africa (Cossalter 1987). In extremely dry areas when annual rainfall is less than 250-300 mm seedlings can survive for 2 to 3 years but then die. In the island environment of Cape Verde, however, where low rainfall is counterbalanced by higher air moisture, cooler temperatures and lower evapotranspiration, A. holosericea has withstood an average annual rainfall of about 200 mm in a 5-year period.

In Senegal, it reportedly tolerates saline and waterlogged soils (Cossalter 1987).

The wide variability in soils and climate suggest major provenance differences will occur in growth rates and drought and frost tolerance. Provenance trials have been started, but results are not yet available.

FUELWOOD AND CHARCOAL: The wood is hard and has a high density of about 870 kg/m. With calorific values for wood and charcoal of 4670 Kcal/kg and 7535 Kcal/kg, respectively, it is a good quality fuel

(Cossalter 1987; CTFT 1983). The rapid early growth rate makes it a highly productive fuelwood source.



The shaded area is the natural range of Acacia holosericea (Turnbull, et al. 1986).

FODDER: The fodder potential is mainly due to the large phyllode biomass produced during the dry season, a period when most non-Australian acacias traditionally used for fodder shed their leaves. Fresh phyllodes are not palatable for cattle and sheep, but when the branches are lopped the dry foliage is eaten readily. Four-year-old trees in Senegal have produced about 3 tons of dry phyllodes per hectare, but estimates of crude protein and in vivo digestibility are low and suggest A. holosericea has a low feed value (Vercoe 1987).

WINDBREAKS & LAND REHABILITATION The large, dense crown of this shrubby acacia enables it to form a screen. In Africa it is used to form the lower part of a multistorey windbreak with the taller Eucalyptus camaldulensis, a species with which it is frequently found in its natural range (Hamel 1980).

Advantage can be taken of the fast growth, dense crown, nitrogen fixing ability and vigorous colonizing characteristic of this species to revegetate and restore degraded mining areas (Langkamp and Dalling 1983). It also shows promise for sand dune fixation in Senegal and Somalia (Hamel 1980).

ORNAMENTAL: The silvery foliage, early appearance of long yellow flower spikes, and prominent twisted pods make A. holosericea an attractive ornamental shrub or small tree.

ESTABLISHMENT: For good germination, seed (95,500 to 175,000/kg) should be scarified by mechanical abrasion or immersed for one minute in boiling (100 C) water. Coppicing is generally regarded as poor, but contradictory reports suggest its resprouting ability may be influenced by tree age, season of cutting and height at which the cutting takes place.

GROWTH Seedling growth is rapid. On favorable sites in Central Australia it has reached 4 m tall in 18 months. On drier sites 3 m growth in 3 years is average, and growth rate diminishes in succeeding years (Kube 1987). In Senegal a growth rate of 4.8 m in 40 months has been recorded in an area with 585 mm rainfall and a 7-month dry season (Cossalter 1987). At Bambey, Senegal, 4 year old Acacia holosericea produced 13 tons/ha of green wood and almost 3 tons/ha of dry phyllodes, demonstrating its considerably greater productivity than the local Acacia Senegal.

SYMBIOSIS: A. holosericea forms nodules with rhizobium and develops endomycorrhizal associations. Greatly stimulated growth has been reported when seedlings were inoculated with a selected rhizobium and the endomycorrhizal fungus, Glomus mosseae (Cornet and Diem 1982).

PESTS: This acacia appears to be relatively free of pests and diseases in cultivation and resists termite attack.

PROBLEMS: The early and abundant seeding habit has the potential to make A. holosericea a weed species under certain conditions. Like many acacias, it is relatively short-lived' from as little as 4-5 years to not more than 10-12 years, and this may be a problem under some circumstances.

Acacia holosericea

REFERENCES

Booth, T.H. and T. Jovanovic. 1988. Assaying natural climatic variability in some Australian species with fuelwood and agroforestry potential. Commonwealth Forestry Review 67(1):27-34.

Comet, F. and H.G. Diem. 1982. Etude comparative de l'efficacite des souches de Rhizabium d' Acacia isolees de sols due Senegal et effet de la double symbiose Rhizabium - Glomus mosseae sur la croissance de Acacia holosericea et A. raddiana Bois et Forets des Tropiques 198:3-

15.

Cossalter, C. 1987. Introducing Australian acacias into dry, tropical Africa. pp 118-122. ID J.W. Turnbull (ed) Australian acacias in developing countries. ACIAR proceedings No. 16 (ACIAR: Canberra).

Hamel, O. 1980. Acclimatization and utilization of phyllodineous acacias from Australia in SenegaL pp. 361-373. In H.N. LeHouerou (ed) Browse in Africa. (International Livestock Centre for Africa Addis Ababa).

Kube, P. 1987. Growth rates, establishment techniques, and propagation of some Central Australian acacias. pp. 77-80.

In J.W. Tumbull (ed) Australian acacias in developing countries. ACIAR Proceedings No. 16 (ACIAR: Canberra).

Langkamp, P.J. and M.J. Dalling. 1983. Nutrient cycling in a stand of Acacia holosericea Australian Journal of Botany 31:141- 9.

Simmons, Marion. 1981. Acacias of Australia. Thomas Nelson Australia, Melbourne. 325 pp.

Turnbull, J.W., P. Martensz and N. Hall. 1986. Acacia holosericea. pp 144-5. In Multipurpose Australian Trees and Shrubs. ACIAR Monograph

No. 1.

Vercoe, T.K. 1987. Fodder potential of selected Australian tree species. pp. 95-100. In J.W. Turnbull (ed) Australian acacias in developing countries. ACIAR Proceedings No. 16 (ACIAR: Canberra).

Acacia leucophloea - shade and fodder for livestock in arid environments

Native to arid areas in South and Southeast Asia, Acacia leucophloea (syn. Mimosa leucophloea) is easily identified by its white bark and large wide spreading limbs. It is most often utilized as shade for livestock and as a source of dry-season fodder. Growing well on alluvial or infertile soils, A. Ieucophloea also has great potential as a reforestation species for degraded sites. Currently, it is not commonly planted for this purpose. Common names for this species often refer to its light color; white-bark acacia (English), safed kikkar (Hind)), safed babul (Bengali), goira (Onya), sarai, velvelam (Tamil). Other common names include pilang and besok (Indonesian).

Botany

Acacia leucophloea (Roxb.) Willd. (Leguminosae Mimosoideae) is a large thorny tree attaining heights of 35 m and diameters at breast

height (dbh) of 100 cm (Nielsen 1992, Heyne 1950). It may be deciduous. Mature trees become less thorny and can live to be 100 years old. Trunks are stout, dividing into several large diameter branches. Open-grown specimens have a characteristic wide umbrella-like crown. In India, the trunk is often crooked (Troup 1983), but reported as straight in Indonesia (Heyne 1950). Generally, the bark is white to yellowish gray, smooth and exfoliates in long strips. On old trees, the bark becomes black and rough (Troup 1983, Heyne 1950). In harsh environments and on poor soils this species remains a shrub or small malformed tree.

The feathery green foliage offers a strong contrast to the light-colored bark. Leaves are bipinnately compound having 5-30 pairs of leaflets. Circular glands are found on the rachis below the junction of paired-pinnae (Nielsen 1992, Troup 1983). Spines, 2-5 mm long. occur at the base of leaves. The leaves may fall during the cold or dry seasons and regrow with the rains. The conspicuous flowers are light-yellow to cream in color and are borne in abundance during the rainy season. Flowering occurs July through November in India (Troup 1983) and December through March in Indonesia (Djogo 1992). The pods are yellow, green or brown in color, flat and fairly straight. They measure 10-20 cm long, 5-10 mm wide and ripen from February to June in India (Troup 1983) and July to September in Timor (Djogo 1992). Pods

should be collected before they split and disperse their seed. Healthy pods contain 10-20 smooth oblong seeds of dark brown color and 6x4 mm in see (Kumar and Bhanja 1992).

Ecology

Acacia leucaphloea is a component of dry-forests. savannas, bush woodlands, and desert ecosystems from sea level to elevations of 800 m. In these areas, rainfall is only 4001500 mm/year and dry seasons may persist for 9-10 months. Temperatures are extreme, varying from-1to49C.

Acacia leucophloea is common on sands, infertile rocky soils, limestone soils, organic clays and alluvial areas. Plant growth is usually slow. On fertile soils, A. Ieucophloea seedlings grow quickly, up to 60 cm a year, but on such sites faster growing associate species usually dominate. Under irrigation, height growth may reach 7-10 meters in 5-6 years. Seedlings are light demanding and sensitive to weed competition. fire and frost. In order to exploit sufficient soil moisture. seedling root growth generally exceeds shoot growth. Once established, trees are very tolerant of drought fire and frost. Reports concerning A. leucophloea tolerance of saline conditions are contradictory. This question needs future investigation. Pruned or injured trees produce

thorny branch and stump sprouts.

Distribution

Acacia leucophloea's native range through South and Southeast Asia is non-contiguous. Its largest continuous distribution is arid India through Sri Lanka. Bangladesh, Burma and much of Thailand. Other populations occur in southern Vietnam; Java and Bali of central Indonesia: and Timor of eastern Indonesia (Nielsen 1992. Troup 1983). This species has not been widely introduced to other regions.

Uses

Wood. The wood of this species is strong. heavy and hard with a specific gravity of 0.71. It seasons well and takes a good polish (Troup 1983). The beck-red heartwood is very beautiful and is used to make decorative furniture. The pale yellow sapwood is perishable. Commodities produced from the wood include poles, farming implements, carts. wheels, turnery, construction timbers and fuel. The utilization of this species is limited because its wood has irregular interlocked grain. a rough texture, is difficult to work and is not durable.

Fodder and Pasture. Acacia Ieucophloea is an important dry-season

fodder and pasture tree throughout its range. Leaves, tender shoots and pods are eagerly eaten by goats, sheep and cattle. Singh (1982) reports that leaves contain 15% crude protein and 19% crude fiber. However, due to hydrocyanic acid toxicity A. leucophloea should not be used as a sole feed (Bhadoria and Gupta 1981). During dry seasons, this tree protects livestock and understory pasture from excessive temperatures. Grass beneath the trees remains succulent while exposed grass becomes dry and unpalatable. In eastern Indonesia, populations of this species have declined significantly due to heavy use as a dry-season fodder. Farmers do not replants. leucophloea because of its slow growth.

Other uses. The inner bark of A. leucophloea has a foul aroma. It produces a reddish-brown stain used to manufacture dyes and tannins (Heyne 1950). Fibers from the inner bark are used to make fish nets and rough rope. Additionally, a water soluble gum of fair quality can be extracted from the bark. The leaves yield a black dye and the bark produces tannin and dye (Heyne 1950. Troup 1983). Heyne (1950) reports the bark is used to distill liquor in India and seed sprouts are eaten as vegetables in Java. The vivid colors of its leaves. flowers and bark make A. leucophloea a beautiful, yet underutilized, ornamental tree.

Silviculture

Propagation. Seeds of A. leucophloea (37,000-50,000/kg) have hard seedcoats. Under natural conditions they germinate unevenly. To encourage uniform germination. seed should be scarified. Two methods are recommended: 1) submerge seeds in boiled water until the water cools - roughly 24 hours, or 2) soak seeds in sulfuric acid for 10-30 minutes followed by a cool water soak for 24 hours (Kumar and Bhanja 1992). The visibly swollen seeds should be removed from the water and sown immediately.

Management. Acacia Ieucophloea can be established by direct sowing. stump sprouts or seedlings. Direct sowing is preferred because the large roots of seedlings may hamper transplanting. Troup (1983) recommends the following method. Immediately prior to the rainy season, the sowing site should be cleared of weeds and the soil well cultivated. When the rains arrive sow scarified seed at a depth of I cm. Germination begins within a week.

Seedlings are sensitive to vegetative competition and browse damage. Weed control must be maintained for a minimum of two years. Livestock must be excluded from plantations until trees are beyond their reach. Annual cultivation around the seedlings improves growth

and survival. Interplanting A. leucophloea at low densities with crops or pasture grasses can benefit both crops and trees (Troup 1983, Djogo 1992). Although this species is slow growing it should not be disregarded. Acacia Ieucophloea is a good reforestation species for poor soils in low rainfall areas. Otherwise underutilized, these sites could become useful fodder and fuel plantations.

Symbiosis

Acacia leucophloea fixes atmospheric nitrogen through a symbiotic relationship with Rhizabium bacteria which enables it to survive on infertile sites. Quantitative information concerning the amount of nitrogen fixed in this relationship is lacking.

Limitations

The wide crown of A. leucophloea competes with adjacent crops for sunlight limiting the trees usefulness on farms. The wood degrades quickly and is difficult to work.

References

Bhadoria, B.K. and R.K. Gupta. 1981. A note on hydrocynic acid content in Acacia leucophloea Roxb. Willd. Current Science 50: 689-690.

Djogo, A.P.Y. 1992. The possibilities of using local drought resistant multipupose tree species as alternatives to lamtoro (Leucaena leucocephala) for agroforestry and social forestry in West Timor. Working Paper No. 32. EAPI, East West Center, Honolulu, Hawaii, USA. 41 p.

Heyne, K. 1950. De nuttige planter van Indonesie (The useful plants of Indonesia). N. V. Uitgeverij W. van Hoeve, Bandung, Indonesia. pp 713-715.

Kumar, S.V. and M. Bhanja. 1992. Forestry seed manual of Andhra Pradesh. Research &L Development Circle. Andhra Pradesh Forest Department, Hyderabad, India 100 p

Nielsen, I.C. 1992. Flora Malesiana: Mimosaceae (Legununosae-Mimosoideae), vol. 11 :45.

Singh, R.V. 1982. Fodder trees of India. Oxford and IBH Publishing. Co. New Delhi, India. pp 367-69.

Troup. R.S. 1983. Troup's Silviculture of Indian Trees. vol IV Leguminosae. Forest Research Institute and Colleges, Dehra Dun. India. pp 33-38.

Acacia nilotica - Pioneer for Dry Lands

Acacia nilotica (L.) Willd. ex Del. (Leguminosae, subfamily Mimosoideae) is one of about 135 thorny African Acacia species. Variation is considerable with nine subspecies presently recognized, three occurring in the Indian subcontinent and six throughout Africa (Brenan 1983.) They are distinguished by the shape and pubescence of pods and the habit of the tree.

BOTANY. In habit A. nilotica varies from a shrubby tree with wide spreading crowns in savanna habitats (ssp. subalata, leiocarpa, adstringens, hemispherica and kraussiana), to a 20 meter tree (ssp. nilotica, tomentosa, and indica) in riverine situations. Ssp. cupressiformis has ascending branches like a poplar.

Acacia nilotica is easy to recognize by its bright yellow flowers in round heads, straight stipular spines often slightly deflexed, and dark indehiscent pods compressed over the seeds. Flowering is prolific, and can occur a number of times in a season. Often only about 0.1% of flowers set pods (Tybirk 1989.) The taxa form a polyploid complex: most are tetraploids (2n=4x=52); but higher numbers have been found in ssp. nilotica (2n=8x=104) & ssp. tomentosa (2n=16x=208) (Nongonierma 1976.)

ECOLOGY. There are two very distinct ecological preferences in the African subspecies. Subspecies subalata, leiocarpa and adstringens occur in wooded grassland, savanna and dry scrub forests. Subspecies nilotica and tomentosa are restricted to riverine habitats and seasonally flooded areas. Subspecies kraussiana prefers dry grasslands and savannas, especially on compacted sandy loam, shallow granite or clay soils along drainages and rivers, but away from flooding.

On the subcontinent, ssp. indica forms low altitude dry forests usually on alluvium and black cotton soils. It has been widely planted on farms throughout the plains of the subcontinent. The species grows on saline, alkaline soils, and on those with calcareous pans. Subspecies hemispherica is restricted to dry sandy streams beds near Karchi, ssp. cupressiformis has similar preferences to ssp. indica though is less resilient to weed competition.

A. nilotica occurs from sea level to over 2000 m. It withstands extremes of temperature (-1 to 50 C), but is frost tender when young. Annual rainfall varies from 250 - 1500 mm. Trees are generally deciduous during the dry season, though riverine ssp. can be almost evergreen.

DISTRIBUTION. The species is naturally widespread in the drier areas of Africa, from Senegal to Egypt and down to South Africa, and in Asia

from Arabia eastwards to India, Burma and Sri Lanka. It has also been cultivated elsewhere, including Australia, Cape Verde islands, Indonesia, Iran, Iraq, Nepal, Vietnam, and the West Indies.

USES. Wood. Since the time of the Pharoahs, large timber trees have been exploited from the riverine forests of the Nile. At present the Sudan forests are managed on a 20-30 year rotation producing termite resistant timber especially suitable for railway sleepers. In India and Pakistan riverine plantations are managed on a 15-2D year rotation for fuelwood and timber.

The dark brown wood is strong, durable, nearly twice as hard as teak, very shock resistant, and is used for construction, mine props, tool handles and carts. It is best carved in a green state. It has a high calorific value of 4950 kcal/kg, making excellent fuelwood and quality charcoal. It burns slow with little smoke when dry.

Fodder. The pods and leaves contain 8% digestible protein [12.4% crude protein], 7.2 MJ/kg energy, and are rich in minerals (Le Houerou 1980). In part of its range smallstock mainly consume it, but elsewhere it is also very popular with cattle. Pods are used as a supplement to poultry rations in India. Dried pods are particularly sought out by animals on rangelands. In India branches are commonly lopped for

fodder. Pods are best fed dry as a supplement, not as a green fodder.

Agroforestry. Babul (ssp. indica) is a popular farm tree of the central plains of India. More recently interest has centred on the fastigiate form (ssp. cupressiformis). This subspecies makes an ideal windbreak surrounding fields; its narrow crown shades less than other windbreak species.

Land Rehabilitation. In India this species is used extensively on degraded saline/alkaline soils, growing on soils up to pH 9, with a soluble salt content below 3%. It also grows well when irrigated with tannery effluent, and colonises waste heaps from coal mines. Over 50,000 hectares of the Indian Chambal ravines have been rehabilitated with A. nilotica by aerial seeding (it is one of the 3 most frequently used trees for this purpose).

Tannins. The bark of ssp. indica has high levels of tannin (12-20%) which are used for tanning leathers. Ten year old trees yield 35-40 kg of bark. The pods of ssp. nilotica have been used for tanning in Egypt for 6,000 years. Subspecies adstringens is used for both tanning and dye making. Deseeded pods from ssp. indica have 18-27% tannin levels, whereas ssp. tomentosa and nilotica reach up to 50%.

Other Uses. The tannin also contributes to its medicinal use as a powerful astringent. It is also a powerful molluscicide and algicide. Fruits added to ponds in Sudan kill snail species which carry schistosomiasis without affecting the fish.

There are many other reported uses (Fagg & Greaves 1990). The tree makes effective live fencing, a good host plant for growing sandalwood, and an important source shellac in the Sind. The gum is used in paints and medicines and has been collected for a millennia. It has similar properties to gum arabic (from A. senegal) and is frequently used in calico printing in India.

SILVICULTURE. Propagation. It is a pioneer species, easily regenerated from seed. The nutritious indehiscent pods have evolved for animal dispersal. A mature tree can produce 2,000-3,000 pods in a good fruiting season, each with 8-16 seeds, yielding 5,000 - 16,000 seed/kg depending on the subspecies.

Hard coated seeds can be extracted by pounding the pods or collected from animal pens after the pods have been eaten (Sheikh 1989). Pretreatment is needed. Mechanical scarification works best for small seed lots. Acid scarification from 60 - 120 minutes (depending on seed provenance or age), or pouring boiling water over the seeds and

allowing them to cool are also effective.

Seed from natural populations of some subspecies are available from India and some Sahelian countries. A broader range of germplasm and Rhizabium inoculum is available from the Oxford Forestry Institute (Oxford OX1 3RB UK) for field trials.

Management. The species can be direct seeded or established by seedlings. In the nursery long poly tubes (20 x 7 cm) should be used so as not to restrict rapid tap root growth. Frequent root pruning is advised. Nursery grown seedlings are usually outplanted after 6 months, but in some cases stay in the nursery up to a year.

Establishment varies depending on the site. Seedlings are shade intolerant. In irrigated plantations in the Sind and Punjab, 10-15 seeds are spot sown at 2x3 m spacing on the tops of trenches. They are thinned to 3-4 seedlings after 3-4 months. Further thinning occurs at 5 year intervals. Rotations are 20-25 years. In the Thal desert, Pakistan (250 mm of rain), promising growth resulted from irrigation on a 10 day interval. Growth rates varied considerably depending on the sites, with maximum mean annual increment of 13 m/ha at 20 yrs old and 10.5 m/ha at 30 years recorded.

LIMITATIONS. A wide range of pests and diseases affect this species. Of economic importance is the stem borer Cerostema scabrator on young plantations in India. Euproctis lunata & E. subnotata occasionally defoliate patches of forest in Sukkur and Hyderabad. Bruchid beetles attack the seeds, destroying up to 70 %. Buprestid beetles cause a dieback disease in Sudan. Fungal rots (Fomes papianus & F. badius) attack unhealthy trees, and powder post beetles (Sibixylon anale & Lyctus africanus) attack the sapwood of felled timber.

Acacia nilotica can become weedy when introduced out of its native range, particularly in more humid zones. Thorniness can be a problem when introduced to areas where people do not traditionally use thorn trees.

PRINCIPAL REFERENCES:

Brenan, J.P.M. 1983. Manual on the taxonomy of Acacia species: Present taxonomy of four species of Acacia (A. albida, A. senegal, A. nilotica, A. tortilis). FAO, Rome, Italy. 47 p.

Fagg, C.W. and A. Greaves. 1990. Acacia nilotica 18691988. CABI/OFI Annotated bibliography No. F42. CAB International, Wallingford, Oxon, UK. 77 p.

Le Houerou, H.N. 1980. Chemical composition and nutritional value of browse in tropical West Africa. In H.N. Le Houerou (ed), Browse in Africa, the Current State of Knowledge. ILCA, Ethiopia. p 261-289.

Nongonierma, A. 1976. Contribution a l'etude du genre Acacia Miller en Afrique occidentale. II. Caracteres des inflorescences et des fleurs. Bulletin de l'IFAN Serie A. 38 (3) 487-657.

Tybirk, K 1989. Flowering, pollination, seed production of Acacia nilotica. Nordic Journal of Botany 9 (4) 375-381.

Sheik, M.I. 1989. Acacia nilotica (L.) Willd. ex Del. Its production, Management and Utilization. Pakistan. Regional wood energy development programme in Asia, GCP/RAS/111/NET Field document no. 20, FAO, Bankok 10200, Thailand. 45 p.

Adenanthera pavonina: an underutilized tree of the humid tropics

Adenanthera pavonina (L.) (family Leguminosae, subfamily Mimosoideae) has long been an important tree in Southeast Asia and the Pacific Islands. Cultivated in home gardens and often protected in forest clearings and village common areas. this useful tree provides quality fuelwood, wood for furniture, food, and shade for economic crops like coffee and spices. The tree has been planted extensively

throughout the tropics as an ornamental and has become naturalized in many countries. The scientific name is derived from a combination of the Greek aden, "a gland," and anthera, "anther"; alluding to the anthers being tipped with a deciduous gland. The tree is known by a host of common names, including red-bead tree, red sandalwood, and Circassian-bean in English; raktakambal (India); saga (Malaysia); lope (Samoa and Tonga); coralitos, peronias, and jumble-bead (Caribbean).

Botany

A medium- to large-sized deciduous tree, A. pavonina ranges in height from 6-15 m with diameters up to 45 cm, depending upon location. The tree is generally erect, having dark brown to grayish bark, and a spreading crown. Multiple stems are common, as are slightly buttressed trunks in older trees. The leaves are bipinnate with 2-6 opposite pairs of pinnae, each having 8-21 leaflets on short stalks. The alternate leaflets, 2.0-2.5 cm wide and 3 cm long, are oval-oblong with an asymmetric base and a blunt apex, being a dull green color on top and a blue-green beneath. The leaves yellow with age.

Flowers are borne in narrow spike-like racemes, 12-15 cm long, at branch ends. They are small, creamy-yellow in color, and fragrant. Each flower is star-shaped with five petals, connate at the base, and having

10 prominent stamens beering anthers tipped with minute glands.

The curved pods are long and narrow, 15-22 cm by 2 cm, with slight constrictions between seeds, and dark brown in color turning black upon ripening. The leathery pods curve and twist upon dehiscence to reveal the 8-12 showy seeds characteristic of this species. The hard-coated seeds, 7.5-9.0 mm in diameter, are lens-shaped, vivid scarlet in color, and adhere to the pods. The ripened pods remain on the tree for long periods and may persist until the following spring. There are reportedly 1600 seeds per pound (Little and Wadsworth 1964).

Ecology

This species is common throughout the lowland tropics up to 300-400 m. Adenanthera pavonina is a secondary forest tree favoring precipitation ranging between 3000-5000 mm for optimal growth. Found on a variety of soils from deep, welldrained to shallow and rocky, this tree prefers neutral to slightly acidic soils. Initial seedling growth is slow, but rapid height and diameter increment occur from the second year onward. The tree is susceptible to breakage in high winds, with the majority of damage occurring in the crown. Rapid resprouting and growth following storm damage has been recorded in the Samoan Islands (Adkins 1994).

Distribution

Adenanthera pavonina is endemic to Southeast China and India, with first reports being recorded in India. The tree has been introduced throughout the humid tropics. It has become naturalized in Malaysia. Western and Eastern Africa and most island nations of both the Pacific and the Caribbean.

Uses

There are historical accounts from Southeast Asia and Africa of using all parts of tree for traditional medicines (Burkill 1966, Watt and Breyer-Brandwijk 1962). Adenanthera pavonina is extensively cultivated as an ornamental for planting along roadsides and in common areas. The fast growth and spreading crown of light, feathery foliage offer attractive shade. Interplanted among field and tree crops (spices, coffee, coconuts), along field borders as part of a windbreak or in plantation, A. pavonina is a valuable agroforestry species (Adkins 1994, Clark and Thaman 1993).

Source Little and Wadsworth, 1964

Adenanthera pavonina

Wood Products. Adenanthera pavonina is esteemed for fuelwood in the Pacific Islands, often being sold in local markets. The wood burns readily producing significant heat, and is used in both above- and below-ground ovens. Good sized fuelwood, larger than 11 cm in diameter. can be produced in five years. The wood is hard and durable having red-colored heartwood with light-gray sapwood. It is close-and even-grained, making it useful for constructing furniture, cabinets, and

decorative wood products (Benthall 1946, Clark and Thaman 1993). It is also valued for home building.

Seeds. Known as "food trees" in Melanesia and Polynesia, the seeds of this tree are roasted over a fire and eaten by children and adults alike. Nutritional studies have shown one quarter of the seed weight to be oil with a high percentage of protein, and a fatty acid composition favoring high digestibility for both humans and livestock (Balogun and Fetuga 1985, Burkill 1966). Histoncally, the seeds were used as weight measures for jewelry and goldsmithing due to their small variation in weight (Benthall 1946, Burkill 1966). The bright red seeds are still used today in fashioning necklaces and decorative ornaments.

Foliage. The small leaves breakdown easily making for good use as a green manure. As a supplemental source of fodder, the leaves are fairly high in digestible crude protein (1722%), but low in mineral content (Rajaguru 1990).

Silviculture

The tree is cultivated from seed. The seed coat is extremely hard and requires scarification if even germination is to occur. Untreated seeds can be stored up to 18 months without losing viability (Basu and

Chakraverty 1986). Manual scarification, immersing the seeds in boiling water for one minute, or treatment with sulfuric acid has shown to significantly increase germination percentage. Following treatment, seed can be directly sown in the field or in a nursery. Germination occurs within 7-10 days with young seedlings obtaining a height of 8-15 cm in approximately three months. Seedling maturity occurs two to three months later at 20-30 cm in height. Nursery stock transplants well.

Growth is initially slow, but increase rapidly after the first year. Following the first year of establishment, average annual growth rates of 2.3-2.6 cm in diameter and 2.0-2.3 m height have been recorded in American Samoa (Adkins 1994). Trees planted 1 x 2 m apart for windbreaks, and at a spacing of 2 x 2 m in plantations can be thinned in three to five years to provide fuelwood and construction materials. As a shade tree, spacing varies from 5-10 m depending on the companion crop and site. The trees resprout easily allowing for coppice management with good survival .

Despite an inability to suppress weeds. the seedlings are rather hardy and can survive with minimal maintenance. Adenanthera pavonina is compatible with most tropical field and tree crops, allowing for their usage in integrated production systems.

Symbioses

Although Allen and Allen (1981) indicate the inability of A. pavonina to nodulate, this legume is generally considered to be nitrogen-fixing. Sparse, fast growing, brown nodules with isolates confirmed to be Rhizobium have been observed by Lim and Ng (1977). The author observed root nodules, both in old nursery stock and in the field during research conducted in American Samoa. Norani (1983) confirmed the presence of VA mycorrhiza on the roots of nursery stock.

Limitations

Despite its susceptibility to crown damage in high winds, the ability to recover is remarkable. No insect or disease problems have been reported.

Research

Additional investigation concerning the nitrogen-fixing ability on native and naturalized populations is required. Continued research on fuelwood production and fodder usage is necessary.

References

Adkins, R. v-C. 1994. The role of agroforestry in the sustainability of South Pacific Islands: Species Trials in American Samoa. MS. Thesis, Utah State University. Logan, Utah. 133 p.

Allen, O.N. and E.K. Allen. 1981. The Leguminosae: a source book of characteristics, uses, and nodulation. University of Wisconsin Press. Madison, Wisconsin. 812 p.

Balogun, A.M. and B.L. Fetuga. 1985. Fatty acid composition of seed oils of some members of the Leguminosae Family. Food Chemistry, 17(3): 175-82.

Basu, D. and R.K. Chakraverty. 1986. Dormancy. viability and germination of Adenanthera pavonina seeds. Acta Botanica Indica, 14 (1): 68-72.

Benthall, A.P. 1946. Trees of Calcutta and its neighborhood. Thacker Spink and Co. Calcutta. 513 p.

Burkill, I.H. 1966. A dictionary of the economic products of the Malay peninsula, 2 ea., Volume I, A-H. Government of Malaysia and Singapore. Kuala Lumpur, Malaysia. 1240 p.

Clark, W.C. and R.R.Thaman. (eds). 1993. Agroforestry in the Pacific

Islands: Systems for sustainability. United Nations University Press. Tokyo, Japan. 279 p.

Lim, G. and H.L. Ng. 1977. Root nodules of some tropical legumes in Singapore. Plant and Soil, 46: 317-27.

Little, E.L. Jr. and F.H. Wadsworth. 1964. Common trees of Puerto Rico and the Virgin Islands. Agriculture Handbook No. 249. USDA Forest Service. Washington, D.C. 144-46 p

Norani, A. 1983. A preliminary survey on nodulation and VA mycorrhiza in legume roots. Malaysian Forester, 46: 171-74.

Rajaguru, A.S.B. 1990. Availability and use of shrubs and tree fodders in Sri Lanka. In: Devandra, C. (ed). Shrubs and tree fodders for farm animals International Development Research Cantre Ottawa, Ontario. Canada. pp: 23743.

Watt, J.M. and M.G. Breyer-Brandwijk. 1962. The medicinal and poisonous plants of southern and eastern Africa. 2 ed E & S Livingstone, Ltd. London, England. 1457 p.

Albizia lebbeck - A Promising Fodder Tree for Semi-Arid Regions

Providing high quality fodder during dry seasons is one of the most serious problems faced by many small-scale farmers in developing countries. Albizia lebbeck is particularly promising as a fodder tree for semi-arid regions in the tropics and subtropics, and it has many other uses as well.

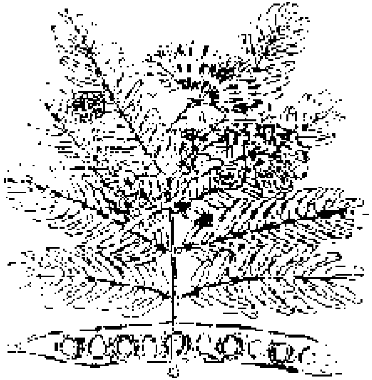
BOTANY: A. lebbeck (L.) Benth. is a moderate to large deciduous tree that reaches 30 m in height in rain forests. The tree develops a straight bole when grown in dense forests, but is spreading and low branching in the open. Unless coppiced frequently, trees will annually produce an abundance of seed from papery pods about 20 cm long and 3 cm wide (author). Common names such as "woman's tongue" and "rattle pod" derive from the noise of pods shaking in the wind. Foliage is pale green when young and gray-green at maturity, and consists of 24 pairs of pinnae 50-100 mm long with 3-11 pairs of leaflets up to 50 mm long. Flowers are cream colored, hemispheric pompons.

ECOLOGY: The species is native to India, Burma and the Andaman Islands, and naturalized in many other tropical and subtropical areas (Streets 1962). In these regions A. lebbeck, also known as "Siris" or "Indian Siris", grows in a wide range of climates, covering an annual rainfall range of 600 - 2500 mm. However, it also has been grown successfully in areas with an annual rainfall as low as 400 mm. It grows

in Himalayan valleys up to 1600 m. The species is adapted to a wide range of soil types, from acid soils to alkaline and saline conditions (Prinsen 1986). Older trees withstand grass fires and night frosts of considerable intensity. Such stresses kill off above-ground growth of young trees, but new growth usually follows.

FODDER: Most livestock readily eat leaves and young twigs of this fine fodder tree. Crude protein concentration is about 20% for green leaves, 13% for leaf litter, and 10% for twigs. Edible material has no known toxic compounds. In general, the digestibility of edible material from leguminous fodder trees is lower than that of leguminous herbs. In this regard, A. lebbeck is average. In vitro digestibility ranges from 45% for mature leaf to 70% for young leaf. In vitro digestibility of twigs is around 40% considerably higher than for twigs of most other fodder trees.

Studies in Townsville, Australia, (lat. 19 S. annual rainfall c. 900 mm) have shown that trees do not have to be browsed directly, as leaves, flowers and pods fall sequentially during the dry season (Lowry, unpublished). Pradhan and Dayal (1981) measured an annual leaf litter yield of 5000 kg/ha from Indian Siris compared to 1800 kg/ha from a Eucalyptus hybrid and 8000 kg/ha from Acacia arabica.



Albizia lebbeck

TREES IN PASTURES: There is evidence that pasture herbage production is increased by low densities of A. lebbeck. Yields of Panicum maximum and speargrass under a canopy of A. lebbeck in a subhumid area of northern Australia were significantly higher than yields between the trees, 1710 vs. 753 kg/ha, for trees sufficiently isolated for considerable lateral light penetration (Lowry et al. 1988). Maintenance of moisture content appeared at least partly responsible for the difference. Increased grass growth was observed under a number of other tree species, but the difference was not as conspicuous and consistent as with A. lebbeck, suggesting the major factor was the right degree of shading. In a lower rainfall region, however, a much greener color of grasses under the A. lebbeck canopy suggested that

increased yields were the result of increased levels of available nitrogen (Prinsen, unpublished).

YIELDS: A. lebbeck can be grown as a singlestemmed tree or as a multi-stemmed shrub. In the latter form it coppices as readily as Leucaena leucocephala. In a stand of naturalized A. lebbeck growing in shallow soil in a subtropical 750 mm rainfall area in Australia, estimates of average annual production of dry edible matter varied in different management systems. Stands of mature trees completely pruned back to stem once every three years produced 1700 kg/ha/yr, Stands in hedgerows at a row distance of 3 m and defoliated by cattle twice a year produced 2500 kg/ha/yr. This production estimate compares favorably with a leucaena yield of 1500 kg/ha/yr in the same region, which indicates that A. lebbeck could serve as an alternative to leucaena in the lower rainfall tropics and subtropics. Although the digestibility of leucaena leaf is higher, A. lebbeck is less frost susceptible and better suited to acid soil.

In plantings corresponding to 2,500, 10,000, and 40,000 trees/ha in Puerto Rico, above ground biomass per unit area increased with density during the first 24 months, yielding 12.6, 14.5 and 17.4 t/ha, respectively (Parrotta 1988). After 36 months, however, the figures were 21.7, 29.5 and 18,7 t/ha. The percentage of above ground biomass

contained in leaves increased with stand density, from 13% to 23% in the 2,500 and 40,000 tree/ha stands, respectively, at 36 months.

WOOD: Heartwood is brown to dark, and sapwood is white and large. Timber, with a specific gravity of 0.55 - 0.60, is very suitable for construction, furniture and veneer. Pulp is short-fibered and used for paper production only when mixed with long-fibred pulp (Anonymous 1970). Wood provides good fuel and has a caloric value of 22 kilojoules per kg (Anonymous 1970). In India, annual wood yields of 5 m/ha were recorded in rotations of 10 - 15 years, but yields depend on environmental conditions.

NODULATION: A. lebbeck is not Rhizobium specific, and native strains are nearly always capable of producing an abundance of nodules.

PESTS AND DISEASES: This species has had no known serious pests or diseases, although a psyllid, probably of the genus Heteropsylla, recently was reported as seriously affecting seedlings in India (Hegde and Relwani 1988). The infestation could not be controlled with three sprayings of 0.2% Malathion, but was controlled by two sprayings of Nuvacron (0.05%) one week apart. Some records exist of termites damaging seedlings and fungal diseases attacking leaves in India. In Australia borers may kill off a few branches. However, no cases of

significant yield losses have been reported.

ESTABLISHMENT: Seeds germinate well without scarification, but germination may be improved by immersing seed in boiling water for 3 seconds and then allowing it to cool and dry. Direct sowing is possible, but rows must be well-weeded for a fey. years. Another method is to raise seedlings in nursery beds for one year or more and then transplant them as stumps with about 25 cm root and 10 cm shoot (Anonymous 1970). This would considerably reduce the field establishment period.

OTHER USES: The tree is used as a folk remedy for many ailments. Another common use is as an avenue tree, and sometimes it is used to shade coffee and tea. Saponins and tannins in the bark can be used for making soap and in tanning, respectively. Bee keepers like the species for the light-colored honey its nectar provides, and the tree hosts the lac insect. Soil-binding ability makes it useful for soil conservation plantings (Sommen 1981).

REFERENCES:

Anonymous. 1970. Kokko (siris) Indian Timber Information Series No. 6, Forest Research Institute and Colleges, Dehra Dun, India.

Little, E.L., and F.H. Wadsworth. 1,64. Common Trees of Puerto Rico and the Virgin Islands. U.S. Department of Agriculture, Agricultural Handbook No. 249.

Hegde, N. and L. Relwani. 1988. Psyllids attack Albizia lebbeck Benth. in India NFTRR6:43-44.

Lowry, J.B., B.C. Lowry and R. Jones. 1988. Enhanced grass growth below a canopy of A. lebbeck. NFTRR6:45-46.

Parrotta, J.A. Early growth and yield of Albizia lebbeck au a coastal site in Puerto Rico. NFTRR6:47-49.

Pradhan, I.P, and R Dayal. 1981. Farm forestry in agricultural economy. Indian Forester 107:665-667.

Prinsen J.H 1986. Potential of Albizia lebbeck (Mimosaceae) as a tropical fodder tree - a review of literature. Trop. Grasslands 20(2).78-83.

Prinsen. J.H. Unpublished. Over a period of five years observations/measurements were carried out in three stands of nauuralized A. lebbeck near the "Bean Pastures" Pasture Research Station in South East Queensland (2538'S, 15145'E, altitude 130 m, 735

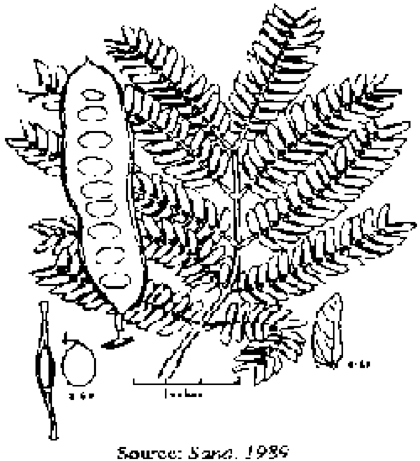
mm mean annual rainfall.)

Sommen, F. van Der. 1981. Farm Forestry, In A Manual of Australian Agriculture Fourth Edition Ed. R.L. Reid (William Heinemann:Melbourne;. pp. 277-280.

Streets, R.J. 1962. Exotic Forest Trees in the British Commonwealth. Clarendon Press, Oxford. pp 169-170.

Albizia odoratissima - Tea Shade Tree

Albizia odoratissima, Benth. (Syn. Mimosa odoratissima, Roxb.) is a medium sized tree highly valued for shade and soil improvement in tea plantations of the Asian subcontinent. It is particularly popular in North-east India and Bangladesh. About 75% of total tea shade trees in Bangladesh are of this species (Sane 1989). On the subcontinent it is known as karuvagai, karmaru, bansa, bilkumbi (Troup 1921), chamkoroi (Hasan 1963), tetua-koroi (Kamaluddin 1984), and kalasiris (Sane 1989).



Albizia odoratissima

Botany

Albizia odoratissima (Leguminosae, Subfamily Mimosoideae) is a multipurpose woody legume which obtains a height of 22-26 m and diameter of 120-150 cm. On good sites five-year-old trees can be 5 m in height and 14 cm in diameter. A mean annual diameter increment of 1.3 cm has been recorded for this species (Troup 1921). The bark is dark grey to light brown in color with horizontal lenticels. The crown is relatively dense. The dark green leaves are bipinnately compound, downy, with 6-9 pinnae and 16-20 pointed asymmetrical leaflets.

Flowers are corymbs, pale yellowish white, fragrant, and generally appear from March to June. Fruits appear in early August and start ripening at the end of October. The thin flat pods are 13-20 cm long and brown when ripe (Hasan 1963, Sana 1989). Trees produce large amounts of pods, each containing 8-12 seeds. Albizia odoratissima is deciduous, with a short leafless period from December to February. New leaves normally appear before the old ones have completely fallen. Branching habit is uniform, but irregularities occur when the tree is damaged.

Ecology

Albizia odoratissima tolerates a wide range of temperatures and rainfall. In its natural range the maximum shade temperature varies from 37-50C and the minimum from 0-15C. Normal rainfall varies from 650-3000 mm with a dry season from November to March. It occurs from sea level to 1500 meters (Troup 1921) and grows sporadically in both dry and moist deciduous forest zones.

Growth of A. odoratissima is best in deep, well drained sandy soils (Sane 1989). The species prefers soils with large amounts of organic matter. It tolerates hot humid conditions, but does not tolerate water-logging. On poor soils growth is stunted. Young plants are susceptible

to frost. Albizia odoratissima is classified as moderately light demanding.

Juvenile trees require shade. Trees coppice well, shoots reaching a height of 3 meters in two years. It is susceptible to fire, but resistant to weed competition and drought. It regenerates naturally in sheltered areas with good soil.

Disbribution

Albizia odoratissima occurs naturally in Southern China, Burma, Peninsula India, and Tropical Africa. Under tropical conditions the species is not gregarious. It is frequently found on hill slopes and sometimes in valleys.

Uses

Shade. Albizia odoratissima has been extensively planted as a shade tree in tea and coffee plantations. The shade extends the productive life of crop plants and increases annual yields. Recommended spacing varies from 6x6 to 12x12 m. Albizia odoratissima benefits tea and coffee production in many ways. Its well developed root system decreases erosion and utilizes the subsoil moisture and nutrients not available to tea and coffee plants. Through leaf litter. A. odoratissima

provides organic matter and soil nutrients to the rhizophere of understory plants. Tree canopies decrease soil desiccation, suppress weed growth and protect plants from hail and rain storms. Albizia odoratissima's presence in the tea monoculture reduces incidence of tea pests, particularly red spider mites and scarlet mites. The shade also provides plantation laborers a comfortable working environment under otherwise hot tropical conditions.

Wood uses. Albizia odoratissima produces valuable fuelwood. Dead and defective branches from shade trees are a major source of fuel for plantation laborers. The heartwood of mature trees is a beautiful dark brown color. The premium quality wood is suitable panelling and furniture. It is also used for cans, wheels, farm implements and construction timbers. Wood weight at 12% moisture content is 735 kg/cubic meter. The wood is 2040% stronger than teak (Anon. undated).

Other uses. The pods of Albizia odoratissima are eaten by monkeys. The leaves are an excellent green manure and cattle fodder. Sana (1989) reports Albizia odoratissima contributed 16 kgs of nitrogen per hectare from 655 kgs of dry weight leaf liter.

Silviculture

Seed collection and handling. Pods should be collected while on the tree immediately after they turn brown. Half-opened pods are also collected from beneath trees. Following collection, pods are dried in the sun for 5-7 days. Pods are then lightly pounded with a hammer to extract seeds. Extracted seeds are dried again in the sun for 34 days and then stored in bags under well ventilated, dry conditions. If seeds are to be stored for a long period, they should be treated with a 5% DDT or Heptachlor dust at the rate of 100 grams per kg of seeds (Anon. 1988). There are approximately 21,000 seeds per kg. To break dormancy seed can be soaked; a) in cool water for one hour, b) in 80C water for two minutes, or c) in boiling water for 30 seconds. Removed from the water, moist seed is stored overnight and sown the following morning. Seedlings emerge within a week. Fresh seed may have a germination rate of 99%. Germination of year-old seed decreases to 55-65%.

Propagation. Nursery production should be initiated in November or December, 4-5 months before the planting season. Well drained sandy loam soil from beneath A. odoratissima trees is recommended for nursery use. If available, well decomposed compost should be mixed with the soil at a ratio of 1:3. Additionally, 500 grams each of triple super phosphate (TSP) and lime should be added to every cubic meter of nursery soil. The use of large nursery bags is recommended to encourage growth of a deep taproot. In each nursery bag 2-3 seeds

should be sown at a depth 5-20 mm and covered with a thin layer of sand. Every two weeks seedlings should be fertilized with a well decomposed liquid compost or a standard phosphorus and potassium fertilizer. In large nurseries, 4-10 cm seedlings are sprayed every two weeks for protection from insects and fungal diseases. Recommended spray contains 300 ml of malathion and 300 grams of copper oxychloride in 200 liters of water (Anon. 1988).

Albizia odoratissima is also established by direct seeding or stump cuttings. For quick establishment, stump cuttings give the best results. Stumps are prepared in the late dormant season immediately before buds swell. Trees with stem diameters of 57 cm are appropriate for stumps. Selected trees are cut at a height of 1.5-2 meters and all the lateral branches are removed. It is best to select trees with few lateral branches below the 1.5-2 meter cutting height. Trees should have well developed roots. Carefully, expose the root system to a depth of 90 cm. Sever the taproot at 80-90 cm and prune all lateral roots. Stumps should be planted immediately in pits 90 cm deep and 75 cm wide.

Planting and fertilization. At the beginning of the spring rains seedlings are ready for field planting. Seedlings are planted in pits 90 cm deep and 45 cm wide. They should be fertilized during planting. Recommended fertilization rates per seedling are 10 kgs of rotted cattle

manure, 200 g TSP, 2.5 kg wood ash and I kg slaked lime. Components should be well mixed with the soil from the planting pit and replaced.

Fertilization of young shade trees improves tree growth and plantation production. For trees under 2.5 m height broadcast 300 grams TSP in a 1.5 meter diameter-circle around the tree. For trees up to 4 m height 333 grams TSP is applied to a 3 meter diameter-circle. Fertilization should be repeated three times per year; April, June and August (Anon. 1988).

Symbiosis

Through a symbiotic relationship with Rhizobium bacteria, Albizia odoratissima fixes atmospheric nitrogen. Under natural conditions seedlings generally bear abundant root nodules. For nursery production it is wise to use soil from under a stand of A. odoratissima. No quantitative data is available on the Rhizabium specificity of this species.

Limitations

Albizia odoratissima is prone to attack by caterpillars, root bores, and root diseases, particularly as a young tree (Barua 1989). Dieback, branch canker, and red rust are also problems for young trees.

Damping-off, a fungus infection, is common in poorly managed nurseries. In India, heart-rot of this species is caused by Ganoderma applanatum (Lenn, 1992). Albbia odoratissima sometimes produces uneven shade (Barua 1989) which causes management problems under plantation conditions.

Tree Improvement

Tree improvement programs for superior canopy characteristics and resistance to insects and disease should be initiated. In Bangladesh improved planting stock is obtained from root suckers of select varieties. Root cuttings of 1-2 cm diameter and 15-20 cm length are placed under heavy shade in a moist rooting bed. One-third of the root is exposed and two-thirds buried in the soil. Spacing between cuttings is approximate 2030 cm. Within a few weeks the stock is ready for transplanting (Anon. 1988).

References

Anon, 1988. Guide line on management of shade trees. GL No. 5 The Consolidated Tea and Lands Company (BD) Ltd. The Baraoora (Sylhet) Tea Company Ltd (Incorporated in Great Britain) 1-4.

Anon, undated. Indian forest utilization vol. 11925 pp.

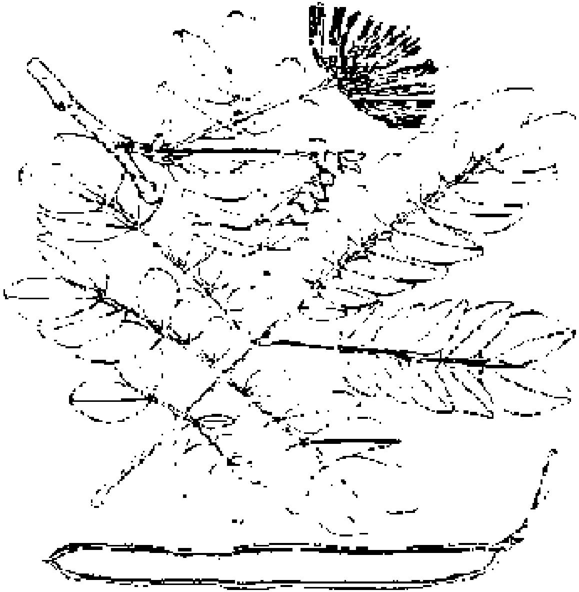
Barua, D.N. 1989. Science and practice in tea culture. Ten, Research Association, India 402-436.

Hasan, K.A. 1963. Shade trees for tea-their functions and behavior. Tea Journal of Pakistan 1(2):14 pp.

Kamaluddin, M, 1984. 1984. Forest Ecology, Institute of Forestry, University of Chittagong. Chittagong, Banlgadesh 164 pp.

Albizia saman: pasture improvement, shade, timber and more

Albizia saman (Jacq.) F. Muell. (Leguminosae, Subfamily Mimosoideae) is a fast growing tree which obtains a large size. It is most common as a pasture, shade or ornamental tree, but has numerous uses. This New World tree is so widely cultivated and used in Southeast and South Asia it is often mistaken as native to that area. It was formerly classified as Samanea saman, Pithecellobium saman and Emerolobium saman. Common names include saman, monkey pod, raintree, cow tamarind, algarrabo and guango.



Source: Little and Wadsworth, 1989

Albizia saman

Botany

Albizias are related to and often mistaken for Acacias - in the Philippines acacia is a common name for A. saman. Albizia saman can obtain a height of 3045 m and diameter breast height (DBH) of 150-250 cm. Open-grown specimens have short stems and stout wide-spreading

nearly horizontal branches. The umbrella-shaped crown may be wider than the height of the tree. The brown gray bark is rough and furrowed into ridges and plates (Little and Wadsworth 1989). Limb bark is lighter in color. Twigs are stout and green. The bipinnately compound leaves are 25 40 cm long dark green above and light green below. The stalkless leaflets are arranged in pairs numbering from 12 to 32 (Little and Wadsworth 1989). ! Leaflets are wider towards the apex. Both leaves and leaflets are progressively larger towards their terminal ends.

The showy flower heads, composed of many narrow pink flowers, are found near the end of twigs and appear from March to September (Hensleigh and Holaway 1988). The dark-brown to black pods are hard and thick with a raised seam. They are 8-20 cm long and about 2 cm wide. The pods do not readily open and remain on trees for long periods. Seeds are red-brown oblong and squarish. There are 5000 8000 seed/kg.

Ecology

Albizia saman is found in the tropics from sea-level to 1000 meters where the temperature is 20-35 Celsius. It is a common component of dry forests and grass savannas. Annual rainfall in these areas is 600-3000 mm/year. Albizia saman easily survives dry seasons of 2 4

months. While more common on drier sites, this species grows best in moist, well-drained fertile soils (Hensleigh and Holaway 1988). It tolerates heavy clays and infertile or waterlogged soils. Although normally found in neutral to moderately acid soils, it will grow in soil with pH as low as 4.6 (Franco et al. 1995).

Distribution

This species is native from Southern Mexico and Guatemala south to Peru, Bolivia and Brazil. It is naturalized throughout the tropics and has been introduced to sub-tropical areas.

Uses

Shade and ornamental Albizia saman is planted along roads throughout the tropics. In parks and commons, its high arching branches provide welcome protection from the heat of the tropical sun. Having crowns of great diameter, trees furnish ample shade. Trees serve as windbreaks and are cultivated for their beautiful pink flowers.

Wood. The wood of Albizia saman is highly valued for the manufacture of furniture, cabinets, decorative veneers, bowls and other handicrafts. The chocolate heartwood and yellow sapwood form a beautiful contrast. The light-weight wood (specific gravity 0.48) is strong,

durable, works easily and takes a good finish (Chudnoff 1984). It shrinks so tattle that products made from green wood dry without warping (NAS 1979). Albizia saman is a good quality fuel and charcoal, producing 5200-5600 kcal/kg (F/FRED 1994). Other uses of the wood include fencing, construction timbers, plywood and the manufacture of crates, wheels and boats.

Pasture fodder. Albizia saman is a valuable component of pasture systems. Its shade protects livestock from the hot tropical sun. Its nutritious pods contain 12-18% crude protein and are 40% digestible (F/FRED 1994). Relished by livestock, pods are an important dry-season fodder. Tree leaves are also nutritious, but are not an important fodder. The shade and nitrogen-rich leaf-liner of A. saman improve the nutritional value of understory grass (Allen and Allen 1981). During the dry-season, grass beneath trees remains green and succulent while exposed grass becomes dry and unpalatable. Leaves fold inward at night which may increase the amount of moisture, rain and dew, reaching the understory. In the morning leaves unfold giving full shade and conserving soil moisture.

Agroforestry. This species is used as shade for tea, coffee, cacao, nutmeg and vanilla. Performance has been fair in alley-and hedgerow-cropping studies. Initial growth is slower than other woody perennials,

but A. saman coppices well and yields nitrogen-rich green manure. However, shallow roots and large branch size compete heavily with companion crops, especially in dry areas. In these systems, A. saman must be heavily pruned. In most areas, other species will be more appropriate for alley-and hedgerow-cropping studies. Albizia saman is appropriate in home gardens where it provides a service role and multiple products simultaneously.

Other uses. Children eat the pods which contain a sticky sweet-flavored pulp. A fruit drink is also made from the pulp. Honey is produced from the flowers. The bark yields gums and resins. In Thailand, A. saman is an important host plant for lac production (Subansenee 1994).

Silviculture

Propagation. Seeds of A. saman have hard, impermeable seedcoats. Two methods of seed scarification are recommended. For small quantities of seed, cut through the seedcoat opposite the micropyle, or pointed-end of the seed, taking care not to damage the seed embryo. For large quantities of seed, pour boiled water over the seeds, soak and stir for two minutes. Drain off the hot water. The hot water should equal five times the volume of seeds. With either method of scarification, the seed should be soaked in cool water overnight before

sowing (NFTA 1989). Seed should be sown at a depth equal to its width in large nursery bags, 10cm x 20cm. The recommended nursery mixture is 3 parts soil: I part sand: I part compost. Seedlings should receive partial shade for 2-4 weeks and then be exposed to full sunlight. After 3-5 months seedlings will be 20-30 cm tall and ready for field planting. Direct sowing is possible, but success depends on rigorous weed control. Albizia saman can be propagated by cutting or stump cutting.

Management. Open-grown A. saman have short trunks and spreading limbs which are considered poor form for timber production. Close spacing, 1.5-2 meters, does produce straighter trees with less branching. but boles retain a spiral form. For this reason, A. saman is not commonly planted in single purpose timber plantations. In pastures, home gardens or other multiple-purpose plantings, tree spacing will depend on companion plants and management strategy.

A light-demanding species, A. saman grows fast and is tolerant of heavy weed competition. However, survival and growth can be improved through vigorous weed control until trees achieve dominance over competing vegetation. Wood production varies by site and management system. A good site can produce 10-25 m/hectare/year under a 10-15 year rotation (F/FRED 1994).

Symbiosis

Albizia saman forms nitrogen fixing symbiosis with many strains of Rhizabium. In the Geld it readily forms root nodules.

Limitations

Heterophylla cubana, Psylla acacia-baileyanae and other defoliators are common pests (Braze 1990) but do not cause serious stress problems. Wide spreading branches and shallow roofs make A. saman susceptible to damage during intense storms. The destruction of natural forests threatens the genetic diversity of this species. In response to tints threat, the Oxford Forestry Institute has included A. saman in its gene conservation program (Hughes 1989).

References

Allen, O.N. and E.K. Allen. 1981. The Leguminosae: a source book of characteristics, uses and nodulation. Wisconsin Press. Madison, Wisconsin, USA. pp. 590-92.

Braza, R.D. 1990. Psyllids on nitrogen fixing trees in the Philippines. NFTRR 8:62-63.

Chudnoff, M. 1984. Tropical timbers of the world. Agriculture Handbook 607. USDA Forest Service. Washington, DC. p. 134.

F/FRED. 1994. Growing Multipurpose Trees on Small Farms (2nd ed.). Module 9. Species fact sheets. Bangkok, Thailand. Winrock International, pp. 22-23. Franco, A., E.F.C. Campello, LE. Dias and Sk de Faria 1995. Revegetation of acidic residues from bauxite mining using nodulated and mycorrhizal legume trees. In: D. Evans and L. Szott (eds.), Nitrogen fixing trees for acid soils. Nitrogen Fixing Tree Research Reports (Special Issue). Morrilton, Arkansas, USA. In press.

Hensleigh, T.E. and B.K. Holaway. 1988. Agroforestry species for the Philippines. US Peace Corps. Washington, DC. pp. 281-84.

Hughes, C E. 1989. Intensive study of multipurpose tree genetic resources. Oxford Forestry Institute, University of Oxford, UK. pp. 66-79.

Little, EL. and F.H. Wadsworth. 1989. Common frees of Puerto Rico and the Virgin Islands. Agriculture Handbook No. 249. USDA Forest Service. Washington, DC. pp. 164-66.

NAS. 1979. Tropical legumes: Resources for the future. National Academy of Sciences, National Research Council. Washington, DC. pp.

202-03.

Macklin, B., N. Glover, J. Chamberlain and M. Treacy. 1989. NFTA cooperative planting program establishment guide. Nitrogen Fixing Tree Association. Morrilton, Arkansas, USA. 36 p.

Subansenee, W. 1994. Economic value of Albizia saman. In: JB Raintree and HA Francisco (eds.). Marketing of Multipurpose Tree Products in Asia Bangkok, Thailand. Winrock International, pp. 229-35.

Cajanus cajan: It's More than Just a Pulse Crop

A variety of cultivars and the many ways they can be used in farming systems have made pigeonpea (Cajanus cajan) popular to small-scale farmers. It is the major pulse crop of the semiarid tropics. has been used for centuries in intercropping systems, and is an ideal source of fodder food and firewood in agroforestry systems.

BOTANY: C. cajan (L.) Millsp. is a leguminous shrub that can attain heights of 5 m. Pigeonpea probably evolved in South Asia and appeared about 2000 BC in West Africa, which is considered a second major center of origin. The slave trade took it to the West Indies, where its use as bird feed led to the name "pigeonpea" in 1692 (van der Maesen 1986). Leaves are trifoliate and spirally arranged on the stem. Flowers

occur in terminal or axillary racemes, are 2-3 cm long (Purseglove 1968), and are usually yellow, but can be flecked or streaked with purple or red. Pods are flat. usually green in color, sometimes hairy, sometimes streaked or colored dark purple, with 2-9 seeds/pod. Seeds are widely variable in color, 6-9 mm in diameter, and weigh 4-25 g/100 seed (Sheldrake 1984). C. cajan was long considered to be one of two species (with a minor W. African species) of the genus Cajanus DC. However, this genus is now thought to be congeneric with Atylosia and Endomallus, and also includes species of Rhynchosia and Dunbaria (van der Maesen 1986). Cajanus is now recognized as having 32 species.

Cajanus cajan

ECOLOGY: Pigeonpea is hardy, widely adaptable, and more tolerant of drought and high temperatures than most other crops. It grows on acid sands in the Sahel and alkali clays in India. Frost or excessive soil

salinity are not tolerated. and waterlogging for 3-4 days severely reduces yields (Chauhan 1987). Various cultivars are grown from sea level to 3.000 m.

USES: Food. Pigeonpea is best known as a human food. Shon-duration shrubby varieties such as ICPL 87 can yield 5-8 t/ha of grain when grown as sole crops (Reed 1987). In India, decorticated. split dried peas (dahl) are an important protein source. Dahl is 25% protein and has a good balance of all amino acids except methionine and cystine, which are slightly deficient for the human diet (Faris et al. 1987). Some anti-nutritional factors are present, but are destroyed by cooking. In the Caribbean and East Africa, pigeonpeas are eaten green as a vegetable and are commercially grown and canned in the West Indies. Vitamin A (470 mg/1OOg) and C (25 mg/1OOg) contents of vegetable pigeonpeas are five times those of green peas (Faris et al. 1987). When grown as a perennial, pods may be picked ripe or green for a long time. The vegetable line ICPL24 produced 11 t/ha of green pods in five pickings in Gujarat, India (Faris et al. 1987).

Animal feed. Pigeonpea is an excellent fodder species. Crude protein values of fresh forage range from 15-24% (Whiteman and Norton 1981). Its exceptional nutritional value and high productivity can give good liveweight gains. In Hawaii, Henke et al. (1940) reported cattle

weight gains of 280 kg/ha/yr in pure pigeonpea compared with 181 kg/ha/yr in mixed grass pastures over a 6.5 mo grazing period. Foliage is retained well into dry seasons. Although forage production depends on the stage of the crop, growing conditions, and management, experimental yields exceeding 50 dry tons/ha/yr have been reported in intensivaly managed cut and carry sole stands (Whiteman and Norton 1981). Under less intensive management, 3-8 dry t/ha/yr can be expected. Poor early growth makes it unable to compete well in mixtures with grasses. Grain, whole pods, and milling trash have been proposed as a substitute for soybeans and maize in poultry and pig feed, but deficiencies in some amino acids and antinutritional factors may limit its suitability unless expensive additives or processing are used (Wallis et al. 1986).

Wood. Pigeonpea sticks are an important household fuel in many areas. Productivity more than makes up for comparatively poor fuel characteristics (low specific gravity and high moisture content). Stick yields of 7-10 dry t/ha/yr are routinely reported for medium and early duration Lines, and yields of 30 t/ha/yr from irrigated, early duration verieties have been reported in India (ICRISAT 1986). Perennial varieties can produce 10 t/ha/yr of dry material over a 2-3 year period on good sites. Sticks also produce thatch and basket materials.

Other Uses. Pigeonpea is nodulated with Rhizabium of the cowpea type and is an effective green manure crop. Whiteman and Norton (1981) recommend incorporating high density, plantings at or about the time of flowering. When allowed to perennialize, pigeonpea can drop 1.6 dry t/ha/yr of litter in the first year (Sheldrake and Nuayunan 1979). It is used in folk medicine in West Africa and has been proposed as a nurse crop in India (Purseglove 1968).

CROPPING SYSTEMS: Pigeonpea is used in a great variety of cropping systems throughout the tropics. Although average grain yield (650 kg/ha) and harvest index (20-25%) are low, its hardiness and ability to grow on residual soil moisture make it attractive to small farmers (Sheldrake and Narayanan 1979). Early growth is slow, making it an ideal, noncompetitive intercrop with cereals such as sorghum and millet. Such systems give full sorghum yields and over 70% of the pigeon pea grain harvest that could be obtained if the two crops were grown separately (Willey et al. 1981). Pigeonpea is a short day plant, and its maturation period is related to daylength sensitivity of particular cultivars (Sheldrake and Narayanan 1979). Farmers in India, where pigeonpea is usually grown as an annual, exploit this trait. In the north, it is planted as a late-maturing crop (9-11 most) at relatively wide spacings (50,000/ha) during the longest summer days. In the peninsula, medium duration varieties (6-8 mos.), which flower as days

grow shorter, are planted solely or intercropped with cereals (Willy et al. 1981; Sheldrake 1984). Early varieties, which are usually determinate (flowers borne on terminal racemes) and photoperiod insensitive, are sown densely (100,000 plants/ha) as sole crops during the rainy season or the post-rainy season, when they use stored soil moisture and benefit from fewer pests and diseases (Sheldrake 1984).

In Africa, greater use is made of its perennial nature. In East Africa, long duration pigeonpea is sown with cereals or short duration grain legumes such as cowpea. After the grain crop is harvested, pigeonpea grows to its full height and pods are used as a green vegetable or pulse. In the next year, pigeonpea is either ratooned and the cereals are planted, or it is allowed to dominate the field for pod production (Omanga and Matala 1987). Cereals are rarely planted among unratooned pigeonpea in the second year, because it is too competitive. Animals allowed to graze fields after cereals are removed eagerly browse the pigeonpea (Omanga and Matala 1987).

Ongoing work at ICRISAT suggests it can be used as a semi-permanent, perennial component in alley cropping. Its traditional as as a rotational/fallow crop in East Africa and as a part of shifting agriculture in SE Asia deserves more attention. It has been used as food and fodder bearing windbreaks and live fences. It is widely planted as a backyard

plant for shade and as a green vegetable.

ESTABLISHMENT: Pigeonpea is best established by direct seeding in a well-prepared field. Gaps should be filled with seedlings grown in pots. No pre-germination treatment of seeds is needed.

BREEDING SYSTEMS: Pigeonpea (2n=22) is mostly self-pollinating, but a range of 3 - 95% outcrossing has been reported. This is probably a function of environment and populations of pollinating insects (Sheldrake 1984). When pure lines need to be maintained, it may be necessary to cover plants with muslin bags to exclude insects. The "wrapped flower" character, with overlapping petal lobes, delays Power opening and has been used to increase the degree of selfing (Sheldrake 1984). Male sterile lines have been developed and are used in hybridization programs. One ICRISAT hybrid, ICPH8, consistently yielded 25% more grain than the best control in 15 trials in India (Walks et al. 1986). Interspecific hybrids with species of the congeneric genus Atylosia have shown promise as fodder and cover crops.

PESTS AND DISEASES: In India, wilt (Fusarium udum) and sterility mosaic (mite-borne virus?) are the most important diseases (ICRISAT 1986). Wilt and leaf spot (Mycovellosiella cajani) are important in East Africa (Omana and Matala 1987). Rust (Uredo cajani) is the major

disease in the Caribbean (Reed 1987). Root rot (Phytophthora dreschsleri) can be a problem in poorly drained fields. Resistance to these diseases, notably wilt and sterility mosaic, exists and should be exploited when pigeonpea is used as a perennial or grown in areas of heavy rainfall. Important insect pests include the pod borer, (Heliothis armigera, and the podfly, Melanagromyza obtusa, (Reed 1987). Scale insects (Coccus spp.) can build up rapidly and severely damage perennial stands. Insect resistant lines are not yet widely available.

OBTAINING SEEDS: Small seed packets of a perennial variety are available from NFTA. For other seeds, contact ICRISAT, Patancheru, Andhra Pradesh 502324, India.

REFERENCES:

Chauhan, Y.S. 1987. Screening for tolerance to salinity and waterlogging: case studies with pigeonpea and chickpea. IN: Adaptation of chickpea and pigeonpea to abiotic stresses. Proc. of Consultants' Work. 19-21 Dec. 1984, ICRISAT India

Faris, D.G., K.B. Saxena, S. Mazumdar and U. Singh. 1987. Vegetable pigeonpea a promising crop for India Patancheru, A.P. 502 324, India ICRTSAT.

Henke, LA., S.H. Work and A W. Bun 1940. Bed cattle feeding trials in Hawaii. Univ. of Hawaii Agric. Exp. Station Ball. 85 Honolulu, Hawaii U.S.A

ICRISAT. 1986. Annual Report, 1985. Patancheru, India

Purseglove, J.W. 1968. Trop. Crops: Dicotyl. Longman, London.

Reed, W. 1987. ICRISAT's research on pigeonpea. IN: Res. On grain legumes in Eastern and Central Africa Summ. proc. of the consultative group meeting for Eastern and Central African Reg. Res. on grain legumes, 8-10 Dec. 1986. ILCA, Addis Ababa, Ethiopia. ICRISAT, India .

Sheldrake, A.R. 1984. Pigeonpea IN: Goldsworthy and fisher oafs., The Phys. of Trop. Field Crops. Wiley, London

Sheldrake A.R. & A. Narayanan. 1979. Growth, dev. & nutrient uptake in pigeonpeas. J. Agric. Sci. Camb. 92:513-526. van der Maesen, L.J.G. 1986. Cajanus DC and Atylosia W.&A. (Leguminosae). Agric. Univ. of Wageningen Papers 85-4 (1985)

Wallis,E.S., D G. Paris, R. Elliot & D.E Byth 1986. Varietal improvement of pigeonpea for smallholder livestock production systems. Workshop on Crop-Livestock Systems Res., Khon Kaen, Thailand, July 7-11, 1986.

IRRI, Los Banos, Philippines.

Whiteman, P.C. and B.W. Norton. 1981. Alternative uses for pigeonpea. IN: Proceedings of the International Workshop on Pigeonpeas, Volume 1. 15-19 December 1980. ICRTSAT, India

Willey, RW., M.R. Rao and M. Natarajan. 1981. Traditional cropping systems with pigeonpeas and their improvement IN: Proceedings of the International Workshop on Pigeonpeas, Volume 1. 15-19 December 1980, ICRISAT, India

Calliandra calothyrsus - an Indonesian Favorite Goes Pan-Tropic

Villagers in Java arc largely responsible for the increasing worldwide popularity of an American tree, Calliandra calothyrsus. The species was introduced there as a nurse tree for coffee plantations. Villagers recognized its potential for rapid production of excellent fuelwood on poor land and planted it widely, stimulating interest in the species around the world.

BOTANY: Calliandra calothyrsus Meissn. is a fast growing multi-purpose tree in the Acacia Sub-family (Mimosoideae) of the legumes. The plant is a multi-stemmed shrub with showy red flowers that grows 4 to 6 m in height but can reach 12 m (DBH 33 cm) in favorable conditions (NAS,

1983). With their bipinnate leaves, calliandras superficially resemble Leucaena and Mimosa species. Leaves are normally shed in prolonged dry seasons.

Calliandra calothyrsus

ECOLOGY: Calliandra's optimum rainfall range appears to be 2000 to 4000 mm/yr, but it can grow well in some areas with much less. II was one of the top performers out of 27 species evaluated in Kenya at a site receiving 1000 mm/yr (KREDP 1986), and in its native range in Latin America it grows in areas with as little as 700 mm/yr (FAO 1985). It grows up to 1500, 1800 and 2000 meters in elevation in Java, Latin America and Kenya, respectively, with better growth at lower

elevations. Temperature is probably the main factor. In Hawaii and Kenya, growth rates decreased significantly below mean annual temperatures of 20 C. Calliandra grows in a wide range of soils, including acidic sites (to pH 5.0). It does not tolerate water logging (NAS 1983).

FUELWOOD: Calliandra yields large quantities of excellent firewood and charcoal with an energy yield of 4500-4750 Kcal/kg from dry wood. The small-diameter, dense wood is ideal for domestic uses and small industries. Annual yields from established plantations in Java have been between 35 and 65 m/ha (NAS 1983). Trees have been coppiced annually for ore than 20 years.

SOIL IMPROVEMENT: Through biological nitrogen fixation, erosion control, and green manure/leaf litter, calliandra can improve soil quality and yields from associated crops. When cut on short rotations (4 months) most of the biomass is in leaves (BPT 1983), which are 4.5% N. Calliandra is commonly used as an improved fallow in Java, providing significant income from sale of fuelwood and charcoal. Interplanting it with plantation trees has increased yields of the larger trees (NAS 1983). The use of calliandra in alley cropping has gained popularity in Indonesia, the Dominican Republic, Kenya and elsewhere, particularly in highlands above the usual range of leucaena.

FODDER There initially was much optimism about the forage value of calliandra, and positive reports of its use have come from different areas. Leaves and young green shoots have a crude protein content of 22%, and wet fodder yields of up to 46.2 t/ha/yr have been reported (Kidd and Taogaga 1984). However, a high content of condensed tannins (up to 10%) causes the digestibility to be rather low, from 35-42% (Baggio and Hueveldop 1982). Careful experimentation is still required to determine calliandra's true forage value, and selection could lead to improved fodder varieties. Certainly the dried leaflets would seem to have no role in animal feeding. Sheep and goats can probably use fresh leaves mixed with other feeds and if there is a suitable period of adaptation. In one trial, sheep grew best with a mixture containing 40-60% calliandra (NAS 1983). Rabbits will eat significant amounts when it is mixed with other forages. Copiously produced seeds, with 27% protein and 7% fat, are a potential nutrient source.

REFORESTATION: Calliandra is a good pioneer species, especially on marginal sites. It is direct seeded in areas with very steep slopes and poor soils in Java.

OTHER USES: Calliandra produces flowers and copious nectar almost all year round, and honey yields from calliandra plantations are as high as 1 t/ha/yr. Calliandra is Greek for 'beautiful stamens,' and its red

flowers make it a popular ornamental. It also is a suitable host for the shellac insect.

PRODUCTION: Calliandra seeds (14,000-19,000/kg) require no pretreatment, though hot-water treatment has been reported to speed up germination. Calliandra can be direct seeded or stump cuttings can be used. Stumps should be taken from approximately 1 meter tall plants by cutting the stem back to 30 cm and the roots back to 20 cm. Limited provenance collections have been made and are being evaluated at CATIE, Turrialba, Costa Rica.

PESTS AND PROBLEMS: Calliandra seems to be free of any serious pests (NAS 1983, Bandara, et al. 1986). In Kenya trees produce few seed because a species of beetle eats the flowers and flower buds. There is a possibility that calliandra can become weedy. If stems are harvested roughly or cut too low (recommended height is 0.5 meters), stumps can become susceptible to fungal attack.

PRINCIPLE REFERENCES:

Baggio, A. and J. Heuveldop. 1982. Initial performance of Calliandra calothyrsus in live fences for the production of biomass. Tropical Agricultural Research and Training Center. CATIE. Turrialba, Costa Rica.

Bandara, M.M.S.P.K., H.P.M. Gunasena, and M.A.S.K. Ranasinghe. 1986. Insect attacks on some introduced nitrogen-fixing trees grown in Sri Lanka. Nitrogen Fixing Tree Research Reports, Vol. 4:36-39.

Balai Penelitian Ternak (Research Institute for Animal Production). 1985. Research Report 1984/1985. BPT, Bogor, Indonesia.

Catchpoole, D.W., G.J. Blair, and D A. Ivory. 1986. The contribution of four tree legume species to feed supply and the nitrogen economy of forage systems in Sulawesi. in Forest Genetic Resources Information, No. 13, FAO.

Chang, B. and H. Martinez. 1985. Germplasm Resources of Calliandra calothyrsus Meissn. in Central America and Panama. in IITA Annual Report and Research Highlights, 1986. Ibadan, Nigeria. Pages 29-30.

Kenya Renewable Energy Development Project. 1986. Calliandra for Kenya. KREDP, 1986.

Kidd, T.J. and T. Taogaga. 1984. Survival and herbage yield of six nitrogen-fixing trees intercropped with taro in Western Samoa. Nitrogen Fixing Tree Research Reports, Vol. 2:22-23.

Mabynddin, Prapti. 1983. Nutritive value of tree legume leaves. in 1983

Research Report, Balai Penelitian Ternak, Ciawi, Bogor, Indonesia.

National Academy of Sciences. 1983. Calliandra: a versatile small tree for the humid tropics. National Academy Press, Washington, D.C.

Erythrina edulis: multipurpose tree for the tropical highlands

Cultivated for centuries, Erythrina edulis is an important food source for humans and animals in the tropical highlands of South America. The seed is a component of many diets, and the trees also provide shade in coffee and cacao plantations, support for vine crops, green manure, live fenceposts, wood for construction and fuel. and medicinal preparations.

Botany

Erythrina edulis Triana ex M. Micheli is one of about 115 Erythrina species in the subfamily Papilionoideae of the Leguminosae (syn. Fabaceae) family. Over a normal life span of 30 to 40 years, the leafy trees grow up to 14 m tall with stem diameters up to 37 cm and crown diameters up to 7 m. The stem and branches are covered with stout prickles. The alternate leaves are trifoliate with long petioles and two nectar-producing glands at the base of each leaflet.. The flower cluster (raceme), supported on a stout stalk, consists of 180 to 200 short-stalked flowers arranged in threes around the axis. The flowers have a

reddish-green calyx and a crimson corolla with an upper petal (standard) and two lateral petals forming the keel. The pistil is surrounded by 10 stamens. The two-petaled flowers face upward, forming a large cup in which nectar gathers (Ruskin, 1989).

Erythrina edulis is cross pollinated by sucking insects, bees. wasps and birds. Seeds mature 65 days after flowering. Fruits hang in bunches of 9 and 18 cylindrical pods. Pod size varies widely, but averages 32 cm long and 3 cm in diameter with six seeds. The seed coat is generally brownish-red but is sometimes yellow or black (Acero, 1989).

Distribution

Erythrina edulis is distributed from M,rida in Venezuela, to the mountain ranges of Colombia and the Andes mountains of Ecuador, Peru and Bolivia. It is commonly known as chachafruto, balu, basul or sachaporoto in Colombia, guato in Ecuador, and pashuro, pajuro, basul sachaporoto or sacha purutu in Argentina and Bolivia (Ruskin, 1989).

Ecology

Erythrina edulis is a pioneer species that grows best in full sunlight, but trees can tolerate some shade in the early stages of growth. In Colombia, the species occurs from elevations of 1200 to 2600 m, with

an optimum range from 1600 to 2200 m. In Peru, E edulis grows from 900 to 3200 m (Martel 1989). In the species's native range, annual rainfall varies from 450 to 1800 mm and temperatures are between 5§ and 25§C. The trees grow well in loose-textured sandy loams and in heavy clay soils. They do not tolerate frequent frosts.

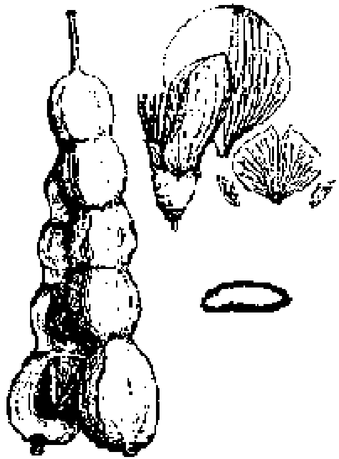
Uses

Human food. The seeds contain 23% protein, 1% fat, 8% crude fiber and 84% moisture. They have a good balance of amino acids and a digestibility after cooking of about 50%. Seeds must be boiled at least 45 minutes or fried thoroughly before being eaten. As a paste, they provide a nutritious base for tortillas, desserts, pies, soups and food for infants. They are also boiled, sun dried, ground and added to flour. Research indicates that uncooked E. edulis seeds can be toxic if consumed over a long period (Perez et al., 1979). Seeds of all other Erythrina species are highly toxic.

Forage. The leaves and tender branches can be fed to cattle goats, horses, pigs, guinea pigs and rabbits. Leaves contain 24% protein, 29% crude fiber (dry weight) and 21% total carbohydrates. They are rich in potassium but low in calcium (Surco, 1987). Seeds and pods can be fed fresh to cattle and goats, but should be cooked before feeding to pigs,

chickens, rabbits or fish. The pods contain 21% protein. 23% crude fiber (dry weight), 24% carbohydrates and 91% moisture. Cooked seed can replace up to 60% of the concentrate fed to chickens and fish (Martin and Falla, 1991).

For maximum fodder production, the trees can be planted in protein banks at a close spacing (1.0 x 0.5 m). They are first pruned at 10 months and then at six- or four-month intervals. A two-year-old protein bank can produce up to 80 tons of leaves and tender branches per ha. or the leaves can be dried and ground to produce 6 tons of chicken feed rich in carotene (Vargas and Ocampo, 1991).



Erythrina edulis pod, flower and seed. Not to scale. From Krukoff and Barneby (1974) and Martel (1989).

Shade and support Erythrina edulis is widely used as a shade tree for coffee or as a support for vine crops such as pepper, betel and grape. In Colombia, trees are spaced at 6 x 6 to 8 x 8 m in coffee plantations or 5 x 5 m with vine crops (Vargas and Ocampo, 1991). Annual pod production from three- to four-year-old trees at a 6 x 6 m spacing can average 30 kg/tree or 8 tons/ha (green weight): annual pod production from 20-year-old trees can average 177 to 21 I kg/tree.

Live fenceposts. In Colombia, live fenceposts are established from stakes at 2-m intervals and allowed to grow for 30 months before pruning or attaching barbed wire. Stakes should be at least 4 to 6 cm in diameter and 2 m long. Pruned at four-month intervals, leafy branches from 1 km of fencing can provide up to 30 tons of fodder per year; unpruned, the same fenceposts can provide up to 85 tons of fruit (Vargas and Ocampo, 1991).

Medicine. In Colombia, a soap made from the bark, branches and leaves of E. edulis is used to wash dogs with skin disease. In Peru, the seed is mixed in a liquid concoction to treat inflammation of the bladder. The flowers are used to treat eye irritations (Acero, 1989).

Silviculture

Seed treatment. Erythrina edulis is easily propagated from seed or cuttings, but seedlings tend to root deeper and live longer than cuttings. Seed should be removed from pods immediately and stored in paper bags in a cool, dark place. They lose viability quickly and should be planted within eight days of harvesting. Viability can be extended up to 20 days by dipping seeds for a moment in molten paraffin so that a thin layer of paraffin coats the entire seed. Seed size varies widely: Acero (1989) reports 60 fresh seeds per kg in Colombia, while Martel (1989) reports 146 fresh seeds per kg in Peru.

Establishment Larger seeds tend to produce more vigorous seedlings. Plant seeds in l-kg polyethylene bags with the convex side facing upwards and slightly exposed. Leave room between planting bags to allow space for leaf development (Vargas and Ocampo, 1991). Germination begins in 5 to 10 days. Shade the seedlings in the nursery and reduce shade partially in the last two weeks before outplanting. At 60 days, seedlings may be planted out in holes 30 cm deep.

Erythrina edulis can also be direct seeded. Cultivate the soil thoroughly to a depth of 30 cm and plant two seeds per hole. Thin to one seedling after four or five weeks. Weed periodically in a l-m circle around the

plants. Seedlings grow rapidly (2.5 m in the first year) and begin producing fruit in approximately 24 to 27 months.

Cuttings of 4 to 6 cm diameter, and usually I m in length, should be planted to a depth of 30 to 50 cm within three days of harvesting (Vargas and Ocampo, 1991). Cuts should be made with well-sharpened tools to avoid damage that can lead to rotting; the top cut should be at a 45' angle. Sealing the cuts with paraffin, plastic, mud or other material can increase survival rates. Cuttings begin producing fruit about 18 months after planting.

Erythrina edulis forms a nitrogen-fixing symbiosis with Rhizobium in the cowpea miscellany (Acero, 1989). Large nodules form in the upper soil surface and decrease in size with increasing soil depth.

Limitations

Erythrina edulis does not tolerate long periods of drought, especially during early stages of establishment. It does not grow well in strongly acidic soils (pH below 4.5). Stem borers damage terminal shoots and cause lateral branching. Butterfly larvae (Terastia meticulosalis) bore into seeds. Trees are also susceptible to nematodes (Helicotylenchus sp., Hoplotylus sp. and Meloidogyne sp.) (Francia Varon de Agudelo,

personal communication).

Future research needs

The large differences observed in seed size suggest the existence of genetic variation. Rangewide provenance collection and testing is needed to determine differences in fruit yield, biomass production, nutrient content and adaptability. Research would also be useful on improved methods to increase seed viability. Symbiotic relationships need to be explored and quantified. Finally, traditional agroforestry uses of E. edulis and pest and disease management need funkier documentation.

References

Acero, E. 1989. Informe final silvicultura y productividad del chachafruto Erythrina edulis. Pan 1. Bogota: Universidad Distrital - CIID-CONIF.

Krukoff, B.A. and Barneby, R.C. 1974. Conspectus of species of the genus Erythrina. LLOYDIA (Journal of Natural Products). 37:359.
Martel, A. 1989. Erythrina edulis Triana, especie de gran potencial para asociaciones agrofrestales; advances de su propagacion. Technical Note 01. FAO/Holland/DGFF Project, 30 pp.

Martin, D. and Falla, J.A. 1991. Evaluacion de los efectos biologicos de la sustitucion de concentrado por harina de chachafruto Erythrina edulis (15 y 30%) en la alimentacion de pollos de engorde bajo un esquema de producci¢n de economia campesina. Thesis in Zootechnology. Valle (Colombia): Universidad Nacional de Colombia-Palmira.

Pati¤o, J.E. 1992. Suplementaci¢n de cabras con chachafruto Erythrina edulis. Thesis in Zootechnology. Valle (Colombia): Universidad Nacional de Colombia-Palmira.

Perez, G., de Martinez, C. and Diaz, E. 1979. Evaluacion de la calidad de la proteina del chachafruto Erythrina edulis. Bogota: Universidad Nacional de Colombia.

Ruskin, F.R. 1989. Basul. In Lost crops of the Incas. Washington, DC: National Academy Press, pp. 164 71.

Surco, J. 1987. Evaluaci¢n de minerales nutricios en las semilla de Erythrina edulis. Cuzco (Peru): Universidad Nacional San Antonio Abad del Cuzco.

Vargas, L.R. and Ocampo, M.P., eds. 1991. El chachafruro o balu - protector de aguas y suelos superalimento humano, forraje para el ganado. Extension Bulletin 7. Bogota: Federaci¢n Nacional de Cafeteros

de Colombia, p. 22.

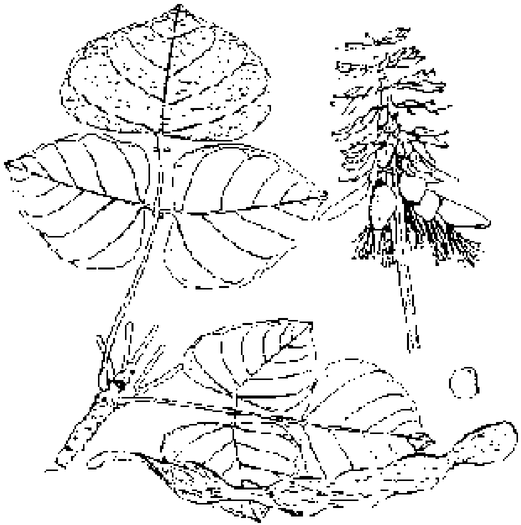
Erythrina variegata: more than a pretty tree

Erythrina variegate is a showy, spreading tree legume with brilliant red blossoms. Commonly known as the 'Indian coral tree' in Asia or 'tropical coral' in the Pacific, this highly valued ornamental has been described as one of the gems of the floral world. It has also proven valuable for fodder production and as a sturdy component of windbreaks. It is a useful species for soil enrichment because it nodulates readily and prolifically in both acid and alkaline soils. Farmers in India appreciate E. variegate as fodder, light timber and, more recently, pulp for the paper industry.

Botany

Erythrina variegata is a medium to large tree, commonly reaching 15 to 20 m in height in 20 to 25 years. It has an erect, spreading form, typically with several vertically oriented branches emerging from the lower stem. On favorable sites. the stem can reach a diameter at breast height (dbh) of 50 to 60 cm in just 15 to 20 years. The smooth bark is streaked with vertical lines of green, buff, grey and white. Small black prickles cover the stem and branches. These become longer if the tree

suffers moisture stress. They typically drop off as the girth of the stem expands (Hegde, 1993). The leaves are trifoliate. The leaflets are commonly variegated, medium to light green, heart shaped, 7 to 12 cm wide and 12 to 18 cm long. The trees are deciduous, typically losing their leaves before flowering except under very humid conditions.



Erythrina variegata L. From Little and Skolmen (1989), p. 143.

Brilliant orange-red flowers emerge in dense, conical inflorescences 5 to 7 cm long and 2 to 3 cm wide, usually after the leaves have dropped. Flowering is normally followed by a lavish production of seed. The pods

are thick and black - 1.5 to 2 cm wide and 15 to 20 cm long. Each contains 5 to 10 egg-shaped seeds. These are glossy brown, red or purple and are 6 to 10 mm in diameter and 12 to 17 mm long.

A column-shaped cultivar, 'Tropic Coral' or 'Tall Erythrina', is used extensively in windbreaks and as an ornamental in parks and gardens. Through cultivation, it has spread from New Caledonia to Australia, Hawaii and southern Florida. Unlike other cultivars, the leaves of 'Tropic Coral' remain on the tree through flowering.

Ecology

Erythrina variegata is well adapted to the humid and semiarid tropics and subtropics, occurring in zones with annual rainfall of 800 to 1500 mm distributed over a five- to six month rainy season. The species is most commonly found in warm coastal areas up to an elevation of 1500 m. The trees prefer a deep, well-drained, sandy loam, but they tolerate a wide range of soil conditions - from sands to clays of pH 4.5 to 8.0. They can withstand waterlogging for up to two weeks and are fairly tolerant of fire. Erythrina variegata is bird-pollinated, outcrossed and sometimes genetically incompatible.

Distribution

Erythrina variegata is native to the coast of India and Malaysia. It has been widely introduced in coastal areas of the Old World tropics, extending from East Africa and Madagascar through India, Indochina, Malaysia, northern Australia and Polynesia. The seeds can float on salt water for months, facilitating the spread of the species. Introduced to the Americas, it was so well established by 1825 that Candolle described two new species based on trees considered to be native to the New World (McClintock, 1982). It is now a very popular hedge species in southern Florida.

Uses

Support for vine crops. Farmers in India use E variegate to support climbing plants such as betel (Piper belle), black pepper (Piper nigrum), vanilla (Vanilla planifolia) and yam (Dioscorea spp.) (Hegde, 1993). Trees established to support vines are usually planted at a spacing of 2 x 2 to 2 x 3 m. Vines are planted three to four months after establishment of the tree seedlings or during the following rainy season. During the hottest months. foliage from the closely spaced trees shades the vines and keeps them moist. When the days become cooler, the leaves fall and the vines receive more direct sunlight, which matches their requirements at this time.

Shade. Coffee and cacao growers establish E. vanegata shade trees from large cuttings (2 to 3 m long and 2 to 5 cm in diameter) at a spacing of 8 x 10 m. The trees are pollarded once a year to a height of 2 to 3 m to produce a spreading crown. The pruned leaves are usually spread in the plantation as mulch. The branches may be used as fuelwood.

Windbreaks. Enthrina variegata, particularly the columnar variety, is widely used as a windbreak for soil and water conservation. The trees have a strong, vertical root system that does not seem to compete too severely with adjacent crops (Rotar et al., 1986). Windbreaks are normally established from large cuttings planted in lines at a spacing of about 2 m.

Live fenceposts. Erythrina variegata makes excellent live fenceposts. Farmers commonly establish fenceposts from three-year-old upright branches about 15 cm in diameter and 2.5 m long. These are normally stacked in the shade in an upright position and left to cure for one week before planting.

Fodder. The foliage of E variegata makes an excellent feed for most livestock. Leaves normally contain 16 to 18% crude protein and have an in-vitro dry-matter digestibility of 50%. A tree of average size, pruned three or four times a year, produces from 15 to 50 kg of green fodder

annually depending on growing conditions. Trees maintained in coffee plantations benefit from associated cultivation practices - they can produce up to 100 kg of fodder from one annual harvest. The leaves have no known toxicity to cattle.

Wood. The wood of E. variegata is light and soft, with a specific gravity of 0.2 to 0.3. Each shade tree in a coffee plantation can yield from 25 to 40 kg of wood from annual pollarding. The wood is used to construct floats, packing boxes, picture frames and toys, and, in India, it is increasingly used for pulp production. The timber requires careful seasoning, preferably kiln drying. It does not split on nailing, but holds nails poorly.

Medicinal. Enthrina variegata has a reputation for medicinal properties in India, China and Southeast Asia. The bark and leaves are used in many traditional medicines, including paribhadra, an Indian preparation said to destroy pathogenic parasites and relieve joint pain. Juice from the leaves is mixed with honey and ingested to kill tapeworm, roundworm and threadworm (Hegde, 1993). Women take this juice to stimulate lactation and menstruation. It is also commonly mixed with castor oil to cure dysentery. A warm poultice of the leaves is applied externally to relieve rheumatic joints. The bark is used as a laxative, diuretic and expectorant.

Other uses. With their rapid growth and prolific nodulation, all erythrinas are a good source of organic matter for green manure. The nitrogen-rich litterfall decomposes rapidly, making nutrients available for plant uptake. The dry foliage of E. variegata normally contains from 1 to 3% nitrogen.

Aqueous leaf extracts of E variegata have also proven highly toxic to certain nematodes (Mohanty and Das, 1988).

Silviculture

Establishment. Erythrina variegate is successfully propagated from seed or large stem cuttings. Seed should be scarified by soaking in hot water (80 C) for 10 minutes and then in tepid water overnight. Treated seeds normally germinate within 8 to 10 days. Well-watered seedlings are normally ready for planting at 10 weeks.

Woody cuttings establish best under dry conditions. They should always be held for at least 24 hours before planting to prevent attack by soil fungi. Cuttings establish quickly, producing axillary shoots in three to four weeks and then rooting. To produce tall trees with straight stems, it is important to retain the terminal bud of branch cuttings. The column shaped form, 'Tropic Coral', may not reproduce true to form

from seed and should thus be propagated from cuttings.

Management. Enthrina variegata generally requires little maintenance. Once established, seedlings grow rapidly, usually to 3 m in one year. Cuttings typically produce more and larger side branches than seedlings; they should be pruned when young if upward growth and a clear bole are desired.

Limitations

This species is a host to the fruit-piercing moth Othreis fullonia, a destructive insect pest in the Pacific region. The larvae feed on the tree and the adults 'pierce' important commercial fruits such as oranges, guava, papaya. banana and grapes, causing serious economic losses (Muniappan, 1993). The light wood, with 60 to 65% moisture content, is not useful as a fuel. Even when dry, it produces smoke when burned.

Further Reading

Hegde, N. 1993. Cultivation and uses of Erythrina variegata in Western India. In S.B. Westley and M.H. Powell, eds. Erythrina in the New and Old Worlds. Paia. HI (USA): NFTA, pp. 77-84.

Little, E.L. and Skolmen. R.G. 1989. Common forest trees of Hawaii

(native and introduced). Agricultural Handbook 679. Washington, DC: USDA Forest Service, pp. 142-44.

McClintock, E. 1982. Erythrinas cultivated in California. Erythrina Symposium IV. Allertonia. 3(1): 139-54.

Mohanty, K.C. and Das, S.N. 1988. Nematicidal properties of Erythrina indica against Meloidogyne incognita and Tylenchorhynchus mashhoodi. Indian Journal of Nematology. 18(1):138.

Muniappan, R. 1993. Status of Erythrina species and the fruit-piercing moth in the Pacific. In S.B. Westley and M H. Powell, eds. Erythrina in the New and Old Worlds. Paia, HI (USA): NFTA, pp. 340-44.

Raven, P.H. 1974 Erythrina (Fabaceae): achievements and opportunities. LLOYDIA (Journal of Natural Pruducts) 37:321-31

Rotar, P. P. Joy, R.J and Weissich, P. R. 1986. 'Tropic Coral': tall erythrina (Erythrina variegate L). Research Extension 072. Honolulu, HI (USA): University of Hawaii.

Faidherbia albida - inverted phonology supports dryzone agroforestry

The African winterthorn is famous for its unusual phonology. It sheds

its leaves with the rains and is green during the dry season, favoring crop production beneath its canopy and reducing the need for a fallow period on poorer soils.

Botany

Faidherbia albida (Del.) A. Chev. (syn. Acacia albida Del.) is a monotypic genus in the legume subfamily Mimosoidae. Normally a deciduous tree to 15m it can reach 25m or more in southern Africa, with a large rounded crown and spreading branches, and trunk diameters of 1m or more. It is distinguished by its phonology, whitish twigs and paired thorns, blue green bipinnate leaves lacking a petiolar gland, but with glands between nearly all its 2-12 pinnate pairs. The inverted phenology does not occur in seedlings until their tap roots are well into the water table.

Flower buds appear soon after leaves on current season's growth. About 100 creamy white flowers occur on spikes up to 16 cm long, but most abort and normally 5 or less mature into pods 3-4 months later (Zen-Nlo & Joly in Van Den Beldt 1992). Pods (11-30 cm long x 1.4-6.7 cm wide) are orange to reddish brown, often coiled or twisted, and contain up to 30 seeds. Seeds are dispersed by herbivores eating the indehiscent pods or by the pods floating down rivers. Populations in

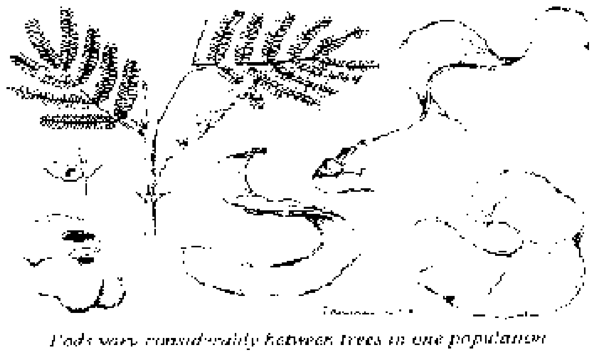
Cameroon show levels of outcrossing from 50-100%, with variation in a population throughout the flowering season. It is a diploid species (2n = 26) over most of its range; a polyploid (2n = 52) has been recorded from Israel (Halevy 1971).

Distribution d Ecology

Its natural range extends throughout dry tropical Africa into the Middle East and Arabia, from 270 m below sea level in Palestine up to 2500 m in Sudan (Wickens 1969). It has been introduced into India, Pakistan, Nepal, Peru, Cyprus, Cape Verde and the Ascension Islands. It grows in a wide range of climates and habitats, either scattered or gregarious, in closed canopy woodland or open savanna and in cultivated lands. It is usually a pioneer on alluvial flats but can form pan of a fire climax vegetation in the west African savannas, where optimal conditions are between 500-800 mm annual rainfall. In east Africa it grows well with 1800 to 8 mm or less, provided it taps underground water. It is susceptible to frost damage.

The species develops into large populations on deep sands and alluvia in the Sahelian belt, heavy vertisols in the Ethiopian highlands. and around many of the rift valley lakes or riverine and valley bottoms in east and southern Africa. It withstands flooding for a number of months

along the Zambesi and Nile rivers and in paddy fields.



Faidherbia albida (Pods vary considerably between trees in one population.)

Uses

Agroforestry. The mulch created by falling leaf litter and the canopy shade at planting time creates as improved microclimate (better rainfall infiltration, reduced evapotranspiration and temperature extremes) resulting in increased crop yields (Charreau & Vidal 1965 and Poschen 1986 in CTFT 1988). Geiger et al. (in Vandenbelt 1992) argue that the fertility effect may in pan be due to the tree developing on more fertile microsites rather than creating them. Animal dung and urine commonly accumulate under these shade trees.

In Zimbabwe, average leaf fall was calculated at 0.73 t/ha/yr at 11 trees/ha (Dunham 1989) compared with 0.580.97 t/ha/yr at 10 trees/ha in Senegal. Small leaflets rapidly decompose and increase the soil organic matter. In sandy Senegalese soils, mineralized carbon increased by 73%, and total N and available P almost doubled under the canopy compared with open fields (Charreau & Vidal 1965 in CTFT 1988). The species is well suited to subsistence farming when the crop is a cereal (millet, sorghum and maize). Groundnuts yields can be depressed under the canopy from increased vegetative growth due to excess N in relation to P & K. Trees also integrate well in the rice paddy fields and are used as shade for coffee. Analysis of economic returns from cereal cropping under F. albida in the eastern highlands of Ethiopia showed an income gain of 82% was possible where cropping was under 65 trees/ha compared to treeless fields (Poschen 1986 in CTFT 1988).

Fodder. The nutritional value of leaves and fruit is well documented. Pods fall towards the end of the dry season when fodder is scarce; leaves and branchlets are lopped around this fume. Fruit production is highly variable between trees and between years. Average pod production ranges from 6 to 135 kg/tree/yr in the Sudanianzone. In Zimbabwe (Mane pools) 2 trees averaged 161 kg/tree/yr (Dunham 1990), and a single tree varied from 40-339 kg/yr. Average pod

production in the Mana woodland was 590 kg/ha/yr at 11 tree/ha. The pods fall over a period of months. In west Africa pods a e sometimes shaken down, collected, and fed to animals or sold in markets or at roadsides.

Trees are lopped in a number of countries for leaves and fuelwood, but this in turn affects the pod production and can extend foliage retention into the rainy season. Leaves, pods and seeds contain 200, 150 and 260 g total protein/kg of dry matter; total protein digestibility can reach 73%. Tannins limit digestibility, but incorporating pods into low quality fodder enhances ingestion without reducing digestibility. Milling the pods increases digestion of seeds.

Other uses. While the wood is used for fuel, it is lighter (specific gravity 0.6-0.7) and less suitable than many African acacias. Because of its size, the wood is locally used for dugout canoes, mortars, doors and some light carpentry but it is susceptible to borers. Cooked seeds are eaten as a human famine food both in Ghana, Nambia, Zambia and Zimbabwe. Flowering later than most plants, it is a useful source of pollen and nectar for honey bees and log beehives are made from its bark. Widely used for local medicines, Ovambo Namibians use its bark for toothbrushes and is reputed to contain Fluorine. Thorny branches are used for fencing.

Establishment and Growth

Hard coated seeds store well under dry conditions, and are often extracted by pounding the pods in a mortar. Pretreatment is needed for rapid uniform germination. Mechanical scarification works best for small lots. Dipping seed for 5-15 minutes in cone. sulphuric acid or covering the seed with boiling water then allowing to cool for 24 hours are also effective. There are 7,000-20,000 seeds/kg, the seeds are smaller in west Africa than those from the east and south. Seeds can be sown directly or nursery planted, ideally using long poly tubes (30x8 cm), with regular watering and frequent mechanical root or air root pruning (CTFT 1988). Seedlings can be transplanted 3-6 months later. Spacing at 10x10 m is common, but varies with moisture availability and local farming traditions. Establishment in farmers' fields affords protection and weeding as the species is vulnerable to competition. Tractor ploughing between mature trees can promote coppicing from damaged roots.

Extremely variable growth rates have been recorded because of genetic and site variation. Isozyme studies at OFI & ClRAD-F"ret indicate a large genetic diversity within the species, distributed into 3 major areas, west, southern and northeastern Africa with the latter being a key area of diversity. Larger seeded east and southern African

provenances initially grow faster than the west African provenances and have a higher shoot/root ratio, but can collapse after a couple of years in the more and west Africa where water tables are deep. On average 1-1.5m annual height growth has been recorded on favourable sites in Africa. Clonal propagation from shoot and root cuttings and from callus has been developed although elite stock needs to be identified. Seed from a broad range of provenances is available from members of the African Acacia trials network (OFI, ClRAD-F"ret, DFSC, FAO).

Symbiosis

Faidherbia albida nodulates with Bradyrhizobium bacteria, common in tropical soils, and has VA mycorrhizal associations. It develops both surface and deep tap roots and in sandy Sahelian soils the highest densities of Bradyrhizobium were found at the water table 30-35 m below the surface. In moister sites abundant nodules can be found near the surface (Dupuy & Dreyfus in Van Den Beldt 1992).

Limitations

Apart from damage from foraging animals and rodents, the principal pests and diseases are insects and nematodes. Bruchid beetles can

destroy up to 50% of the seeds. Seedlings are attacked by sap sucking insects or cochineal bugs. and nematodes (Meloidogyne javanica, M. icognita) favored by the moist nursery conditions. Caterpillars of the moth Crypsotidia conifera can defoliate adult trees by up to 50% in Nigeria and Zimbabwe. For control methods see CTFT (1988). Insect galls (leaf and flower) and parasitic plants occur sporadically in its native range. It is less susceptible to fungal diseases due to its inverted phonology, but leaf blight (Rhizectonia solani) has been recorded on nursery plants in India. Felled timber is susceptible to a variety of wood borers. It is vulnerable to competition in establishment. The thorns can be a deterrent to farmers not used to them.

References

Centre Technique Forestier Tropical (1988) Faidherbia albida A Chev. (syn. Acacia albida Del.) Monographie. CTFT/CIRAD. Nogent-sur-Marne, France. 72pp. (English version 1989).

Dunham, K. M. (1989) Litterfall, nutrient-fall and production in an Acacia albida woodland in Zimbabwe. Jour. of Trop. Ecol. 5, 227-238

Dunham, K. M. (1990) Fruit production by Acacia albida trees in Zambezi riverine woodlands. Jour. of Trop. Ecol. 6, 445457

Halevy, G. (1971) A study of Acacia albida in Israel. La-Yaaran 21 (313) 97-89, 52-63

Van Den Beldt, R.J. (Ed.) (1992) Faidherbia albida in the West African Semi-arid Tropics Proceedings of a Workshop, 22-26 April 1991, Niamey, Niger. ICRISAT & ICRAF, Patancheru, A.P. 502324, India. 206pp.

Wickens, G.E. (1969) A study of Acacia albida Del. (Mimosoidae). Kew Bulletin, 23(z): 181-202.

Flemingia macrophylla - A valuable species in soil conservation

The slow decomposition rate of its leaves, along with its dense growth, moderate drought tolerance, ability to withstand occasional flooding, and coppicing ability, make Flemingia macrophylla especially useful for mulching, weed control, and soil protection.

BOTANY: Flemingia macrophylla (Willd.) Merr., a member of the Papilionoideae sub-family of the Leguminosae, is known under many aliases. The most important synonym is F. congesta, and the genus also has been called Moghania. The authors usually cited in connection to F. macrophylla (Prain, Kuntze) have not validly published the name (Gillet et al. 1971). Flemingia is a woody, leguminous, deep-rooting, shrub, up

to 2.5 m in height. Leaves are trifoliate. Leaflets are papery, with a glabrous upper surface. Flowers are in dense racemes with greenish standards with red blotches or stripes. Pods are small and turn brown when ripening, dehiscent generally with two shiny black seeds in the vessel. Flemingia is native to Asia, but is considered naturalized in Sub-Saharan Africa (Asare et al. 1984).

Flemingia macrophylla

ECOLOGY: F. macrophylla can be found from sea level up to 2000 m. The minimum rainfall required is about 1100 mm, while the species has been found to thrive under equatorial rainfall conditions in the Cameroons (2850 mm). Flemingia is a hardy plant that can resist long dry spells, and it is capable of surviving on very poorly drained and

occasionally water-logged soils. The species is naturally found growing along watercourses in secondary forest and on both clay and lateritic soils. Keoghan (1987) reports that in Indonesia it has outstanding adaptation to acid (pH 4.6) and infertile soils with high soluble aluminum (80% saturation) 1987). It grew well in a soil with a pH of 4.5 in Costa Rica (Bazill 1987). The plant is tolerant of light shade and is moderately able to survive fires.

WEED CONTROL: Probably the most interesting feature of the species is the relative resistance of its leaves to decomposition. Approximately 40% of a mulch layer made of flemingia leaves (4 tons DM per hectare), was still left after 7 weeks, compared to 20% for Leucaena leucocephala (Budelman, unpublished). The flemingia mulch formed a relatively solid layer that effectively prevented germination of weed seeds and/or stunted their early development for 100 days.

In experimental rubber plantations in Ghana, a flemingia mulch reduced the number of required weedings per year from six to two (Anon. 1964). Temperatures at a soil depth of 10 cm were 7-8 C lower in a mulched plot (5000 kg DM per ha) than under bare soil. Soil moisture under a flemingia mulch has been shown to be significantly higher than under mulches of Glincidia septum and Leucaena leucocephala.

An alley farming trial in Nigeria compared the ability of fallows and mulches of flemingia, Cassia siamea and Gliricidia septum to control weeds. The trees/shrubs were not cut during a 2-year establishment period. In a 120-day test of the decomposition rate of foliage from the first cutbacks from these hedges, cassia lost 46% of its dry matter, flemingia 58% and gliricidia 96% (Yamoah et al. 1986a). For later prunings over two maize cropping seasons, gliricidia prunings decayed completely in a 120-day period, cassia lost 85%, and flemingia 73%. However, cassia showed the greatest potential for controlling weeds during both the 2-year fallow and the two maize crops, primarily because of the greater shade cast by its canopy during the establishment period.

BIOMASS PRODUCTION: At 10,000 plants per hectare, flemingia produced a yearly average of 12.4 tons of leaf DM over 4 quarterly cutting intervals.

FODDER VALUE: Flemingia appears to have some value as a dry season browse (Skerman 1977), although its digestibility value is less than 40% (Brewbaker and Glover 1987). Palatability of immature herbage is considerably better than that of old, mature, herbage (Keoghan 1987). Reported crude protein values range from 17.9% (Laquihon, pers. comm.) and 14.5 to 183% (Asare 1985). A 14-week cutting interval and

35-cm cutting height produced the highest leaf DM yield in a fodder production trial in Ghana (Asare 1985). Increasing the cutting interval from 12-14 weeks decreased crude protein contents, however (Asare 1985).

A qualitative evaluation trial in a pine plantation in Costa Rica indicated that flemingia was one of several species worthy of further study as a shade tolerant forage legume for silvopastures (Bazill 1987). Shrubby legumes were considered especially useful toward the end of the tree rotation, when densely shaded grasses and herbaceous legumes are not vigorous enough to overcome grazing and trampling.

Skerman (1977) reports that flemingia with centrosema was selected as the most promising for mixing with grasses for temporary pastures on arable land in Ghana, and that in Malaysia it is used to support creeping legumes.

ALLEY FARMING: Flemingia has lower leaf nutrient levels (espedally K, Ca and Mg) than Leucaena leucocephala and Glincidia sepium, but the amounts are still substantial (N = 235 to 2.83%; P = 0.19 - 0.25%; K = 0.98 -1.40%; Ca = 0.65%; MB = 0.20%). Maize yields in Flemingia macrophylla (F.m.) alleys compared to control plots and alleys of Gliricidia sepium (G.s.) and Cassia siamea (C.s.) in a trial at IITA,

Nigeria, are compared in the following table (Yamoah et al. 1986b):

Treatment	First Crop			Second Crop		
Control*						
0 kg N	1509			704		
30 kg N	1644			1076		
60 kg N	1674			1408		
90 kg N	1887			1524		
Tree Alleys	F.m.	G.s.	C.s.	F.m.	G.s.	C.s.
Prunings Removed	2353	1977	2318	1772	1891	1329
Prunings Left	2384	2543	2863	2095	2177	1992
Prunings + 30 kg N	2872	2787	2965	2235	2434	2276
Prunings + 60 kg N	3064	2776	3095	2363	2707	2299
Prunings + 90 kg N	3324	3117	3239	2821	2302	2122

* Total area including maize and hedgerow.

Maize Grain Yield (kg/ha)

The trees were planted 0.5 x 4 m, cut back two years after planting, and pruned three times during the subsequent two cropping periods. In Southeast Asia, the Mindanao Baptist Rural Life Center in Mindanao, Philippines, and World Neighbors report that flemingia has become popular with farmers practicing hedgerow intercropping (Laquihon and Fisher, personal communications).

OTHER USES: Although much of flemingia's biomass is not woody, fuelwood can be a secondary product. A 2-year-old stand with a spacing of 0.5 x 4 m produced 6.8 tons of dry woody stems/ha in Nigeria (Yamoah et al. 1986b). The shrub is used in India as a host plant to the Lac insect, and is sometimes intercropped with food crops during its establishment period (Purkayastha et al. 1981). Glandular hairs from dried pods yield a powder that imparts a brilliant orange color to silks (Allen and Allen 1981). Hill tribes in India use the roots in external applications against ulcers and swellings (Bernet 1978). The species has been used a covercrop for coffee in the Ivory Coast and Cameroon, sisal plantations in Tanzania, cocoa plantations in Ghana and the Ivory Coast (experimental stations). and rubber in Sri Lanka and Malaysia.

ESTABLISHMENT: There arc 45.00(1 to 97,000 seeds per kg. Tests at NFTA indicate that the standard hot water treatment ensures the best germination. Chandrasekera (1980) found that treatment in concentrated sulfuric acid for 15 minutes provided better germination than hot water. Young plants grow slowly and need care (weed control) during the first two to three months. NFTA has limited quantities of seed available for trials.

PESTS AND PROBLEMS Flemingia is an off-season host for the podfly. Melanagromyza obtusa, an important pest of pigeonpea, especially in central and northern India (IPN 1985).

NOTE TO READERS: Fiemingia macrophylia is a relatively unstudied species just beginning to be tested and used in many areas. Much remains unknown about its environmental requirements, uses and management. Anyone working with this species is urged to contribute information that could be included in a later edition of this NFT HIGHLIGHT or NFTBR.

PRINCIPAL REFERENCES:

Asare, E.O. 1985. Effects of frequency and height of defoliation on forage yield and crude protein content of Flemingia macrophylla. In

Proceedings of the XV International Grassland Congress, August 2431,1985, Kyoto, Japan.

Asare, EO., Y. Shebu and EA. Agishi. 1984. Preliminary studies on indigenous species for dry season grazing in the Northern Guinea Savanna Zone of Nigeria. Trop. Grass. 18(3), p. 148-152.

Brazill. Y.A.E. 1987. Evaluation of tropical forage legumes under Pinus caribea var. Hondurensis in Costa Rica. Turrialba. Agrof. Syst. 5:97-108.

Chandrasekera. LB. 1980. Ground covers in the tea plantations in Sri Lanka. Bull. Rubber Res. Inst. (Sri Lanka) 15:20-23.

Gillett, J.B., R.M. Polhill and B. Vetdcourt. 1971. Flora of tropical East Africa (E.T.A.) leguminosae, pan 4. sub-family Papilionoideae. Crown agents for Overseas Govemments and Administrations, London, U.K.

Int. Pigeonpea Newsletter. 1985. A survey for offseason survival of pigeonpea podfly around Pantnagar. India. 4:5}54.

Keoghan. 1. 1987. Smallholder Cattle Development Project Indonesia: Report of the Forage Consultant. Department Pertanian Dircktorat Jenderal Peternakan Proyek Pengembangan Petani Ternak Kecil. Jakarta. Indonesia.

Purkayartha, B.K, B. P. Singh and Moti Ram . 1981 . Intercropping of tuber and rhizome crops within mixed plantation of young lac hosts. Albizia lucida and Moghania macrophylla. Indian Journ. Agric. Sci. 51(8):574-576.

Skerman. P.J. 1977. Tropical forage legumes. FAO Plant Production and Protection Series No. 2. FAO. Rome. p. 506.

Yamoah. C.F.. AA. Agboola and K Maiongoy. 1986a. Decomposition. nitrogen release and weed control by prunings of selected alley cropping shrubs. Agrof. Syst. 4:239-246.

Yamoah, C.F., AA. Agboola and K Malongoy. 1986b. Nutrient contribution and maize performance in alley cropping systems. Agrof. Syst. 4:247-254.

(Far a complete list of references cited contact NFTA.)

Gliricidia - Its Names Tell Its Story

Names of the fast-growing tropical tree Gliricidia septum (Jacq.) Steud. tell us much about its many uses. The species' name is Latin for "rat killers"; Madre de cacao" is Spanish for "mother of cocoa.; as is "Palo de hierro" for "tree of iron"; and "quick stick. is an English name from

Jamaica. Gliricidia's versatility and multiple uses explain why it has spread worldwide from its origin in Mexico and Central America.

Rat killer" is derived from the poisonous mash made by mixing ground leaves with cooked grain (Standley and Steyermark 1946).

Mother of cocoa,. adopted from the Aztec-Indians, tells about gliricidia's value as shade in cacao plantations. It was introduced into Sri Lanka in the late 18th century for shading coffee. Later, it was interplanted with tea as a source of nutrients such as N (3-4% dry weight of leaves) and K (35%).

Scientists in India in the 1930s studied gliricidia as a green manure crop and urged farmers to "slash your manure budgets. by planting trees on bunds and field borders. A traditional African cropping system uses gliricidia as a support plant for yams and then as a fallow crop to rebuild soil fertility (Agboola et. al. 1982). Vanilla in Uganda, pepper in Costa Rica and passionfruit in Sri Lanka all are commonly supported by gliricidia. Filipinos seek old gliricidia stumps for orchid props.

Gliricidia shows exciting potential in alley cropping studies, providing nutrients, weed control and soil stabilization when intercropped with maize, cassava, taro, cucurbits and other crops (IITA 1983; Kidd et. al.

1985). Gliricidia grown in hedgerows 4 meters apart and pruned 5 times a year produced 100 to 200 kg N/ha annually, maintaining maize yields (IITA 1984).

"Quick-stick" refers to how easy it is to propagate this tree with cuttings. Leafless sticks 0.5-2 m in length root with ease in almost any soil (Simmonds 1951), making gliricidia a favored tree for fences and boundaries that can be periodically lopped for firewood and animal feed. Single clones line roads and fields throughout the Old and New Tropics. Fencing wire links the trees.

Gliricidia

Gliricidia coppices vigorously and tolerates regular browsing and lopping. Regrowth from trees spaced 1.5 m apart in a 5-year-old boundary fence in Costa Rica was harvested at 3, 6 and 9 months and yielded an average of 0.6, 13 and 1.1 tons of forage (dry matter)/km, respectively (Beliard 1984).

Evaluations of gliricidia as animal feed for beef and dairy cattle, chickens, sheep and goats have shows promising results. Numerous studies have reported its high feed value, with average protein levels between 22 and 27% DM (dry matter), reported its high feed value, with average protein levels between 22 and 27% DM (dry matter), crude fiber of 14% DM, and digestibility values ranging from 50 to 75%. Long-term feed value studies are being conducted by the international Livestock Center for Africa (ILCA 1983).

"Tree of iron" describes gliricidia's hard, durable wood, which is resistant to weathering and fungal attack. It is a preferred firewood species in Central America with a specific gravity of 0.48 and a heating value of 4762 kcal/kg, measured at 15 months of age. Filipino farmers traditionally have planted gliricidia to supply the fuelwood needed for curing tobacco. Yields up to 40 m/ha/yr have been obtained (Wiersum

1982).

Wide soil and climatic adaptability characterize gliricidia. It grows well on acidic soils of low fertility where leucaena does not thrive (Chadhokar 1982). Growth of over 3 m in height in one year was reported on an eroded Oxic paleustalfs with low P status (IITA 1983), as well as on acidic beach soils in southern Thailand (TISTR 1984).

Nodulation has been observed in many countries (Allen and Allen 1981) and occurs within 3 months of stake plantings, with nodule numbers of 50-150 per plant (Chadhokar 1982). Gliricidia seeds store well, with virtually no loss of viability [D a year at 17C and 50% humidity (author). Considerable genetic variation occurs among seed progenies (Salazar 1986).

Six to nine species are recognized in the genus. Chromosome numbers are reported to be 2n=20 and 2n=22. Plants around the world are probably derived from a narrow gene base due to its ease of vegetative propagation. Major germplasm collections have been made by scientists at ILCA, CATIE, NFTA, and OFI/Oxford and are under evaluation in trials at the University of Hawaii (author).

Proceedings of an international workshop on the uses and management

of gliricidia held April 1987 at CA TIE, Turrialba, Costa Rica were published in NFTRR Volume 5, and the Gliricidia production and use manual is now available from NFTA.

PRINCIPLE PUBLICATIONS:

Allen, O.N. and Ethel K Allen. 1981. The Leguminosae: A Source Book of Characteristics, Uses and Nodulation. Wisconsin Press, Wisconsin. Pages 300-301.

Chadhokar, P.A. and H.R. Kantharaju. 1980. Effect of Gliricidia maculataon growth and breeding of Bannur ewes. Trop. Grasslands 14:78.

Chadhokar, PA. 1982. Gliricidia maculata: A promising legume fodder plant. World Animal Review 44:36-43.

Djuwadi and D.S. Radite. 1981. Agroforestry activities within the scope of the Imogiri development project for critical areas of the Gadjahmada University. in K F. Wiersum, ed. Observations on Agroforestry on Java, Indonesia. Pages 112-118.

International Institute of Tropical Agriculture. 1983. Annual Report. Ibadan, Nigeria. Page 153.

Iyer, V.S. and S. Rangaswami. 1973. Occurrence of robinetin in the heartwood of Gliricidia maculata. Curr. Sci 42(1) 31.

Montilla, JJ., A. Reveron, B. Schmidt, H. Wiedenhofer, and P.P. Castillo. 1974. La harina de follaje de Rabo de Raton (Gliricidia sepium) en raciones pare ponedores. Agronomia Tropical, Venezuela 24(6):505-511.

Neal, M.C. 1965. In Gardens of Hawaii Honolulu, Bernice P. Bishop Mus. Special Pub. 50:449.

Otarola, A. and L. Ugalde. 1983. Productividad y tables de biomasa de Gliricidia sepium (Jacq.) Steud, en bosques naturales de Nicaragua. CATIE. Turrialba, Costa Rica. 39 pages.

Roskoski, J., G. Castelleja, I. Frias, E. Pardo, and A. Vaugas-Mena. 1980. Woody tropical legumes: Potential sources of forage, firewood and soil enrichment. in Tree crops for energy coproduction on farms. National Tech. Infor. Serv. Springfield, Virginia. Pages 135-155.

Simmonds. N.W. 1951. Notes on field management at the botany department of the Imperial College of Tropical Agriculture Trinidad. Trop. Agriculture, Trin. 28(1/6):70-75.

Wiersum, K.F. 1982. Fuelwood as a traditional and modern energy source ID the Philippines. FAO Project Working Paper No. 6. Manila, Philippines. Page 27.

Hippophae rhamnoides: an NFT valued for centuries

Hippophae rhamnoides L., commonly known as sea buckthom. is an arborescent shrub of wide adaptability distributed throughout more than 20 countries of Europe and Asia. The species has a history of utilization that goes back at least 12 centuries. An actinorhizal plant, sea buckthorn has the capacity to fix atmospheric nitrogen and thus enrich the soil. It is used successfully as a windbreak and to stabilize sand dunes, and several of its products have high value.

Botany

Sea buckthom is a deciduous shrub or small tree, with thorns and unisexual flowers It is dioecious and wind pollinated, Its fruit is a drupe, reddish orange, varying in length from 5 to 12 mm, with a tart, bittersweet taste. Each fruit has one bonehard seed. Shrubs usually begin to bear fruit after three years and give maximum yields after seven to eight years.

Hippophae rhamnoides L., commonly known as sea buckthorn.

The trees have an extensive, shallow root system and root suckering is common. Plants degenerate after approximately 15 years and then reproduce by suckering.

Rousi (1971) divided the genus Hippophae into three species. More recently, Lian (1988) revised the taxonomy, dividing the genus into five species. Hippophae rhamnoides is by far the most common and references to Hippophae are usually to this species.

Ecology

Sea buckthorn grows anywhere in temperate latitudes, from sand dunes near the sea to the Eurasian plateau at 5200 m above sea level. Plant characteristics vary considerably according to this wide range of climatic conditions. For instance, these "shrubs" can reach 18 m in height in certain zones.

This is a light-demanding species. Trees growing in forested areas will die if the canopy density exceeds 50%. However, they are extremely drought tolerant, with extensive root systems that scavenge soil humidity and groundwater aggressively. They grow readily in areas that receive as little as 250 to 800 mm of rainfall annually. For example, there is a large area of natural Hippophae forest on the loess plateau of China, including the semi-arid regions of Shanxi, Shaanxi and Gansu Provinces.

The species is also well adapted to cold climates. There are 18,000 ha of natural Hippophae forest in Siberia where the temperature commonly drops well below O§C. Sea buckthorn is also tolerant of alkaline and saline soils. It is reported to grow in the Qaidam Basin of China where the salt content of the soil ranges from 0.6 to 1.1% and the pH is 9.5.

Distribution

Sea buckthorn is native to the temperate zones of Asia and Europe, where it is widely distributed. It is also well represented at higher altitudes in the sub-tropical zones of Asia. Russia has approximately 200,000 ha of natural Hippophae forest plus more than 6,000 ha in plantations. With 920,000 ha, China has the largest area under Hippophae of any country, and also the largest variety of Hippophae species.

Uses

Food. Sea buckthorn fruit is rich in vitamins C, E, K, B. and B2, as well as niacinamide, pantothenic acid, carotenoids and other substances such as oil, sugar, malic acid, amino acids and pectin. The vitamin C content of the Chinese sea buckthorn (Hippophae rhamnoides subsp. sinensis Rousi) fruit can be as high as 1253 mg/100 g.

Numerous food products are made from the fruit of this species. For instance. sea buckthorn wine is well known in Russia. In that country, a new variety has been bred by hybridizing geographically distant plants: it produces as much as 10,000 kg/ha of fresh fruits. In China, poor peasants have become prosperous by collecting and processing the

fruit.

Hippophae leaves also contain various nutritious substances and minerals. They are commonly used as tea.

Medicine. There are records of the medicinal use of sea buckthorn as early as the eighth century A.D. The Tibetan medical classic, Four Books of Pharmacopeia, lists 84 prescriptions for the preparation of sea buckthorn medicines. According to one account, a Tibetan lame considered this plant as a general panacea and made extensive use of its roots, stems, leaves. flowers, fruits and seed. The plant was widely used as a folk medicine in ancient Greece. the Roman Empire, Mongolia and Russia. Oil from the fruit acts as an antioxidant and may thus be used to treat wounds, frost bite and pathological problems of the alimentary mucous membranes. Serotonin (5-hydroxy-tryptamine) extracted from sea buckthorn possesses antitumor capabilities.

Animal reed. The ancient Greeks named the genus Hippophae, or "glittering horse," because they believed that horses became plump and healthy when maintained on pastures with these trees. Today, herdsmen in northwest China often feed sea buckthorn leaves to their animals. In Russia, fodder supplements of sea buckthorn by-products are reported to improve liveweights and coat condition. Feeding poultry

with meal made from sea buckthorn fruit and fruit oil has been observed to increase the pigmentation of egg yolks and body fat. The oil also increases flesh pigmentation in rainbow trout.

Ecological benefits. Hippophae possesses a strong capacity to fix atmospheric nitrogen in its root nodules when associated with the actinomycete, Frankia. Most soils possess enough Frankia to support nodulation. In one stand on the east coast of England, annual nitrogen fixation was estimated as high as 179 kg/ha (Stewart and Pearson, 1967).

All of the plant's characteristics, especially its strong nitrogen-fixing ability and rapid growth, make it a good species for improving soil fertility, controlling erosion. conserving water, and stabilizing sand dunes. In mixed plantings, it can promote the growth and development of adjacent plants. Sea buckthorn also shows a strong tolerance for toxic pollutants in the soil and air. It can thus be used to revegetate heavily industrialized areas or to reclaim mining sites.

Other uses. Cosmetics derived from sea buckthorn are widely used in Romania, Russia and China. Massage creams. day creams and a shampoo developed in Romania have received international patents. In addition, the trees yield good-quality fuelwood. In China's western

Liaoning Province, a six-vear-old sea buckthorn plantation can produce 6.32 t/ha of wood, Sea buckthorn is also useful as an ornamental shrub.

Silviculture

Management varies according to objectives and environment factors. The species propagates well asexually because lignified branches of any age possess a strong ability to form adventitious roots. Hippophae rhamnoides can also be propagated from softwood cuttings under mist. For introduction or breeding trials. seed propagation is the most suitable treatment.

The seeds retain their viability after indoor storage for three to four years. Under suitable conditions. they will germinate during any season of the year. In 1977, a large plantation was successfully established on the loess plateau of China by broadcasting seed from aircraft.

Limitations

The wide adaptability and varied reproductive strategies of Hippophae rhamnoides indicate that it could be a serious weed in some environments. Its extensive. suckering root system may make it unsuitable for agroforestry technologies that include close tree/crop associations. In addition, thorns on the stem and branches often make

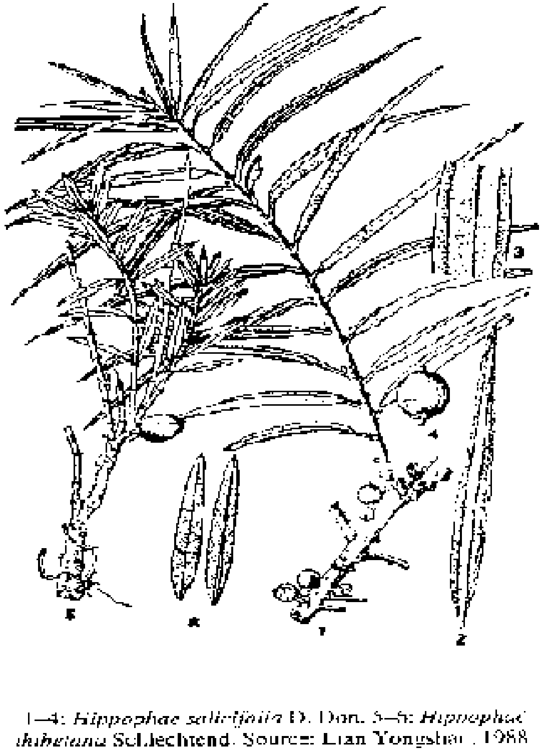
it difficult to harvest the fruits.

References

Lian Yongshan. 1988. New discoveries of the genus Hippophae L. (Elaeagnaceae). Acta Phytotaxonomica Sinica. 26(3):235-37.

Rousi, A. 1971. The genus Hippophae L: a taxonomic study. Annales Botanica Fennici. 8(3): 177-277.

Stewart, W.D.P. and Pearson, M.C. 1967. Nodulation and nitrogen fixation by Hippophae rhamnoides in the field. Plant and Soil. 26(2):348 60.



1-4: Hippophae salicifolia D. Don. 5-6: Hippophae thibetana Schlechtend. Source: Lian Yongshan. 1988.

Ougeinia dalbergioides: a multipurpose for sub-tropical and tropical mountain regions

Ougeinia dalbergioides Benth. (Leguminosae, Subfamily Papilionoideae) is a monotypic genus formerly classified as Ougeinia oojeinensis and Dalbergia ougeinesis. It is a valuable timber and fodder species restricted to India. The natural forests containing this tree have been severely degraded by timber exploitation. Ougeinia dalbergioides is most commonly called sandan.

Ougeinia dalbergioides Benth.

Ougeinia dalbergioides

Botany

Ougeinia dalbergioides is a medium-sized semi-deciduous tree, commonly attaining 40-50 cm in diameter breast height (DBH) and 7-14 meters in height (Troup 1921). The stem is often crooked, but in some areas the tree is straight. The bark. varying from pale pinkish-brown to dark bluish gray, is somewhat rough and exfoliates in irregular thin soft scales. Leaves are pinnately trifoliate, smooth above and lightly pubescent below. The obovate leaflets are generally 6-12 cm long and 2-15 cm wide. but size varies greatly. Leaf margins are entire.

The light-pink to white flowers emerge in clusters from February to May. The previous years branches generally do not bear flowers. Branches bearing flowers are leafless, while others retain leaves. Flowering trees are conspicuous and afford a beautiful sight. Pods have a distinct seam, are 5-10 cm long and I cm wide. They mature and ripen in May to June and fall chiefly in June. Normally, pods remain closed until seeds germinate. Mature pods yield 2-5 viable seeds. The smooth brown seeds are 10-12 mm long and 5 mm wide. Trees do not seed heavily each year (Troup 1921).

Ecology

Ougeinia dalbergioides is native to sub-tropical regions of India. It is common at elevations of 300-1500 m. At higher elevations it remains a

small tree. The optimum mean annual temperature in its habitat ranges from 20-47C with a relative humidity from 49-90%. The optimum rainfall appears to range from 950-1900 mm. This species is not found in wet regions Characteristic of limestone soils. sandan grows well on dry exposed sites and eroded hills (Troup 1921). It also occurs on alluvial soil, red clay, black cotton, and rocky soil. Its best growth and greatest size is attained in the lowlands on alluvial soils. Sandan is a component of mixed deciduous and sal (Shorea robusta) forests. It is associated with pines at the higher limits of its elevation range.

Distribution

Ougeinia dalbergioides is found in the sub-Himalayas foothill and plains of the Punjab eastwards to Bhutan. It is also common in Central and Northern India and in some parts of Southern India. It is an important species in Uttar Pradesh and Madhya Pradesh.

Uses

Wood. Ougeinia dalbergioides yields a valuable timber. The sapwood is grey and narrow, the heartwood is light golden brown, hard, strong, heavy and elastic - specific gravity is 0.84 and average weight is 865 kg/cubic meter. The wood air seasons slowly without much

degradation. The wood can be kiln-seasoned without difficulty, but requires slow and careful drying. Planks 2-5 cm thick require 16-20 days to season (Pearson and Brown 1932; Trotter 1944). The wood does not require preservative treatment. It is difficult to work, but turns well and takes polish readily. Though originally considered difficult to peel, it is now frequently utilized for plywood. The timber of this species is superior to teak (Tectona grandis) in terms of shock resistance, shear strength and hardness (Pearson and Brown 1932). Sandan timber in the manufacture of agricultural implements, construction timbers, furniture and textile mill implements. It is also a specialty timber for marine plywood. It is a good fuel with a calorific value of 4900-5200 Kcal/kg (Krishna and Ramaswami 1932).

Fodder. The leaves are highly valued as cattle feed. Farmers lop side branches, but often spare the main limbs to assure good growth and future supplies of fodder. In some areas, natural stands of this species are such important fodder resources, timber harvesting is forbidden. Leaves contain 1215% crude protein (Singh 1982).

Other uses. Bark fibers are suitable for making rope (Pearson and Brown 1932; Trotter 1944). The bark is used as a fish poison and to reduce fevers. A sap exudate is used to make a medicine to treat dysentery. The tree is a host-plant for lac producing insects. The

resulting shellac is of high quality (Purkayastha and Krishnaswamy 1958).

Propagation

Ougeinia dalbergioides is readily propagated from seed. The seeds do not retain their viability for long and should be used within 12 months of maturity. Once collected seed should be properly dried and stored in sealed containers. A kilogram contains 28,000-33,000 seeds. To maximize germination, pods should be broken into fragments containing one seed and soaked in water for 24 hours before sowing (Uniyal and Nautiyal 1992). Seed should be sown I cm deep. Germination occurs in 3-8 days. Direct sowing is very successful and highly recommended (Troup 1921; Kadambi and Dabral 1955).

Nursery-propagation accelerates seedling growth, however the large taproot of sandan makes transplanting difficult.. Establishment by stump sprouts gives good results. One-year old seedlings with root-collar diameters of 5 cm are recommended. For stump production. seedlings should be cut 2-3 cm above the root-collar and 20-25 cm below. Propagation by root cuttings is successful, but stem cuttings yield poor results.

Silviculture

Young trees and seedlings need a moderate amount of shade. However, once established O. dalbergioides requires full sunlight for its best development Although young trees are drought and frost sensitive. mature trees are hardy. A tree spacing of 3 x 6 m is recommended for timber production.

Mean annual growth increment averages between 3-20 mm in DBH. Trials in Srinagar indicate keeping seedlings free of heavy weed competition for 3-4 years will improve growth and survival. Under this management scheme, trees attained heights of 4-5 m and DBH of 10.5 cm in 6 years. Conversely, heavy weed competition can kill seedlings. Sandan coppices well and produces abundant root-suckers. This characteristic is particularly useful for controlling erosion along steep banks and eroded hillsides. Fast-growing coppice and root-suckers attain 7-10 m in height and 12-17 cm in DBH after 20 years. Coppice and root-suckers can be managed for timber production. In Madhya Pradesh forests are commonly managed simultaneously for sandan and teak production. The exploitable diameter for O. dalbergioides timber is generally 30 cm.

Limitations

Sandan is very susceptible to heart rot (Fomes caryopnhylla), buff brown pocket rot (Polystictus nilgheriensis) and white spongy rot (Asterostromella rhodospora). The tree is also susceptible to a number of defoliators and borers. The latter also attack dead wood (Kadambi and Dabral 1954). Timber exploitation has degraded the natural stands of this species. To reverse this condition, improved natural forest management and the establishment of large-scale tree plantations are necessary.

Symbiosis

As with many other leguminous plants, Ougeinia dalbergioides forms nitrogen fixing symbiosis with Rhizabium bacteria. Reliable estimates of its nitrogen fixing capacity are not available.

Genetic Variation

A variant of this species has been reported to occur at a frequency of 4% in Srinagar. Variants differ morphologically from the normal plants by producing narrower leaves with 46 leaflets instead of three. The morphological difference has been retained by trees established in an arboretum in 1985 (Purohit et. al 1987). These plants grow 30% slower than the normal plants. Detailed invesugations on the physiology of

variant plants are in progress.

References

Kadambi, K and S. N. Dabral. 1955. Studies in the suit ability of different methods of artificially regenerating forest trees. Indian Forester 81(2):129.

Krishna, S. and S. Ramaswami. 1932. Calorific values of some Indian woods. Forest Bulletin No. 79, (New Series). Chemistry, Government of India, Central Publication Branch, Calcutta.

Pearson, R. S. and H.P. Brown. 1932. Commercial timbers of India. Volume I Government Press, Publication branch, Calcutta. p 352-356.

Purkayastha, B. K. and S. Ktishnaswamy. 1958. Trials of Albizia lucida and Ougeinia dalbergioides as new lac hosts for the baisakhi crop in Chota Nagpur. Indian Forester 84(3):137

Purohit, A. N., A. R. Nautiyal, P. Thapliyal, and S. K. Bhadula. 1987. Physiology of Ougeinia dalbergioides Benth. and its morphological variant. 1. Germination, growth behavior and carbon dioxide exchange rate. The International Tree Crops Journal 4:165-175.

Singh, R.V. 1982. Fodder trees of India. Oxford & IBH Publishing Co., New Delhi. 259 p.

Trotter, H. 1944. The commercial timbers of India and their uses. Government Press Delhi. 227 p.

Troup, R. S. 1921. The Silviculture of Indian Trees. Volume I Oxford University Press, Oxford. p 228-296.

Uniyal, R. C. and A. R. Nautiyal. 1992. Effect of presoaking in water in germination of Ougeinia dalbergioides seeds. Nitrogen Fixing free Research Reports 10:176-177.

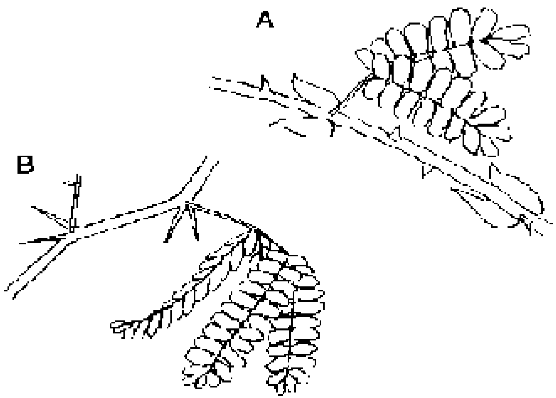
Prosopis cineraria: A Multipurpose Tree for Arid Areas

Prosopis cineraria is a versatile species, providing fodder fuel, food, timber, and shade, as well as affecting soil improvement and sand dune stabilization. It is commonly used in dryland agroforestry in India and Pakistan. The tree is known locally as jandi or khejri (India), jand (Pakistan), and ghaf (Arabic). Its synonym is P. spicigera.

BOTANY. Prosopis cineraria (L.) Druce (family Leguminosae, subfamily Mimosoideae) is one of 44 species of leguminous trees and shrubs in the genus. It is a small, thorny, irregularly branched tree, 5-10 m high.

Evergreen or nearly so, it forms an open crown and has thick, rough gray bark with deep fissures.

Leaves are alternate, bipinnately compound with 1-3 pairs of pinnae. Each pinna has 7-14 pairs of leaflets, 4 15 mm long and 2-4 mm broad. The thorns are straight with a conical base and distributed sparsely along the length of the stem. They first become visible when the seedlings are 6-8 weeks old. In this respect, P. cineraria differs from the thorny New World species of Prosopis (e.g., P. juliflora) which have thorns in pairs at the nodes but thornless internodes.



Young branches of (A) *Prosopis cineraria* and (B) *P. juliflora*, showing the differing position of thorns.

Young branches of (A) Prosopis cineraria and (B) P. juliflora, showing the differing position of thorns.

The 0.6 cm yellow-green flowers are borne on 5-23 cm spike-like racemes. Up to 25 dull brown seeds, 0.3-0.8 cm long, are contained in each of the light yellow pods, which are long (8-19 cm), narrow (0.4-0.7 cm), and cylindrical. As with other Prosopis, rooting can be very deep; the tap root of P. cineraria may penetrate vertically up to 20 m or more (Mahoney 1990).

ECOLOGY. P. cineraria occurs naturally in the dry and arid regions of India, Pakistan, Afghanistan' Iran, and Arabia. It is one of the principal species on higher and older alluvium in the Indus river valley. It is extremely drought tolerant, growing in areas with as little as 75 mm annual rainfall, generally 150-400 mm (FFN 1991), with dry seasons of eight months or more (NAS 1980).

Slightly frost hardy and tolerant of temperatures up to 50C, it grows at altitudes from sea level to 600 m. The tree is found in alluvial and coarse, sandy, often alkaline soils where the pH may reach 9.8. In vitro studies have confirmed the nodulation of P. cineraria with Rhizobium.

In areas such as the Wahiba Sands in Oman there exist isolated, ancient P. cineraria trees. It also grows gregariously on sand. Under less extreme conditions, P. cineraria, often in association with Acacia tortilis, may form open dry, woodlands, which are important

communities within the desert ecosystem. There is considerable phenotypic variation between individuals in crown shape, growth rate, and branching. Ecotypes growing in highly saline coastal areas have also been identified.

USES. Wood: P. cineraria provides excellent firewood (calorific value, cat 5,000 kcal/kg) and charcoal. Its wood is favored for cooking and domestic heating (Mahoney 1990). Hard and reasonably durable, the wood has a variety of uses for house building, posts, tool handles, and boat frames, although poor tree form limits its usefulness as timber.

Fodder The leaves are an available, excellent, and nutritious fodder, readily eaten by many animals including camels, goats, and donkeys. The tree produces leaves during the extremely dry summer months when most other trees are leafless. Leaves contain 13.8% crude protein, 20% crude fiber, and 18% calcium (FFN 1991). The pods also provide a good fodder, containing a dry, sweet pulp.

Food: Pods are eaten as a vegetable in the human diet in some areas. In Rajasthan, green pods called sangri are boiled and dried (FFN 1991). The flowers are valuable for honey production. The bark can be used in leather tanning and yields an edible gum. Bark and flowers are used medicinally (NAS 1980). In times of famine, the powdered bark has

been mixed with flour and made into cakes (Bhandari 1978).

Land use: P. cineraria effectively stabilizes sand dunes and can withstand periodic burial (Gates and Brown 1988). Because of a deep taproot, trees are not believed to compete for moisture or nutrients with crops grown dose to the trunk. During the growing season it casts only light shade and is therefore suitable as an agroforestry species. Farmers in arid and semi-arid regions of India and Pakistan have long believed it to increase soil fertility in crop fields. Yields of sorghum or millet increased when grown under P. cineraria, as a result of higher organic matter content, total nitrogen available phosphorus, soluble calcium, and lower pH (Mann and Shankarnarayan 1980). Other crops traditionally grown amid scattered khejri are maize, wheat, and mustard.

SILVICULTURE. Seeds (25,000/kg) remain viable for decades in dry storage and establish well with 80-90% germination (Mahoney 1990). Soaking seeds in tepid water for 24 h is recommended as a pre-germination treatment. The round end of the seed may also be scarified by scratching or nicking with a file or knife.

P. cineraria is difficult to propagate by cuttings, although treatment with rooting hormones has proved successful in India. Propagation by

root suckers and by air layering has been reported. Recent attention has also been given to micropropagation of this species, but it appears that in vitro propagation is more difficult with P. cineraria than with many other Prosopis species. The tree is also considered slower growing than other Prosopis.

Seedlings are raised in a nursery and transplanted when 2-3 months old at the onset of the rainy season. Trees can be planted in dose lines as a hedge with 1 m spacing between trees (Mahoney 1990), but tree densities of 50-100/ha are recommended for both agroforestry and silvopastoral systems. One or two weedings are necessary during the first year owing to slow initial growth rate. Early pruning to encourage straight growth is recommended (NAS 1980). The tree responds well to irrigation, tolerating up to 50% sea water.

The tree coppices readily (NAS 1980). Maximum yields of fodder are obtained when the trees are pollarded on a three-year-rotation. Villagers traditionally lop their trees in winter and store the sun-dried leaves for dry season fodder.

YIELD. The trees reach 3-5 m high in 5-6 years with an average diameter of 6 cm. Annual firewood yields of up to 2.9 m/ha have been reported (NAS 1980). A moderate sized tree may yield 45 kg of dry leaf

fodder per year.

RESEARCH. Although P. cineraria plays a vital role as an agroforestry species in some parts of its natural range, little success has been achieved in planting it elsewhere. Further work is needed to establish the range of conditions under which it might prove useful. P. cineraria displays considerable genetic variation, particularly in populations dose to the edge of its natural range, which are often threatened by overgrazing. Genetic conservation of this valuable resource is considered a priority.

LIMITATIONS. Desert locusts (Shistocarica gregaria) and Melolonthidae beetles attack the foliage, and bruchid beetles feed on the mature dried seeds. Termites (Odontoteomen obesus), white grubs (Halorachia spp.), and the gallfly (Goccidomulid gall)) are also important pests. There is little information on diseases of P. cineraria. This NFT is not suitable for planting in riverine areas or subhumid environments where it can become an aggressive colonizer and spread rapidly.

PRINCIPAL REFERENCES:

Bhandari, M.M. 1978. Flora of the Indian Desert. Scientific Publishers, Jodhpur, India.

Burkart, A. 1976. A monograph of the genus Prosopis (Leguminosae, subfam, Mimosoideae). J. Am. Arb. 57(3/4): 219-249; 450-525.

**FFN. 1991. Spotlight on species: Prosopis cineraria. Farm Forestry News, Vol. 4, No. 3. Gates, P.J. and K Brown. 1988. Acacia tortilis and Prosopis cineraria: Leguminous trees for arid areas.
Outlook on Agriculture 17:61-64.**

Leakey, R.R.B. and F.T. last. 1980. Biology and potential of Prosopis species in arid environments with particular reference to P. cineraria. J. Arid Environments 3:9-24.

Mahoney, D. 1990. Trees of Somalia - A field guide for development workers. Oxfam/HDRA, Oxford. p. 133-136.

Mann, H.S. and K.A. Shankarnarayan. 1980. The role of Prosopis cineraria in an agropastoral system in Western Rajasthan. In Browse in Africa, edited by H.N LeHouerou International Livestock Centre for Africa, Addis Ababa, Ethiopia. p. 437-442.

NAS (National Academy of Sciences). 1980. Firewood Crops. Vol. 1. National Academy Press, Washington, D.C. p. 150-151.

Prosopis alba and Prosopis chilensis: Subtropical semiarid fuel and

fodder trees

Prosopis alba and Prosopis chilensis are native to the semi-arid regions of northwestern Argentina and northern Chile. Locally they are called el arbor or, the tree, because of their widespread occurrence and importance. Since these species have often been confused in the literature, it is useful to treat them together. Once leaf patterns have been observed, differences between species become obvious.

BOTANY. Prosopis alba (Grisebach) and P. chilensis (Molina Stuntz) (subfamily Mimosoideae, family Leguminosae) are small to medium-sized trees up to 12 m in height and 1 m in diameter. Both species have thorny and thornless variants. The most distinguishing feature between the two are the number and spacings of leaflets.

The trees have compound leaves each with numerous leaflets along several pairs of pinnae. P. alba usually has 2-3 pairs of pinnae (but up to 4 or 5) with 30-50 sets of 10 mm long leaflets per pinnae (Burkart 1976). P. chilensis generally has fewer leaflets per pinnae (about 10-29) and usually no more than two pair of pinnae per leaf. In P. alba, the 1-2 mm wide leaflets nearly touch the pinnae, while in P. chilensis, leaflets are about 1 cm apart.

Abundant, greenish-white to yellow flowers occur on spike-like racemes. Pods of both species are beige to off-white, from which the species name alba, or white, originates. In contrast, other Argentine species have red-tinged to dark purple pods (P. flexuosa and P. nigra).

The pods of P. alba are typically 20 cm long, 4-5 mm thick, and 20-25 mm wide. They are sickle-shaped with the entire pod occurring in the same plane. Although P. chilensis pods are the same color, they are shorter (about 15 cm) and not as wide (about 15 mm). The pods of P. chilensis are seldom flat and have a tendency to be rolled up along the long axis. P. alba pods also usually have a thicker mesocarp indicating a greater pod sugar content. The name P. chilensis has been incorrectly applied to the North American species P. glandulosa and P. velutina, and to the naturalized P. juliflora that occurs in the Sudan.

ECOLOGY. Over 20 species of Prosopis occur in the semiarid and arid regions of northwestern Argentina, making Argentina the center of genetic diversity for Prosopis, although probably not the center of origin (Burkart 1976). P. alba is native to the plains and low sierra of subtropical Argentina, extending into Uruguay, Paraguay, southern Brazil, and Peru (Burkart 1976) up to 1,500 m elevation.

In Argentina, P. chilensis grows in regions that experience lower winter

temperatures and lower rainfall than P. alba (E. Marmillon, pers. comm.). In areas with groundwater between 3 and 10 m below the surface, such as in drainage channels and along groundwater sinks, P. chilensis may occur in areas with less than 250 mm rainfall. If no groundwater is available, annual rainfall must exceed 350-400 mm for large trees (25-100 cm diameter) to occur. Trees of both species have been identified that grew in seawater salinity (Rhodes and Felker 1987).

Over most of the trees' range the climate is subtropical with annual temperatures averaging about 20C. In northern Argentina along the border with Paraguay, the frosts are light (-3 or -4C), but further south near Cordoba occasional frosts of -12C occur. When grown in Texas, nearly all spineless trees of P. alba froze to ground level with frosts of - 12 C. Both species occur in areas that experience 45C, so high temperature stress is not a problem.

USES. Wood: The wood of these trees is relatively dense (about 700-800 kg/m) and makes an excellent fuel whether burned directly or first converted to charcoal (Tortorelli 1956). The timber is valued for furniture, doors, cobblestones, and parquet floors. The reddish/brown wood has a volumetric shrinkage much lower (ca. 5%) than that of other quality furniture woods (ca. 15%). As a result, joints in furniture

have much less tendency to open during conditions of changing humidity.

Fodder The pods but not the leaves of the trees are readily eaten by domestic livestock. Pods are high in sugar (about 35%) (Oduol et al. 1986) and contain 10-12% crude protein. Seeds are sometimes ground into a concentrate for animal feed. Large trees, 40 cm in basal diameter and 7 m in canopy diameter, may produce 40 kg of pods under optimal conditions. Because of water constraints, tree spacings must be considerably greater than canopy diameters.

Food: The pods of both trees are eaten by native peoples, especially as a ground flour. Contemporary milling techniques and product formulations with Prosopis flour has been described (Sounders et al. 1986). Bees produce honey from the flowers.

Other uses: The large size of the trees and more rapid growth than other Prosopis (e.g., P. glandulosa) have led to widespread use of P. alba and P. chilensis for shade windbreaks, and as ornamentals in Argentina and in Arizona and California, USA. They also contribute nitrogen and organic matter to soils (Johnson and Mayeux 1990). These trees are candidates for erosion control and soil stabilization in arid lands.

SILVICULTURE. Establishment Seeds are difficult to extract from the gummy pulp. Prosopis pods can be ground in a meat grinder after drying pods in an oven at 52C overnight, which will also serve to scarify the seeds. For good germination seeds require scarification of the seed coat with a file or knife. There are about 36,000 seed/kg.

Outstanding trees have been cloned using roofings or cutting techniques that require control over light intensity and air temperatures (Klass et al. 1984). To obtain the highest survival under semi-arid controls seedlings are grown in long (38 cm) narrow (3.8 x 3.8 cm) cardboard plant bands and planted with the container still on (Felker et al. 1988). Mechanical and chemical weed controls to maximize growth are available (Felker et al. 1986).

Yield: Biomass yields of trees grown under short rotation systems (3 yrs) on close spacings (1.5-3.0 m) have been high. Field trials in Texas, USA, using a high productivity P. alba clone, produced 39 dry metric tons/ha in three years at a site with 650 mm annual rainfall (Felker et al. 1989). Trees grew about 2.2 m in height per year. However, excellent weed control coupled with mechanical cultivation was required to achieve these high yields.

SYMBIOSES. A single rhizobia strain that effectively nodulated 13

Prosopis species (Felker and Clark 1980) is available from LiphaTech (3101 West Custer Ave., Milwaukee, Wisconsin 53209). Rhizobium for Prosopis species is also available from NifTAL through NFTA.

PROBLEMS AND PESTS. Twig girdling insects (Oncideres spp.) cause minor damage to these trees. An undescribed "disease" causes the terminal shoots to die. Over a period of years this necrosis gradually spreads downward and eventually may kill the entire tree. These Prosopis can become weeds in heavily grazed areas.

PRINCIPAL REFERENCES:

Burkart, A. 1976. A monograph of the genus Prosopis (Leguminosae subfam. Mimosoideae). J. Arnold Arb. 3:217-249; 4:450-525.

Felker, P. and P.R. Clark. 1980. Nitrogen fixation (acetylene reduction) and cross inoculation in 12 Prosopis (mesquite) species. Plant and Soil 57:177-186.

Felker, P., D. Smith, and C Wiesman. 1986. Influence of chemical and mechanical weed control on growth and survival of tree plantings in semi-arid regions,. Forest Ecology and Management 16:259-267.

Felker, P., C. Wiesman, and D. Smith. 1988. Comparison of seedling

containers on growth and survival of Prosopis alba and Leucaena leucocephala in semi-arid conditions. For. Ecol. Manage. 24:177-182.

Felker, P., D. Smith, C. Wiesman, and R.L. gingham. 1989. Biomass production of Prosopis alba clones at two non. irrigated field sites in semi-arid south Texas. For. Ecol. Manage. 29:135-150.

Johnson, H.B. and H.S. Mayeux. 1990. Prosopis glandulosa and the nitrogen balance of rangelands: extent and occurrence of nodulation. Oecologia 84:176-185.

Klass, S., R.L. gingham, L. Finkner-Templemen, and P. Felker. 1984. Optimizing the environment for rooting cuttings of highly productive clones of Prosopis alba (mesquite/algaroba). J. Hort. Science 60:275-284.

Oduol, PA., P. Felker, C.R. McKinley, and C.R. Meier. 1986. Variation among selected Prosopis families for pod sugar and pod protein contents. For. Ecol. Manage. 16:423-433.

Rhodes, D. and P. Felker. 1987. Mass screening Prosopis (mesquite) seedlings for growth at seawater salinity. For. Ecol. Manage. 24:169-176.

Saunders, R.M., R. Becker, D. Meyer, F.R. del Valle, E. Marco, and M.E. Torres. 1986. Identification of commercial milling techniques to produce high sugar, high fiber, high protein and high galacto mannan gum fractions from Prosopis pods. For. Ecol. Manage. 16:169-180

Tortorelli, L. 1956. Maderas y Basques Argentinos. Acme Agency Press, Buenos Aires, Argentina. 646 p.

Robinia pseudoacacia: Temperate Legume Tree with Worldwide Potential

Very few nitrogen fixing trees are temperate, and very few of these are legumes. The genus Robinia, with four species native to temperate regions of North America, is noteworthy for an ability to tolerate severe frosts.

Robinia pseudoacacia L., or black locust (family Leguminosae, subfamily Papilionoideae), is among the few leguminous NFTs adapted to frost-prone areas. It is also adaptable to enviromnental extremes such as drought, air pollutants, and high light intensities (Hanover 1989). Rapid growth, dense wood, and N2 fixing ability make it ideal for colonizing degraded sites.

BOTANY. Black locust is a medium-sized tree reaching 15-35 m in

height and 0.3-1.0 m in diameter. Long (2045 cm) pinnate leaves consist of 5-33 small, oval, alternate leaflets. Sharp spines are found at the nodes of young branches but are rare on mature wood. The smooth bark becomes reddish-brown and deeply furrowed with age. White to pink, fragrant flowers in 10-25 cm long, hanging racemes appear in early summer soon after the leaves. The closed flowers require bees to force petals open for cross-pollination. The small pods contain 4 8 hard-coated seeds which can persist in the soil for many years. Seed crops occur every 1-2 years beginning at age 3; pods open on the tree in winter and early spring. Although it can occur as a polyploid, it is primarily diploid (N = 10).

ECOLOGY. Black locust is native to regions with 1,0001,500 mm annual rainfall, yet it is drought-tolerant and survives on as little as 400 mm. Its natural distribution includes the Appalachian and Ozark mountains of the eastern US between 35-43 N latitudes. It occurs on upland sites in hardwood forests with black oak, red oak, chestnut oak, pignut hickory, yellow poplar, maple, and with ash along streams. In the northern part of its range at 800 m elevation it occurs with Picea rubra and Acer saccharum (Keresztezi 1988b).

First introduced to France and England in 1600, black locust has become increasingly important throughout Europe and in parts of Asia

(Keresztesi 1988a). It now covers 18% of Hungary's forested areas. It is grown in temperate and subtropical regions in the US, Europe, New Zealand, India, China, and Korea. It has even been grown at higher, cooler elevations in the tropics (e.g. in Java). Trees tolerate temperatures from 40C to -35C. It is found on a variety of soils with pHs of 4.6 to 8.2, but grows best in calcareous, well-drained loams. Trees do not tolerate water-logging. Extremely intolerant of shade the trees are pioneers on disturbed soils or burned sites, often reproducing prolifically from root sprouts (Fowells 1965). Black locust dominates early forest regeneration in many native forest stands where it occurs (Boring and Swank 1984).

SILVICULTURE. Propagation: Black locust seeds (35,000-50,000 seeds/kg) require scarification for good germination. Treatment with concentrated sulfuric acid for 20-50 min is most effective. Seeds can also be nicked, soaked in boiling water for several minutes, or washed in aerated cold water for 2-3 days.

Trees sucker readily from roots and also graft easily. They can be propagated, with difficulty, from hardwood cuttings (15-30 cm long and 1-2 cm diameter) collected in winter or early spring. Treatment with indole acetic acid improves rooting. The tree responds well to tissue culture and has been mass propagated by this method. In nursery

culture black locust is either direct seeded or root sections (5-8 cm long) planted. Robinia pseudoacacia seed is available from NFTA; improved seed is available from James Hanover (MSU).

Growth and yield: The species has one of the highest net photosynthetic rates among woody plants. Black locust grows rapidly, especially young. Trees can reach 3 m tall in one growing season and average 0.5-1.5 m height and 0.2-2 cm diameter growth per year. Trees attained 12 m ht in 10 yrs and 20 m ht in 25 yrs in Kashmir (Singh 1982), and 26 m ht and 27 cm diameter in 40 yrs in the US. Intensive management combined with genetic selection gave experimental dry weight yields up to 40 t/ha/yr under short rotation. On fertile sites it can yield more than 14 m/ha/yr (9.5 t/ha/yr) on a 40-yr rotation with only moderate management. On poor sites, such as strip mines in the US, oven-dry biomass yields range from 3.1 to 3.7 t/ha/yr. Timber volume in a 20-yr-old stand ranged from 63 to 144 t/ha (Keresztesi 1988a), and aboveground biomass in a 38-yr-old native mixed forest stand in N. Carolina, US, was 330 t/ha (Boring and Swank 1984). Fuelwood plantations in S. Korea coppice readily and are lopped annually for fuel (NAS 1983).

TREE IMPROVEMENT. R. pseudoacacia has been cultivated for over 350 years. Natural variation in numerous traits has often been observed and

many cultivars described. Surles et al. (1989) showed a high degree of polymorphism (71%) for 18 enzyme systems in black locust. Most of the diversity resided within seed sources with low geographic variation. Cultivars vary in crown and stem form, growth rate, growth habit (upright vs. prostrate), leaf shape, thorniness, flowering characteristics, and phenology. Clonal selection, early pruning, and close spacing have been effective means of producing straight-stemmed black locust in plantations' especially m Eastern Europe. Comprehensive germplasm collections and plantings for provenance tests were begun in 1982 at Mich. State Univ. Efforts in crossbreeding are under way to improve the tree for growth rate, borer resistance, stem form, thorn-lessness, or other traits (Hanover et al. 1989). In Hungary, a large array of tall clones is in commercial use (Keresztesi 1983), based on seeds from trees of "shipmast locust" originating from Long Island in New York State.

USES. Wood: Black locust wood is strong and hard with a specific gravity of 0.68, yet it has the lowest shrinkage value of US domestic woods. The wood makes a good charcoal. Wood energy yield is typical of temperate broadleaf trees, about 19.44 x 106 J/kg (Stringer and Carpenter 1986). The beautiful light to dark brown wood is used to make paneling, siding, flooring, furniture, boat building (substitute for teak), decking, vineyard or nursery props, fruit boxes, and pallets. It is

also a preferred wood for pulp production. Black locust wood is highly resistant to rot (Smith et al. 1989).

Fodder Black locust has become an important tree in the Himalayas where it is heavily lopped for fodder (Singh 1982). Leaves have a crude protein content of 24%. However, tannins and lectin proteins found in leaves and inner bark can interfere with digestion in ruminants and in nonruminants (Harris et al. 1984). Tannin levels are high in young leaves but decrease as leaves mature.

Honey: Bees harvest Robinia nectar to produce a honey regarded as one of the world's finest. Tree improvement specifically for late flowering and high nectar sugar content is ongoing in Hungary and the US.

Other: The tree is used extensively to rehabilitate surface mine tailings in the US. In Hungary, black locust is often grown for wood on small private farms (Keresztesi 1986) A dense growth habit makes black locust suitable for windbreaks, a use most common in China. Black locust may even prove useful for alley cropping in temperate climates. Researchers at the Rodale Research Center in Pennsylvania are experimenting with intercropping black locust with vegetables. Numerous reports indicate the beneficial effect of this NFT to associated plants through improved soil fertility. Mixed plantings of black locust

and conifers, however, can lead to reduced growth or death of the slower growing conifers because of shading and over-topping.

PESTS AND PROBLEMS. The most serious pest to black locust in the US is the locust borer, Megacyllene robiniae (Forster). There is some evidence for genetic resistance to the borer. Another insect confined to trees in the US is the locust twig borer, Ecdytolopha insiticiana (Zeller). Aphids, Nectria cankers, leaf miners, and Rimosus heart rot also affect the tree (Hoffard and Anderson 1982). Its propensity to root spout aggressively can also cause problems.

RHIZOBIUM. Robinia is fairly specific in its Rhizobium requirements. Although it will form nodules with a variety of exotic strains, for effective N-fixation, strains from native trees work best. Newly introduced trees require inoculation; inoculum may be gotten from the soil of black locust stands, or from NFTA. The tree's fine roots are also colonized by VA mycorrhizae.

PRINCIPAL REFERENCES:

Boring, L.R and W.T. Swank. 1984. The role of black locust (Robinia pseudoacacia) in forest succession. J. Ecol. 72:749760.

Fowells, HA. (ed). 1965. Silvics of Forest Trees of the United States.

USDA, Forest Service, Agric. Handbook No. 271.

Hanover, J.W. 1989. Physiological genetics of black locust (Robinia pseudoacacia L.): A model multipurpose tree species. Proc. Conf. on Fast Growing Nitrogen Fixing Trees, 1989, Marburg, W. Germany.

Hanover, J.W., T. Mebrahtu, and P. Bloese. 1989. Genetic improvement of black locust: A prime agroforestry species. Proc. First Conf. on Agroforestry in N. America, Aug. 1989, Guelph, Ontario, Canada.

Hoffard, W.H. and R.L. Anderson. 1982. A guide to common insects, diseases, and other problems of black locust. USDA Dept. Agric. Forestry Rep. SA-FR-19.

Keresztesi, B. (Ed). 1988a. The Black Locust. Akademiai Kiado, Budapest, Hungary.

Keresztesi B. 1988b. Black locust: The tree of agriculture. Outlook on Agric. (Great Britain) 17(2):77-85.

Singh, R.V. 1982. Fodder Trees of India. Oxford and IBA Public. Co., 66 Janpath, New Delhi 110001, India.

Stringer, J.W. and S.B. Carpenter. 1986. Energy yield of black locust

biomass fuel. For. Sci. 32:1049-1057.

Surles, S.E., J.L. Hamrick. and B.C. Bongarten. 1989. Allozyme variation in black locust (Robinia pseudoacacia). Can. J. For. Res. 19:471479.

A full list of highlight references is available from NFTA.

Sesbania grandiflora. NFT for beauty, food, fodder and soil improvement

Sesbania grandiflora is a tree that grows rapidly, provides light shade, and is often grown as an ornamental. This soft-wooded tree's leaves are used as fodder and its Rowers as food. Grandiflora is planted in gardens for its intercropping compatibility and soil-improving properties.

Botany

Sesbania grandiflora (L.) Poir. is a tree that grows to 8-10 m in height. The pink-red or white flowers of this papilionaceous (pea-like flowered) legume are unusually large (5-10 cm in length and about 3 cm wide before opening); this novelty may be the principal reason for grandiflora having been distributed by man throughout the tropics and subtropics. Within its genus, S. grandiflora is a member of the subgenus Agati, and it is thus more closely related to the unusual littoral

sesbanias of Pacific islands than to the more typical sesbanias of subgenus Sesbania, such as the perennial S. sesban and the annual sesbanias grown for green manure (such as S. cannabina).

Grandiflora's pinnate leaves may be 30 cm long, with 12-20 pairs of oblong, rounded leaflets averaging 3-4 cm long and about 1 cm wide. The leaves are borne at the terminals of branches, and the canopy is open, with a thin crown which produces light shade. Its racemes bear 2-3 flowers. The pods are usually 30-50 cm long by about 8 mm wide. The seeds are tan to red-brown, 6-8 x 3-5 mm, 14-20 weighing 1 g. The trunk may reach 25 cm diameter at breast height Grandiflora may live 20 years or more.

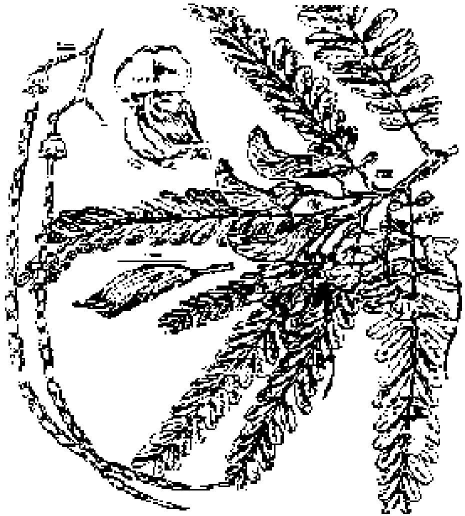
Grandiflora is very closely related to the endemic Australian species, S. formosa. This relationship supports the supposition that grandiflora may have originated in Indonesia. S. formosa bears white flowers and is often indistinguishable from grandiflora to the casual observer. The two species appear to have similar growth habits and adaptivity, and it is possible that S. formosa also can be used for the purposes described here for grandiflora.

Distribution

Grandiflora is found in cultivation throughout the tropics and subtropics.

Ecology

Because wild populations of grandiflora are unknown, its natural habitat is uncertain. Grandiflora is grown most successfully in the lowland tropics (below 1000 m elevation) and warm, frost-free subtropics. It can be grown in regions with as little as 800 mm rainfall or as much as 2000 4000 mm. It seems to prefer a bimodal rainfall distribution, growing rapidly during wet seasons but capable of withstanding prolonged dry seasons of up to nine months.



Sesbania grandiflora, from Sachet, M.-H 1987. The littoral species of Sesbania (Leguminosae) in the South Pacific islands and its relatives. Bulletin du Museum National d'Histoire Naturelle, section B. 4th series, Adansonia 9:3-27. (Focuses on subgenus Agati.)

Grandiflora is tolerant of soil salinity and waterlogging, and withstands occasional short periods of flooding. It is well adapted to heavy clay soils.

Uses

Fodder, food, and soil improvement are the principal uses for grandiflora

Fodder. Grandiflora is valued as a fodder in many regions. In south-central Lombok, Indonesia, grandiflora grown around rice paddy bunds provides up to 70 percent of the diets of cattle and goats during the annual eight-month dry season (Mudahan Hazdi, personal communication). The leaves contain as much as 25 30 percent crude protein.

Although ruminants readily consume grandiflora fodder, and its digestibility is high, some feeding studies have indicated that antinutritional factors are present. Until further research provides clear guidelines, caution should be used in feeding S. grandiflora to ruminants and other animals, and restricting feeding to less than 30 percent of dry matter intake is suggested. Grandiflora leaf is toxic to chickens and should not be fed to them or other monogastric animals.

Soil improvement. Grandiflora is often maintained in gardens and around crop fields for its contribution of nitrogen. The light shade cast by its canopy does not block much light, allowing the growth of companion plants. Falling leaflets and flowers recycle nutrients to the ground. Seedlings grow rapidly enough that they have been used

similarly to annual green manure crops. For example, grown around paddy bunds for incorporation before planting the subsequent rice crop.

Wood. The wood is rather light and not ideal for firewood or pulping; the bark is thick and corky and is a further detriment to either of these uses. The trunks may be used as poles for temporary shelters and sheds, but they may not last very long due to rots and insect infestation.

Food. Leaves, seed pods, and flowers of grandiflora are prepared as food. The young, tender pods are cooked similarly to other green beans. In South Asia the young leaves are chopped and sauteed, perhaps with spices, onion, or coconut milk. In the Philippines, unopened white flowers are a common vegetable, steamed or cooked in soups and stews after the stamen and calyx have been removed, Selection of white-flowered varieties that flower profusely has resulted from this use in the Philippines.

Other uses. Grandiflora has been used to shade nurseries and some crops, such as turmeric, as support for climbing crops such as pepper and betel vine, and as an element of windbreaks. The leaves of the tree have various uses in the herbal medical lore of certain regions.

Culture and Management Grandiflora is grown from seed, which may be planted without scarification. Stored seeds lose viability within a year or two. Seeds may be direct-sown or transplanted from nurseries; bare-rooted transplants are usually successful.

Seedling growth of grandiflora may be very rapid. Under harsh conditions or neglect, however, seedling survival may be poor. The leaf canopy is open and casts only light shade, hence its popularity in gardens.

Grandiflora cannot be coppiced or pollarded. Harvesting leaves for fodder must be done selectively, to avoid complete defoliation, and cannot be done more than a few times per year. More intensive harvesting, such as managing as a hedgerow, reduces the life of the tree. For example, cutting at I m high five times a year can result in tree modality. Because grandiflora establishes so rapidly, frequent replanting is a management option if heavy harvesting results in tree decline.

Where flowers and pods are harvested for consumption as vegetables, the structure of the tree is shaped by pruning so that the canopy remains low, within reach for convenient harvesting.

Symbiosis

The rhizobia strains that nodulate sesbanias are somewhat specialized and may not be present where sesbanias have not been grown previously. Test plantings should be done to see if infective rhizobia are present in the soil, or if use of a rhizobia seed inoculant at planting will be necessary.

Limitations

Grandiflora's soft wood is susceptible to damage by insects. Fodder cuttings cannot be severe. Seed recovery may be limited by pod pests. Seed viability declines after one year.

References

Evans, Dale 0. 1990. What is Sesbania? Botany, taxonomy, plant geography, and natural history of the perennial members of the genus. In: B. Macklin and D.O. Evans (eds), Perennial Sesbania species in agroforestry systems. Nitrogen Fixing Tree Association. p. 5-19.

Evans, D.O., and Macklin, B. (eds). 1990. Perennial Sesbania production and use. Nitrogen Fixing Tree Association. 41 p.

Evans, D.O., and Rotar, P. P. 1987. Sesbania in agriculture. Westview Press, Boulder, Colorado, U.S.A.
Financial support for this NFT Highlight was provided by the Rockefeller Brothers Fund through the Southeast Asia NGO Support Program.

Sesbania sesban: widely distributed multipurpose NFT

Sesbania sesban is a many-branched, soft-wooded tree that grows rapidly and is useful for fodder and green manure. This species has long been used for browse and soil improvement in India and Africa. Recent interest in multipurpose, nitrogen fixing trees has caused it to be collected, studied, and recommended for fodder "banks" and alley cropping.

Botany

Sesbania sesban (L.) Merrill is a tree that grows to 8 m height. This papilionaceous (pea-like flowered) legume bears racemes of 4-20 yellow flowers that may be lightly to heavily streaked with purple. Sesbans have pinnate leaves with 20-50 opposite pinnules on a rachis 3-12 cm long. The leaf rachis and the underside of the leaflets are often pubescent. The pods are usually 10-20 cm long and contain up to 40 seeds that are brown, or dark green mottled with black. The trees

usually have one main stem, but they may develop many side branches if they have space. Sesban's many branches often give the tree a shrubby appearance. It tends to have a spreading habit due to its wide branching angle (as wide as 45-60§).

Within its genus, sesban is classified in the subgenus Sesbania, and thus is more closely related to the annual sesbanias grown for green manure (such as S. cannabina, others?) than to the other well known perennial species of the genus, S. grandiflora, which is in the subgenus Agati (Evans 1990). Several varieties of sesban are recognized The botanical distinctions among sesbanias are often difficult for non-botanists to see, and sometimes sesban is confused with the annual types of sesbania

Ecology

Sesban occurs naturally in semiarid to subhumid areas with 500-2000 mm of rainfall. It seems to do well under bimodal rainfall distributions, where heavy rains and even flooded conditions are followed by a progressively drier season. It grows from sea level to 2000 m elevation, but the upper limit is uncertain. It does not tolerate frost It is uniquely well adapted to periodic waterlogging and flooding. Soil alkalinity and salinity is tolerated to a considerable degree. Some research suggests

that certain sesban types may grow well on acidic soils.

Sesbans are relatively short-lived, and under intensive browsing or cutting management will not last more than 3-5 years. Their rapid seedling growth is conducive to short-term fallows and to replanting if management should reduce growth vigor.

Distribution

Sesban is found throughout the tropical and subtropical pans of Africa, Asia, and Australia It is not widely distributed in the Americas. Africa is its center of diversity, and sesban probably originated there its former name is S. aegyptiaca. From northeastern Africa, S. sesban var. sesban and its variants were spread across southern Asia, possibly by man. Within Africa, S. sesban var. nubica is the type most commonly found, and there are several sesbanias closely related to sesban, such as S. goetzei and S. cinerascens (Gillett 1963).

Sesbania sesban

Uses

Sesban is mostly used as fodder and for soil improvement, its wood is used only to a lesser extent (Evans and Macklin 1990).

Fodder. The leaves and tender branches of sesban are high in protein

(20-25% crude protein) and have high digestibility when consumed by ruminants, such as cattle and goats. Antinutritional factors are suspected to be present in sesban fodder. Feeding sesbania fodders to monogastric animals (such as chickens, rabbits, and pigs) is not recommended.

Reports of feeding sesban to ruminants conflict. Trials in Australia feeding sesban to heifers showed live weight gains, but trials with young goats in Samoa found a lack of weight gain. Until further research provides clear guidelines, caution should be used in feeding ruminants with sesban fodder at more than 10-20 percent of diet.

Soil improvement. Sesban establishes quickly and grows rapidly. In Africa it is often allowed to grow scattered throughout annual crop fields for the nitrogen it provides. It has been used in experimental alley cropping systems to provide mulch and greenleaf manure to intercrops. Sesbans can be somewhat shallow rooted, and may compete with adjacent crops.

Wood. Sesban's wood is light in weight compared to the woods of Calliandra and Leucaena, but it is often harvested for firewood in Africa and India. It has been used in India to make charcoal. The wood is not durable and should not be considered for timber use. The branches have

been used as poles in temporary structures such as sheds and mud daub hues.

Because sesban grows so rapidly, it has potential for pulpwood production. Plantings at about 10,000 trees/ha have produced 15-20 tons of woody biomass (dry weight) in one year.

Food. Flowers of sesban are known to be added to stews and omelets in some regions, perhaps mainly as a decorative element.

Other uses. Various medicinal uses for sesban have been recorded in Africa and Asia (Evans and Rotar 1987, Evans and Macklin 1990). The leaves and flowers are used in medicinal poultices and teas, which are said to have the effect of astringence, or contraction of body tissues. Bark exudates from sesban produce a gum of medium commercial quality.

Culture and Management

Sesban is generally propagated from seed, although it has been rooted from cuttings, and research has revealed that it can be established by tissue culture. Seed scarification usually improves germination. Recommended hot water scarification is a 30-second dip in water heated to just below boiling. Seed weights range from 55-80 per gram

for S. sesban var. sesban to 80-130 per gram for var. nubica.

Plants grown for fodder production can be placed as close as 30-50 cm apart in rows I m apart. Appropriate distances between rows in alley cropping will depend on the variety grown, the ecology of the site, and intensity of management.

Experimental fodder cutting trials have yielded 20 tons/ha dry matter in the first year. However, sesban cannot be managed with the severity that Leucaena tolerates in fodder and wood biomass production systems. If sesban is cut too low (below 50-100 cm) or too frequent (more than 4-6 cuttings per year) death of the plants can result When cutting sesban it is recommended to leave 10-25% of the foliage on the plants.

In some climates, such as the highlands of Kenya, sesban may have a sparse canopy and weed competition can be a problem. This characteristic makes sesban a good intercrop. Sesban has been grown with the fodder grass Brachiaria mutica in India, and to provide shade to young coffee plants in Kenya. In climates where sesban grows more vigorously, weeds are shaded out and companion plants may be adversely affected; this type of growth has been observed in Hawaii and Jamaica (Rosherko et al. 1991).

Symbiosis

The rhizobia strains that nodulate sesbanias are somewhat specialized and may not be present where sesbanias have not been grown previously. Test plantings should be done to see if effective rhizobia are present in the soil. If not use of a rhizobia inoculant at planting will be necessary.

Limitations

Sesban is not a tree for timber or reforestation in the ordinary sense of forestry or silviculture. Because the range of its ecological adaptability is not yet well known, test plantings should be done before large-scale plantings are planned. Sesban has been observed occasionally to die back under cutting management fungal infection may be the cause. Leaf-feeding insects sometimes limit production. Seed chalcids can reduce seed recovery.

References

Evans, Dale O. 1990. What is Sesbania? Botany, taxonomy, plant geography, and natural history of the perennial members of the genus. In: B. Macklin and D. O. Evans (eds), Perennial Sesbania species in agroforestry systems. Nitrogen Fixing Tree Association. p. 5-19.

Evans, D. O., and Macklin, B. (eds). 1990. Perennial sesbania production and use. Nitrogen Fixing Tree Association. 41 p.

Evans, D. O., and Rotar, P. P. 1987. Sesbania in agriculture. Westview Press, Boulder, Colorado, U.S.A.

Gillett, J. B. 1963. Sesbania in Africa (excluding Madagascar) and southern Arabia. Kew Bulletin 17:91-159.

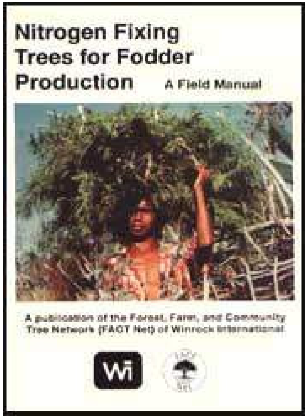
Roshetko, J. M., Lantagne, D.O., and Gold, M. A. 1991. Direct seeding of fodder tree legumes in Jamaican pastures. Nitrogen Fixing Tree Res. Reports, 9:68-70.

Financial support for this NFT Highligh, was provided by the Rockefeller Brothers Fund through the Southeast Asia NGO Support Program.

Home"" """""> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

Nitrogen Fixing Trees for Fodder Production - A Field Manual (Winrock, 1996, 125 p.)

(introduction...)



Acknowledgments

This manual was written by the participants of the International Workshop on Nitrogen Fixing Trees for Fodder held in Pune, India from March 20 - 25,1995. The workshop was organized by BAIF Development Research Foundation and the Forest, Farm and Community Tree Network (FACT Net formerly the Nitrogen Fixing Tree Association) of Winrock International. Members of the planning committee were Narayan Hegde of BAIF, Joshua Daniel of the FACT Net India Program and James Roshetko of Winrock International. They were assisted by

BAIF staff members Tinku Dhar, Sandhya Bharambe, Vinayak Kelkar and Suresh Lakade, as well as Trudy Stacy of Winrock International.

Financial support for the workshop was provided by the:

- **United States Department of Agriculture, Forest Service - International Forestry (USDA/FS/IF)**
- **Danish International Development Agency (DANIDA) in New Delhi**
- **Indo Swiss Project of Andhra Pradesh (ISPA)**
- **National Bank for Agricultural & Rural Development (NABARD)**
- **BAIF Development Research Foundation**
- **Winrock International**

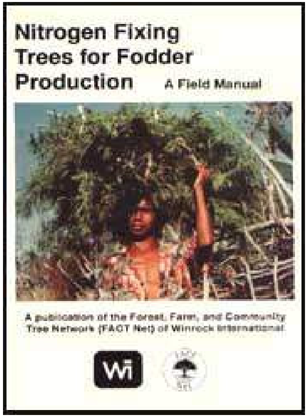
Specific support for this manual was provided by USDA/ FS/IF and Winrock International.

The authors of this manual deserve special thanks. They worked diligently during the workshop to prepare drafts of each chapter. After the workshop, many authors continued to provide useful comments through correspondence. Additionally, Mark Powell and Mary Mackey provided technical commentary, Doris Cook provided computer support, and Joyce Olds provided graphic and design assistance.

The editors offer their sincere thanks to these individuals and

organizations.

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



Nitrogen fixing trees for fodder production

James M. Roshetko and Ross C. Gutteridge

Livestock play an important role in small-scale farming systems throughout the world. They provide traction to plow fields, manure to fertilize crops, and food products for human consumption. Most often livestock graze fallow fields, pastures and woodlands deriving most of their sustenance from crop residue, grasses and other herbaceous plants. A smaller but important component of livestock diets comes from tree fodder. Farmers harvest tree fodder from natural forests, savanna and woodlots. Additionally, they often deliberately propagate trees on their farms to expand fodder resources.

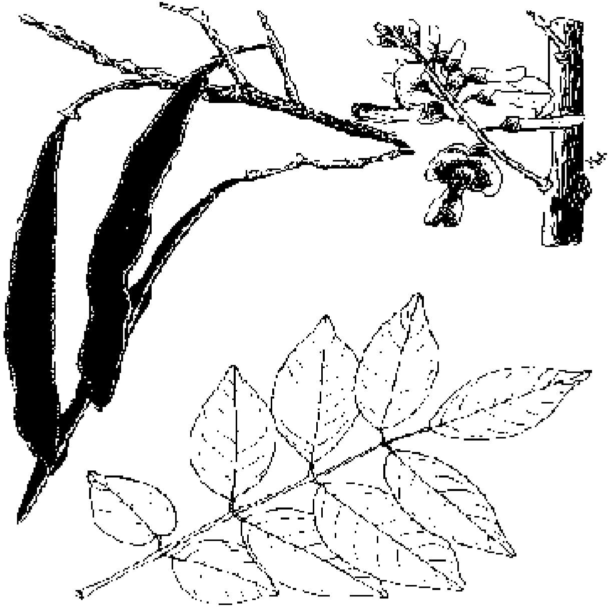
Many of the most important fodder trees are nitrogen fixing species. Through a symbiotic relationship with Rhizobium soil bacteria these species are able to fix atmospheric nitrogen into a form they can use for growth. This ability enables nitrogen fixing trees (NFTs) to tolerate infertile sites and produce protein-rich fodder without high inputs of artificial N fertilizer. Nitrogen fixation is discussed in more detail in Chapter 2.

There are a number of characteristics that make NFT species

particularly valuable for fodder. These include:

- **the ability to fix atmospheric nitrogen**
- **adaptability to poor and difficult sites**
- **fast growth**
- **the ability to compete with other vegetation**
- **multiple uses and complementary tree architecture**
- **productivity under repeated harvesting**
- **high nutritive value and acceptability to animals**
- **easy propagation**

Flemingia macrophylla - a widely used nitrogen fixing fodder tree.
Source. National Taiwan University, 1965



Gliricidia septum - a widely used nitrogen fixing foddder tree. Source: Little and Wadsworth, 1989.

In order for a NFT to be productive it must have the ability to survive and compete in the climatic and soil conditions of the site in question. Humid zone species are not productive in arid environments, lowland species are not productive in alpine regions. When propagating NFTs, the site's environmental conditions should be matched with the

environmental requirements of potential species. Elevation, mean annual precipitation, length of annual dry season, mean annual temperature and soil characteristics are of particular importance. Tree selection for specific sites is discussed in Chapter 3. Many NFTs grow well on infertile or difficult sites. This ability is valuable as most fertile soils are used for food crop production, leaving marginal or poor soils for fodder tree production. NFTs help improve the sites when their nitrogen-rich leaves and branches senesce, fall to the ground as litter and are incorporated into the soil.

Seed germination and seedling growth of fodder trees should be relatively fast. This will provide a rapid supply of livestock feed and enable trees to compete with other vegetation. Competition between tree seedlings and pre-existing grasses can be intense. Normally, several months of weed control is necessary to assure successful fodder tree establishment. Fodder tree propagation and establishment methods are discussed in Chapter 2. In some situations tree species can be excessively competitive; do not allow these trees to dominate or eliminate useful companion plants. Before introducing a new species to an area establish a small evaluation trial to determine its potential. If the trees show signs of becoming weedy, early prolific seeding or root sprouts, remove them before these problems occur.

Most nitrogen fixing fodder trees provide multiple products and services. They are planted on contours to stabilize soil, on boundaries as living fences, with grasses and shrubs to form multiple layer fodder banks, or scattered around the farm where site characteristics are too poor to support food crops. In all of these systems, fodder trees may also provide fuelwood, poles, timber, fruit or other products for home consumption and sale in local markets. Simultaneously, fodder trees may decrease erosion, rejuvenate soil, or serve as ornamentals. Many NFTs have deep roots that utilize nutrients in the subsoil below the rhizophere of companion crops. Through leaf and branch litter, these trees recycle nutrients to the soil surface for use by other plants. Conversely, trees with shallow roots may compete heavily with other plants. Such trees are inappropriate components of most agroforestry or intercropping systems. Some NFTs have wide spreading crowns which cast light shade. These trees improve the micro climate for livestock, pasture grasses and shade loving crops. NFTs with vertical crowns cast little shade and are ideal companion plants for crops which need full sunlight. Always choose a fodder tree species that provides products and services that are complementary to the landowner's objectives and management system. Detailed information on various fodder production systems is provided in Chapter 4.

The main purpose of establishing nitrogen fixing fodder trees is to

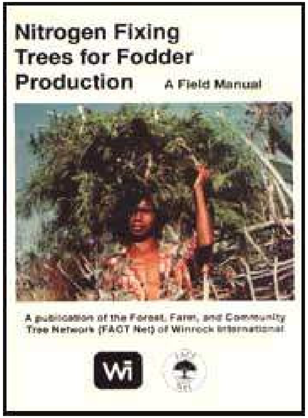
produce reliable quantities of livestock feed. To achieve this goal, trees must be able to with stand repeated defoliation by cutting or grazing. Neither tree growth nor survival should be adversely affected by an intensive management regime. Vigorous resprouting and high foliage productivity under repeated harvesting over many years is a trait required of fodder trees. Such long-lived hardy trees will enhance the sustainability of a livestock production system. A species intolerant of repeated harvesting is useless as a reliable fodder source.

Generally, nitrogen fixing fodder trees have a high nitrogen/protein content in their foliage. This characteristic is significant because protein is often the nutrient that limits livestock performance. During dry seasons and droughts, grasses and other herbaceous feeds desiccate and suffer a decrease in protein and nutrient value. Trees have deep root systems that allow tree fodder to remain green and nutritious during dry periods when it can be utilized as a supplement to improve the digestibility and nutritive value of dry feeds. Besides high nutrient content, tree fodders often contain levels of anti-nutritive compounds that assist digestion without harming the animal. More information on the nutritive value of tree fodders is found in Chapter 5. The selected fodder tree should also be acceptable to the livestock being raised. Large quantities of some fodders can be safely consumed only by ruminants (cattle, buffalo, goats, sheep, etc.). Other fodders have

offensive smells or textures. Livestock must "learn" to eat these fodders before the species can be fully utilized. Before introducing a new species to an area, test local livestock's acceptance of the new fodder.

A final characteristic required of fodder trees is ease of propagation. A species can not furnish reliable quantities of fodder if establishment is difficult or prolonged. Fodder trees must produce adequate sup plies of viable seed, or be easily propagated by vegetative methods. Vegetative propagation is time consuming when establishing large areas and only practical with a limited number of fodder trees (see Chapter 2). In most circumstances, it is best to select a fodder species which produces viable seed in the environment in which it is planted, or a fodder species for which dependable inexpensive supplies of seed are available on a commercial basis. When producing seed of NFTs the factors to be considered include genetic diversity, quality of mother trees, location of collection area, collection techniques and seed handling and storage procedures. Basic guidelines for seed collection and multiplication of nitrogen fixing fodder trees are summarized in Chapter 7.

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



Fodder tree establishment

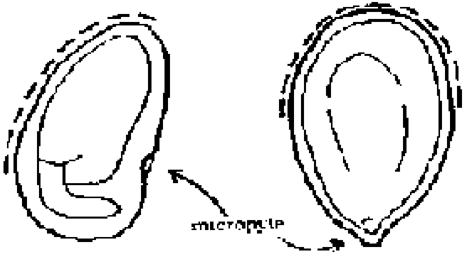
James M. Roshetho and Ross C. Gutteridge

Site Preparation To assure adequate establishment of nitrogen fixing fodder trees, it is necessary to practice thorough site preparation. This

is particularly important in grass ecosystems, where fodder trees are often planted. The objective of site preparation is a seed bed with limited weed competition, where tree seedlings can thrive. At a minimum, remove all vegetation within 50 cm of the position where seedlings or seed will be planted. Both above ground and below ground plant biomass (i.e. stems and roots) must be removed. If rows of fodder trees are being established, meterwide seed beds the length of the rows must be prepared. For individual fodder trees, seed beds one meter-diameter are sufficient. Removal of vegetation can be achieved by manual, mechanical, chemical or a combination of means. Cultivating the soil of the seed bed will also help seedling establishment and growth. The size and depth of the seed bed depends on the planting site, soil type, tree species, and fodder production system. Site preparation methods used locally for other tree crops should be appropriate for fodder trees also. A well-prepared seed bed also encourages weed growth. To minimize weed growth and competition, site preparation should occur immediately before fodder tree establishment.

A few precautions are warranted. The use of burning as a site preparation method is not recommended, unless experienced personnel are present. The removal of 100% of the vegetation from a site is not advisable. Complete removal of the vegetation is costly and leaves the

site vulnerable to soil erosion. Furthermore, some of this vegetation may provide a useful fodder, mulch, fuel or other product. If vegetation is not impeding tree seedling establishment, it should not be removed.



The seedcoat is nicked opposite the microphyle or hilum (along the dotted line) to avoid damaging the seed embryo. Source: FACT Net.

Propagation Seed Scarification Nitrogen fixing fodder trees are usually established by directly sowing seeds or by transplanting seedlings. The seed of many of fodder species have hard, waxy or thick seedcoats that inhibit water absorption and delay germination. Under natural conditions, seedcoats are degraded by exposure to sun, rain, wind and animals. This slow process results in uneven seed germination. When establishing a fodder production system it is easiest to protect the seedlings when they are of uniform age and size. Uniform seedling size can be achieved through seed scarification - a process designed to penetrate the protective seedcoat and allow seed to absorb water and

germinate at a uniform rate. The most common scarification treatments are cool water, hot water, acid and nicking.

Cool water - Seeds are soaked in cool, room-temperature water until they swell. The volume of water should be five times the volume of seeds. Soaking time is 12-48 hours depending on species, provenance, age and quality of seed. This treatment is appropriate for seeds with a thin or soft seedcoat, recently harvested seed, seed of small-size, and large quantities of seed.

Hot water - Boiling water is poured over the seeds at a volume five times the volume of seeds. The seeds must be stirred gently during the 2-5 minute soak. Hot water can kill the seed - it is important not to soak the seed for too long! Pour off the hot water, replace it with cool water and soak for 12 hours. This treatment is appropriate for seeds with hard or thick seedcoats, old seed, and large quantities of seed. It is best to treat a small quantity of seed first to make sure your technique is correct before attempting to treat large quantities of seed.

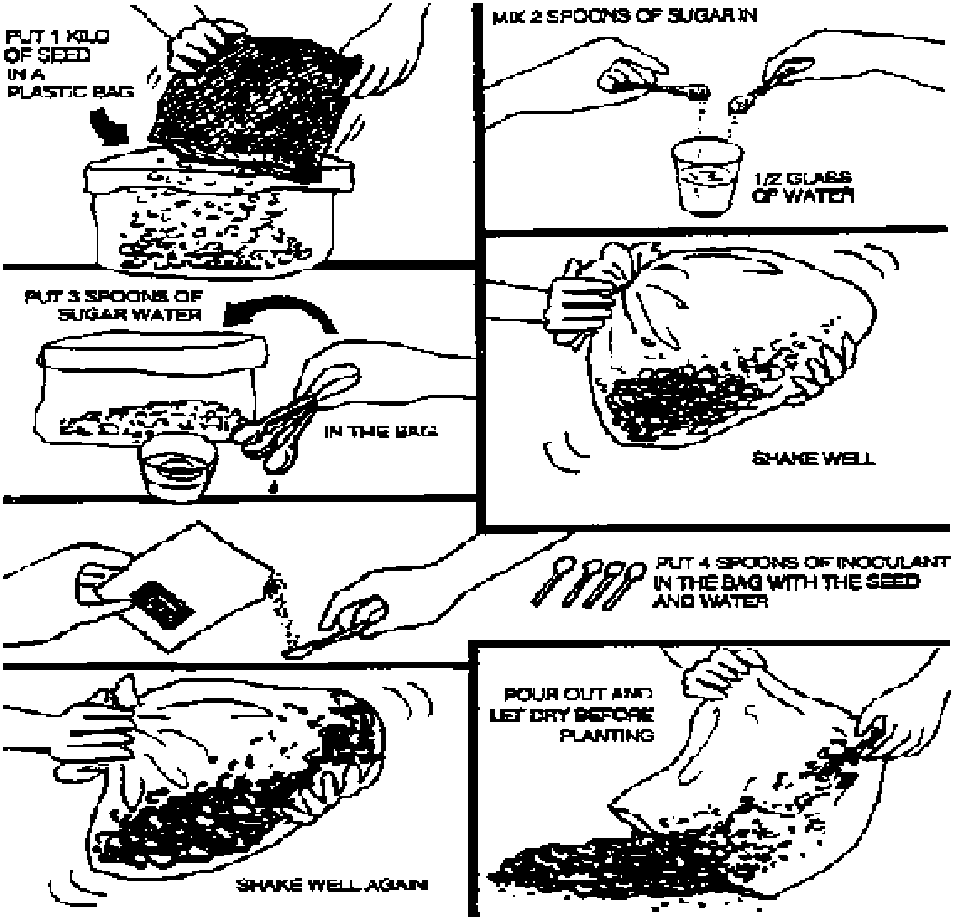
Acid - Cover seeds with sulfuric acid for 10 60 minutes. Seed should be completely submerged but just below the surface of the acid. Acid can kill the seed - do not soak the seed for too long! Gauge the length of acid treatment by the appearance of the seed. The waxy gloss of the

seedcoat should be replaced by a dull appearance. A pitted appearance indicates damage - remove the seeds before this occurs. Remove seed from acid, rinse with water for 10 minutes and soak in cool water for 12 hours. Do not pour water into the acid or a violent reaction will occur! The acid can be used several times. This treatment is appropriate for seeds with hard and thick seedcoats. Acid treatment can be dangerous! In most circumstances it is not recommended!
Nicking - Cut or scrape a small hole in the seedcoat. A knife, nail clipper, file, sand paper or sanding block can be used for this operation. To avoid damaging the seed embryo, cut or scrape the seedcoat opposite the micropyle. Soak the nicked seed in water for 12 hours. This treatment is appropriate for all types of seed. However, nicking seed by hand is time consuming and only feasible for small quantities. Large quantities of seed may be nicked using a meat grinder, gristmill or thresher.

No treatment - Some seeds germinate quickly without treatment. Application of the above methods may be impractical, make seed difficult to handle or decrease viability. No treatment is needed for tiny seed (i.e. Desmodium spp.); seeds with thin or incomplete seedcoats; and recalcitrant seed (i.e. Erythrina edulis).

The length of the initial soak in cool water, hot water or acid will vary

according to species, provenance, age and quality of the seed. If large numbers of seedlings will be produced, or nursery operations will last for several years, it is recommended that several soaking times be tested in order to determine the most suitable time length for local conditions. As noted, with all methods the last process is to soak seed in cool water for 12 hours. This final process allows seed to absorb water, results in visible swelling and further hastens germination. To improve this process, and thus germination, this period may be increased up to 48 hours. Once removed from the final soaking sow seed immediately! The scarification process allows seeds to germinate quickly by penetrating the protective seedcoat. If sowing is delayed, the seed will dehydrate resulting in decreased seed viability and weak seedlings. Table 1 summarizes appropriate seed scarification methods for common nitrogen fixing fodder trees. Appendix A lists organizations that furnish seed of nitrogen fixing fodder trees.



Application of Rhizabium inoculant to seeds of nitrogen fixing trees.

Source: NifTAL Project.

Rhizobium Inoculation. The seed of nitrogen fixing trees should be treated with Rhizobium inoculum after scarification and prior to sowing. Rhizobium bacteria and NFTs form a symbiotic relationship that enables the trees to "fix" atmospheric nitrogen into a form useful for plant growth. This relationship allows NFTs to grow on infertile or degraded soils where available nitrogen is in low supply. The nitrogen fixation process occurs in nodules formed by the bacteria on the tree roots. To determine the health of nodules cut them open. A red or pink color indicates nodules are fixing nitrogen. Green, brown or black nodules are not fixing.

There are many strains of Rhizobium bacteria. These strains and NFTs often exhibit exclusive preferences for each other. Some bacteria will form nodules with some NFTs but not others. Likewise, trees may form nodules with many strains or just a few. A successful match will produce healthy nodules. If an NFT is native or naturalized in an area, the soil will likely contain appropriate Rhizobium strains. However, if the tree does not occur locally, or the site is degraded, populations of the appropriate Rhizobium strains may be too low to form healthy nodules.

To assure an effective Rhizobium-NFT match, it is best to use a Rhizobium inoculant. Inoculants are produced in laboratories and contain 1000 times the bacteria found in most soils. The bacteria in the inoculants are alive. They are sensitive to heat, dehydration, direct sunlight and low temperatures. It is best to use inoculants when received - viability decreases greatly after 6 months. When storage is necessary, the inoculant should be placed in an airtight bag (being sure to exclude all air) and stored in a moist, cool and dark place. Inoculant is available from organizations listed in Appendix A. When ordering inoculants be sure to specify the NFT species you plan to inoculate.

To apply inoculants, first cover seeds with a sticker solution. Place seeds in a plastic bag or bucket and cover them with a solution made of gum arable, sugar or vegetable oil. Either dissolve 40 g of gum arabic in 100 ml of hot water and allow to cool, or dissolve 1 part sugar in 9 parts water. Combine 2 ml of one of these mixtures, or 2 ml of vegetable oil, with 100 g of seeds and shake or stir until the seeds are well covered. Then add 5 mg of inoculant and shake or stir until the seeds are well covered with inoculant. Allow the inoculated seeds to dry for 10 minutes to eliminate any stickiness and sow immediately. Do not store inoculated seed - the bacteria will die.

Species	Treatments	Seeds/kg
[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]
Acacia aneura	A; C	75,000-95,000
Acacia angustissima	C; D	90,000-100,000
Acacia holosericea	A for 1 min.; C	70,000-80,000
Acacia leucophloea	A; B for 10-30 min.; C	37,000-50,000
Acacia melanoxylon	A; B for 15min.; C	60,000-100,000
Acacia nilotica	A; C; D	7,000-11,000
Acacia polyacantha	D	10,000-25,000
Acacia saligna	A; C	14,000-25,000
Acacia senegal	C; D	10,000-30,000
Acacia seyal	A; B; C	20,000-25,000
Acacia tortilis	A; C; D	12,000-18,000
Adenanthera pavonina	A for 1 min.; B	3,600
Albizia lebbeck	A; C; D	6,000-16,000
Albizia odoratissima	A for 1 min.; D	21,000
Albizia procera	A; C	20,000-24,000
Albizia saman	A; C	6,000-8,000
Cajanus cajan	D; E	5,000-12,000
Calliandra calothyrsus	A; C; D	16,000-20,000
Chamaecytisus palmensis	A for 4 min.	38,000-42,000
Dalbergia spp.	D	10,000-30,000
Desmodium spp.	E	500,000-600,000
Enterolobium cyclocarpum	C; D	800-2,000
Erythrina edulis	E - (recalcitrant seed)	60-160
Erythrina poeppigiana	D; C	3,000-5,000
Erythrina variegata	A	3,000-5,000
Faidherbia albida	A; B for 20 min.; C; D	20,000-40,000
Flemingia macrophylla	A; B for 15 min.; D	50,000-60,000
Gliricidia sepium	C; D; E	7,000-12,000
Leucaena spp.	A; B for 5-15 min.; C	22,000-35,000
Ougeinia dalbergioides	D for 24 hours	28,000-33,000
Paraserianthes falcataria	A; B for 10 min.; C	40,000-50,000
Pithecellobium dulce	C; E	9,000-25,000
Pongamia pinnata	E	15,000
Prosopis spp.	A; C	20,000-50,000
Robinia pseudoacacia	A; B for 20-60 min.; C	35,000-50,000
Sesbania grandiflora	C; D	20,000 30,000
Sesbania sesban	A; C; D	85,000-100,000

Key: A - Hot water; B - Acid; C - Nicking; D - Cold water; E - No treatment

Table 1. Seed scarification treatments for selected nitrogen fixing fodder tree species (Revised from Macklin eta/. 1989).

Seedlings can also be inoculated in the nursery after germination. Mix inoculant in cool water and irrigate the seedlings with the suspension. Keep the mixture well shaken and irrigate until the inoculant is washed into the root zone. A 50 g bag of inoculant is sufficient to inoculate 10,000 seedlings. For more information on the NFTs-Rhizobium relationship and inoculation methods consult Keyser (1990), Postgate (1987) and Somasegaran and Hoben (1985).

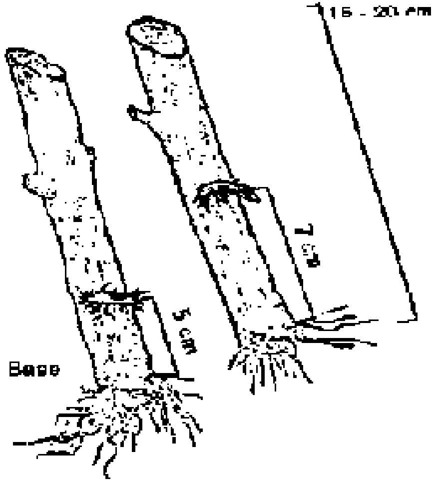
It may not always be possible to obtain laboratory-produced inoculant. At such times, soil containing the appropriate bacteria can be gathered from under trees of the same species being grown in the nursery. Choose healthy trees that are growing well and have abundant red or pink nodules. Some of this soil can be mixed with nursery potting mix or added to planting pits. Inoculation by this method assures that the bacteria will be appropriate for the tree species and the local environment. However, this approach may not be as effective as using a correct laboratory-produced inoculant.

VAM Inoculation. Like Rhizobium, vesicular-arbuscular mycorrhizal fungi (YAM) are soil organisms that invade the roots of NFTs and other

plants to form symbiotic relationships. Plants provide VAM food in the form of carbohydrates. VAM infection improves plant survival and growth by enhancing the root's ability to absorb moisture, macro-nutrients and micro-nutrients from the soil. Increased access to phosphorus is a specific advantage of VAM symbiosis. This relationship helps plants to colonize infertile or degraded sites. Unlike other mycorrhizae, VAM does not produce visible external hyphae; its branched hyphae are mainly contained within the infected root. The spores of VAM are formed near infected roots in the organic layer of the soil. They are large and are not disseminated by wind like the spores of other mycorrhizae. To assure the VAM-plant association, seedlings or seed should be inoculated in the nursery. Inoculation is particularly important when trees are to be planted on degraded sites where the organic soil has been removed.

VAM inoculation is usually accomplished by incorporating the organic soil from beneath a healthy host-plant into the nursery soil at a rate of 5-10% per volume. This method is simple and appropriate for most farm-level or community nurseries. However, it entails moving large amounts of soil and may transfer pathogens from forest soils to the nursery. It is not possible to sterilize forest soils because the process will also kill the VAM. For larger nurseries, a second option is to construct a "VAM production bed." First, collect infected soil as

described above and completely fill a nursery bed. Next, sow seed of the appropriate host plant at a close spacing. Once well established, the roots of the infected plants, an VAM, will permeate the soil in the nursery bed. Remove the soil and roots, and then finely chop and mix them into the nursery soil as an inoculant at a rate of 5-10% per volume. This method, while more expensive and management intensive than collecting soil beneath a healthy host-plant, is appropriate if many seedlings are to be produced over a number of years. Healthy host-plants should be maintained in the VAM production bed to assure continued supply of VAM inoculant.



Some species of nitrogen fixing fodder trees can be propagated from small stem cuttings 15-20 cm in length and 1.0-1.5 cm in diameter. Scarring on the lower portion of the stem will promote rooting. Approximately 50-75% of the cutting should be buried in the soil. source: FACT Net.

Recent advances in technology have made laboratory production of VAM inoculants practical. Several commercial inoculants are available which are appropriate for NETs. Companies offering VAM inoculants are listed in Appendix A. Readers interested in more information on VAM and inoculation are encouraged to consult Casetellano and Molina (1989), Ferguson and Woodhead (1982), and Malajczuk et al. (undated).

Seed Sowing. As previously mentioned, seed can be sown in the nursery or directly in the field. In either case, the seed bed or nursery soil should be well cultivated and free of weeds. Seeds should be sown in the soil to a depth of once or twice their width. In field plantings where rapid soil drying is likely to occur, the depth of sowing can be increased to 10 times the width of the seed. The seed should be covered with soil, sand or mulch. When using mulch, be sure it does not contain weed seeds! For most species germination will occur within 1-3 weeks. Young germinants are sensitive to dehydration, weed competition and

insects. Care must be taken to guard against these dangers.

For nursery production, standard local nursery methods are recommended. Further information on nursery practices and management is available in standard texts on the subject. Depending on the species, seedlings are ready for transplanting to the field after 6 -16 weeks in the nursery. Seedlings should be "hardened" in direct sunlight for at least one week before transplanting, preferably at the beginning of the wet season. Because of the large number of trees planted in most fodder production systems, establishment is usually achieved by direct sowing. This method is more cost-effective than nursery production, however, there is less control over the planting site. Direct sowing operations should be conducted only during the rainy season.

Vegetative Propagation. Some nitrogen fixing fodder species can be established from vegetative cuttings. Propagation techniques differ greatly from species to species but generalizations are possible. Gliricidia sepium and most Erythrina species are commonly propagated by large cuttings 1-3 meters in length. These species, as well as, Albizia spp. and Dalbergia spp. are also reproduced by small stem cuttings 15-20 cm in length and 1.0-1.5 cm in diameter. Ougenia dalbergioides can be propagated by root cuttings of similar size.

Straight and healthy stems, branches, coppice growth or roots are recommended for vegetative propagation. Branch cuttings may retain their original morphology resulting in crooked trees. While crooked trees are not aesthetically pleasing, their morphology has no negative effect on fodder production or quality. Cuttings are usually harvested at the end of the dry season or beginning of the rains. The use of sharp clean tools will produce healthy undamaged cuttings. The cuttings of some species can be stored for up to 15 days before planting. Storage should be in a cool, dry and shady place with good aeration. Do not pile cuttings directly on the ground. Large cuttings should be stored vertically.

Water accumulation on the tips of cuttings can cause stem rot. To avoid this problem the apical (top) end of cuttings should be cut at a 45 angle. Rooting is promoted by scarring the lower portion of the cutting which will be buried. Scarring should be done with a sharp knife and should penetrate the cambium. If available, treat scars with a rooting hormone. Cuttings should be planted, not "pushed" into the ground - "pushing" will cause damage to the bark and result in weak roots. Large cuttings should have 30% of their length buried in the soil. Small cuttings should have 50-75% of their length buried. If small cuttings are raised in a nursery, large containers or deep beds must be used. Cuttings will be ready for transplanting to the field after 2-4 months.

It should be noted that root development of cuttings is generally shallow. Cuttings generally produce shallow root systems without a strong, deep taproot. Shallow root systems leave trees vulnerable to drought and blow-down during windstorms. Also, while cuttings provide quick establishment, time and labor-costs per plant are greatly increased. In most fodder production systems, propagation by seed is preferred.

Field Management After germination or transplanting, the top growth of most nitrogen fixing fodder seedlings is slow.

Initially, the seedling's growth energy is allocated to root system development. While this growth pattern aids long-term tree survival, it does not assist young seedlings become established among pre-existing vegetation - even where adequate site preparation has been completed. In most ecosystems, competition for sunlight, soil moisture and soil nutrients is intense and young slow-growing trees are often the losers. Competition is particularly intense when trees are planted in grass ecosystems. Grasses, and other herbaceous plants, have intensive root systems with many fine roots which densely permeate the upper soil layers. By contrast, trees have extensive root systems with thick roots which sparsely penetrate large volumes of soil. Grasses and trees are ecologically antagonistic, once present, grasses often prevent the

establishment of trees.

When trees are small, grass and other weed competition must be controlled. While management regimes differ by site and species, a good recommendation is to remove all vegetation within 50 cm of the trees every 2-4 weeks. The objective is to deny weeds the opportunity to impede tree growth. As trees gain size, the frequency of weed control operations can be reduced. However, weed control must be maintained until the trees achieve a dominant position and begin to suppress competing vegetation. This usually occurs within 6-12 months of tree establishment. It is not necessary or desirable to remove 100% of the weed competition. Some vegetation - particularly grasses - are valuable fodder and improve the overall productivity of the fodder production system.

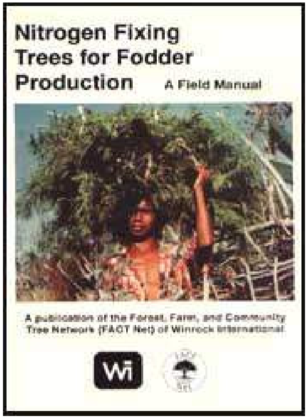
Fertilizer application can improve fodder tree growth and survival. However, little information is currently available concerning appropriate fertilization regimes for most fodder trees. A detailed study undertaken at the University of Queensland in Australia indicated that Leucaena leucocephala has a high requirement for phosphorus and calcium. On infertile soils, growth responses will occur at rates up to 225 kg P/ha and 230 kg Ca/ha. However, if the L. Ieucocephala plants have formed an association with VAM, much lower rates of phosphorus

fertilizer give the same response.

When fertilizers are applied it is essential to practice thorough weed control. The intensive root systems of herbaceous weeds respond quickly to fertilizer application. Trees respond more slowly. Left unchecked, weeds will suppress trees. Fertilization without adequate weed control results in decreased fodder tree survival and growth. In rural areas, fertilizers can be expensive or unavailable. For these reasons, fodder trees on small-scale farms are generally not fertilized.

The longevity of fodder trees is increased when the first harvest is delayed until trees are 9-21 months old. Actual age at first harvest depends on environmental conditions and tree growth. Under arid or poor soil conditions, growth will be slow and the first harvest should be later. When growth is fast, the first harvest can be sooner. The goal is to allow trees to establish deep roots. The resultant healthy plants will have ample carbohydrate reserves to resprout quickly and vigorously after harvesting. Fodder production per harvest and long-term fodder production both increase when the first harvest is delayed. The first harvest, whether by cutting or grazing, may terminate the downward growth of the roots. This is an important consideration, particularly in arid and semi-arid environments.

Fodder trees are a valuable crop that can sustain or increase livestock production. They should be managed intensively. Most often fodder trees are established in integrated systems with grasses or other fodder crops. While trees and herbaceous plants are ecologically antagonistic, their fodder products are complementary, together forming well-balanced livestock diets. Fodder trees should be managed to improve the livestock production system, not necessarily to maximize tree growth or tree fodder production.



Selecting species of nitrogen fixing fodder trees

James M. Roshetho, J.C. Dagar, Sunil Puri, D.Y. Khandale, P.S. Takawale, G. Bheemaiah, and Narayan C. Basak

There are numerous nitrogen fixing tree species which can be used as fodder resources. Each of these species has a unique combination of environmental requirements and secondary uses. When establishing tree fodder production systems, be sure to select species that are appropriate for local environmental characteristics and provide the necessary products and services. The selection process should include evaluation of the planting site; identification of the primary and secondary uses of the trees in the systems; and review of information on suitable species.
The minimum site characteristics to be evaluated include elevation, average annual rainfall, and average annual temperature. Additionally,

number of months with less than 50 mm of rainfall, annual maximum and minimum temperatures, and soil parameters are also useful. Important soil parameters are texture, depth, drainage, pH, and nutrient content (nitrogen, phosphorus and potassium). Table 1 provides a list of common nitrogen fixing fodder trees summarized by average annual rainfall and temperature ranges. Table 2 lists common nitrogen fixing fodder trees and their other uses. More detailed information on select species is available in extension bulletins and research journals. The Forest, Farm, and Community Tree Network (FACT Net) publishes fact-sheets and a research journal on multiple-purpose trees species. Fact-sheets are available in English, Spanish, Indonesia, Chinese, Vietnamese and Khmer for many of the species listed in Table 1. Some English-language Fact-sheets are reproduced in Appendix D. The International Centre for Research in Agroforestry (ICRAF) also publishes information on multiple-purpose trees and shrubs which can be used as fodder resources. ICRAF resources include a computerized database and research reports.

If a large number of species are suitable for the environmental conditions of the planting site, it may be appropriate to conduct a species screening trial. This is particularly important when exotic trees are introduced to an area for the first time. Always include native or naturalized trees in a screening trial. These commonly known species

will provide a standard by which exotic species can be judged. There is a chance that exotic species may become weeds outside of their native range. If exotic species show signs of becoming weeds, remove them immediately. Be sure to remove the complete root system, otherwise trees may re-establish from by stump sprouts.

Screening trials should always be established where soil and environmental conditions are similar to the proposed planting areas. If planting areas differ greatly, then more than one screening trial may be necessary. Establish one trial in each distinct planting area. The screening trial site should be uniform, so that differences in tree growth and survival are not confused with differences in soil fertility, water availability or other factors. Each species included in the screening trial should be established in a single block of 25 to 36 trees. Tree spacing will vary by site and proposed management system, 1 x 1 or 2 x 2 meters is common. If the trees are being screened for use in a hedgerow, a linear layout should be used. Depending on hedgerow design and management, in-row spacing may vary from 10 cm to 1 or more meters.

Trees on the outside of blocks, or ends of hedgerows, may be influenced by conditions adjacent to the trial. When evaluating the screening trial, these 'border trees' should not be measured. A

minimum of 9 to 16 trees should be measured to evaluate each species. Depending on the objectives of the screening trial, evaluation parameters may include survival, height growth, diameter growth, total biomass production, or leaf biomass production. Height and diameter is recorded for each non-border tree and the mean reported for each species. Basal diameter is recorded for the first year or until diameter at breast height can be measured. Biomass production can be recorded and reported per tree or per area basis. When trial results are reported, always include: location of trial, site and soil characteristics, number of trees measured, age of trees at measurement, planting method, tree layout and spacing, management practices (weeding, fertilization, etc.), and other details of interest. This information will make results meaningful to other people and make comparison with other trials possible.

Readers interested in establishing screening trials, research trials or provenance trials are encourage to consult Burley and Wood (1976), Webb et al. (1980), Briscoe (1989), Macklin et al. (1989), or MacDicken et al. (1991).

Mean annual rainfall more than 1,000 mm	
Mean annual temperature < 20°C	**Mean annual temperature > 20°C**
Acacia angustissima	*Alnus nepalensis*[a,e]
Adenanthera pavonia[a]	*Enterolobium cyclocarpum*[a,b,c]
Albizia chinensis	*Cajanus cajan*[a,b,c,e,f]
Albizia lebbeck[a,b,c,e]	*Chamaecytisus palmensis*[a,b]
Albizia odoratissima[a]	*Pongamia pinnata*
Albizia procera[a]	*Robinia pseudoacacia*[a,b]
Albizia saman[a,b,e,f]	
Cajanus cajan[a,b,c,e,f]	
Calliandra calothrysus[a,b,c,d,e,f]	
Desmodium spp.	
Desmanthus virgatus	
Enterolobium cyclocarpum[a,b,c]	
Erythrina edulis[a,b]	
Erythrina variegata[a,c]	
Erythrina spp.	
Flemingia macrophylla[a,b,c,d,e,f]	
Gliricidia sepium[a,b,c,d,e]	
Inga edulis[a,b]	
Leucaena diversifolia[a,b,c,e]	
Leucaena leucocephala[a,b,e,f]	
Ougeinia dalbergioides[a]	
Paraserianthes falcataria[a,c]	
Pithecellobium dulce[a,c]	
Pongamia pinnata	
Sesbania grandiflora[a,b,c]	
Sesbania sesban[a,b,c]	

[a,b,c,d,e,f] Fact sheets are available from the *FACT Net* in English (a), Spanish (b), Indonesian (c), Chinese (d) Vietnamese (e), and Khmer (f).

Table 1 a. Common nitrogen fixing fodder tree species summarized by mean annual rainfall and mean annual temperature: species suitable for

high-rainfall areas.

— Mean annual rainfall less than 500 mm —

Mean annual temp. <20°C

Acacia aneura[a]
Acacia holosericea[a,c]
Acacia leucophloea[a]
Acacia nilotica[a,c]
Acacia saligna[a]
Acacia senegal[b]
Acacia seyal[b]
Acacia tortilis[a]
Albizia lebbeck[a,b,c,e]
Dichrostachys cinerea
Faidherbia albidia[a]
Pithecellobium dulce[a,b]
Prosopis alba / chilensis[a,b]
Prosopis cineraria[a]
Prosopis glandulosa[a]
Prosopis pallida[a]

Mean annual temp. >20°C

Acacia aneura[a]
Acacia seyal[b]
Acacia leucophloea[a]
Albizia lebbeck[a,b,c,e]
Dichrostachys cinerea
Hippophaë rhamnoides[a]
Pithecellobium dulce[a,b]
Prosopis alba / chilensis[a,b]
Prosopis cineraria[a]

— Mean annual rainfall 500—1,000 mm —

Mean annual temp. <20°C

Acacia angustissima
Acacia holosericea[a]
Acacia leucophloea[a]
Acacia nilotica[a,c]
Acacia saligna[a]
Albizia chinensis
Albizia lebbeck[a,b,c,e]
Albizia odoratissima[a]
Albizia procera[a]
Albizia saman[a]
Cajanus cajan[a,b,c,e,f]

Mean annual temp. >20°C

Acacia leucophloea[a]
Albizia chinensis
Albizia lebbeck[a,b,c,e]
Albizia odoratissima[a]
Albizia procera[a]
Alnus nepalensis[a,e]
Chamaecytisus palmensis[a,b]
Dichrostachys cinerea
Enterolobium cyclocarpum[a,b,c]
Hardwickia binata
Hippophaë rhamnoides[a]

Dichrostachys cinerea
Enterolobium cyclocarpum[a,b,c]
Gliricidia sepium[a,b,c,d,e]
Hardwickia binata
Leucaena pallida
Pithecellobium dulce[a,b]
Pongamia pinnata
Sesbania grandiflora[a,b,c]
Sesbania sesban[a,b,c]

Leucaena diversifolia[a,b,c,e]
Leucaena pallida
Pithecellobium dulce[a,b]
Robinia pseudoacacia[a,b]
Pongamia pinnata
Sesbania sesban[a,b,c]

[a,b,c,d,e,f] Fact-sheets are available from the *FACT Net* in English (a), Spanish (b), Indonesian (c), Chinese (d) Vietnamese (e), and Khmer (f).

Table 1b. Common nitrogen fixing fodder tree species summarized by mean annual rainfall and mean annual temperature: species suitable for medium- and low-rainfall areas.

Species	LF	WB	IC	PI	HG	SP	TP	FP	SI	HF	OR
Acacia aneura	X						X		X	X	
Acacia angustissima		P	X	P				P	P		X
Acacia holosericea		X						X	X	X	X
Acacia leucophloea		X		X		P	X	X		X	P
Acacia nilotica	X	X					X	X	X		
Acacia saligna		X						X			X
Acacia senegal								X	X	X	
Acacia seyal								X			
Acacia tortilis		X		X				X		X	
Adenanthera pavonina		X	X		X	X	X	X	X	X	X
Albizia chinensis		X	P			X	X	X	X		
Albizia lebbeck		X	P	X		X	X	X			X
Albizia odoratissima		X				X	X	X	X		
Albizia procera		X				X	X	X		X	X
Albizia saman		X		X			X	X	P	X	X
Alnus nepalensis		X				X	X	X	X		X
Cajanus cajan			X		X			X	X	X	
Calliandra calothyrsus	X	X	X			X		X	X		X
Chamaecytisus palmensis	X	X		X			X	X			
Dalbergia sissoo		X			X		X	X		X	X
Desmodium gyroides			P	X					P		
Desmodium nicaraguense			P	X					P		
Desmanthus virgatus			P						P		

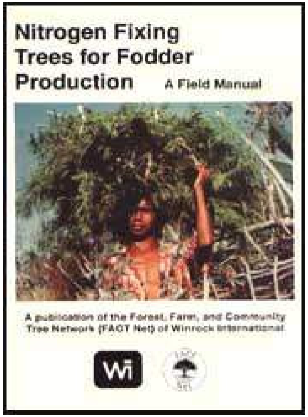
Dichrostachys cinerea							X	X	X		
Enterolobium cyclocarpum			P	X		X	X			X	
Erythrina berteroana	X	X	P	P		X				X	X
Erythrina edulis	X	X	P			X				X	
Erythrina fusca	X	X	P	P		X				X	X
Erythrina poeppigiana	X	X	P	P		X				X	
Erythrina variegata	X	X	P	P		X					X
Faidherbia albida		X	X			X		X	X	X	
Flemingia macrophylla			X			X			X		
Gliricidia sepium	X	X	X	X	X	X		X	X	X	X
Hardwickia binata		X					X	X	P		
Hippophae rhamnoides		X						X	X	X	
Inga edulis			P	X	X	X	P	P	P	X	
Leucaena diversifolia			X	X		X	X	X	X		
Leucaena leucocephala		X	X	X	X	X	X	X	X	X	
Leucaena pallida			X					X	P	X	
Ougeinia dalbergioides							X	X			
Paraserianthes falcataria		X	X		P	X	X	X	X		X
Pithecellobium dulce	X	X			X					X	X
Pongamia pinnata		X					X	X			X
Prosopis alba/chilensis		X					X	X	X	X	X
Prosopis cineraria		X	X					X	X	X	
Prosopis glandulosa			X				X	X	X	X	
Prosopis pallida							X	X		X	
Robinia pseudoacacia		X	P	X	X		X	X			X
Sesbania grandiflora			X		X				X	X	X
Sesbania sesban			X		X			X	X	X	

Table 2. Common nitrogen fixing fodder trees species summarized by use.

Uses include living fence (LF), windbreak (WB), intercropping (IC), pasture improvement (PI), home garden (HG), shade for perennial crops (SP), small or large timber production (TP), fuelwood production (FP), soil improvement (SI), human food (HF) and ornamental (OR). "X" denotes that the species has actually been used for the purpose

designated; "P" denotes that the species has potential for such a use.

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



Fodder production systems

R. T. Paterson, Joshua Daniel, G.R. Korwar, P.S. Pathak, M. De S. Liyanage, Mila G. Ejercito, Roland Lesseps, Soulivanh Novaho, Takashi Kate, A.S. Gill, James M. Roshetko and A.N.F. Perera

NFTs can be employed in many different fodder production systems in tropical areas of the world. The existing and potentially useful systems vary greatly from region to region. The degree of intensification of the systems is influenced by physical factors - soils; climate; species of domestic animals - together with socio-economic factors - human population pressure; availability of credit; and access to markets for both inputs and sale of products.

In this chapter, the principal tree fodder production systems are sub-divided according to their degree of intensification. Extensive systems are defined as those where the fodder trees are found either occurring, naturally or artificially established, at low densities. These trees are often in association with herbaceous pastures, annual crops or other woody species which may be used for non-fodder purposes such as production of fibre, fruit, fuelwood and timber. In these systems, the main objective of keeping animals may not be strictly commercial, since considerations such as food security, capital savings and social

obligations may be of primary importance.

At the other extreme, intensive systems are those where attempts are made to maximize fodder production from relatively small areas of land, to optimize animal productivity within the inherent constraints of the chosen system. These production methodologies will normally be strictly commercial in nature and the animals will be managed in an attempt to maximize cash profit.

Small-scale farmers in developing countries normally access fodder resources from several of the systems to meet their fodder needs, farmers often develop hybrids of the fodder production systems mentioned here.

EXTENSIVE SYSTEMS

Scattered Trees In Pasture and Rangelands

The dry, tropical, deciduous forests and tropical thorn forests, under the influence of biotic and edaphic pressure, behave as savannas. Grazing animals in these systems are largely supported by the seasonal production of grasses growing under, or between the trees. Most of these ecosystems produce low levels of biomass production (0.5-1.0 t/ha/yr of dry matter DM). Many of these areas could be profitably

converted into improved silvopastoral systems which would increase land productivity, reduce soil erosion and protect the lands from further environmental degradation. NFTs with fodder potential that could be used in such systems include species of Acacia, Albizia, Dichrostachys, Faidherbia, Hardwickia, Leucaena, and Prosopis.

In such improved systems, up to 650 trees/ha (commonly 100-400 trees/ha) could be planted in rows, either as mixtures or as single species. Spacing would vary with tree species, but would normally range from 4 x 4 to 6 x 6 m, or wider. Regular tree distribution provides uniform shade to rangeland. Uniform shade reduces excessive soil temperatures, prolongs the succulent phase of understory grasses and legumes and furnishes livestock a pleasant more productive environment.

The age at first harvest will vary with soil, climate and the tree species. Cutting should be delayed until the trees have grown beyond the reach of the grazing animals, to prevent direct browsing. Under dry conditions, the first harvest from fast growing trees might be delayed until 2-3 years after establishment. For Hardwickia binata, prunring and thinning during a 5-year establishment period results in accelerated growth. Fodder harvest should start after the establishment phase.

The tree foliage should only be used during periods of fodder shortage - i.e. the dry seasons. Migratory grazers usually lop trees only once per year, while settled agro-pastoralists may lop twice. The survival of a number of short duration species is favored by lopping only once per year, although species such as Leucaena leucocephala and Sesbania sesban may be cut two or more times per year. With most deciduous species, a flush of growth of leaves and flowers takes place during the summer months. Cutting is delayed until the dry season when other sources of feed are scarce. The foliage should be cut before the leaves start to fall, in order to prevent loss of feed quantity and quality. Cutting regimes should be determined through testing under local conditions.

Trees should be lopped at a minimum height of 2 meters without removing more than two thirds (67%) of the foliage at any one time. However, in practice, it is common for more than 90% of the leaves to be harvested, even though this is known to reduce subsequent growth and survival of the trees. In many studies, species of Acacia, Albizia, Hardwickia and Leucaena produce maximum annual yields under cutting regimes that remove only 30-60% of the foliage at each lopping.

In most pastoral situations, the lopped branches are allowed to fall under the tree for consumption by livestock. This often results in

maximum utilization of the available fodder, as leaves, pods and tender twigs will all be consumed. Where the fodder is removed for feeding to animals in confinement, usually only the leaves are taken from the field. While this may reduce the amount of available feed, the wilting associated with the delay in feeding may increase animal intake of those species which contain volatile anti-nutritive factors (e.g. Gliricidia septum). Alternatively, there are suggestions that wilting will decrease the digestibility and voluntary intake of foliage of trees such as Calliandra calothyrsus.

Lopping produces not only leaves and pods for fodder, but also branches and sterns for firewood, fence construction or other uses. The ratio of edible to non-edible material (E/NE), fodder to total biomass, is therefore an important variable to be considered in the selection of species. The actual ratio in any given situation will depend, to some extent, on the tree management regime used and on the animals to which the fodder is fed. But many species display clear differences in their foliage to woody biomass ratio. Representative production levels and E/NE ratios for a range of mature NFTs (age 8-9 years) under silvopastoral systems are shown in Table 1.

Species	Density trees/ha	Ratio E/NE[1]	Fodder t/ha DM	Pod t/ha DM	Wood t/ha DM	TOTAL t/ha DM
Acacia tortilis	400	0.50	0.2	0.2	0.8	1.2
Albizia amara	400	0.67	1.0	—	1.5	2.5
Albizia lebbeck	400	0.58	1.1	—	1.9	3.0
Dichrostachys cinerea	650	1.00	0.5	0.4	0.5	1.5
Hardwickia binata	650	1.50	1.2	—	0.8	2.0
Leucaena leucocephala	650	1.08	1.3	—	1.2	2.5
Prosopis cineraria	400	0.47	0.8	—	1.7	2.5

[1] Ratio of edible to non edible material

Table 1. Representative yields from NFTs in silvopastoral systems

Scattered Trees In Croplands

Fodder trees are commonly found growing in tropical croplands. They may be either planted by the farmer, or be left in place when the land is cleared from woodland or forest. Whatever their origin, they may be pollarded, coppiced or lopped for fodder. There is no fixed density or planting pattern for these trees, often the population is low (50-100 trees/ha), and the arrangement is random. Generally, to minimize competition with the accompanying crop, the species chosen for this purpose should have a sparse canopy. For those species which produce a dense canopy, lopping is scheduled to decrease competition. Foliage resulting from such loppings be used as fodder or left in the field as green manure for crops. The remaining foliage is usually reserved for

the dry season after the harvest of the crop. Foliage may be left in the field for consumption or carried to animals in confinement. In either case, the tree fodder is usually mixed with crop residues to improve the utilization of this poor quality roughage.

NFTs grown in this type of fodder production system include Acacia nilotica, Albizia lebbeck, Alnus nepalensis, Dalbergia sissoo, Erythrina variegata, Faidherbia albida, Gliricidia septum, Pongamia pinnate, Prosopis cineraria, Sesbania grandiflora and S. sesban. The choice of species is governed to a large extent by the degree of competition that it will present to the crop during the main growing season. For example, F. albida is an ideal species because it tends to shed its leaves during the wet season and therefore presents minimum competition to the crop. By contrast, A. nilotica can produce a dense canopy and provide serious competition for moisture. Caution should be used when introducing this species to new areas, particularly semi-arid regions. It is important to recognize that a species valuable for one site may be problematic at others.

In addition to producing fodder, this type of system may improve crop production. During the non-cropping season, animals feeding in the fields contribute to soil fertility through their droppings. Crop residues left in the field also recycle nutrients to the soil. Tree shade decreases

soil desiccation and offers a pleasant and more productive environment for animals and farm workers. The presence of trees can reduce wind speed, which in turn will reduce soil desiccation and erosion. The consequent improvements in soil physical and chemical properties can result in higher crop yields under trees than in similar areas without tree cover.

Linear Plantings

The potential of NFTs as fodder species in linear plantings has been widely accepted in the tropics. Common forms of these planting patterns are discussed below, and a list of species suitable for each purpose is given in Table 2.

Farm and Field Boundaries. Tree species are often planted along the perimeter of the farm or field boundaries for demarcation and to provide a range of products including fruit, timber, fuelwood and fodder. Species are often chosen for their ability to grow erect, and to resist repeated defoliation by pruning or lopping. They should provide minimal competition with the companion crops for moisture, nutrients and light, and should not be allelopathic.

Windbreaks. To protect arable crops from high velocity winds and wind

erosion, trees are commonly planted adjacent to fields. These windbreaks may be single or multi-rows. In multi-row windbreaks, tall species are flanked by shorter species. The purpose of windbreaks is to slow the wind, not stop it. If the barrier becomes too dense, strong winds can cause crop damage behind the windbreaks. It is therefore necessary to prune and thin the trees at regular intervals to maintain a semi-permeable barrier. This ensures the regular availability of wood products, as well as high-quality animal fodder. Encroachment by advancing sands from deserts or coastal dunes can be controlled by rows of trees, called shelterbelts. Depending on species selection, shelterbelts may also provide fodder.

Live Fencing. Conventional barbed-wire fencing with metal or wooden posts is often too expensive for small-scale farmers. Live fence posts are an alternative many farmers use to reduce the high costs of fencing materials. Further savings can be made by using impenetrable live hedges of NFT species to replace other purchased inputs. In either case, the prunings from live fencing can provide nutritious fodder for livestock. Species chosen as live fencing should be easy to establish, preferably by vegetative means, should have a deep root system and should not compete strongly with the adjacent crop for moisture and nutrients. They must withstand repeated pruning and lopping at a constant height of 1.5-2.0 m. Gliricidia septum and Erythrina spp. are

commonly employed for living posts. These species, as well as Acacia angustissima, Calliandra spp., Desmodium spp. and Sesbania sesban, make effective hedges.

Along Roads, Railways and Canals. NFTs are planted along roads, railways and canals to provide shade for people and animals, as well as to decrease evaporation from soil and water. Species for these niches must be chosen with care. In general, erect shade and timber trees are best. Fodder may be a secondary product from these trees. It is also possible to include fodder trees in the mix of species.

Farm Boundaries	Windbreaks	Live Fencing	Along Roads & Canals
A. nilotica	*A. nilotica*	*A. angustissima*	*A. nilotica*
D. sissoo	*A. lebbeck*	*Calliandra* spp.	*A. lebbeck*
Erythrina spp.	*Casuarina* spp.	*Desmanthus* spp.	*A. saman*
F. albida	*D. sissoo*	*Desmodium* spp.	*D. sissoo*
H. binata	*Erythrina* spp	*Erythrina* spp.	*Leucaena* spp.
Leucaena spp	*Leucaena* spp.	*G. sepium*	
	S. sesban	*Leucaena* spp.	
		S. sesban	

Table 2. NFTs for planting in linear arrangements

Natural Woodlands and Forests

Woodlands and forests often contain many NFTs of significant fodder value. Side branches and pods of these trees may be periodically harvested for livestock feed. Fallen litter and pods may either be browsed in place, or gathered and carried to livestock. An advantage of the latter method is that the material can be stored for use in times of feed shortage.

The harvesting of fodder from these public lands is often unregulated. Where fallen leaves and pods are gathered for removal, the only damage is the loss of nutrient inputs to the soil. On the other hand, uncontrolled lopping frequently results in over-utilisation of the most productive and nutritious tree species. This is undesirable, because less useful species will grow unhindered under reduced competition. In time, these less useful species will dominate the site, leading to reduced vigour and poor regeneration of the preferred fodder species. Under extreme conditions, the preferred species will eventually die out. Only through education of local users and careful management can the degeneration of these forests be prevented.

In general, establishment and thinning in these natural forests occur without human intervention. Thus, there are no recommended tree spacings and densities. Similarly, there are no general management regimes for age at first harvest, frequency of cutting and intensity of

utilization. Management regimes must be based site characteristics. Moderate use and protection are key to long-term sustainable production. Supplemental tree planting, protection of natural regeneration and the removal of undesired species will improve the species mix and fodder production of this system.

Examples of woodland and forest genera that produce significant quantities of edible leaves include Acacia, Albizia, Dichrostachyus, Erythrina and Prosopis. With some species, the pods are a more important fodder resource than the leaves. These include Acacia plenifrons, Albizia saman, Enterolobium cyclocarpum, Faidherbia albida and Prosopis juliflora.

Regeneration Strategies

While regeneration programs are often initiated for purposes that have little to do with animal production, livestock can be direct beneficiaries of such activities where suitable fodder species are present, or included in the mixture to be planted. Important considerations include protection and encouragement of natural vegetation; natural regeneration and enrichment planting of NFTs; nurse cropping with NFTs; and silvopastoral systems. In many cases, at the conclusion of the renovation phase, the regenerated land will be used under one of

the categories discussed above.

In the selection of NFT species for revegetation, emphasis must be given to the ability to establish and survive in difficult, deteriorated habitats. Many species have been tried on rocky, gravelly and generally degraded lands. Those that have survived best under the most harsh conditions in India include Acacia tortilis, Albizia amara, and Hardwickia binata. Some typical planting arrangements and production levels are shown in Table 3.

	Enrichment Planting	Nurse Cropping	Silvopastoral Systems
Geometry	In gaps in the natural vegetation	Alternate rows with other species	Compact blocks
Spacing (m)	5-6 m apart	4 x 2 or 4 x 3	4 x 5 or 4 x 6
Biomass production (t/ha/yr)	5-6	7-8 (good thinning management)	8-10 (10 year rotation)

Table 3. Planting arrangements used for regeneration

A number of points need to be considered concerning successful restoration of degraded habitats. The watershed approach should be used, since measures taken on a particular area can be destroyed or negated by neglect further up the slope. Contour trenches are effective in reducing run-off and conserving both soil moisture and nutrients.

Cover crops of Stylosanthes hamata, Leucaena leucocephala and similar fast-growing species can be employed to colonise and enrich the exposed soil sub-strata. These plants will decrease erosion and provide high quality fodder, while encouraging better growth from companion plants. To allow good plant establishment, it is important that animals be excluded from the area for a period of at least 3-4 years. This can be achieved through the use of fences and trenches, but must also include community involvement and cooperation. The land will not be useless to the community during this critical establishment period. Fodder from the herbaceous cover-crop species can be periodically harvested for removal and feeding to livestock.

The natural regeneration on the site should be managed to maximize the production of useful biomass. Undesirable species should be removed, and useful species should be pruned for desirable form. Management can also be used to reduce shading and promote beneficial grasses and herbaceous legumes. While pruning and thinning may take place after 2-3 years, lopping of the regenerated species should not take place until year five.

INTENSIVE SYSTEMS

Fodder Trees with Plantation Crops

Plantation crops play a vital role in the economy of developing countries in the humid tropics. The integration of these systems with livestock farming has been a productive and profitable practice of sustainable landuse. Coconut (Cocos nucifera), oil palm (Elaeis guineensis) and rubber (Hevea braziliensis) have great potential for the interplanting of fodder trees. Among nitrogen fixing fodder trees, Calliandra, Gliricidia and Leucaena are compatible with plantation crops. These fodder trees are commonly grown as hedges along boundaries or in the avenues between the rows of the plantation.

By virtue of the wide spacing adopted in coconut plantations, almost 70% of the land could be utilized for the intensive cultivation of companion species. Recent studies have demonstrated that NFT hedgerows can be successfully grown at spacings of 4 x 0.5 m in young plantations with coconut trees spaced 10 x 5 m apart. In mature coconut and oil palm plantations, where 7 x 7 or 9 x 9 m spacing is common, the fodder species may be grown in double rows spaced 2 x 1 m apart, giving a density of 2,400 trees/ha. In contrast, there are less opportunities for fodder tree production in rubber plantations because of the narrow 5 x 5 m spacings. NFTs can be grown only during the pre-tapping period. After this period, usually about 6 years, the plantation canopy will close preventing further understory cultivation.

To maximize fodder production, the NFT hedge should be allowed to grow for one year before the first harvest. Thereafter, the hedge can be pruned 3 4 times per year at a height of 100 cm. The foliar material can be used directly for feeding livestock, particularly during the dry season when the high protein content of the foliage can supplement low quality roughage from crop residues. Where animals are not an integral part of the production system, the foliage can be used as green manure to restore soil fertility to both degraded lands and plantation areas. Coffee (Coffea arabica and C. robusta), cacao (Theobroma cacao) and tea (Camellia sinensis) are plantation crops often grown with an overstory of nitrogen fixing shade trees. Trees are spaced from 3 x 3 to 12 x 12 m throughout the plantation and periodically pruned to maintain the desired level of shade. Most of the biomass removed during pruning remains in the plantation as green manure. However, when fodder species are employed as shade trees, some of this material can be used as livestock feed. Commonly used, dual purpose shade/fodder species include Albizia chinensis, A. odoratissima, A. procera, Gliricidia sepium, Erythrina poeptugiana, E. subumbrans and E. variegate. Albizia saman and Paraserianthes falcataria have also been used for these purposes.

Alley Farming

Alley cropping was originally developed as a diversified, sustainable

farming technique to combine soil conservation with crop production. Annual or permanent crops are grown in alleys between dense single or double hedgerows of NFTs. Distance between double-rows is 50 cm. Spacing within the row varies from 5-50 cm. Between hedgerows spacing is 1-5 m. To limit competition for light, hedgerows are pruned periodically to a height of 40-100 cm. The leafy prunings are applied to the soil in order to recycle nutrients to the crop. Woody material is used as fuelwood, poles or other purposes. Leafy prunings harvested during the last weeks of crop growth or in the dry-season can be removed for use as animal fodder. Alternatively, during the non-cropping season, animals can graze directly on hedgerows and the crop residues. In either case, the nutrient loss from the system is minimal if the animal manure is returned to the field as fertilizer for the subsequent crop. Where animals are a notable component, this system is usually referred to as alley farming, rather than alley cropping.

Sloping Agricultural Land Technology (SALT) is a form of alley cropping where the primary aim is to control erosion on steeply sloping land, while producing crops for sale and subsistence. Hedgerows of NFTs are planted on the contours at spacings of 1 to 5 meters. Pruned periodically, hedgerows provide green manure for crops and fodder for livestock. Woody material from the prunings is often laid on the ground at the base of the trees to provide a further physical barrier against

erosion. Some of the woody material can be used or sold as fuelwood. Permanent crops such as coffee, citrus and cacao are planted on the farm for income generation and home use. The land not occupied by hedgerows, or permanent crops, is planted to subsistence crops such as maize, sweet potatoes, pineapples, peanuts and mung beans.

The choice of NFT species for use in alley farming is of paramount importance. The ideal species would: establish easily; grow rapidly; remain productive under repeated harvest; show excellent fodder and green manure characteristics; have a deep root system that was non-competitive with crops; tolerate environmental extremes (drought, water logging, soil acidity); have a high edible to non-edible material ratio; have small leaflets which were retained in the dry season; and be free from pests and diseases. Species commonly used in alley farming include Calliandra calothyrsus, Desmodiun rensonii, Flemingia macrophylla, Gliricidia septum and Leucaena leucocephala. Sesbania sesban is also commonly used in alley farming systems. However, under repeated heavy harvesting S. sesban mortality may increase and plant longevity decrease. To prolong survival of this species 10 to 25% of the foliage should be retained after each harvest.

Fodder Banks or Reserves

In areas with a long dry season, it is advantageous to reserve an area of fodder specifically for use in times of feed scarcity. The objective of such reserves is to maximize fodder production from a small area. Thus, reserves are commonly fertilized with farmyard manure or inorganic fertilizers in accordance with local recommendations. Indeed, it is of great importance to return the manure to the reserve, in order to avoid rapid depletion of soil fertility and reduction of fodder yield. Reserves can be composed of pure grasses (energy bank), of pure legumes (protein bank), or of a combination of grasses and legumes (protein-energy bank). As a sole feed, the energy bank provides only a maintenance ration to ensure animal survival during the dry season. The protein bank is a high-quality feed used to supplement low-quality feeds (crop residues, dry season grasses, etc.) to provide a production ration. The protein-energy bank is designed to provide a complete diet which is balanced in terms of both digestible protein and energy.

To maximize fodder production trees should be planted at close spacings. In protein banks in-row spacing of NFTs ranges from 5-50 cm. Between row spacings of 50-150 cm are common, although if the area is to be directly grazed, wider walk-ways are necessary every fourth or fifth row to allow animals access to the entire bank.

Protein-energy banks are usually managed under a cut-and-carry

system. NFTs are usually associated with Napier grass (Pennisetum purpureum), or at altitudes over about 1,800 m, with Guatemala grass (Tripsacum laxum). Guinea grass (Panicum maximum) is more persistent and appropriate if the bank is to be managed under grazing. In the Caribbean, it is common to plant alternate rows of grass and NFTs, or one row of trees to two rows of grass. In India, double rows of each component give the best results. In Kenya, with a bimodal rainfall pattern, highest yields of both biomass and crude protein are achieved with one row of trees to three or four rows of grass. The most productive tree-to-grass ratio must be determined for each region. Between row spacings in protein-energy banks is usually 100 cm.

Establishment should take place at the beginning of the rains. It is often best to plant tree seedlings, in order to reduce competition from the fast-growing grass. After three months, when grass has reached a height of 120-150 cm, it should be cut to a height of 10 cm. The first harvest of NFTs should be delayed until they have reached a minimum height of 180 cm, after about 6-8 months for most sites. NFTs should be cut to a height of 60 80 cm.

Since the banks are intended only for dry season use, impose routine management at the end of the growing season - the second growing season where rainfall is bimodal. Banks should be rotationally grazed or

cut at intervals of eight to ten weeks during the dry season. At the start of the rains, the whole area should be cut back to the heights noted above. Under management that avoids over-utilization, banks should remain productive for at least eight years, at which time it may be necessary to replant the grass component to ensure continued high levels of production. The useful life of the tree component should exceed 20 years.

Animal production will vary widely, depending upon the type of bank, soil fertility, fertilizer regime applied, and climate. Without irrigation, where annual rainfall is in excess of 1,000 mm and with the farmyard manure returned to the soil, annual yields from commercial scale protein banks of 10 t/ha of leaf DM (with about 25% crude protein) have been obtained. With protein-energy banks yields of 15 t/ha of DM from the grass (7% crude protein) and 5 t/ha leaf DM from the NFTs (25% crude protein) are possible.

Intensive Feed Gardens

Unlike fodder banks, intensive feed gardens (IFGs) are designed to provide feed throughout the year. However, the objectives of these two systems are identical, i.e., to maximize fodder production from a small area. Like protein-energy banks, IFGs contain both grasses and NFTs

and are intended to provide a complete diet balanced in terms of digestible protein and energy. IFGs are designed to allow small-scale farmers to maximize animal production when agricultural land and feed resources are limited. This system is appropriate for the semi-arid to humid tropics, and provides excellent erosion control on sloping land.

The proportion of the IFG devoted to tree and grass components varies by site and management objectives. Approximately half the garden should be established in NFTs and half in grass. Grass and NFTs should be arranged in adjacent double-rows across the garden. In-row spacing of NFTs should be 5-50 cm and the distance between double-rows is 50 cm. In-row spacing of grasses should be 35-40 cm and the distance between double-rows is also 50 cm. Distance between rows of grasses and NFTs should be 75-100 cm. Wide access rows for livestock are not necessary because gardens are managed by the "cut-and-carry" method. Grazing should not be allowed. The arrangement described here, while generally suitable, should be altered to meet the needs of each situation.

IFGs should be established at the beginning of the rainy season. NFTs should be established by direct sowing or transplanting seedlings 4-6 weeks before grass. This will minimize competition between components during the critical establishment period. During this period,

all invasive weeds should be removed. Grasses can be harvested 6-8 weeks after planting, and thereafter every 4-6 weeks. Cutting height for grasses is 15 cm. NFTs are not cut before they attain a height of 180-200 cm, approximately 812 months after planting. Thereafter NFTs can be harvested every 8-12 weeks at a height of 100 cm. To maintain soil moisture and fertility, 50-70% of the NFT biomass harvested should be applied to the garden as green manure. Farmyard manure or organic fertilizers should also be applied according to local recommendations.

An IFG of 200 m meets the feed needs of 5-6 goats, a 400 m garden should feed one cow. Because IFGs are utilized year-round, plant longevity is less than in fodder banks. When biomass yields decrease, grass and NFTs should be replanted. Appropriate grass species for this system include Napier (Pennisetum purpureum), Guinea (Panicum maximum), Para (Bracharia mutica) and African Star (Cynodon plectostachus). Appropriate NFTs are Acacia angustissima, Cajanus cajan, Calliandra calothyrsus, Desmodium rensonii, Flemingia macrophylla, Gliricidia septum and Leucaena leucocehephala.

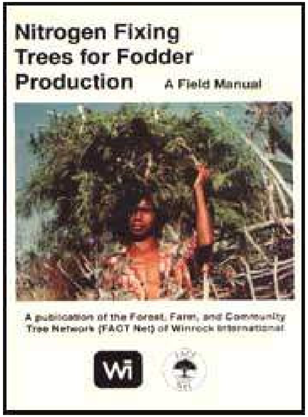
System	Establishment		Harvest Management			Productivity		
	Planting Arrange-ment	Density or Spacing	Age at First Harvest	Cutting Frequency	Cutting Height	Cutting Season	Plant Parts Consumed	DM Yields
Extensive								

1. Scattered trees in range	scattered	100-400/ha	2 yrs min.	1-2 per yr	2 m	dry	leaves, pods	
2. Scattered trees in crop	scattered	50-300/ha	2 yrs min.	1-2 per yr	2 m	dry	leaves, pods	—
3. Linear plantings	linear	1-4 m	1 yr min.	1-2 per yr	1.5-2 m	dry	leaves, pods	1-3 t/ha
4. Woodland and forest	—	—	—	unplanned	branches	all year	leaves, pods	—
5. Rehabil-itation	scattered or in gaps	400-600/ha	3 yrs	1 per yr	over 2 m	dry	leaves, pods	2-3 t/ha
Intensive								
1. Perennial plantations	double rows	2 x 1 m, 2400/ha	9-12 mths	3-4 per yr	1 m	all year	leaves	2-3 t/ha
2. Alley Farming	double rows	5-50 cm x 3-5 m	12 mths	3 per yr	15-150 cm	all year	leaves	2-5 t/ha
3. Fodder banks (protein-energy banks)	hedgerows: 1:1 to 4:1 with grass	5-40 cm x 1 m	9 mths	8-10 wks (grass and trees together)	g. 40 cm t. 1 m	dry	leaves (pods in first harvest)	g. 5-15 t/ha t. 5-10 t/ha
4. Intensive food gardens	hedgerows	g. 40 x 50 cm t. 5-50 x 50 cm	g. 6-8 wks t. 8-12 mths	g. 4-6 wks t. 8-12 wks	15 cm t. 1 m	all year	leaves	g. 5-20 t/ha t. 5-15 t/ha

Note: g. = grass, t. = fodder tree. All systems can be utilized for cattle, sheep or goats, for either direct browse, or for cut and carry

Table 4. Summary of the main features of the fodder production systems

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



Nitrogen Fixing Trees for Fodder Production - A Field Manual (Winrock, 1996, 125 p.)

Nutritive value and animal production from fodder trees

B. W. Norton and M.R Alam

Fodder trees provide a significant natural source of feed for grazing animals in many different parts of the world. The relative contribution to the diet will depend on both the availability and accessibility of tree fodder and the feed preference of the animal species at that particular time of the year. Alternatively, tree fodders are often harvested by farmers to supplement low quality feeds offered to animals raised in housed or confined systems. In this case, feed quality is judged by the farmer and not the animal. There is also increasing interest in the intensive cultivation of fodder trees in agroforestry systems, and the value of fodder trees in these systems depends on troth the amount of fodder produced (yield/ha or yield/tree) and the relative intake and quality of tree fodder and understory forage. The establishment of such agroforestry systems requires prior determination of the tree species best adapted to the prescribed environment and the potential nutritive value of the chosen species.

Nutritive value may be broadly defined as the ability of a feed to provide the nutrients required by an animal for maintenance, growth and reproduction. It is a function of both voluntary feed intake (FI) and

the efficiency of extraction of nutrients from the feed (digestibility, D). In the absence of anti-nutritive factors, forage intake is often positively correlated with D, and the intake of digestible nutrients (nutritive value = FI x D) is directly related to animal production (live-weight gain or milk production). It is for this reason that techniques have been developed which purport to predict D (in vitro and in sacco digestibility), and these values used as an index of forage quality. Although these techniques have proved valuable for grass forages, there is little evidence to support the use of these techniques for either forage legumes or tree fodders (Jones and Wilson 1987). The reason is that, unlike grasses, there is often little correlation between FI and D in animals consuming tree fodders, and hence estimates of D are not necessarily indicative of digestible nutrient intake. The major factors which might affect nutritive value are therefore voluntary feed intake, nutrient content of the feed and the extent to which nutrients are extracted from the ingested feed.

Chemical composition and its interpretation

Chemical composition alone, as measured by the proximate and elemental analysis systems, is an inadequate indicator of nutritive value. These measurements take no account of either the form or availability of nutrients, and, at best, may provide information on

potential nutrient content. Analyses based on detergent extraction are more useful since plant dry matter is separated into a completely digestible fraction (neutral detergent solubles, NDS) representing cell contents, and a partially digestible fraction (neutral detergent fiber, NDF) representing plant cell walls. There is now an extensive literature on the chemical composition of fodder trees (Skerman et al. 1988, Norton 1994a, Devendra 1995) from which some general guidelines can be drawn (Table 1). The crude protein (CP) content, N content x 6.25, of fodder tree leaves is usually high (150-250 g/kg) and exceeds that required for the maintenance of fermentation in the rumen (65-85 g/kg). Unlike grasses, the protein content of tree leaves remains relatively constant throughout the year. However the high CP content of fodder trees leaves may not confer any direct nutritional benefit to the animal unless these proteins are protected against ruminal degradation. The presence of condensed tannins in some fodder tree leaves affords some protection against ruminal degradation, and thereby delivers significant amounts of plant protein for absorption in the intestinal tract. Macro- (Na, K, Mg, Ca, S) and micro element (Cu. Mn, Zn, Co, I, Se) analysis provides values which may be compared with animal requirements. However, while values less than predicted requirements are indicative of deficiency, values greater than requirement are not necessarily indicative of sufficiency. There are few reports of elemental deficiencies in fodder tree leaves, and because tree leaves seldom form

all of the diet, deficiencies are likely to be rare under practical feeding conditions. The following feed composition measurements are therefore considered most useful for describing the potential nutritive value of tree leaves: dry matter (DM), organic matter (DM-ash), crude protein and NDF.

The presence of toxic and anti-nutritive factors

Low palatability of tree leaves may be related to either physical (hairiness, steminess, etc) or chemical feeding deterrents. Many fodder trees contain saponins, alkaloids or polyphenolic compounds (Norton 1994b), and the detection and analysis of these substances often requires sophisticated analytical techniques not commonly available in most laboratories. The potential toxicity of tree leaves may be determined by feeding in a diet to laboratory rats. However toxicity in rats may not always be seen in ruminants which may degrade potential toxins in the rumen. It has also been demonstrated that the effects of some potentially toxic substances (e.g. mimosine from Leucaena) may be considerably reduced where leaves form less than 30% of the diet. It has also been shown that drying or wilting may alter the potency of some toxins. The detection and measurement of condensed tannins is a relatively simple procedure, and should be included in routine analytical measurements on fodder trees where possible.

Species	Crude protein (Nx6.25)	Fat	Ash	NDF*	Crude fiber	ADF*	Lignin	Tannin	References**
Acacia aneura	156		49		341			44	1
	149	34	39		286				2
	107	56	41						3
	114	64	40	490			194		4
	110		35	511		396	206	70	5
Acacia angustissima	225		46					60	1
Albizia chinensis	263		46	603		348	145	33	6
	151	44	53		316				7
	211		146	364		246		23	9
Albizia lebbeck	240		90					ND*	1
	222	18	46		377				6
	181	47	80		266				7
Calliandra calothyrsus	212		43	259		209	69	111	8
	170	40		602		229	64	96	10
Chamaecytisus palmensis	264		54	416				ND	13
	164		53	290				ND	13
Desmodium gyroides	198		65					71	1
Desmanthus virgatus	146		85	256		195	91		12
	115	24	58		390				7
Enterolobium cyclocarpum	250		55					ND	10
	168	53	50		122				7
Faidherbia albida	147	17	57		165				6
	197	18	72		198				7
Gliricidia sepium	276		60	255		216	94	30	8

150		55	272		212	56		12
276	24	104						14
234	14	107	231					14
261		22		186	232	88		15
256					279	91		18
183		54	656		357		20	9

continued

Table 1. The chemical composition (g/kg dry matter) of foliage from a selected range of tree legume species. Source: Forage Tree Legumes in Tropical Agriculture, 1994, R. C. Gutteridge and H.M. Shelton, eds. CAB INTERNATIONAL, Wallingford, UK. 180 pot

Species	Crude protein (Nx6.25)	Fat	Ash	NDF*	Crude fiber	ADF*	Lignin	Tannin	References**
Leucaena leucocephala	267		57	312		226	99	37	8
	203	55	93		182				6
	269			383		220	68		16
	258		69	909		234	87	55	5
Sesbania grandiflora	348	42	126		75				11
	280	40	100		140	258	81	ND	17
	250	30	90		190	217			17
	281			371					16
	206		118	244					9
Sesbania sesban	218		80	219		153	36	ND	8
	263	9	100		122				7
	194		74		329				18
	152	16	86		353				19

* NDF = neutral detergent fiber, ADF = acid detergent fiber, ND = none detected

**References: 1. Ahn *et. al.* (1989); 2. Norton *et. al.* (1972); 3. McMeniman (1976); 4. Leche *et al.* (1982); 5. Goodchild (1990); 6. Le HouÉrou (1980b); 7. Gohl (1981); 8. Robertson (1988); 9. Ash (1990); 10. Ahn (1990); 11. Brewbaker (1986); 12. Bamualim *et. al.* (1980); 13. Borens & Poppi (1990); 14. Chadhokar (1982); 15. Carew (1983); 16. van Eys *et. al.* (1986); 17. Soedomo *et. al.* (1986); 18. Singh et al. (1980); 19. Lamprey et al. (1980)

Table 1. continued. The chemical composition (g/kg dry matter) of foliage from a selected range of tree legume species. Source: Forage Tree Legumes in Tropical Agriculture, 1994, R. C. Gutteridge and H.M. Shelton, eds. CAB INTERNATIONAL, Wallingford, UK. 180 pp.

Predictive techniques for digestibility

The measurement of digestibility is useful where it provides a

prediction of the intake of digestible nutrients. Where possible, feeding trials to measure both voluntary feed intake and in vivo digestibility should be undertaken. However, as discussed later, for fodder tree leaves such measurements have a limited value. There is evidence that factors other than the rate of digestion in the rumen determine the voluntary intake of tree foliage by ruminants. Low leaf intakes may be associated with high leaf digestibility if the leaves contain appetite depressants such as alkaloids and tannins. Alternatively high feed intakes associated with low leaf digestibilities may be the result of the rapid passage of small leaflets from the rumen. Many leguminous fodder trees have pinnate leaves containing small leaflets. Lowry (1989) has observed that sheep consumed significantly more fallen Albizia lebbeck leaf (DM digestibility 43%) than fresh leaf (DM digestibility 64%), supporting the view that the measurement of digestibility alone is of limited value for the prediction of nutritive value. Although in vitro and in sacco (incubation in ruminal fluid) assays are commonly used to rank feeds in terms of digestibility, such assays are of little value for ranking fodder trees in relation to nutritive value. The continued use of such assay demands that a relationship be established between these assays and feed nutritive value.

Feeding trials to determine nutritive value Tree fodders are most commonly used as supplements to low quality forages rather than sole

feeds for ruminants. This suggests that the most important information about the nutritive value of tree fodders is the level of supplementation which optimizes nutrient intake. This level will vary with the quality of tree fodders and of basal diet, and will vary with different plant parts and fodder tree species. The following technique has been adopted at the University of Queensland to provide information on: a) a comparison between low levels of fodder tree leaf supplementation with urea/molasses, b) the level of supplementation which maximizes nutrient intake, and c) the nutritive value of fodder tree leaves as the sole feed source. These results are obtained by offering a low quality diet (barley straw) ad libitum to 3 groups of animals. Fodder tree leaves were then provided at rates of O. 1% and 2% of liveweight to each group. A fourth group was offered tree leaves ad libitum without barley straw. The group without leaf supplements was given a mixture of urea and molasses (100g containing 30% urea), this supplement providing about the same amount of N and digestible energy as the lowest level of tree leaf supplementation. Table 2 shows some results obtained from these trials (Norton et. al. 1992), and clearly demonstrates the relative merits of the different fodder trees as supplements for goats. As expected, digestible DM intake (nutritive value) was closely related to animal production (liveweight gain). It is significant that for both Leucaena and Sesbania, there appears to be no benefit in levels of supplementation greater than about 33%, but for

Albizia, net nutritive value decreased as levels increased above 30%. In this case, Albizia was of low nutritive value when fed as the sole feed, and its nutritive value was maximized by feeding at low levels (27%) in the diet. It is also clear from Table 2 that when tree leaves are fed as the sole source of feed, digestible DM intake may be a poor indicator of nutritive value. This information is useful for making recommendations on optimum levels of fodder tree leaf use in cut-and carry systems and in agroforestry grazing systems where intermittent use is made of fodder tree reserves.

Fodder tree species	Level of supplementation (% in DM)	Voluntary DM intake (g/kg/d)	Digestible DM intake (g/kg/d)	Liveweight change (g/d)
L. leucocephala	0*	17.9	8.7	61
	33	20.5	17.8	71
	65	30.9	17.7	66
	100	27.0	16.8	46
A. chinensis	0*	18.9	8.7	—
	27	27.8	15.7	—
	61	27.4	13.4	—
	100	24.6	11.8	—
S. sesban	0*	17.7	8.5	41
	33	28.7	17.5	47
	66	31.7	20.3	63
	100	27.8	17.8	9

* Basal diet + 70 g molasses + 30 g urea

Table 2. Mean values for the voluntary dry matter (DM) intakes

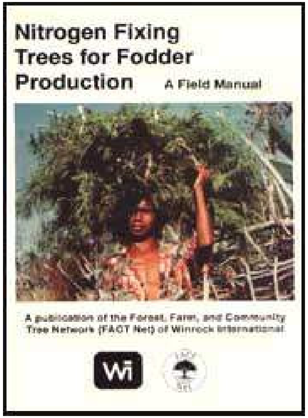
(g/kg/d) digestible DM intakes (g/kg/d) and liveweight changes (g/d) of goats offered basal barley straw diets supplemented with increasing levels of dried Leucaena leucocephala, Albizia chinensis and Sesbania sesban leaf.

Grazing trials and animal productivity

Although the establishment and implementation of grazing trials to evaluate the productive potential of fodder trees is a long term and expensive investment, these trials provide definitive information on the value of fodder trees in animal production systems. Introduced fodder trees may be used in many different ways in grazing systems. They may act as an autumn or winter reserve for strategic grazing, as a sole source of feed for the intensive finishing of stock or as an integrated forage source which is continuously grazed by stock. Prior to the commencement of such trials, the objectives of the experiment must be clearly defined, and the number of animals and areas of land used be sufficiently large to permit meaningful statistical analysis of the data. Appropriate control treatments must also be included to allow comparison with existing systems under the same environmental conditions. A minimum period of one year is required to permit assessment of seasonal effects on tree and animal productivity. The fodder tree banks established should be mature enough to withstand

the stocking pressure applied, and in some circumstances it may take up to 3 years before tree banks can be grazed. Stocking rate is the major determinant of animal productivity from pasture, and an appropriate range of stocking rates should be applied to test the potential productivity of the system. It is not possible to be prescriptive about the design of such experiments, since different environments and systems of production will impose particular constraints on experimental design and interpretation.

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



Problems and constraints with fodder trees

Tony Oude Hengel, Asim K. Biswal, Francis A. Xavier and R. V. Singh

Like all agricultural innovations, the integration of fodder trees in farming systems should be socially acceptable, technically sound, and economically viable, in the perception of farmers (Werner et al., 1993). Often, the introduction of fodder trees creates more problems concerning people and their livelihood, than with the technical aspects of tree planting. This chapter addresses the common problems encountered by fodder tree promotion programs.

Social acceptability There is a great lack of knowledge concerning the human aspects of growing fodder trees. Before starting any fodder tree promotion program, it is an absolute necessity to hold discussions with the client or client-group. Their needs and aspirations should be

assessed and used to design the program. Specifically, their needs for fuelwood, construction wood, soil-fertility maintenance, fodder, fruit-trees or cash crops should be determined and incorporated into a fodder tree promotion program. If they are not interested in fodder trees, approach another group of clients or alter the goals of the program.

Once the client-group is established, allow them to determine what assistance is required. Then, working with the group, resolve how the program can best assist them. Within the group there will be various sub-groups (women, men, social-classes, age groups, etc.) having different preferences for tree types or species. One sub-group may want tall fodder trees which will also produce timber. Another sub-group may prefer a fodder shrub that produces fuel and can be used as a living fence. Convene a separate meeting with each sub-group to discuss preferences of land-use, tree types and tree species. These discussions should provide all subgroups an opportunity to communicate their opinion, and help define and prioritize their needs. Through this process the program will avoid promoting fodder production systems or tree species that are inappropriate for the clients.

Demonstration areas may need to be established when, the clients or program suggest a radical change in the landuse systems or the

introduction of exotic tree species. Demonstration areas are most useful when established on farmer's land. The farmer should be given the authority to manage the area as they wish. They should be encouraged to experiment and compare the 'suggested' landuse system with their own innovations. This process will help develop 'new' systems that are appropriate for local cultural and environmental conditions. A training component should be created to extend the 'new' system to other clients and local residents. During training activities participants should be encouraged to provide critical analysis of the system and management techniques. Such input will hasten the development of locally appropriate systems. The proof of a successful system is its spontaneous adoption by other clients or local residents.

Two social problems that require specific mention are tenure rights and the use of common land.

Land- or tree-tenure rights may limit the ability of an individual or group to manage or utilize trees. A person may have the right to plant or use a tree, but this often does not preclude use by other people. In many cases, trees on private land are not the exclusive property of the landowner. Other community members and the government may share tree use rights with the landowner. Such lack of control often makes landowners reluctant to plant trees. Land- and tree-tenure rights must

be fully investigated before a fodder tree promotion program is initiated. A change in these rights may make farmers inclined to plant more trees.

Common lands are usually owned by the government, but used by the community. Government management is often limited to regulating use, and does not include increasing productivity. There is great scope to improve fodder production on these lands. Proper planning and cooperation between the community and government is essential. The first step is to convene meetings between the government and community to establish goals and management priorities that are acceptable to both parties. the sub-groups of the community should be involved. A management plan should be written to define present and future usergroups, the vegetation to be used and established, harvest quotes, product distribution, and land protection measures. The management plan must be sustainable and should be reviewed annually.

Technical soundness It usually takes a long time to determine which species are suited to a particular area and how they should be managed in various landuse-systems. However, through a review of general literature and discussions with client-farmers and local research institutes, the most promising species and landuse systems can be

identified quickly. Information gathering activities should focus on fodder species (grasses, shrubs and trees) as well as the other plants that grow in the area. This information will help identify fodder trees species that are not currently utilized locally. Discuss problems with local research institutes and inquire about their work. Identify mutual areas of interest and try to have your clients' technical problems added to the institute's research agenda. When possible, use demonstration areas to study the topics which interest both your program and the research institute. This is a practical way of involving the research institute with your program's activities.

Four common technical problems may be encountered once your program starts planting fodder trees. These include seedling protection, plant diseases and pests, inadequate seed supply, and fodder toxicity or palatability.

Seedling Protection. Immediately after germination, the seedlings of many NFTs grow slowly. During this period seedlings are very vulnerable to vegetative competition and browsing animals. To help protect seedlings from these dangers observe the following recommendations:

- **use only healthy seed or seedlings;**

- **plant seedlings, or sow seed, only at the onset of the rainy season;**
- **when possible, combine tree establishment with cultivation of agricultural crops;**
- **use micro-catchments to improve water retention and infiltration;**
- **periodically remove competing vegetation until trees are well established;**
- **use living fences to shield seedlings (Gliricidia and Erythrina are common living fences);**
- **use temporary fences of branches, thorny bushes or bamboo-mats to shield seedlings; and**
- **organize plantation guards through community organizations.**

Plant Pests and Diseases.

Nitrogen fixing fodder trees are often established in extensive plantings of one or a few species. Such 'monocultures' are vulnerable to pest and disease problems. Worldwide damage by the 'leucaena psyllid' demonstrates the potential danger of monocultures. Even in diversified plantings of fodder trees, pest and disease problems do occur. Walter and Parry (1994) provide information on the insect pests of leguminous fodder trees. Boa and Lenn, (1994), Lenn, and Boa (1994), and Lenn, (1992) provide detailed information on the diseases of leguminous trees. Updates on the leucaena psyllid and its management are available

in Bray (1994) and Geiger et. al. (1995).

Inadequate seed supply. The success of any fodder tree program is limited by the quality and quantity of the seed available for tree establishment. Often, adequate quantities of high-quality seed are not available to fodder tree promotion programs. To avoid this problem, programs should maintain a list of reliable seed suppliers and, when possible, establish seed production areas. A list of seed suppliers appears in Appendix A. Chapter 7 provides more information on the establishment and management of seed production areas.

Fodder toxicity & palatability. Fodder toxicity and palatability greatly influence feed intake and utilization. Although many compounds that cause toxicity problems in tree fodders have been isolated, detailed information on most of these compounds is not known. An exception to this generalization is the minosine toxicity of Leucaena. Fortunately the toxic effect of most compounds is negligible when tree fodder composes less than 30% of the diet. Palatability of many tree fodders is improved by drying, wilting or ensiling. Palatability is also increased by mixing fodder with additives like salt or molasses. Chapter 5 discusses the nutritive value of tree fodders in detail.

Economic viability

There is an enormous lack of information and experience concerning the economic evaluation of fodder tree production systems. The economic viability of these systems depends on the quantity and quality of fodder produced, the unit of land under production, opportunity costs of the land and capital, labor costs, animal productivity, marketability, prices of animal products, secondary benefits, etc. While appraising fodder tree production systems consider both the direct and indirect benefits. In many areas, tree fodders supply livestock with valuable nutrients and minerals. These substances can not be supplied by expensive feed concentrates which subsistence farmers can not afford. Under intensive management, small areas can produce large quantities of tree fodder enabling farmers to increase livestock production, diversify farm yields, and respond flexibly to farming costs and market prices. Fodder tree branches replace dung-cakes as a fuel source, enabling farmers to use dung as fertilizer to improve soil fertility and structure. Timber harvested from mature fodder trees is used by the farmer or sold in local markets. Placing a monetary value on many of these benefits may be difficult. Working together, programs and farmer-clients must determine the economic value of their fodder production systems and all alternative landuses systems. Those systems which best serve the clients should be promoted.

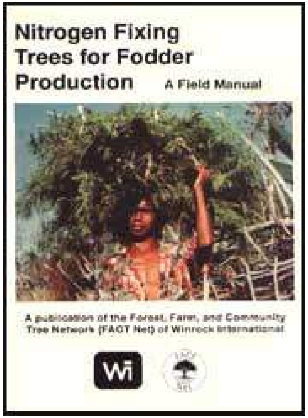
Networking

As a first step to solve problems associated with the introduction of fodder trees, and also to gain exposure to new ideas, it is helpful to maintain contact with people working on similar subjects. This can be accomplished by participating in agroforestry networks which publish newsletters, other types of periodicals and handbooks. Three such organizations are listed below. In some areas, local or regional organizations may serve a similar purpose.

Forest, Farm, and Community Tree Network (FACT Net), c/o Winrock International, 38 Winrock Drive, Morrilton, AR 72110 USA.

International Centre for Research in Agroforestry (ICRAF), PO Box 30677, Nairobi, KENYA.

Forest, Trees and People. Community Forestry and Planning Division, Forestry Department, FAO, Via delle Terme di Caracella, I-00100 Rome, ITALY.



Seed collection and multiplication

Ross C. Gutteridge, Janet Stewart, H.P.N. Gunasena, F.B. Patil, P.K. Mutty and N.N. Pathak

Seed to be used for multiplication should be of superior genetic quality, and also as genetically diverse as possible. Leucaena leucocephala is the only NFT species for which seed has been produced in commercial

quantities and for which a seed certification scheme exists in some countries. Seed of other NFT species is produced in a number of countries, but the quality and genetic origins of the seed is often unknown.

Rather than relying on external sources of seed supply, it may be more appropriate for extension personnel to collect and multiply seed of selected NFTs for distribution in their particular regions. This chapter provides broad guidelines on how to approach this process.

Local Seed Collection

In most cases, seed or cuttings for multiplication must be selected from locally available material. Although a detailed evaluation of fodder yields and quality may not be feasible, a selection of superior specimens is possible. Occurring in farm fields, many fodder trees are privately owned. The farmers who use the trees may be able to identify superior trees in terms of yield, response to repeated lopping, timing of fodder production and even perceived effects on animal production. Seed should be collected from these superior trees. It will often be necessary to pay farmers for the right to collect seed and for the fodder foregone during seed maturation. Generally, trees used for seed production can not be lopped for at least one year.

Seed should never be collected directly from provenance trials. Most nitrogen fixing fodder trees are thought to be outcrossing (an exception is L. Ieucocephala which is largely selfing). Cross pollination between provenances will result in seed of mixed parentage. The trees grown from this seed will not have the same characteristics for which the superior provenance was selected. Once superior material has been identified, the organization which proved the original seed may be able to provide larger quantities of the same provenance for establishment of a seed production area (seed orchard).

Genetic Diversity

It is very important to ensure adequate genetic diversity in seed collections. Genetic diversity will minimize the risk of inbreeding and vulnerability to pests and disease, as well as provide a broad genetic base for any future selection. Seed to be used for seed orchard establishment should be collected from at least 50 different trees located at least 100 m apart. Since most nitrogen fixing fodder trees are outcrossing, seed from trees dose together is more likely to be paternally related - received pollen from the same tree. In natural ecosystems, mother trees close together are more likely to be maternally related originated from seed of the same tree. The aim of the seed collection strategy is to minimize relatedness of the seed and so

capture as much genetic diversity as possible.

Some species, such as Gliricidia septum, are easily propagated from cuttings which can be used instead of seed as the basis for multiplication. However, it is still important to ensure adequate genetic diversity by including cuttings from at least 50 plants in the multiplication area. Again, the cuttings should come from widely separated plants. In areas without a pronounced dry season, G. septum does not set seed well. Cuttings may be the only means of propagation.

Caution must be exercised when collecting seed or cuttings from any planted stand of trees, including fence-lines, windbreaks, woodlots or large plantations. Often, such stands have been propagated with seed collected from a small number of trees. They already have a narrow genetic diversity. If these stands do not show superior quality over natural stands, seed and cuttings should not be collected from them. When possible, investigate the genetic origins of the seed used to establish these stands.

Establishment of Seed Orchards

Multiplication of good quality seed (or cuttings) in an orchard provides an easy and reliable way of repeatedly obtaining planting material for

distribution to farmers, without having to repeat the lengthy seed collection procedure described previously.

It is essential to locate seed orchards of open-pollinated species as far away as possible from unselected trees of the same species. This distance will minimize cross-pollination which would reduce the gain achieved through the selection of superior trees. The distance required to achieve this isolation depends on the mode of pollination employed by the tree species. Ideally, the distance should be at least 1 km. This may not always be practical. Alternatively, nearby trees of the same species may be lopped before flowering to eliminate the source of undesirable pollen. Seed set within the stand can also be improved by encouraging the appropriate pollinators. For instances, by placing healthy beehives in orchards of bee-pollinated species.

Seed trees should be planted at wide spacing, for example 4 x 4 m. Some nitrogen fixing fodder trees, such as L. leucocephala and G. septum, are precocious seeders - setting seed within 1 to 2 years. Other species, such as Prosopis cineraria, take 7 to 8 years to set seed. This interval can be reduced to 3 to 4 years by using vegetative material to establish the seed orchard. Vegetatively propagated seed orchards have the additional advantage that the genetic identity of selected superior trees is maintained, whereas with open-pollinated seed the identity of

the father (pollen source) is unknown.

Seed Handling Storage

Only mature, well-developed pods should be harvested for seed. Where possible, harvesting should be undertaken during dry periods to avoid contamination by fungal pathogens. Some species, for example Acacia nilotica, display variation in flowering time and seed set which leads to variability in seed quality and viability. To avoid this problem seed should be harvested only during the season which gives the highest quality seed.

The harvested pods should be shelled and the seed dried under shade to a moisture content of 10 to 15%. This process should take 3 to 5 days. The seeds should be winnowed, screened and sorted to remove foreign objects and poor quality seeds. Only fully developed, healthy, undamaged seed should be stored. During storage, seedlots should be labeled with the species name, date of collection, collection site, number of mother trees from which the seed was collected and seed weigh. This information will maintain the identity of the seed source and make subsequent evaluation possible.
Seed should be stored in airtight, insect-proof containers at temperatures below 4C. If possible, it should be dusted with an

appropriate insecticide to minimize damage by bruchids. A sample of seed should be tested for viability before storage and again just prior to distribution. This information will enable managers to determine appropriate planting densities.

Availability of Selected Seed

There have been studies of provenance variation in many nitrogen fixing fodder trees, including; A. nilotica, Calliandra calothyrsus, Faidherbia albidia, G. septum, L. Ieucocephala and P. cineraria. Unfortunately, even when superior provenances have been identified it is often not possible to acquire seeds of these provenances in large quantities. An exception is L. Ieucocephala, for which varieties such as cv. Cunningham (K500) and Taramba (K636) are now commercially available. A hybrid of L. Ieucocephala x Leucaena pallida (KX2) is now commercially available from the Hawaiian Agricultural Research Center. The KX2 hybrid was selected for psyllid resistance and fodder production. In Australia there are plans for the release of commercial cultivars of Sesbania sesban derived from ILCA (International Livestock Centre for Africa) accession no. 15036.

For G. septum, superior material has been identified through a worldwide provenance trial organized by the Oxford Forestry Institute

(OFI). The Guatemalan provenance 'Retalhuleu' (or 'Maya type' - OFI nos. 14/84, 60/87 125/91) has shown consistently superior growth on a wide range of sites. Seed of this provenance has been distributed to several countries for establishment of seed multiplication areas. Small quantities are available for multiplication purposes from OFI. A list of organizations able to supply Retalhuleu seed is being prepared.