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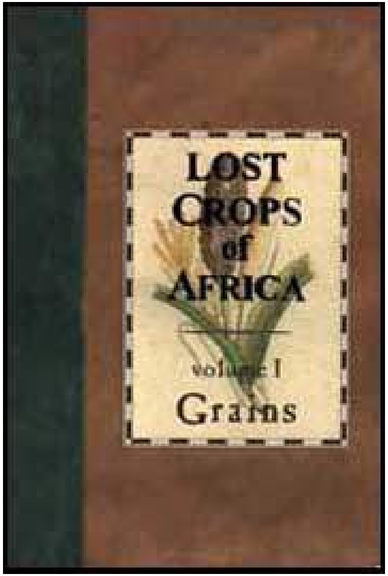
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of
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Grains

Appendix F

References and Selected Readings

AFRICAN RICE

Buddenhagen, I.W. and G.J.Persley, eds. 1978. Rice in Africa: Proceedings of a Conference Held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, 7-11 March 1977. Academic Press, New York. 356 pp.

Carney, J.A. 1993. From hands to tutors: African expertise in the South Carolina rice economy. Agricultural History 67(3):1-30.

Clayton, W.D. 1968. West African wild rice. Kew, Bulletin 21:487-488.

Clement, G. and K. Goli. 1987. Yield capacity of Oryza glaberrima as an upland crop. L'Agronomie Tropicale 42(4):275-279.

Fatokun, C.A., A.F. Attere, and H.R. Chheda. 1986. Variation in inflorescence characteristics of African rice (Oryza glaberrima Steud.). Beitraefe zur Tropischen Lundwirtschaft und Veterinaermedizin 24(2):153-159.

Ghesquiere, A. 1985. Evolution of Oryza longistaminata. Pp. 15-25 in Rice Genetics. International Rice Research Institute

(IRRI), Los Banos.
Jusu, M.S. and S.S. Monde. 1990. Panicle and grain characters of some glaberrima cultivars in Sierra Leone. International Rice Research Newsletter 15(3):5-6.
Leung, Woot-tseun, W., F. Busson, and C. Jardin. 1968. Food Composition Table for Use in Africa. U.S. Department of Health, Education, and Welfare and the Food and Agriculture Organization of the United Nations (FAO). Bethesda Maryland.
Miezan, K. M.A. Choudhury, A. Ghesquiere, and G. Koffi. 1986. The use of Oryza sativa and Oryza glaberrima in West African farming systems. Pp. 213-218 in Progress in Upland Rice Research. Second International Upland Rice Conference, Jakarta, Indonesia, March 4-8, 1985, IRRI, Manila.
Morishima, H. and H.l. Oka. 1979. Genetic diversity in rice populations of Nigeria: influence of community structure. Agro-Ecosystems 5:263-269.
Netting, R. McC., D. Cleveland, and F. Stier. 1980. The conditions of agricultural intensification in the West African

Savannah. Pages 187-505 in S.P. Reyna, ea., Sahelian Social Development. USAID, Abidjan. (especially the section entitled "Interior Niger Delta of Mali")

Ogbe, F.M.D. 1993. Lost crops of Nigeria: West African rice. Pp. 71-94 in J.A. Okojie and D.U.U. Okali, eds., Lost Crops of Nigeria: Implications for Food Security. Conference Proceedings Series No. 3. University of Agriculture Abeokuta, Nigeria.

Ogbe, F.M.D. and J.T. Williams. 1978. Evolution in indigenous West African rice. Economic Botany 32(1):59-64.

Oka, H.I. 1975. Mortality and adaptive mechanisms of Oryza perennis strains. Evolution 30:380392.

Oka H.I. 1977. Genetic variations of Oryza glaberrima: their survey and evaluation. Pp. 77-86 in I RAT [Institut de Recherches Agronomiques Tropicales et des cultures vivrieres] - ORSTOM [Institute Francais de Recherche Scientifique pour le Developpement en Cooperation de Montpellier] Meeting on Africa Rice Species. Paris, 25-26 January 1977. IRAT-

ORSTOM, Paris.
Oka, H.I. 1988. Origin of cultivated rice. In Developments in Crop Science 14. Japan Scientific Societies Press. Tokyo Elsevier, Amsterdam. 254 pages.
Pernes, J. 1984. Les riz. In Gestion des Ressources Genetiques des Plantes. Volume I, Monographies (212 pp.). Volume 2, Manuel (346 pp.). Technique et documentation. Available from Lavoisier, 11 rue Lavoisier, 75384 Paris cedex 08, France.
Porteres, R. 1956. Taxonomie agrobotanique des riz cultives O. sativa Linne et O. glaberrima Steudel. Compilations d'articles du JATBA. Museum National d'Histoire Naturelle, Paris.
Porteres, R. 1956. Journal d'Agriculture Tropical et de Botanique Appliques 3:341, 541, 627, 821. Richards, P. 1986. Coping with Hunger: Hazard and Experiment in a West African Rice-Farming System. Allen and Unwin, London.
Sano, Y., T. Fujii, S. Iyama, Y. Hirota, and K. Komagata. 1981. Nitrogen fixation bacteria in the rhizosphere of cultivated and

wild rice strains Oryza glaberrima, Oryza perennis, Oryza punctata. Crop Science 21(5):758-761.
Sano, Y.. R. Sano, and H. Morishima. 1984. Neighbour effects between two co-occurring rice species, Oryza sativa and O. glaberrima. Journal of Applied Ecology 21:245-254.
Schreurs, W. 1988. Les experiences en riz flottant dur project FENU a Tombouctou. FENU MLI/ 83/006, FAO. PNUD MLI/84/009, Tombouctou. (Copies available from author, see Appendix G.)
Thom, D.J. and J.C. Wells. 1987. Farming systems in the Niger inland delta, Mali. The Geographic Review 77(3):328-342.
Toure, A.l., M.A. Choudhury, M. Goita. S. Koli, and G.A. Paku. 1982. Grain yield and yield components of deep water rice in West Africa. Pp. 103-112 in Proceedings of the /98/ International Deepwater Rice Worlkshop, Bangkhen, Thailand. IRRI, Laguna, Philippines.
Treca, B. 1987. Bird damage in floating rice in Mali. Journal d'Agriculture Traditionnelle et de Botanique Appliques 34:

153-170.
Vallee, G. and H.H. Vuong. 1978. Floating rice in Mali. In l.W. Buddenhagen and G.J. Persley, eds., Rice in Africa. Academic Press, London.
Yabuno, T. 1981. The transfer of a gene for glutinous endosperm to Oryza glaberrima Steud. from a japonica variety of Oryza sativa L. Euphytica 30(3):867-873.

FINGER MILLET

Appa Rao, S., L.R. House. and S.C. Gupta. 1989. Review of Sorghum, Pearl Millet, and Finger Millet Improvement in SADCC/Souther nAfrica Development Coordination Council] Countries. SACCAR/International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Bulawayo, Zimbabwe. 170 pp.
Barbeau, W.E. and K.W. Hilu. 1993. Protein, calcium, iron, and amino acid content of selected wild and domesticated cultivars

of finger millet. Plant Foods for Human Nutrition 43(2):97104.
Engels, J.M.M., J.G. Hawkes, and M. Worede, eds. 1991. Plant Genetic Resources of Ethiopia. Cambridge University Press, Cambridge, UK. 383 pp.
Flack, E.N., W. Quak, and A. von Diest. 1987. A comparison of the rock phosphate mobilizing capacities of various crop species. Tropical Agriculture (UK) 64(4):347-352.
Gupta, S.C. and J.N. Mushonga. 1994. Registration of' 'SDEY 87001' finger millet. Crop Science 34(2):536.
Hiremath, S.C. and S.S. Salimath. 1992. The 'A' genome donor of Eleusine coracana (L) Gaertn. (Gramineae). Theoretical and Applied Genetics 84(5/6):747-754.
Kono, Y., A. Yamauchi, T. Nonoyama, and J. Tatsumi. 1988. Comparison of growth responses of summer cereals with special reference to waterlogging and rooting ability. Japanese Joarnal of Crop Science 57(2):321-331.
Marathee, J.P. Structure & characteristics of world millet economy. 1993. Pp. 159-178 in K.W. Riley, S.C. Gupta, A.

Seetharam, and J.N. Mushonga, eds., Advances in Small Millets. Proceedings of an International Development Research Centre/ICRISAT conference. Oxford International Book House New Delhi.
Mtebe, K., B.K. Ndabikunze N.T.A. Bangu, and E. Mwemezi. 1993. Effect of cereal germination on the energy density of togwa. International Journal of Food Sciences and Nutrition 44(3):175180.
Pius, J., L. George, S. Eapen. and P.S. Rao. 1994. Evaluation of somaclonal and mutagen induced variation in finger millet. Plant Breeding 112(3):239-243.
Purseglove, J.W. 1972. Tropical Crops: Monocotyledons. Volumes I and 11. Longman Scientific and Technical, Harlow, Essex UK John Wiley, New York. 607 pp.
Rachie , K.O. and L. V. Peters. 1977. The Eleusines: A Review of the World Literature. ICRISAT, Hyderabad, India. 179 pp.
Rai, R. 1991. Isolation, characterization and associative N-fixation of acid-tolerant Azospirillum brasilense strains

associated with Eleusine coracana in low pH-Al-rich acid soil. Developments in Plant and Soil Sciences 45:663-671.

Riley, K.W., S.C. Gupta, A. Seetharam, and J.N. Mushonga, eds. 1993. Advances in Small Millets. Proceedings of an International Development Research Centre (IDRC)/ICRISAT conference. Oxford International Book House, New Delhi.

Seetharam, A., K.W. Riley, and G. Harinarayana, eds. 1989. Small Millets Global Agriculture: Proceedings of the First International Small Millets Workshop, Bangalore, India, October 29-November 2, 1986. Oxford & IBH Publishing Company, New Delhi. 392 pp.

Serna-Saldivar, S.O., C.M. McDonough, and L.W. Rooney. 1990. The millets. Pp. 271-300 in K.J. Lorenz and K. Kulp, eds., Handbook of Cereal Science and TechnologY. Dekker, New York.

Shankara, R., N.G. Malleshi, H. Krishnamurthy, M.N. Narayana, and H.S.R. Desikachar. 1985. Development of mini grain mill for dehusking and grinding of cereals. Journal of

Food Science Technology 22:91.
Somasekhara, Y.M., S. Viswanath, T.B. Anilkumar. 1991. Evaluation of finger millet [Eleusine coracana (L.) Gaertn.] cultivars for their reactions to blast (Pyricudaria Elisha Sacc.). Tropical Agriculture 68(3):231-234.
Somasekhara, Y.M., S. Viswanath, and T.B. Anilkumar. 1992. Screening of finger millet (Eleusine coracana) cultivars for multiple disease resistance. Tmpical Agriculture 69(3):293-295.
Tewari, L., B.N. Johri, and S.M. Tandon. 1993. Host genotype dependency and growth enhancing ability of VA-mycorrhizal fungi for Eleusine coracana (finger millet).[World] Jurnal of Microbial Biotechnoloqy 9(2):191-195.
Vittal, K.P.R., K. Vijayalakshmi, and U.M. Bhaskara Rao. 1991. Effects of topsoil, rainfall, and fertilizer on finger millet on an alfisol in India. Soil Science 152(1):3-6.

FONIO (Ache)

Baptist, N.G. and B.P.M. Perera. 1956. Essential amino-acids of some tropical cereal millets. British Journal of Nutrition)0:334-337.
Busson, F. 1965. Plantes Alimentaires de l'Ouest Africain: Etude Botanique, Biologique et Chimique Les Presses de l'Imprimerie Leconte, Marseilles.
Carbiener, R., P. Jaeger, and F. Busson. 1960. Study of the protein fraction of fonio grain. Digitaria exilis (Kippist), Stapf., a protein exceptionally rich in methionine. Ann. Natrit. Alimentation Mem. 14:165-169.
De Lumen, B.O., R. Becker, and P.S. Reyes. 1986. Legumes and a cereal with high methionine/ cysteine contents. Journal of Agricultural and Food Chemistry 34(2):361-364.
De Lumen, B.O., S. Thompson, and W.J. Odegard. 1993. Sulfur amino acid-rich proteins in ache (Digitaria exilis), a promising underutilized African cereal. Journal of Agricultural and Food Chemistry 41(7):1045-1047.
Gbodi, T.A., N. Nwude, Y.O. Aliu, and C.O. Ikediobi. 1986. The

mycoflora and some mycotoxins found in ache (Digitaria exilis Stapf.) in Plateau State, Nigeria. Food and Chemical Toxicology 24(4):339-342.

Harlan, J.R., J.M.J. de Wet, and A.B.L. Stemler. 1976. Origins of African Plant Domestication. Mouton Publishers, The Hague. 498 pp.

Jideani, I.A. 1990. Acha, Digitaria exilis, the neglected cereal. Agriculture International 42(5):132134.

Jideani, I.A. and J.O. Akingbala. 1993. Some physicochemical properties of ache (Digitaria exilis Stapf) and iburu (Digitaria iburua Stapf) grains. Journal of the Science of Food and Agriculture 63(3):369-374.

Oyenuga, V.A. 1968. Nigeria's Foods and Feeding Stuffs (Their Chemistry and Nutritive Value (third ea., rev.). Ibadan University Press, Ibadan, Nigeria. 99 pp.

Oyewole O.B. and J.O. Akingbala. 1993. "Ache" (Digitaria exilis): a little known cereal with high potential. Pp. 323-326 in J.A. Okojie and D.U.U. Okali, eds., Lost Crops of

Nigeria:Implications for Food Security. Conference Proceedings Series No. 3. University of Agriculture, Abeokuta, Nigeria.
Porteres, R. 1955. Les cereales mineures du genre Digitaria en Afrique et en Europe.
Journal d'Agriculture Tropical et de Botanique Applique 2:349-386, 477-510, 620-675.
Riley, K.W., S.C. Gupta, A. Seetharam, J.N. Mushonga, eds. 1993. Advances in Small Millets. Proceedings of an IDRC/ICRISAT conference. Oxford International Book House, New Delhi.
Temple, V.J. and J.D. Bassa. 1991. Proximate chemical composition of Acha (Digitaria exilis) grain. Journal of the Science of Food and Agriculture 56(4):561-563.
PEARL MILLET Andrews, D.J. 1974. Responses of sorghum varieties to intercropping. Experimental Agriculture 1 0:57-63.
Andrews, D.J. and P.J. Bramel-Cox. In press. Breeding varieties for sustainable crop production in low input dryland agriculture in the tropics. Pages 211-223 in D.R. Buxton et al.,

eds. International Crop Science 1. Proceedings of a Conference, Ames, Iowa, July 1993. CSSA, Madison, Wisconsin.
Andrews, D.J. and K.A. Kumar. 1992. Pearl millet for food, feed and forage. Advances in Agronomy 48:90-139.
Andrews, D.J., J.F. Rajewski, and K.A. Kumar. 1993. Pearl millet: a new feed grain crop. Pp. 198208 in J. Janick and J.E. Simon, eds.. New Crops. Purdue University Press, Lafayette, Indiana.
Annegers, J.F. 1973. Ecology of dietary patterns and nutritional status in West Africa 1: distribution of starchy staples. Ecology of Food Nutrition 2(2):107-119.
Annegers, J.F. 1973. The protein-calorie ratio of West African diets and their relationship to protein calorie malnutrition. Ecology of Food Nutrition 2(3):22S-235.
Annegers, J.F. 1973. Seasonal foods shortages in West Africa. Ecology of Food Nutrition 2(4):251257.
Annegers, J.F. 1974. Protein quality of West African foods.

Ecology of Food Nutrition 3(2):125130.
Appa Rao, S. 1987. Traditional food preparations of pearl millet in Asia and Africa. In J.R. Witcombe and S.R. Beckerman, eds., Proceedings of the International Pearl Millet Workshop, 7-11 April, 1986. ICRISAT, Patancheru.
Appa Rao, S., M.H. Mengesha, and V. Subramanian. 1982. Collection and preliminary evaluation of sweet-stalk pearl millet (Pennisetum). Economic Botany 36:286-290.
Badi, S., B. Pedersen, L. Manowar, and B.O. Eggum. 1990. The nutritive value of new and traditional sorghum and millet foods from Sudan. Plant Foods for Human Nutrition 40:5-19.
Bationo, A., C.B. Christianson. and W.E. Baethgen. 1990. Plant density and nitrogen fertilizer effects on pearl millet production in Niger. Agronomy Journal 82(2):290-295.
Bationo, A., C.B. Christianson, and M.C. Klaij. 1993. The effect of crop residue and fertilizer use on pearl millet yields on Niger. Fertilizer Research 34(3):251-258.
Brunken, J.N., J.M.J. de Wet, and J.R. Harlan. 1977. The

morphology and domestication of pearl millet. Economic Botany 31:163-174.
Bunting, A.H. 1984. Advancing agricultural production in Africa: a personal review. Pages 435-445 in D.L. Hawksworth, ea., Advancing Agricultural Production in Africa. Commonwealth Agricultural Bureaux, Farnham Royal, UK.
Burton, C.W. and J.B. Powell. 1968. Pearl millet breeding and cytogenetics. Advances in Agronomy 20:49-89.
Burton, G.W., W.W. Hanna, J.C. Johnson, Jr., D.B. Lenck, W.G. Monson, J.B. Powell, H.D.
Wells, and N.W. Widstrom. 1977. Pleiotropic effects of the tr trichomology gene in pearl millet on transpiration, forage quality and pest resistance. Crop Science 17:613-616.
Burton, G.W. and B.K. Werner. 1991. Genetic markers to locate and transfer heterotic chromosome blocks for increased pearl millet yields. Crop Science 31(3):576-579.
Buxton, D.R. et al., eds. In press. International Crop Science 1. Proceedings of a Conference, Ames, Iowa, July 1993. CSSA,

Madison, Wisconsin. Council of Scientific and Industrial Research (CSIR). 1966. The Wealth of India (volume 8). Publications & Information Directorate, CSIR. New Delhi.
Curtis, D.L., G.W. Burton, and O.J. Webster. 1966. Carotenoids in pearl millet seed. Crop Science 6:300-301. (vitamin-A millets) Geiger, S.C., A. Manu, and A. Bationo. 1992. Changes in a sandy Sahelian soil following crop residue and fertilizer additions. Soil Science Society of America Journal 56(1):172-177.
Hamon, S. 1993. Le mil en Afrique. Proceedings of a meeting on millet (Pennisetum glaucum L.), Montpellier, France, 24-26 November, 1992. Institut Francais de Recherche Scientifique pour le Developpe en Cooperation (ORSTOM), Montpellier. 283 pp.
Hanna, W.W. 1987. Utilization of wild relatives of pearl millet. In J.R. Witcombe and S.R. Beckerman, eds., Proceedings of the International Pearl Millet Workshop, 7-11 April, 1986. ICRISAT, Patancheru.

Hanna W.W. 1990. Transfer of germ plasm from the secondary to the primary gene pool in Pennisetum. Theoretical and Applied Genetics 80(2):200-204.

Hill, G.M. and W.W. Hanna. 1990. Nutritive characteristics of pearl millet grain in beef cattle diets. Journal of Animal Science 68:2061-2066.

Hoseney, R.C. and E. Varriano-Marston. 1979. Pearl millet: its chemistry and utilization. Pages 461-494 in Cereals for Food and Beverages, G.E. Inglett and L. Munck, eds. Academic Press, New York.

Hoseney, R.C., D.l. Andrews, and H. Clark. 1987. Sorghum and pearl millet. Pages 397-456 in Nutritional Quality of Cereal Grains: Genetic and Agronomic Improvement. Agronomy Monograph No. 28. CSSA, 677 South Segoe Road, Madison, Wisconsin 53711.

Hoseney, R.C., E. Varriano-Marston, and D.A.V. Dendy. 1981. Sorghum and millets: anatomy, composition, milling. Pp. 71-144 in Y. Pomeranz, ea., Advances in Cereal Science and

Technology, Volume IV. American Association of Cereal Chemists (AACC), St. Paul, Minnesota.
Howarth, C.J. 1990. Heat shock proteins in sorghum and pearl millet; ethanol, sodium arsenite, sodium malonate and the development of thermotolerance. Journal of Experimental Botany 41(228):877-883.
Hulse, J.H., E.M. Laing, and O.K. Pearson. 1980. Sorghum and Millets: Their Composition and Nutritive Value. Academic Press, New York. 997 pp. International Sorghum/Millet (INTSORMIL) Collaborative Research Support Program/ICRISAT. 1987. Proceedings of the International Pearl Millet Workshop. ICRISAT, Patancheru. 278 pp.
INTSORMIL. 1990. Annual Report 1990. INTSORMIL, University of Nebraska, Lincoln. 246 pp.
INTSORMIL. 1991. Annual Report 1991. INTSORMIL, University of Nebraska, Lincoln. 256 pp.
Kumar, K.A. 1989. Pearl millet: current status and future potential. Outlook on Agriculture 18(2): 46-53.

Lambert, C. 1982. IRAT[Institut de Recherches Agronomiques Tropicales et des cultures vivrieres] et l'amelioration de milt Agronomie Tropical. 38:78-88.
Mahalakshmi, V., F.R. Bidinger, K.P. Rao, and D.S. Raju. 1992. Performance and stability of pearl millet topcross hybrids and their variety pollinators. Crop Science 32(4):928-932.
Marathee, J.P. Structure & characteristics of world millet economy. 1993. Pp. 159-178 in K.W. Riley, S.C. Gupta, A. Seetharam, and J.N. Mushonga, eds., Advances in Small Millets. Proceedings of an IDRC/ICRISAT conference. Oxford International Book House, New Delhi.
Matlon, P.J. 1990. Improving productivity in sorghum and pearl millet in semi-arid Africa. Food Research Institute Studies 22(1):1-43.
Mohammed, M.S. and M.D. Clegg. 1993. Pearl millet-soybean rotation and nitrogen fertilizer effects on millet productivity. Agronomy Journal 85(5):1009-1013.
Niangodo, O. and B. Ouendeba. 1987. Varietal improvement of

pearl millet in West Africa. Pp. 95105 in J.R. Witcombe and S.R. Beckerman, eds., Proceedings of the International Pearl Millet Workshop, 7-11 April, 1986. ICRISAT, Patancheru.

Obizoba, I.C. and J.V. Atii. 1994. Evaluation of the effect of processing techniques on the nutrient and antinutrient contents of pearl millet (Pennisetum glaucum) seeds. Plant Foods for Human Nutrition 45(1):23-34.

Oendeba, B., G. Ejeta, W.E. Nyquist, W.W. Hanna, and A. Kumar. 1993. Heterosis and combining ability among African pearl millet landraces. Crop Science 33(4):735-739.

Pantulu, J.V. and M. Krishna Rao. 1982. Cytogenetics of pearl millet. Theoretical and Applied Genetics 61: 1-17.

Rachie, K.O. and J.V. Majmudar. 1980. Pearl Millet. Pennsylvania State University Press, University Park, Pennsylvania. 307 pp.

Read, J.C. and E.C. Bashaw. 1974. Intergeneric hybrid between pearl millet and buffelgrass. Crop Science 14:401-403.

Serna-Saldivar, S.O., C.M. McDonough, and L.W. Rooney. 1990. The millets. Pp. 271-300 in K.J. Lorenz and K. Kulp, eds., Handbook of Cereal Science and Technology. Dekker, New York.

Singh, P., Y. Singh, B.O. Eggum, K.A. Kumar, and D.J. Andrews. 1987. Nutritional evaluation of high protein genotypes in pearl millet. Journal of the Science of Food and Agriculture 38:4148.

Smith, R.L., L.S. Jensen, C.S. Hoveland, and W.W. Hanna. 1989. Use of pearl millet, sorghum, and triticale grain in broiler diets. Journal of Production Agriculture 2:78-82.

Tostain, S. 1992. Enzyme diversity in pearl millet (Pennisetum glaucum L.). 3. Wild millet. Theoretical and Applied Genetics 83(617):733-742.

PEARL MILLET, Subsistence Types International Development Research Centre (IDRC). 1979. Sorghum and Millet: Food Production and Use. Report of a workshop held in Nairobi, Kenya, July 4-7, 1978. S. Vogel and M. Graham, eds. Report

No. IDRC-123e. IDRC, Ottawa, Canada Wendt, J.W., A. Berrada, M.G. Gaoh, and D.G. Schulze. 1993. Phosphorus sorption characteristics of productive and unproductive Niger soils. Soil Science Society of America Journal 57(3):766-773.
Zaongo, C.G.L., L.R. Hossner, and C.W. Wendt. 1994. Root distribution, water use, and nutrient uptake of millet and grain sorghum on West Africa soils. Sod Science 157(6):379-388.
PEARL MILLET, Commercial Types
Bramel-Cox, P.J., K. Anandkumar, J.H. Hancock, and D.J. Andrews. In press. Sorghum and millets for forage and feed. In D.A.V. Dendy. ea., Sorghum and Millets: Chemistry and Technology. AACC, St. Paul, Minnesota.
D.A.V. Dendy, ea., In press. Sorghum and Millets: Chemistry and Technology. AACC, St. Paul, Minnesota.
Hoseney, R.C. and E. Varriano-Marston. 1980. Pearl millet: its chemistry and utilization. Pp. 462494 in G.E. Inglett and L. Munck, eds. Cereals for Food and Beverages: Recent Progress in Cereal Chemistry and Technology. Proceedings of an

international conference, August 13-17' 1979, Copenhagen, Denmark. Academic Press, New York.

Hoseney, R.C., E. Varriano-Marston, and D.A.V. Dendy. 1981. Sorghum and millets: anatomy composition, milling. Pp. 71-144 in Y. Pomeranz, ea., Advances in Cereal Science and Technology, Volume IV. AACC, St. Paul, Minnesota.

Hulse, J.H., E.M. Laing, and O.K. Pearson. 1980. Sorghum and Millers: Their Composirion ahd Nutritive Value. Academic Press, New York. 997 pp.

Kumar, K.A., S.C. Gupta, and D.J. Andrews. 1983. Relationship between nutritional quality characters and grain yield in pearl millet. Crop Science 23:232-235.

Rachie, K.O. and J.C. Majmudar. 1980. Pearl Millet. Pennsylvania State University Press, University Park, Pennsylvania. 307 pp.

SORGHUM

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Andrews, D.J. 1972. Intercropping with sorghum in Nigeria. Experimental Agriculture 8:139-150.

Andrews, D.J. 1974. Responses of sorghum varieties to intercropping. Experimental Agriculture 10:57-63.

Andrews, D.J. and P.J. Bramel-Cox. 1993. Breeding varieties for sustainable crop production in low input dryland agriculture in the tropics. Pages 211-223 in D.R. Buxton et al., eds. International Crop Science 1. Proceedings of a Conference, Ames, Iowa, July 1993. CSSA, Madison, Wisconsin.

Bramel-Cox, P.J., K. Anandkumar, J.H. Hancock, and D.J. Andrews. In press. Sorghum and millets for forage and feed. In D.A.V. Dendy, ea., Sorghum and Millets: Chemistry and Technology. AACC, St. Paul, Minnesota.

Brand, T.S., H.A. Badenhorst, and F.K. Siebrits. 1990. The use of pigs both intact and with ileorectal anastomosis to estimate the apparent and true digestibility of amino acids in untreated, heat-treated and thermal-ammoniated high-tannin grain sorghum. South African Journal of Animals Science 20(4):223-228.
Bunting, A.H. 1984. Advancing agricultural production in Africa: a personal review. Pages 435-445 in D.L. Hawksworth, ea., Advancing Agricultural Production, in Africa. Commonwealth Agricultural Bureaux, Farnham Royal UK.
Buxton, D.R. et al., eds. In press. International Crop Science 1. Proceedings of a Conference, Ames, Iowa, July 1993. CSSA, Madison, Wisconsin. de Milliano, W.A.J., R.A. Frederiksen, and G.D. Bengston, eds. 1992. Sorghum and Millet Diseases: A Second World Review. ICRISAT, Patancheru. 370 pp.
Dendy, D.A.V., ed. In press. Sorghum and Millets: Chemistry and Technology AACC, St. Paul, Minnesota.
DeWalt, B.R. 1985. Mexico's second Green Revolution: food

for feed. Mexican Studies/Estudios Mexicanos 1(1):29-60.
Doggett, H. 1988. Sorghum. Longmans, London. 515 pp.
Doumbia, M.D., L.R. Hossner, and A.B. Onken. 1993. Variable sorghum growth in acid soils of subhumid West Africa. A/id Soil Research and Rehabilitation 7(4):335-346.
Eggum, B.O. 1990. Importance of sorghum as a food in Africa. Pp. 222-228 in G. Ejeta, E.T.
Mertz L. Rooney, R. Schaffert, and J. Yohe, eds., Sorghum Nutritional Quality: proceedings of a,; international conference held February 26-March 1, 1990. Purdue University, West Lafayette, Indiana.
Einhellig, F.A. and l.F. Souza. 1992. Phytotoxicity of sorgoleone found in grain sorghum root exudates. Journal of Chemical Ecology 18(1):1-11.
Ejeta, G. 1983. Hybrid Sorghum Seed forSudan: Proceedings of a Workshop, November 5-8 1993 Gezira Research Station, Sudan. Agricultural Research Corporation, Wad Medani, Sudan.

Ejeta, G., E.T. Mertz, L. Rooney, R. Schaffert, and J. Yohe, eds. 1990. Sorghum Nutritional Quality: proceedings of an international conference held February 26-March 1, 1990. Purdue University, West Lafayette, Indiana.
Engels, J.M.M., J.G. Hawkes, and M. Worede, eds. 1991. Plant Genetic Resources of Ethiopia. Cambridge University Press, Cambridge, UK. 383 pp.
House, L.R. 1985. A Guide to Sorghum Breeding. 2nd edition. ICRISAT, India. 238 pp.
Howarth, CJ. 1990. Heat shock proteins in sorghum and pearl millet; ethanol. sodium arsenite, sodium malonate and the development of thermotolerance. Journal of Experimental Botany 41(228):877-883.
Hulse, J.H., E.M. Laing, and O.K. Pearson. 1980. Sorghum and the Millets: Their Composition and Nutritive Value. Academic Press, New York. 997 pp.
ICRISAT. 1982. Sorghum in the Eighties: Proceedings of the International Symposium on Sorghum. November 2-7 1981.

Patancheru, A.P. India. ICRISAT, Patancheru.
International Board for Plant Genetic Resources (IBPGR). 1976. Proceedings of the Meeting of the Advisory Committee on Sorghum and Millets Germplasm. Rome. Mimeo.
IDRC. 1979. Sorghum and Millet: Food Production and Use. Report of a workshop held in Nairobi, Kenya, 4-7 July 1978. S. Vogel and M. Graham, eds. IDRC, Ontario, Canada.
IRAT. 1978. L'IRAT et l'amelioration due sorgho. Agronomic Tropicale 32:279-318.
INTSORMIL/ICRISAT. 1987. Proceedings of the International Pearl Millet Workshop.
ICRISAT, Patancheru. 278 pp.
Leng, E.R. 1982. Status of sorghum production as compared to other cereals. Pages 25-32 in Sorghum in the Eighties: Proceedings of the International Symposium On Sorghum. November 2-7 1981. Patancheru, A.P. India. ICRISAT, Patancheru.
Lopez-Pereira, M.A., et al. 1990. New agricultural technologies

in Honduras: an economic evaluation of new sorghum cultivars in southern Honduras. Journal for Farming System Research and Extension 1(2):81-103.
Matlon, P.J. 1990. Improving productivity in sorghum and pearl millet in semi-arid Africa. Food Research Institute Studies 22(1):1-43.
Quinby, J.R. 1971. A Triumph of Research . . . Sorghum in Texas. Texas A&M University Press, College Station. 28 pp.
Quinby, J.R. 1974. Sorghum Improvement and the Genetics of Growth Texas A&M University Press. College Station Texas. 108 pp.
Rooney L.W., A.W. Kirleis, and D.S. Murty. 1986. Traditional foods from sorghum: their production, evaluation, and nutritional value. Pages 317-353 in Advances in Cereal Science and Technology volume 3. AACC, St. Paul, Minnesota.
Serna-Saldivar, S.O., C.M. McDonough, and L.W. Rooney. 1990. The millets. Pp. 271-300 in K.J. Lorenz and K. Kulp, eds., Handbook of Cereal Science and Technology . Dekker,

New York.
Van de Venter, H.A. and W.H. Lock. 1992. An investigation of heat-shock and thermotolerance induction responses as indices of seed vigour in grain sorghum [Sorghum bicolor (L.) Moench.]. Plant Varieties and Seeds 5(1):13-18.
Wenzel, W.G. 1991. The inheritance of drought resistance characteristics in grain sorghum seedlings. South African Journal of Plant and Soil 8(4):169-171.
Zaongo, C.G.L., L.R. Hossner, and C.W. Wendt. 1994. Root distribution, water use, and nutrient uptake of millet and grain sorghum on West Africa soils. Soil Science 157(6):379-388.

SORGHUM, Subsistence Types

Carr S.J. 1989. Technology for Small-scale Farmers in Sub-Saharan Africa. Technical Paper No. 109, World Bank, Washington, D.C. 106 pp.
DeWalt, B.R. 1985. Microcosmic and macrocosmic processes of

agrarian change in southern Honduras: the cattle are eating the forests. Pages 165-185 in Micro and Macro Levels of Analysis in Anthropology: Issues in Theory and Research. Westview Press, Boulder, Colorado and London. International Sorghum/Millet (INTSORMIL) Collaborative Research Support Program. 1990. Annual Report 1990. INTSORMIL, University of Nebraska, Lincoln. 246 pp.
INTSORMIL. 1991. Annual Report 1991. INTSORMIL, University of Nebraska, Lincoln. 256 pp.
Mukuru, S.Z. 1990. Traditional food grain processing methods in Africa. Pp. 216-221 in G.
Ejeta, E.T. Mertz, L. Rooney, R. Schaffert, and J. Yohe, eds., Sorghum Nutritional Quality: proceedings of an international conference held February 26-March 1, 1990. Purdue University, West Lafayette, Indiana.
Rao, N. G P. 1982. Transforming traditional sorghums in India. Pages 39-59 in sorghum in the Eighties: Proceedings of the International Symposium on Sorghum. November 2-7 1981.

ICRISAT, Patancheru.

SORGHUM, Commercial Types

Bennett, W.F., B.B. Tucker. and A.B. Maunder. 1990. Modern Crain Sorghum Production. Iowa State University Press, Ames. 169 pp.
DeWalt, B.R. and D. Barkin. 1987. Seeds of change: the effects of hybrid sorghum and agricultural modernization in Mexico. Pages 138-161 in H.R. Bernard and P.J. Pelto, eds., Technology and Social Change, 2nd ed. Waveland Press, Prospect Heights, Illinois. 393 pp.
Faure, J. 1988. Sorghum utilization in pasta production. Paper presented in the International Workshop on Policy and Potential Relating to Uses of Sorghum and Millets. June 8-12, 1988. SADCC/ICRISAT. Bulawayo, Zimbabwe.
ICRISAT. 1990. Industrial Utilization of Sorghum: Summary of a Symposium on the Current Status and Potential of Industrial

Uses of Sorghum in Nigeria. December 4-6, 1989, Kano Nigeria. ICRISAT, Patancheru, andhra Pradesh, India. 59 pp.

SORGHUM, Specialty Types

Gupta, S.C., J.M.J. dewet, and J.R. Harlan. 1978. Morphology of Saccharam -Sorghum hybrid derivatives. American Journal of Botany 65:936-942. (sorghum relatives)
Gupta, S.C., J.R. Harlan, and J.M.J. dewet. 1978. Cytology and morphology of a tetraploid Sorghum population recovered from a Saccharum = Sorghum hybrid. Crop Science 18:879-883. (sorghum relatives)
Haggblade, S. and W.H. Holzapfel. 1989. Industrialization of Africa's indigenous beer brewing. Pages 191-283 in K.H. Steinkraus, ea., Industrialization of Indigenous Fermented Foods, Dekker, New York. (beer sorghums)
Hahn, D.H., L.W. Rooney, and C.F. Earp. 1984. Tannins and phenols of sorghum. Cereal Foods World 29(12):776-779.

(tannin-free sorghums)
Jabri. A., R. Chaussat. M. Jullien, and Y. le Deunff. 1989. Callogenesis and somatic embryogenesis in leaf portions of three varieties of sorghum with and without tannins. Agronomie (France) 9(1):101-107. (tannin-free sorghums)
Novellie, L. 1982. Fermented beverages. In L.W. Rooney and D.S. Murty, eds., Proceedings, International Grain Sorghum Qua/ity Workshop. ICRISAT, Patancheru.
Novellie, L. and P. De Schaepdrijver. 1986. Modern developments in traditional African beers. Pages 73-157 in M.R. Adams, ea., Progress in Industrial Microbiology, Vol. 23, Elsevier, Amsterdam. (beer sorghums)
Thorat, S.S., P.N. Satwadhar, D.N. Kulkarni, S.D. Choudhari, and U.M. Ingle. 1990. Varietal differences in popping quality of sorghum grains. Journal of Maharashtra AgriculturalUniversities 15(2):173-175. (popping sorghums)

SORGHUM, Fuel and Utility Types

Clegg, M.D, H.J. Gorz, J. W. Maranville, and F.A. Haskins. 1986. Evaluation of agronomic and energy traits of Wray sweet sorghum and the N39x Wray hybrid. Energy Agriculture 6:49-54.
Coleman, O.H. 1970. Syrup and sugar from sweet sorghum. Page 438 in J.S. Wall and
W.M. Ross, eds., Sorghum Production and Utilization. Avi Publishing Company, Westport,,Connecticut.
Cundiff, J.S. and D.H. Vaughan 1986. Sweet sorghum for ethanol industry for the Piedmont. Virginia Agricultural Experiment Station Bulletin 0096-6088, 86-9. Virginia Polytechnic Institute and State University, Blacksburg, Virginia.
Gascho. G.J., R.L. Nichols, and T.P. Gaines. 1984. Growing sweet sorghum as a source of fermentable sugars for energy. Research Bulletin 315. University of Georgia Experiment Station, Athens, Georgia.
Gas Research Institute. 1982. SNC [synthetic natural gas]

from land-based biomass: 1981 program final report. Gas Research Institute, 8600 West Bryn Mawr Avenue, Chicago, IL 60631, USA. 111 pp.
Gibbons, W.R., C.A. Westby, and T.L. Dobbs. 1986. Intermediate-scale. semicontinuous solid phase fermentation process for production of fuel ethanol from sweet sorghum. Applied Environmental Microbiology 51 (1) :115-1 22.
Hills, F.J., R.T. Lewellen, and l.O. Skoyen. 1990. Sweet sorghum cultivars for alcohol production. Calfornia Agriculture 44(1):14-16.
Kapocsi, I., J. Lezanyi, and B. Kevacs. 1983. Utilization of sweet sorghum for alcohol production. Internationale Zeitschrift fuer Landwirtschaften 5:441-443.
Kresovich, S., R.E. McGee, L. Panella, A.A. Reilley,andF.R.Miller. 1987. Application of cell and tissue culture techniques for the genetic improvement of sorghum, Sorghum birolor (L.) Moench: progress and potential. Advances in Agronomy 41:147-170.

Kresovich, S. and D.M. Broadhead. 1988. Registration of 'Smith' sweet sorghum. Crop Science 28(1): 195.

Kresovich, S., F.R. Miller, R.L. Monk, R.E. Dominy, and D.M. Broadhead. 1988. Registration of' 'Grassl' sweet sorghum. Crop Science 28(1):194-195.

Lipinsky, E.S., D.R. Jackson, S. Kresovich, M.F. Arthur, and W.T. Lawhon. 1979. Carbohydrate Crops as a Renewable Resource for Fuels Production, Vol. 1: Agricultural research, Battelle Memorial Institute Columbus Laboratories, Columbus, Ohio 43201, USA

Lueschen, W.E., D.H. Putnam, B.K. Kanne. and T.R. Hoverstad. 1991. Agronomic practices for production of ethanol from sweet sorghum. Journal of Production Agriculture 4(4):619-625.

McClure, T.A., M.F. Arthur, S. Kresovich, and D.A. Scantland. 1980. Sorghums - viable biomass candidates for fuel alcohol production. Volume 1, pp. 123-130 in Proceedings of the IV Internatlonal Symposium on Alcohol Fuels Technology, Guaruja, Sao Paulo, Brasil, 5-8 Oct. 1980 Instituto de Pesquisas Tecnologicas do Estado de Sao Paulo , Sao Paulo .

Miller, F.R. and G.G. McBee. 1993. Genetics and management of physiologic systems of sorghum for biomass production. Pages 41-49 in Methane from Biomass: Science and Technology. Biomass and Bioenergy, Vol. 5, No.l. Pergamon Press, Ltd., Oxford.

Morris, D.J. and 1. Ahmed. 1992. The carbohydrate economy: making chemicals and industrial malerials from plant matter. Institute for Local Self Reliance, Washington, DC.

Rajvanshi A.K., R.M. Jorapur, and N. Nimbkar. 1989. VITA News, October. Pp. 7-8.

Ricaud, R. and A. Arceneaux. 1990. Sweet sorghum research on biomass and sugar production in 1990. Pp. 136-139 in Report of Projects, Louisiana Agricultural Experiment Station, Department of Agronomy, Louisiana State University, Baton Rouge, Louisiana.

Schaffert, R.E. 1988. Sweet sorghum substrate for industrial

alcohol. Paper presented in the International Workshop on Policy and Potential Relating to Uses of Sorghum and Millets. June 8-12, 1988. SADCC/ICRISAT. Bulawayo, Zimbabwe.
Schaffert, R.E. and L.M. Gourley. 1982. Sorghum as an energy source. Pages 605-623 in Sorghum in the Eighties: Proceedings of the Intemational Symposium on Sorghum. November 2-7 1981. ICRISAT, Patancheru.
Smith, B.A. 1982. Sweet sorghum. Page 611 in l.A. Wolf, ea., CRC Handbook of Processing and Utilization in Agriculture. Volume 2. CRC Press, Boca Raton, Florida.
Weitzel, T.T., J.S. Cundiff, and D.H. Vaughan. 1986. Improvement of juice expression after separation of sweet sorghum pith from rind leaf. American Society of Agricultural Engineers
Microfiche Collection No. 86-6579. American Society of Agricultural Engineers, St. Joseph, Michigan.

TEF

Ashenafi, M. 1994. Microbial fore and some chemical properties of ersho, a starter for teff (Eragrostis tef) fermentation. [World] Journal of Microbial Biotechnology 10(1):69-73.
Berhe, T., L.A. Nelson, M.R. Morris, and J.W. Schmidt. 1989. Inheritance of phenotypic traits in tef: I - lemma color, II - seed color, III -panicle form. Journal of Heredity 80:62-70.
Besrat, A., A. Admasu, and M. Ogbai. 1980. Critical study of the iron content of tef (Eragrostis tef). Ethiopian Medical Journal 18:45-52.
Cheverton, M.R. and N.W. Galwey. 1989. Ethiopian t'ef: a cereal confined to its centre of variability. Pages 235-238 in G.E. Wickens, N. Haq, and P. Day, eds., New Crops for Food and Industry. Chapman and Hall, London and New York.
FAO. 1988. Traditional Food Plants. Food and Nutrition Paper 42. FAO, Rome.
Huffragel, H.P. 1961. Agriculture in Ethiopia FAO, Rome. 484 pp.

Jones, G. 1988. Endemic crops plants of Ethiopia I: t'ef (Eragrostis tef). Walia 11:37-43.
Ketema, S. 1988. Status of small millets in Ethiopia and Africa. Pp. 6-15 in Small Millets:
Recommendations for a Network. Proceedings of the Small Millets Steering Committee
Meeting, Addis Ababa, Ethiopia, 7-9 October 1987. International Development Research
Centre, Ottawa.
Ketema, S. 1991. Germplasm evaluation and breeding work on teff (Eragrostis tef) in
Ethiopia. Pp. 323-328 in Engels, J.M.M., J.G. Hawkes, and M. Worede, eds. 1991. Plant
Cenetic Resources of Ethiopia. Cambridge University Press, Cambridge, UK. 383 pp.
Lester, R.N. and E. Bekele. 1981. Amino acid composition of the cereal tef and related species of Eragrostis (Gramineae). Cereal Chemistry 58:113-115.

Mamo, T. and K.S. Kiliham. 1987. Effect of soil liming and vesicular-arbuscular-mycorrhizal inoculation on the growth and micronutrient content of the teff plant. Plant and Soil 102:257259.

Mamo, T. and J.W. Parsons. 1987. Phosphorus~micronutrient interactions in teff(Eragrostis tef). Tropical Agriculture 64:309-312.

Mamo, T. and J.W. Parsons. 1987. Iron nutrition of Eragrostis tef (teff). Tropical Agriculture 64:313-317.

Marathee, J.P. Structure & characteristics of world millet economy. 1993. Pp. 159-178 in
K.W. Riley, S.C. Gupta, A. Seetharam, and J.N. Mushonga, eds., Advances in Small Millets.
Proceedings of an IDRC/ICRISAT conference. Oxford International Book House, New Delhi.

Osuji, P.O. and B. Capper. 1992. Effect of age on fattening and body condition of draught oxen fed teff straw (Eragrostis teff) based diets. Tropical Animal Health and Productlion

24(2):103-108.

Parker, M.L., M. Umeta, and R.M. Faulks. 1989. The contribution of flour components to the structure of injera, an Ethiopian fermented bread made from tef (Eragrostis tef). Journal of Cereal Science 10(2):93-104.

Riley, K.W., S.C. Gupta, A. Seetharam, J.N. Mushonga, eds. 1993. Advances in Small Millets. Proceedings of an IDRC/ICRISAT conference. Oxford International Book House, New Delhi.

Seetharam, A., K.W. Riley, and G. Harinarayana. 1989. Small Millets in Global Agriculture. IDRC, Ottawa. Canada. 392 pp.

Tadesse, E. 1969. T'ef (Eragrostis tef): cultivation, usage, and some of the known disease and insect pests, Part 1. Experiment Station Bulletin No. 60. College of Agriculture, Haile Sellasie I University, Dire Dawa, Ethiopia. 56 pp.

Tadesse, E. 1975. T'ef (Eragrostis tef) cultivars: morphology and classification Part 11.Experiment Station Bulletin No. 66. College of Agriculture, Addis Ababa University, Dire Dawa,

Ethiopia. 73 pp.
Tadesse, D. 1993. Study of genetic variation of landraces of teff (Eragrostis tef (Zucc.) Trotter) in Ethiopia. Genetic Resources and Crop Evolution 40(2):101-104.
Tefera, H., S. Ketema, and T. Tesemma. 1990. Variability, heritability and genetic advance in tef (Eragrostis tef (Zucc.) Trotter) cultivars. Tropical Agriculture 67(4):317-320.
Twidwell, E.K., A. Boe, and D.P. Casper. 1991. Teff: a new annual forage grass for South
Dakota. Extension Extra 8071. South Dakota Cooperative Extension Service, Brookings, South Dakota.
Umeta, M. and R.M. Faulks. 1988. The effect of fermentation on the carbohydrates in tef (Eragrostis tef). Food Chemistry 27:181-189.
Westphal, E. and J.M.C. Westphal-Stevelsr 1975. Agricultural Systems in Ethiopia.
Agricultural Research Reports 82b. Puduc, Wageningen. 278 pp.

Wolde-Gebriel, Z. 1988. Nutrition. In Zein Ahmed Zein and Helmut Kloos, eds., The Ecology of Health and Disease in Ethiopia. Ministry of Health, Addis Ababa.

OTHER CULTIVATED GRAINS

General

Harlan, J.R. 1986. African Millets. Food and Agriculture Organization of the United Nations (FAO), Rome
Harlan, J.R. 1989. Wild grass seed harvesting in the Sahara and Sub-Sahara of Africa. In
Foraging and Farming: the Evolution of Plant Exploitation, D.R. Harris and G.C. Hillman, eds. Unwind Hyman, London.

Emmer

Gasrataliev, G.S. 1982. Forms of T. dicoccum promising for southern Dagestan. Bulletin of the N.I. Vavilov Institute of

Plant Industry 118:5-6.
Hakim, S., A.B. Damania, and M.Y. Moualla. 1992. Genetic variability in Triticum dicoccum Schubl. for use in breeding wheat for the dry areas. FAO/IBPGR Plant Genetic Resources Newsletter 88/89:1 1-15.
Mariam, G.H. and H. Mekbib. 1988. Agromorphological evaluation of T. dicoccum. PGRC/E: ILCA Germplasm Newsletter 6-11.
Robinson, J. and B. Skovmand. 1992. Evaluation of emmer wheat and other Triticeae for resistance to Russian wheat aphid. Genetic Resources and Crop Evolution 3913):159-163.

Barley

Endashaw Bekele. 1984. Relationships between morphological variance, gene diversity and flavonoid patterns in the land race populations of Ethiopian barley. Hereditas 100:271-294.
Engels, J.M.M., J.G. Hawkes, and M. Worede, eds. 1991. Plant

Genetic Resources of Ethiopia. Cambridge University Press. Cambridge, UK. 383 pp.

Huffragel, H.P. 1961. Agriculture in Ethiopia FAO, Rome. 484 pp.

Munck, L. 1988. The importance of botanical research in breeding for nutritional quality characteristics in cereals. Symbolae Botanicae Upsalienses 28(3):69-78.

Nulugeta Negassa. 1985. Patterns of phenotypic diversity in an Ethiopian barley collection, and the Arsi-Bale Highland as a centre of Origin of barley. Hereditas 102:139-150.

Qualset, C.O. 1975. Sampling germplasm in a centre of diversity: an example of disease resistance in Ethiopian barley. Pages 81-96 in O.H. Frankel and J.G. Hawkes, eds., Crop Genetic Resources for Today and Tomorrow, Cambridge University Press, Cambridge.

Westphal, E. and J.M.C. Westphal-Stevels. 1975. Agricultural Systems in Ethiopia. Agricultural Research Reports 82b. Puduc, Wageningen.278 pp.

Ethiopian oats

Baum, B.R. 1971. Taxonomic studies in Avena abyssinica and Avena vaviloviana, and some related species. Canadian Journal of Botany 49(12) 2227-2232

Engels, J.M.M., J.G. Hawkes, and M. Worede, eds. 1991. Plant Genetic Resources of Ethiopia. Cambridge University Press, Cambridge, UK. 383 pp.

Ladizinsky, G. 1975. Oats in Ethiopia (Arena barbata, Avena abyssinica, cereal weeds). Economic Botany 29(3):238-241.

Guinea Millet

Harlan, J.R. 1986. African Millets. Food and Agriculture Organization of the United Nations (FAO), Rome

Kodo millet

De Wet, J.M.J., K.E. Prasada Rao, M.H. Mengesha, and D.E.

Brink. 1983. Diversity in kodo millet, Paspalum scrobiculatum. Economic Botany 37(2):159-163.
Geervani, P. and B.O. Eggum. 1989. Effect of heating and fortification with lysine on protein quality of minor millets. Plant Foods for Human Nutrition 39(4):349-357.
Kapoor, P.N., S.P. Netke, and L.D. Bajpai. 1987. Kodo (Paspalum scorbiculatum) as a substitute for maize in chick diets. Indian Journal of Animal Nutrition 4(2):83-88.
Kaushik, S.K. and R.C. Gautam. 1985. Comparative performance of different millets at varying levels of nitrogen under dryland conditions. Indian Journal of Agronomy 30(4):509-511.
Ketema, S. 1988. Status of small millets in Ethiopia and Africa. Pp. 6-15 in Small Millets: Recommendations for a Network. Proceedings of the Small Millets Steering Committee Meeting, Addis Ababa, Ethiopia, 7-9 October 1987. International Development Research Centre, Ottawa.
Nayak, P. and S.K. Sen. 1991. Plant regeneration through

somatic embryogenesis from suspension culture-derived protoplasts of Paspalum scrobiculatum L. Plant Cell Reports 10(6/7):362-365.

Sridhar, R. and G. Lakshminarayana. 1992. Lipid class contents and fatty acid composition of small millets: little (Panicum sumatrense), kodo (Paspalum scrobiculatum), and barnyard (Echinocloa corona). Journal of Agricultural and Food Chemistry 40(1 1):2131-2134.

Sudharshana, L., P.V. Monteiro, and G. Ramachandra. 1988. Studies on the proteins of kodo millet (Paspalum scrobiculatum). Journal of the Science of Food and Agriculture 42(4):315-323.

WILD GRAINS

Breman, H. and L. Diarra. 1989, Easy methods to follow the changes of vegetation in natural pastures in the Sahel. Rapport CABO - Centre for Agrobiological Rescarch

(Netherlands) No. 102. 40 pp.
Elberse, W.T. and H. Breman. 1990. Germination and establishment of Sahelian rangeland species. 11. Effects of water availability. Oecologia 85(1):32-40. (Eragrostis tremula, kram- kram)
Harlan, J.R. 1989. Wild grass seed harvesting in the Sahara and Sub-Sahara of Africa. In D.R. Harris and G.C. Hillman, eds, Foraging and Farming: the Evolution of Plant Exploitation. Unwin-Hyman, London.
Kumar, A. 1976. Dry matter production and growth rates of three arid zone grasses in culture (Dactyloctenium aegyptium, Cenchrus biflorus and Cenchrus ciliaris). Comparative Physiology and Ecology 1(1):23-26. (Egyptian grass, kram- kram)
McKenzie, B. 1982. Resilience and stability of the grasslands of Transkei Aristida, Themeda, systems grazing, South Africa. Proceedings of the Grasslands Society of South Africa 17:2124. (Drinn, Therneda)

Nicolaisen, J. 1963. Ecology and Culture of the Pastoral Tuareg. Copenhagen National Museum, Copenhagen.

Salih, O.M., A.M. Nour and D.B. Harper. 1992. Nutritional quality of uncultivated cereal grains utilised as famine foods in western Sudan as measured by chemical analysis. Journal of the Science of Food and Agriculture 58:417-424. (Egyptian grass, kram-kram, Shama millet, wadi rice)

Sharma. B.M. and A.O. Chivinge. 1982. Contribution to the ecology of Dactyloctenium aegyptium (L.) P. Beauv.: A nutritious fodder, Nigeria. Journal of Range Management 35(3):326-331. (Egyptian grass)

Siddiqui, K.A. 1987. Contribution of Dactylactenium aegyptiurn (L.) Beauv. to bioreclamation of salt-affected soil. Annals of Arid Zone 26(4):301-303. (Egyptian grass)

United Nations Sudano-Sahelian Office (UNSO). 1990. Lakes of Crass: Regenerating Bourgou in the Inner Delta of the Niger River. Technical Publication No. 2, Spring 1990. UNSO, New York. 16 pp.

POTENTIAL BREAKTHROUGHS FOR GRAIN FARMERS

(Appendix A)

Bruggers, R.L. and C.C.H. Elliott, eds. 1989. Quelea ouelea: Africa's Bird Pest. Oxford University Press, Oxford, UK.

Butler, L.C., G. Ejeta, D. Hess, B. Siama, Y. Weerasuriya, and T. Cai. 1991. Some novel approaches to the Striga problem. Pp. 500-502 in J.K. Ransom, et al., eds., Proceedings of the Fifth International Symposium on Parasitic Weeds. Nairobi, Kenya, 24-30 May, 1991.

Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico City.

Mundy, P.J. and M.J.F. Jarvis, eds. 1989. Africa's Feathered Locust. Baobab Books, Harare, Zimbabwe. 166 pp.

POTENTIAL BREAKTHROUGHS IN GRAIN HANDLING

(Appendix B)

Shankara, R., N.G. Malleshi, H. Krishnamurthy, M.N. Narayana, and H.S.R. Desikachar. 1985. Development of mini grain mill for dehusking and grinding of cereals. Journal of Food Science Technology 22:91.

POTENTIAL BREAKTHROUGHS IN CONVENIENCE FOODS

(Appendix C)

Central Food Technology Research Institute (CFTRI). 1982. Annual Report. Mysore, Karnataka, India.

Coetzee, W.H.K. and AS. Perold. 1958. Pre-cooked and enriched cereal products. South African Journal of Agricultural Science 1:327-333.

Desikachar, H.S.R. 1977. Processing of sorghum and millets for versatile food uses in India.

In D.A.V. Dendy, ea., Proceedings of a Symposium on Sorghum and Millets for Human Food, Vienna, 11-12 May, 1976, Tropical Products Institute, London. 41 pp.
Hoseney, R.C.. E.V. Marston and D.A.V. Dendy. 1981. Sorghum and millets. In Y. Pomeranz, ea., Advances in Cereal Science and Technology, Vol IV, AACC, St. Paul, Minnesota.
Hulse, J.H., E.M. Laing, and O.K. Pearson. 1980. Sorghum and millets: Their composition and nutritive value. IDRC. Ottawa. Academic Press, London.
Malleshi, N.G. and H.S.R. Desikachar. 1981. Varietal differences in puffing of ragi (Eleusine coracana) Journal of Food Science and Technology 18(1):30-32.
Malleshi, N.G. and H.S.R. Desikachar. 1982. Formulation of a weaning food with low hot- paste viscosity based on malted ragi (Eleusitte coracana) and green gram (Phaseolus radiates). Journal of Food Science and Technology 19(5):193-197.
Kumate, J. 1983. Relative Crispness and Oil Absorption Quality of Sandige (Extruded Dough) from Cereal Grains.

M.Sc. Dissertation, University of Mysore. Mysore, India.
Malleshi, N.G. and H.S.R. Desikachar. 1986. Influence of malting conditions on quality of finger millet malt. Journal of the Institute of Brewing 92(1):81-83.
Malleshi, N.G. and H.S.R. Desikachar. 1986. Studies on comparative malting characteristics of some tropical cereals and millets. Journal of the Institute of Brewing 92(1):174-176.
Malleshi, N.G. and H.S.R. Desikachar. 1986. Nutritive value of malted millet flours. Plant Foods for Human Nutrition 36(3):191-196.
Perten, H. 1983. Practical experience in processing and use of millet and sorghum in Senegal and Sudan. Cereal Foods World 28:680-683.
Young, R., M. Haidara, L.W. Rooney, and R.D. Waniska. 1990. Parboiled sorghum: development of a novel decorticated product. Journal of Cereal Science 11:277-289.

(Appendix C is based largely on this paper.)

POTENTIAL BREAKTHROUGHS IN CHILD NUTRITION

(Appendix D)

Bang-Olsen, K., B. Stilling, and L. Munck. 1987. Breeding for high-lysine barley. Barley Genetics 5:865-870.

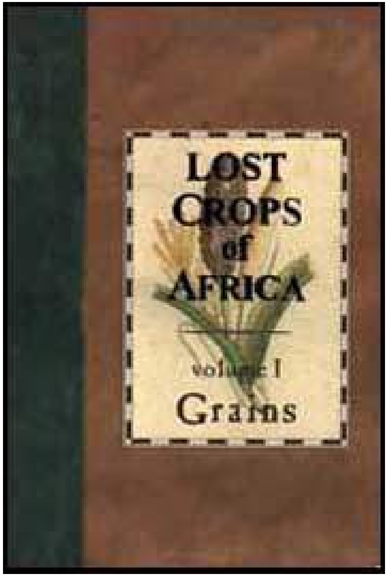
Bang-Olsen, K., B. Stilling, and L. Munck. 1991. The feasibility of high-lysine barley breeding: a summary. Barley Genetics 6:433-438.

Evans, D.J. and J.R.N. Taylor. 1990. Extraction and assay of proteolytic activities in sorghum malt. Journal of the Institute of Brewing 96(4):201-207.

Horn, C.H., J.C. Du Preez, and S.G. Kilian. 1992. Fermentation of grain sorghum starch by co-cultivation of Schwanniomyces occidentalis and Saccharomyces cerevisiae. Bioresource Technology 42(1):27-31.

Kumar, L.S., H.S. Prakash, and H.S. Shetty. 1991. Influence of seed mycoflora and harvesting conditions on milling, popping, and malting qualities of sorghum (Sorghum bicolor). Journal of the Science of Food and Agriculture 55:617-625.
Kumar, L.S., M.A. Daodu, H.S. Shetty, and N.G. Malleshi. 1992. Seed mycoflora and malting characteristics of some sorghum cultivars. Journal of Cereal Science 15:203-209.
Malleshi, N.G. and H.S.R. Desikachar. 1982. Formulation of a weaning food with low hot- paste viscosity based on malted ragi (Eleusine coracana) and green gram (Phaseolus radiatus). Journal of Food Science and Technology 19(5):193-197.
Malleshi, N.G., M.A. Daodu, and A. Chandrasekhar. 1989. Development of weaning food formulations based on malting and roller drying of sorghum and cowpea. International Journal of Food Science and Technology 24:511-519.
Malleshi, N.G., H.S.R. Desikachar, and S. Venkat Rao. 1986. Protein quality evaluation of a weaning food based on malted ragi and green gram. Plant Foods for Human Nutrition

36(3):223230.
Munck, L. 1988. The importance of botanical research in breeding for nutritional quality characteristics in cereals. Symbolae Botanicae Upsalienses 28(3):69-78.
Venkatnarayana, S., V. Screenivasmurthy, and B.A. Satyanarayana. 1979. Use of ragi in brewing. Journal of Food Science Technology 16:204.
Venkat Rao, S., S. Kurien, D.N. Swamy, V.A. Daniel, I.A.S. Murthy, N.G. Malleshi, and H.S.R. Desikachar. 1985. Clinical trials on a weaning food of low bulk based on ragi and green gram. Paper presented at the International Workshop on Weaning Foods, Iringa, Tanzania.


LOST CROPS of AFRICA
volume I
Grains

Appendix G

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FONIO (Ache)

Although fonio has been overlooked by most researchers, two special groups in Senegal have for some years been championing this crop's cause.

One, a program called "Fonio for the World," has been growing and distributing fonio seeds for research and development work. For information on availability of samples and terms under which they are supplied, write to Babacar N'Diaye, Conseiller Agricole charge du Programme "Fonio pour le monde," Conseil General de Diam-Diam, Koungheal, Senegal. The other program, concentrating on laboratory studies, is L'lnstitut des Sciences de l'Environnement of the Universite Cheikh Anta Diop de Dakar, Bote Postal 5005, Dakar-Fann, Senegal.

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CULTIVATED AND WILD GRAINS

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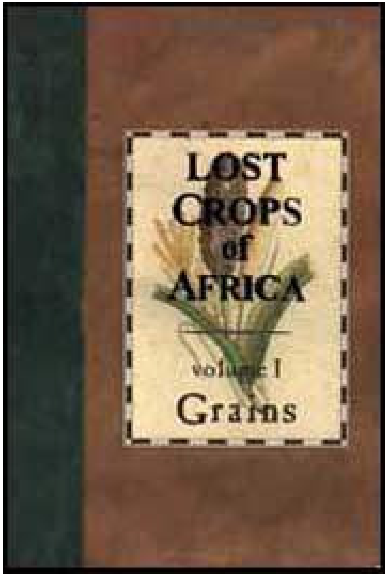
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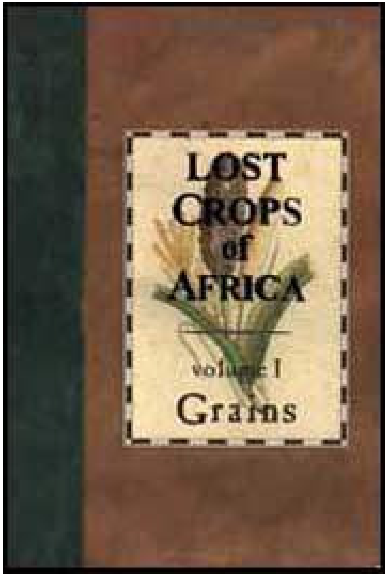


Appendix H

Note on Nutritional Charts

In the earlier chapters we have included tables of nutritional information, as well as charts that show how this information compares with that of a standard cereal such as maize or rice. They appear on the following pages.

Crop	Page

African rice	27
finger millet	44, 45
fonio	64
pearl millet	86, 87
sorghum	134, 135
tef	222, 223
kram-kram	263
shame millet	268
Egyptian grass	269
wadi rice	270

These tables and charts should be taken only as rough indications of the lost crop's merits, not the definitive word. Some species in this book are so neglected that their nutritional components have been reported merely once or twice. It is thus probable that the figures we have used are not representative of average samples, let alone especially nutritious forms. Moreover, natural variation can occur in the nutritional content of grain from any particular species as a result of nongenetic factors such as climate and the availability of nutrients in the soil. It could be, therefore, that even better types will be discovered and developed.

The bar graphs provide what we think is a simple, but visually powerful, representation of the relative nutritional merits of two foods. With them nutritional figures between two foods (or between a food and a recommended daily allowance) can be compared almost instantly. This technique, in which the relative merits can be seen at a glance, was devised specifically for this project, but comparable approaches could be employed equally well in Africa.

The maize and rice values against which the African grains are compared in the bar graphs are taken from U.S. Department of Agriculture tables. The actual figures (converted to a dry-weight basis) are given below.

Component	**Maize**	**Rice**
Food energy (Kc)	408	406
Protein (g)	10.5	8.1
Carbohydrate (g)	83	90
Fat (g)	5.3	0.7
Fiber (g)	3.2	0.3
Ash (g)	1.3	0.7
Thiamin (mg)	0.43	0.08
Riboflavin (mg)	0.22	0.06
Niacin (mg)	4.1	1.8
Vitamin B6 (mg)	0.58	0.02

Folate (µg)	0.0	9.1
Pantothenic acid (mg)	0.47	1.15
Calcium (mg)	8	32
Copper (mg)	0.35	0.25
Iron (mg)	3.0	0.9
Magnesium (mg)	142	130
Manganese (mg)	0.55	1.1
Phosphorus (mg)	234	130
Potassium (mg)	320	130
Sodium (mg)	39	6
Zinc (mg)	2.5	1.2

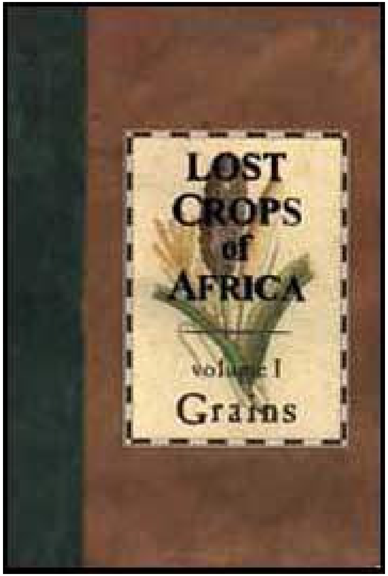
In each of the essential-amino-acid bar graphs, the figures were compared on the basis of the amounts occurring in the protein of each grain (that is, grams per 100 grams of protein). In the other bar graphs, all nutrients were compared on a dry-weight basis so as to eliminate the distortions of different (and varying) amounts of moisture. Digestibility and other metabolic factors were not factored into the calculations. For vitamin A, the values for Retinol Equivalents were derived using standard formulas to convert literature figures given for carotenoids, 13-carotene, or International Units.

Amino Acid	**Maize**	**Rice**
Cystine	1.8	2.0
Isoleucine	3.6	4.3
Leucine	12.3	8.3
Lysine	2.8	3.6
Methionine	2.1	2.4
Phenylalanine	4.9	5.3
Threonine	3.8	3.6

Tryptophan	0.7	1.2
Tyrosine	4.1	3.3
Valine	5.1	6.1
Total	41.1	38.1

Grams per 100 g protein.

In most of the charts in the chapters we have compared the native grains in their whole-grain form with whole-grain rice and maize. A more realistic comparison might have been against polished rice and maize meal (in which the germ has been removed). This is the form in which rice and maize are normally consumed, whereas the native grains - pearl millet, fonio, finger millet, tef, and (in most cases at least) sorghum - are eaten as whole grains. Comparing nutritive values for the forms in which each is actually eaten creates an even more graphic picture of the nutritional superiority of the native grains.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Appendix I

Appendix 1

Lost Crops of Africa Series

This is the first in a series of books highlighting the promise to be found in food plants native to Africa. The second and third volumes in the series are now being prepared for publication, and the fourth, fifth, and sixth are in the planning stage. Following are lists of the plants now being considered.

Volume 2: Cultivated Fruits

Balanites (Desert Date) Balanites aegyptiaca
Baobab Adansonia digitata
Butterfruit (Africado) Dacryodes edulis
Carissa Carissa spp., esp. C. macrocarpa
Horned Melon Cucumis metuliferus
Kei Apple Dovyalis caffra
Marula Sclerocarya caffra

Melon Cucumis melo
Tamarind Tamarindus indica
Watermelon Citrullus lanatus
Ziziphus Ziziphus mauritiana

Volume 3: Wild Fruits

African Medlars Vangueria madagascariensis
Aizen Boscia spp.
Chocolate Berries Vitex spp.
Custard Apples Annona senegalensis
Figs Ficus spp.
Gemsbok Cucumber Acanthosicyos naudinianus
Gingerbread Plums Parinari spp.
Grapes Vitis spp.
Icacina (False Yam) Icacina oliviformis
Imbe (African Mangosteen) Garcinia livingstonei
Milkwoods Mimusops spp.

Monkey Apple Anisophyllea laurina
Monkey Orange Strychnos spp.
Nara Acanthosicyos horrida
Raisin Trees Grewia spp.
Rubber Fruits Landolphia spp.
Sour Plum Ximenia spp.
Star Apples Chrysophyllum spp.
Sugar Plums Uapaca spp.
Sweet Detar Detarium senegalense
Tree Grapes Lannea spp.
Tree Strawberry Nauclea spp.
Velvet Tamarind Dialium guineense
Water Berry Syzygium guineense
Wild Plum Pappea capensis

Volume 4: Vegetables

African Eggplant Solanum macrocarpon

Amaranths Amaranthus spp.
Bitterleaf Vernonia amygdalina
Bitter Melon Momordica spp.
Baobab Adansonia digitata
Bologi Crassocephalum biafrae
Bungu Ceratotheca sesamoides
Bur Gherkin Cucumis spp.
Celosia Celosia spp.
Cleome Cleome gynandra
Crotalaria Crotalaria spp.
Dayflowers Commelina spp.
Edible Flowers Various species
Edible Mushrooms Various species
Edible Trees Various species
Egusi-ito Cucumeropsis mannii
Enset Ensete ventricosum
Ethiopian Mustard Brassica carinata
Fluted Pumpkin Telfairia occidentalis

Garden Cress Lepidium spp.
Gherkins Cucumis spp.
Horned Melon (Kiwano) Cucumis metuliferus
Jilo Solanum gilo
Mock Tomato Solanum aethiopicum
Okra Abelmoschus esculentus
Ogunmo Solanum melanocerasum
Oyster Nut Telfairia pedata
Spirulina Spirulina spp.
Water Leaf Talinum spp.

Volume 5: Legumes

Bambara Groundnut Vigna subterranea
Cowpea Vigna unguiculata
Grass Pea Lathyrus spp.
Guar Cyamopsis tetragonoloba
Groundbean Macrotyloma geocarpa

Lablab Lablab purpureus
Locust Beans Parkia spp.
Marama Bean Bauhinia esculenta
Pigeon Pea Cajanus cajan
Sword Bean Canavalia spp.
Velvet Tamarind Dialium spp.

Volume 6: Roots and Tubers

African Yam Bean Sphenostylis spp.
Anchote Coccinia spp.
Guinea Yam Dioscorea x cayenensis
Potato Yam Dioscorea esculenta
Other Yams Dioscorea spp.
Hausa Potato Solenostemon rotundifolius
Sudan Potato Solenostemon parviflorus
Livingstone Potato Plectranthus esculentus
Wing bean Roots Psophocarpus spp.

Tiger Nut (Chufa) Cyperus esculentus
Vigna Roots Vigna spp., especially V. vexillata

We hope that this set of reports will alert everyone to the wealth of foods that are Africa's own heritage. We also hope to continue the series with volumes on nuts, oilseeds, spices, beverage plants' and others. Collectively, the resulting wealth of knowledge and guidance might well lead to a "second front" in the war on hunger in what is now the most hunger-ravaged part of the world.

We would very much like to hear from readers who would like to contribute to these future volumes. Send your name and the crop in which you're interested to:

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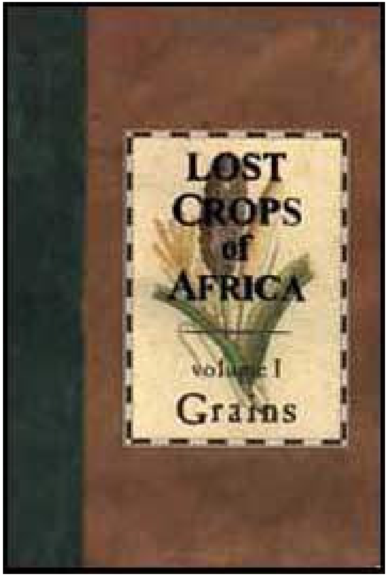
Above all, we'd like to appeal for photographs. Locating pictures for this book on grains has been a monumental headache; finding interesting shots for the future volumes will likely be even harder.



Lost Crops of Africa: Volume 1 - Grains (BOSTID, 1996, 372 p.)

The BOSTID Innovation Program

Since its inception in 1970, BOSTID has had a small project to evaluate innovations that could help the Third World. Formerly known as the Advisory Committee on Technology

Innovation (ACTI), this small program has been identifying unconventional developments in science and technology that might help solve specific developing-country problems. In a sense, it acts as an "innovation scout" - providing information on options that should be tested or incorporated into activities in Africa, Asia, and Latin America.

So far, the BOSTID innovation program has published about 40 reports, covering, among other things, underexploited crops, trees, and animal resources, as well as energy production and use. Each book is produced by a committee of scientists and technologists

(including both skeptics and proponents), with scores (often hundreds) of researchers contributing their knowledge and recommendations through correspondence and meetings.

These reports are aimed at providing reliable and balanced information, much of it not readily available elsewhere and some of it never before recorded. In its two decades of existence, this program has distributed more than 500,000 copies of its reports. Among other things, it has introduced to the world grossly neglected plant species such as jojoba, guayule, leucaena, mangium, amaranth, and the winged bean.

BOSTID's innovation books, although often quite detailed, are designed to be easy to read and understand. They are produced in an attractive, eye-catching format, their text and language carefully crafted to reach a readership that is uninitiated in the given field. In addition, most are illustrated in a way that helps readers deduce their message from the pictures and captions, and most have brief, carefully selected bibliographies, as well as lists of research contacts that lead readers to further information.

By and large, these books aim to catalyze actions within the Third World, but they usually also have utility in the United States, Europe, Japan, and other industrialized nations.

So far, the BOSTID innovation project on underexploited ThirdWorld resources (Noel Vietmeyer, Director and Scientific Editor) has produced the following reports.

Ferrocement: Applications in Developing Countries (1973). 104 pp.
Mosquito Control: Perspectives for Developing Countries (1973). 76 PP.
Some Prospects for Aquatic Weed Management in Guyana (1974). 52 pp.
Roofing in Developing Countries: Research for New Technologies (1974). 84 pp.
An International Centre for Manatee Research (1974). 38 pp.
More Water for Arid Lands (1974). 165 pp.
Products from Jojoba (1975). 38 pp.
Underexploited Tropical Plants (1975). 199 pp.
The Winged Bean (1975). 51 pp.
Natural Products for Sri Lanka's Future (1975). 53 pp.
Making Aquatic Weeds Useful (1976). 183 pp.
Guayule: An Alternative Source of Natural Rubber (1977). 92 pp.
Aquatic Weed Management: Some Prospects for the Sudan

(1976).57 pp.

Ferrocement: A Versatile Construction Material (1976). 106 pp.

More Water for Arid Lands (French edition, 1977). 164 pp.

Leucaena: Promising Forage and Tree Crop for the Tropics (1977).123 pp.

Natural Products for Trinidad and the Caribbean (1979). 50 pp.

Tropical Legumes (1979). 342 pp.

Firewood Crops: Shrub and Tree Species for Energy Production (volume 1, 1980). 249 pp.

Water Buffalo: New Prospects for an Underutilized Animal (1981).126 pp.

Sowing Forests from the Air (1981). 71 pp.

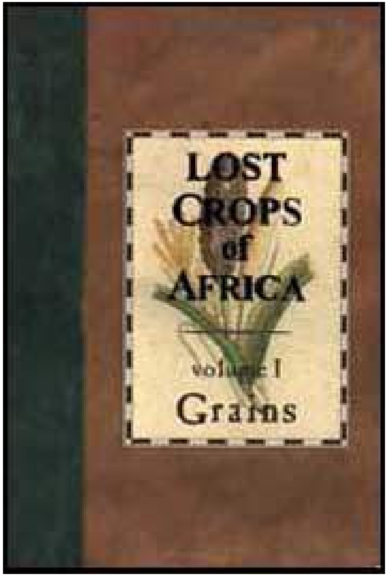
Producer Gas: Another Fuel for Motor Transport (1983). 109 pp.

Producer Gas Bibliography (1983). 50 pp.

The Winged Bean: A High-Protein Crop for the Humid

Tropics(1981). 58 pp.
Mangium and Other Fast-Growing Acacias (1983). 72 pp.
Calliandra: A Versatile Tree for the Humid Tropics (1983). 60 pp.
Butterfly Farming in Papua New Guinea (1983). 42 pp.
Crocodiles as a Resource for the Tropics (1983). 69 pp.
Little-Known Asian Animals With Promising Economic Future(1983). 145 pp.
Firewood Crops: Shrub and Tree Species for Energy Production,Volume 2 (1983). 103 pp.
Casuarinas: Nitrogen-Fixing Trees for Adverse Sites (1984). 128 pp.
Amaranth: Modern Prospects for an Ancient Crop (1984). 90 pp.
Leucaena: Promising Forage and Tree Crop (Second edition, 1984).110 pp.
Jojoba: A New Crop for Arid Lands (1985). 112 pp.
Quality-Protein Maize (1988). 112 pp.

Triticale: A Promising Addition to the World's Cereal Grains (1989).113 pp.


LOST CROPS of AFRICA
volume I
Grains

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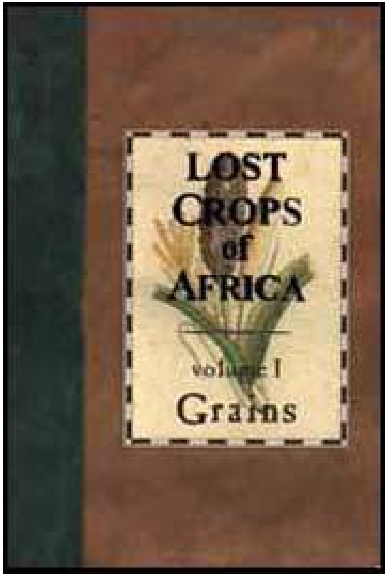

Lost Crops of Africa: Volume 1 - Grains (BOSTID, 1996, 372 p.)

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By 1993, more than 1,000 people had participated in BOSTID's overall study of the lost crops of Africa. Most had participated by nominating species of grains, fruits, nuts, vegetables, legumes, oilseeds, spices, sweeteners, and beverage plants worthy of inclusion.

In a sense, all these people were contributors to this, the first product from the study.

However, the following list includes only those who provided technical details that became incorporated into various chapters of this particular book. To all the contributors, both listed and unlisted, we are truly grateful.

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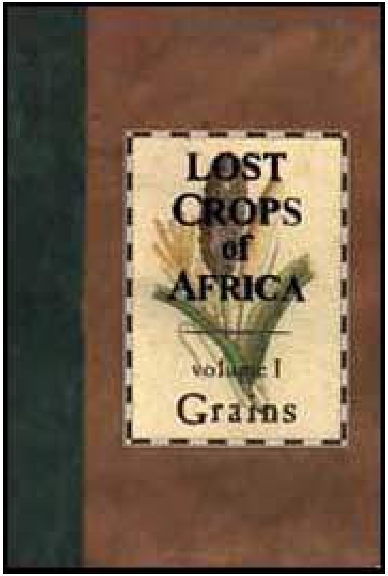

Lost Crops of Africa: Volume 1 - Grains (BOSTID, 1996, 372 p.)

Preface

The purpose of this report is to draw worldwide attention to traditional African cereals and especially to their potential for expanding and diversifying African and world food supplies.

Africa is seen by many observers as a basket case - a vast region incorporating more than 40 nations that appears unlikely to be able to feed its burgeoning population in the coming years. To many observers, there seem to be no ready solutions. Some have given up hope that anything can be done.

What has been almost entirely overlooked, however, is that throughout that vast continent can be found more than 2,000 native grains, roots, fruits, and other food plants. These have been feeding people for thousands of years but most are being given no attention whatever today. We have called them the "lost crops of Africa."

Among the 2,000 lost foods are more than 100 native grasses whose seeds are (or have been) eaten. These can be found from Mauritania to Madagascar. Only a handful are currently receiving concerted research and development, and even those few are grossly underappreciated. Our goal is to demonstrate the potential inherent in these overlooked traditional cereals. Our hope is thereby to stimulate actions to increase the support for, and use of, the best of them so as to increase food supplies, improve nutrition, and raise economic conditions.

It should be understood that most of the plants described are not truly lost; indeed, a few are well known worldwide. It is to the mainstream of international science and to people outside the rural regions that they are "lost." It should also be understood that it is not just for Africa that the grains hold promise. Several of Africa's now neglected cereals could become major contributors to the welfare of nations around the world. This potential is often emphasized in the following chapters in hopes of stimulating the world community into serious and self- interested support for these species that now languish.

This study began in 1989 when the staff officers mailed questionnaires to about 1,000 scientists and organizations worldwide. The questionnaire requested nominations of little-known African food plants for possible inclusion. It contained a list of 77 native African grains, roots and tubers, vegetables, fruits, legumes, oilseeds, nuts, spices, sweeteners, and beverage plants. We anticipated that perhaps 30 of these species would prove to have outstanding merit and that the report would focus on those. What actually occurred, however, was very different.

Within a few weeks of mailing the questionnaire, replies started flooding back in numbers far greater than anticipated; many recipients photocopied their questionnaire and sent the copies (as many as 50 in several cases) on to their colleagues; requests came pouring in from people we had never heard of. The staff could barely keep up with the hundreds of requests, replies, suggestions, scientific papers, and unsolicited writings that began to appear in the mail. Within 4 months, over 100 additional species had been nominated as "write-in candidates." Within a year, at least 100 more were recommended. By then it was clear that the power of this project was far greater than anyone had foreseen. It was decided, therefore, to divide it into sections dealing individually with the different types of foods.

This report on the lost grains of Africa is the first in this series. From the flood of suggestions and information on the native African cereals was fashioned a first draft. Each of its chapters was mailed back to the original nominators as well as to other experts identified by the staff.

As a result, hundreds of suggestions for corrections and additions were received, and each was evaluated and integrated into what, after editing and review, became the current text.

The report is intended as a tool for economic development rather than a textbook or survey of African botany or agriculture. It has been written for dissemination particularly to administrators, entrepreneurs, and researchers in Africa as well as other parts of the world.

Its purpose is to provide a brief introduction to the plants selected and to stimulate actions that explore and exploit them. The ultimate aim is to get the most promising native African grains into greater production so as to raise nutritional levels, diversify agriculture, and create economic opportunities.

Because the book is written for audiences both lay and professional, each chapter is organized in increasing levels of detail. The lead paragraphs and prospects sections are intended primarily for nonspecialists. Subsequent sections contain background information from which specialists can better assess a plant's potential for their regions or research programs. These sections also include a brief overview of "next steps" that could help the plant to reach its full promise. Finally, appendixes at the back of the book provide the following information:

· The addresses of researchers who know the individual plants well;
· Information on potential sources of germplasm; and
· Lists of carefully selected papers that provide more detail than can be presented here.

Because most of these plants are so little studied, the literature on them is often old, difficult to find, or available only locally. This is unfortunate, and we hope that this book will stimulate monographs, newsletters, articles, and papers on all of the species. One of the most effective actions that plant scientists and plant lovers can take is to collect, collate, and communicate the Africa-wide observations and experiences with these crops in such publications. They might also create seed supplies and distribute seeds of appropriate varieties. All this could stimulate pan-African cooperation and international endeavors to ensure that these crops are lost no more.

This book has been produced under the auspices of the Board on Science and Technology for International Development (BOSTID), National Research Council. It is a product of a special BOSTID program that is mandated to assess innovative scientific and technological advances, particularly emphasizing those appropriate for developing countries. Since its inception in 1970, this small program has produced 40 reports identifying unconventional scientific subjects of promise for developing countries. These have covered subjects as diverse as the water buffalo, butterfly farming, fast-growing trees, and techniques to provide more water for arid lands.

Among these reports, the following provide information that directly complements the present report:

· More Water for Arid Lands (1974)
· Triticale: A Promising Addition to the World's Cereal Grains (1989)
· Quality-Protein Maize (1988)
· Amaranth: Modern Prospects for an Ancient Crop (1983)
· Applications of Biotechnology to Traditional Fermented Foods (1992)
· Ferrocement: Applications in Developing Countries (1973)
· Neem: A Tree for Solving Global Problems (1992)
· Vetiver: A Thin Green Line Against Erosion (1993).

Program and staff costs for this study were provided by the U.S. Agency for International Development. Specifically, these were provided by the Office of Nutrition and the Office of the Science Advisor (both of the Bureau for Science and Technology), as well as the Bureau for Africa. The panel would like to acknowledge the special contribution of Norge W. Jerome, Director of the Office of Nutrition, 1988-1991, without whose initiative the project would not have been launched. Other AID personnel who made this work possible include Calvin Martin, Tim Resch, Dwight Walker, John Daly, Frances Davidson, and Ray Meyer.

General support for printing, publishing, and distributing the report has been provided by the Kellogg Endowment Fund of the National Academy of Sciences and the Institute of Medicine as well as from the Wallace Genetic Foundation. We especially want to thank Jean W. Douglas, a foundation director, for her trust and perserverence during this project's long gestation and difficult birth.

The contributions from all these sources are gratefully acknowledged.

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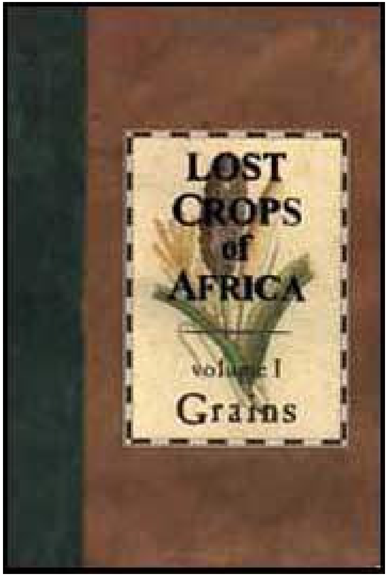
NOTE ON TERMS

Throughout this book the word "Africa" always refers to Africa south of the Sahara. (The plants of North Africa are, biogenetically, part of the Mediterranean-Near East complex of plants, and so are mostly not native to the rest of Africa.) We have preferred to use English common names where possible, except in a few cases where they imply the plant pertains only to one country (for example, Egyptian lupin). Finally, because this book will be read and used in many regions beyond Africa, we have used the internationally accepted name "cassava" rather than its more common African name, "manioc," and "peanut" for "groundout."

Nutritional values are in most cases presented on a dry weight basis to eliminate moisture differences between samples.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AFRICA
volume I
Grains

Appendix I
The BOSTID Innovation Program

Foreword

Africa has more native cereals than any other continent. It has its own species of rice, as well as finger millet, fonio, pearl millet, sorghum, tef, guinea millet, and several dozen wild cereals whose grains are eaten from time to time.

This is a food heritage that has fed people for generation after generation stretching back to the origins of mankind. It is also a local legacy of genetic wealth upon which a sound food future might be built. But, strangely, it has largely been bypassed in modern times.

Centuries ago, chows introduced rice from Asia. In the 1500s, Portuguese colonists imported maize from the Americas. In the last few decades wheat has arrived, courtesy of farmers in the temperate zones. Faced with these wondrous foreign foods, the continent has slowly tilted away from its own ancient cereal wealth and embraced the new-found grains from across the seas.

Lacking the interest and support of the authorities (most of them nonAfrican colonial authorities, missionaries, and agricultural researchers), the local grains could not keep pace with the up-to-the-minute foreign cereals, which were made especially convenient to consumers by the use of mills and processing. The old grains languished and remained principally as the foods of the poor and the rural areas. Eventually, they took on a stigma of being second-rate. Myths arose - that the local grains were not as nutritious, not as high yielding, not as flavorful, nor as easy to handle. As a result, the native grains were driven into internal exile. In their place, maize, a grain from across the Atlantic, became the main food from Senegal to South Africa.

But now, forward-thinking scientists are starting to look at the old cereal heritage with unbiased eyes. Peering past the myths, they see waiting in the shadows a storehouse of resources whose qualities offer promise not just to Africa, but to the world.

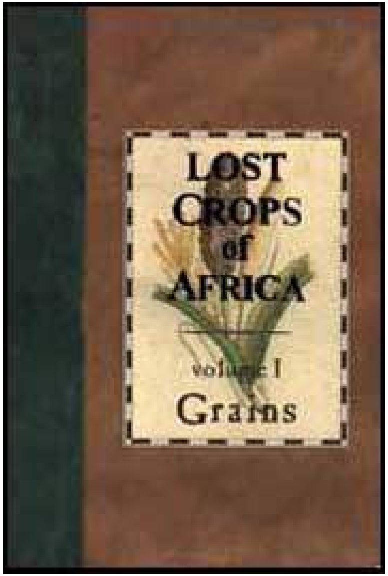
Already, sorghum is a booming new food crop in Central America. Pearl millet is showing such utility that it is probably the most promising new crop for the United States. Nutritionists in a dozen or more countries see finger millet and some sorghums as the key - finally - to solving Africa's malnutrition problem. Food technologists are finding vast new possibilities in processes that can open up vibrant consumer markets for new and tasty products made from Africa's own grains. And engineers are showing how the old grains can be produced and processed locally without the spirit-crushing drudgery that raises the resentment of millions who have to grind grain every day.

That, then, is the underlying message of this book. It should not be seen as an indictment of wheat, maize, or rice. Those are the world's three biggest crops, they have become vital to

Africa, and they deserve even more research and support than they are now getting. But this book, we hope, will open everyone's eyes to the long-lost promise inherent in the grains that are the gifts of ancient generations. Dedicated effort will open a second front in the war on hunger, malnutrition, poverty, and environmental degradation. It will save from extinction the foods of the forebears. And it just might bring Africa the foodsecure future that everyone hopes for but few can now foresee.

Noel D. Vietmeyer

Study Director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Introduction

Africa's savannas are probably the oldest grasslands on earth and have changed little during the last 14 million years. Humans have lived there longer than anywhere else, perhaps more than 100,000 years. Grass seeds have sustained them throughout.

Indeed, gathering Africa's wild-cereal grains is probably the oldest tradition in organized food production to be found anywhere in the world. And the operation was not small. In fact, seeds of about 60 species of wild grasses are still gathered for food in Africa.

In earlier eras, many were ranked as staples. At least 10 of the wild grasses were domesticated and eventually produced by farmers in their fields.

In modern times, however, this wealth of native grains has been neglected and sometimes even scorned. For this reason, we have called them Africa's "lost" grains.

Despite the neglect, these native grains are not unworthy. For the past, for the places they were grown and for the level of support they received, they may have been appropriately judged less useful than wheat, rice, or maize. But for the time that is fast coming upon us,

Africa's sorghum, millets, native rice, and other indigenous cereals seem likely to become crucial for helping to keep the world fed.

INTERNATIONAL PROMISE

The present century has seen near miraculous advances in the productivity of wheat, rice, and maize. Those top three cereals have buffered much of humanity from the disasters of overpopulation. However, the next century - when human population is expected to double - cannot be built on the expectation of redoubling the production of those three.

After the year 2000, it could well be advances in today's "second tier" cereals that are the buffers against famine. It is they that have the greatest amount of untapped potential. Among them, Africa's native grains predominate. Sorghum and pearl millet, for instance, are the fifth and sixth most important cereals in the world, and finger millet is probably the eighth.

Generally they are crops of the poorest countries, which means that their improvement could directly benefit the people in greatest need.

By comparison with modern wheat, rice, and maize - respectively from the Middle East, Asia, and Central America - the grains of Africa still retain much of the hardy, tolerant self- reliance of their wild savanna ancestors. For the future, such resilient crops will be vital for extending cereal production onto the ever-more-marginal lands that will have to be pressed into service to feed the several billion new arrivals. And if global warming occurs, they could even become vital for keeping today's best arable lands in production.

Forged in the searing savannas and the Sahara, sorghum and pearl millet in particular have the merits to become crops for the shifting and uncertain conditions of an overpopulated "greenhouse age."

LOCAL PROMISE

In the last few centuries in Africa, the local grains have been superseded by foreign cereals introduced and promoted by outsiders such as missionaries, colonial powers, or researchers. In recent decades, the production of native grains has plunged even further as millions of tons of imports - particularly wheat and rice - have been sold at subsidized prices.

Despite its long history, Africa's cereal production is now low. The Green Revolution that transformed the tropics and subtropics, from the Indian subcontinent to South America, passed Africa by. In fact, per-capita production of cereals has decreased nearly 20 percent (present annual output being only about 50 million tons or a mere 11 kg per person). It has been estimated that Africa now needs 14 million tons more grain each year than it is producing. With the population growing at 3 percent per year and agricultural production increasing by only 2 percent, that shortfall will reach 50 million tons by 2000.

Obviously a crisis is impending in Africa's food supply.

Improving cereals for Africa should be a great international agricultural endeavor. Maize, rice, and wheat have much to offer and deserve greatly increased support. A crucial objective, though, must be to extend cereal production into areas where environmental stresses and plant diseases currently limit their growth. For these now-marginal lands, Africa's own grains offer outstanding promise. They are tools for helping build a new and stronger food-production framework - one of inestimable value for the hungriest and most destitute nations.

THE SPECIES

This promise (and much more) is described in the body of this book. There, the following species are covered in detail.

African Rice

Most people think of rice as an exclusively Asian crop, but farmers have grown a native rice (Oryza glaberrima) in parts of West Africa for at least 1,500 years. This crop comes in a wealth of different types that are planted, managed, prepared, and eaten in different ways.

Some mature extremely quickly and will fit into seasons and situations where other cereals fail. The grain is much like common rice, although the husk around it is usually red. This plant not only has promise in its own right, its genes might also eventually benefit the production of common rice worldwide. (See chapter 1)

Finger Millet

In parts of East and Central Africa (not to mention India), millions of people have lived off finger millet (Eleusine coracana) for centuries. One of the most nutritious of the major cereals, it is rich in methionine, an amino acid critically lacking in the diets of hundreds of millions of the world's poor. The plant yields satisfactorily on marginal lands, and its tasty grain is remarkable for its long storage life. The fact that certain Africans thrive on just one meal a day is attributed to the nutritive value and "filling" nature of this grain. (See chapter 2)

Fonio (Ache)

An indigenous West African crop, fonio (comprising two species, Digitaria exilis and Digitaria iburua) is grown mainly on small farms for home consumption. It is probably the world's fastest maturing cereal and is particularly important as a safety net for producing when other foods are in short supply or market prices are too high for poor people to afford. But fonio is much more than just a fallback food; it is also a gourmet grain. People enjoy it as a porridge, in soups, or as couscous with fish or meat. The plant grows well on poor, sandy soils. It, too, is rich in the amino acid methionine. It also has a high level of cystine, a feature that is an even rarer find in a cereal. With its appealing taste and high nutritional value, this could become a widespread gourmet grain for savanna regions, perhaps throughout much of Africa or even much of the world. It might well have a big future as a cash crop and export commodity. (See chapter 3)

Pearl Millet

Some 4,000 years ago, pearl millet (Pennisetum glaucum) was domesticated from a wild grass of the southern Sahara. Today, it is the world's sixth-largest cereal crop, but it has even greater potential than most people imagine. Of the major cereals, pearl millet is the most tolerant of heat and drought; it has the power to yield reliably in regions too arid and too hot to consistently support good yields of other major grains.

These happen to be the regions that will most desperately need help in the decades ahead.

Already, water is shaping up as the most limiting resource for numerous economies - even some of the most advanced. Agriculture is usually a country's biggest user of water. Thus, for nations that have never heard of it or that perhaps regard it with scorn, pearl millet might quickly rise to become a vital resource. (See chapters 4,6)

Sorghum

Globally speaking, sorghum is the dietary staple of more than 500 million people in more than 30 countries. Only rice, wheat, maize, and potatoes surpass it in the quantity eaten. For all that, however, it produces merely a fraction of what it could. Indeed, if the twentieth century has been the century of wheat, rice, and maize, the twentyfirst could become the century of sorghum (Sorghum bicolor).

First, sorghum is among the most photosynthetically efficient and quickest maturing food plants. Second, it thrives on many marginal sites where other cereals fail. Third, sorghum is perhaps the world's most versatile food crop. Some types of its grains are boiled like rice, cracked like oats for porridge, "malted" like barley for beer, baked like wheat into flat breads, or popped like popcorn for snacks.

The plant has many uses beyond food as well. Perhaps the most intriguing is its use for fuel.

The stems of certain types yield large amounts of sugar, almost like sugarcane. Thus, sorghum is a potential source of alcohol fuels for powering vehicles or cooking evening meals. Because of the plant's adaptability, it may eventually prove a better source of alcohol fuel than sugarcane or maize, which are the only ones now being used.

Finally, sorghum is a relatively undeveloped crop with a truly remarkable array of grain types, plant types, and adaptability. Most of its genetic wealth is so far untapped and even unsorted. Indeed, sorghum probably has more undeveloped genetic potential than any other major food crop in the world. (See chapters 7-11)

Tef

This staple cereal (Eragrostis tef) is the most esteemed grain in Ethiopia. It is ground into flour and made into pancake-like fermented bread, injera, that forms the basic diet of millions. Many Ethiopians eat it several times a day (when there is enough), particularly with spicy sauces, vegetables, and stews.

Tef is nutritious; the grain is about 13 percent protein, well balanced in amino acids, and rich in iron. In many ways, it seems to have ideal qualities for a grain, yet research has been scanty and intermittent, and so far the crop is all but unknown beyond Ethiopia. In the last few years, however, commercial production has started in the United States and South Africa, and an export trade in tef grain has begun. These seem likely harbingers of a new, worldwide recognition of this crop. (See chapter 12)

Misunderstandings

It is fair to ask why Africa's grains are not better known. At least in part, the reason can be attributed to several unjustified perceptions. Some of these misperceptions that are clouding the world's vision of Africa's native grains are discussed below.

Inferiority of Displaced Crops. Introduced crops have displaced several African ones over the past few centuries. For example, in several areas maize has replaced sorghum; in West Africa, Asian rice has replaced African rice. As a result, there is a strong inclination to consider the introduced crop superior and the native crop obsolete and unworthy of further development.

This is illogical, ill-conceived, and even dangerous. All the world's agriculture is dynamic and every crop gets displaced at certain times and certain places. In much of the eastern United States, for instance, wheat was long ago displaced by soybeans; in the Southeast, peanuts replaced rice; and in the Great Plains, wheat has supplanted maize. But no one in America considers wheat, maize, or rice to be inferior, obsolete, or unworthy.

Misclassification. Africa's cereals are inadvertently discriminated against through the way they are described. People everywhere classify sorghums and millets in a different light from wheat, rice, and maize. All the categories have pejorative connotations. For instance, these grains are typically referred to as:

· "Coarse" grains (that is, not refined; fit for animal feed);
· "Minor" crops (not worthy of major status);
· "Millets" (seeds too small);
· "Famine" foods (good for eating only when starving); and
· "Feed" grains (suitable for animals only).

Poor People's Plants. Many crops are scorned as fit only for consumption by the poor. It happens everywhere. Peanuts, potatoes, and other common crops once suffered from this same discrimination. In the United States the peanut was considered to be "merely slave food" until little more than a century ago, and in the 1600s the English refused to eat potatoes because they considered them to be "Irish food." Cultural bias against peasant crops is a tragedy; the plants poor people grow are usually robust, productive, self-reliant, and useful - the very types needed to feed the hungriest mouths on the planet.

Inferior Yield. Low yield is perhaps the most frequent comment made about Africa's grains. Yet these grains are now mostly cultivated in marginal lands under less than optimal management and the yields therefore do not reflect their true potential.

Moreover, the use of yield figures can be totally misleading. Maize be able to outyield finger millet, pearl millet, hungry rice, and tef, but only when soil fertility, moisture, and other conditions are good. Under poor conditions, African grains often outyield the best products of modern science.

Unworthy Foods. Millets are mainly used for making porridges, fermented products, couscous, and other foods that are alien and therefore somewhat suspect to non-Africans, especially Westerners. This has led outsiders, who often serve as "decision makers," to direct resources away from native grains.

Disparaging comments about African foods are not uncommon in the writings of travelers - especially in Victorian times. They are of course only personal - often highly prejudiced - opinions but, lingering in the literature, they have a pernicious influence that can last for decades or even centuries. Europeans treated the potato and tomato this way when they first arrived from the Americas. Myths about taste and safety helped block the adoption of both for two centuries.

Cost-Effectiveness. Most of Africa's grains are exclusively subsistence crops; the remainder are partially so. Farmers grow them for their own use rather than for market, and therefore there are no statistics on production or costs. A plant may be helping feed millions, but in the international figures on area sown, tonnage produced and exported, and prices paid it never shows. It is as if it doesn't exist.

This situation might be of little consequence were it not for the fact that economic- development funding these days is overwhelmingly judged on "cost-effectiveness." Thus, a crop with no baseline data is at a cruel disadvantage. Maize or wheat researchers can pull out impressive figures to justify the promise of their proposed studies. Finger-millet or fonio researchers can only come up with guesses. To the hard-pressed, cost-conscious administrator - ever fearful of accusations that public funds may be misspent - the decision on which proposal to support is inevitably biased.

Other Cultivated Grains

Some of the cereals described previously are not, strictly speaking, "lost." But there are a number of African food grains that are indeed truly overlooked by modern science. (See chapter 13)

Guinea Millet Perhaps the world's least-known domesticated cereal, guinea millet (Brachiaria deflexa), is cultivated by farmers only in the Fouta Djallon Plateau, a remote region of Guinea. At present, almost nothing can be said about its potential, but it clearly deserves exploratory research and support.

Emmer This rare wheat (Triticum dicoccum) originated in the Near East, but it has a very ancient African heritage. It reached Ethiopia probably 5,000 years ago or more and, although it virtually disappeared elsewhere in the world, it comprises almost 7 percent of Ethiopia's entire wheat production. Moreover, far from abandoning it, Ethiopian farmers over the last 40 years have actually increased the percentage of emmer that they grow.

The plant is adapted to a wide range of environments and should be producible in many parts of the world. The fact that it is little changed from wheat eaten in the times of the Bible and the Koran could give it special consumer appeal. But it can stand on its own culinary merits. It is one of the sweetest and best-tasting cereals.

Irregular Barley Although barley is also not native to Africa, it, too, has been used in Ethiopia for thousands of years. Indeed, Ethiopian barley has been isolated so long that it has been given its own botanical name, Hordeum irregulare, and has developed its own genetic "personality." This ancient barley is grown mainly in Ethiopia, where it ranks fourth among crops, both in production and area. Throughout most of the upper highlands it accounts for over 60 percent of the people's total plant food. Ethiopia is perhaps unmatched with respect to barley diversity. Indeed, some scientists think it is a source of new germplasm that could possibly boost barley growing in Africa and around the world.

Ethiopian Oats In Ethiopia is found a native oats, Arena abyssinica. This species was domesticated in the distant past and is a largely nonshattering plant that retains its grain so people can harvest it. It has long been used in Ethiopia and is well adapted to the high elevations there. It is, however, unknown elsewhere.

Wild Grains

As noted, people in Africa have been eating wild grains for perhaps 100,000 years. In modern times, however, various writers have discounted these grains as mere "scarcity foods." This is obviously wrong: wild grains were eagerly eaten even when pearl millet, for one, was abundant.

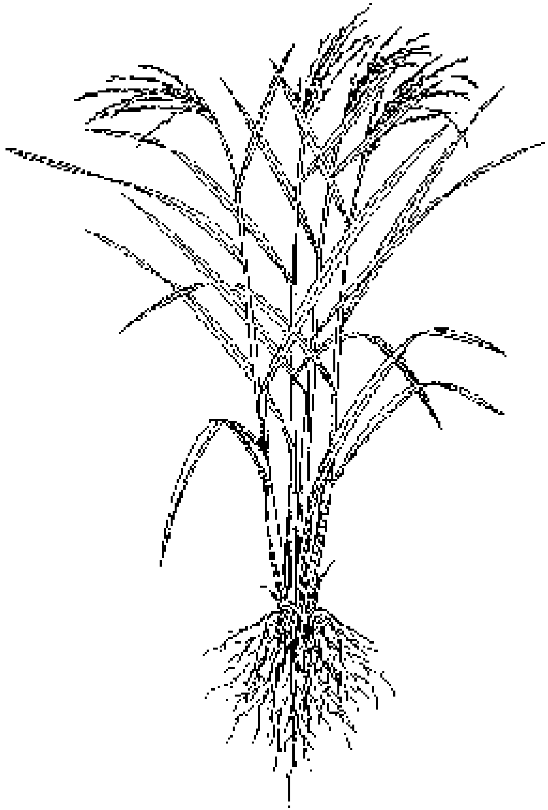
Many modern writers also imply that the wild cereals were gathered only on a small and localized scale. This, too, is apparently false. The harvest in the Sahara, for example, was large-scale, sophisticated, commercial, and much of it was export-oriented. The wild grains were a delicacy that even the wealthy considered a luxury. Examples of such untamed cereals are drinn, golden millet, kram-kram, panic grasses, wild rices, jungle rice, wild tefs, and crowfoot grasses.

Resurrecting the grain-gathering industry of the past might be a way to help combat desertification, erosion, and other forms of land degradation across the worst afflicted areas of the Sahel and its neighboring regions. A vast and vigorous grain-gathering enterprise might perhaps provide enough economic incentive to ensure that the grass cover is kept in place and that overgrazing is controlled. That would bring environmental stability to the world's most alarming case of desertification. (See chapter 14)

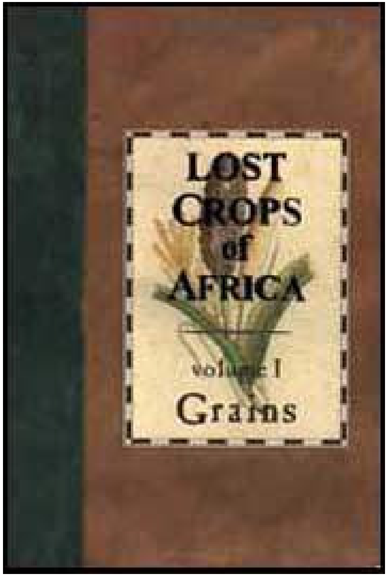
CONCLUSION

These "lost" plants have much to offer, and not just to Africa. Indeed, they represent an exceptional cluster of cereal biodiversity with particular promise for solving some of the greatest food-production problems that will arise in the twenty-first century.

This potential for utility in the future is because Africa's native grains tend to tolerate extremes. They can thrive where introduced grains produce inconsistently. Some (tef, for instance) are adapted to cold; others (pearl millet, for example) to heat; at least one sorghum to waterlogging; and many to drought. Moreover, most can grow better than other cereals on relatively infertile soils. For thousands of years they have yielded grain even where land preparation was minimal and management poor. They combine well with other crops in mixed stands. Some types mature rapidly. They tend to be nutritious. And at least one is reputed to be better tasting than most of the world's well-known grains.



FIGURE


LOST
CROPS
of
AFRICA
volume I
Grains

1. African Rice

To most of the world, rice connotes Asia and the vast agriculture of Far Eastern river deltas.

Indeed, humanity's second major crop is from Asia, and 90 percent of it - the main source of calories for 2.7 billion people - is grown there.

But rice is also African. A different species has been cultivated in West Africa for at least 1,500 years. Some West African countries have, since ancient times, been just as rice-oriented as any Asian one. For all that, however, almost no one else has ever heard of their species.

There are rice relatives in other parts of the world, too. The genus Oryza is among the most ancient grasses and was able to spread to every continent before they drifted too far apart. The result is that different Oryza species are strung out over the tropical regions of the globe, including South America and

Australia. Only one species in Asia and one in Africa were domesticated, however.

Asia's rice is so advanced, so productive, and so well known that its rustic relative has been relegated to obscurity even in Africa itself. Today, most of the rice cultivated in Africa is of the Asian species. In fact, the "great red rice of the hook of the Niger" is declining so rapidly in importance and area that in most locations it lingers only as a weed in fields of its foreign relative. Soon it may be gone.

This should not be allowed to happen. The rice of Africa (Oryza glaberrima) has a long and noteworthy history. It was selected and established in West Africa centuries before any organized expeditions could have introduced its Asian cousin (Oryza saliva). It probably arose in the flood basin of the central Niger and prehistoric Africans carried it westward to Senegal, southward to the Guinea coast, and eastward as far as Lake

Chad. In these new homes, diligent people developed it further.

Like their counterparts in the Far East, Africa's ancient rice farmers selected a remarkable range of cultivars suited to many types of habitats. They produced "floating" varieties (for growing in deep water), weakly and strongly photoperiod-sensitive types (for growing in different latitudes and seasons), swamp and upland cultivars (for growing under irrigated and rainfed conditions, respectively), and early and late-maturing types. And, for all of these, they selected forms with various seed characteristics.

Although modern efforts to expand rice production in Africa have largely ignored this indigenous heritage, African rice is still cultivated in West Africa - especially in remote districts. There, until recently, much of it was reserved as a special luxury food for chiefs and religious rituals. Today, however, farms that grow substantial stands of African rice are few.

The area of most intense cultivation is the "floating fields" on the Sokoto fadamas (flood plains) of Nigeria and the Niger River's inland delta in Mali. However, the crop is also widely, if thinly, spread in Sierra Leone and neighboring areas, as well as in the hills that straddle the Ghana-Togo border.

From one point of view, there seem to be good reasons for abandoning this food of the forebears. In most locations farmers prefer the foreign rice because it yields better and scatters less of its seed on the ground. Millers prefer it because its grain is less brittle and therefore easier to mill. Shippers prefer it as well. For them, African rice is hardly worth a minute's consideration because it is not a trade commodity and most types are red-skinned and therefore unsuitable for mixing with conventional rice in bulk handling.

But these are concerns almost entirely of commercial farming. The situation is quite different where rice is grown strictly for localized, subsistence, or specialty use. There, yield, brittleness, color, or international interest can be unimportant. Indeed, small-scale farmers often prefer African rice. They like the grain's taste and aroma, and even its reddish appearance. They find the plant easy to produce: its rambunctious growth and spreading canopy help suppress weeds and it generally resists local diseases and pests by itself. Also, to some people traditional rituals are meaningless unless the ancient grain is employed.

Moreover, these are not the only advantages. Compared to its Asian cousin, African rice is better at tolerating fluctuating water depths, excessive iron, low levels of management, infertile soils, harsh climates, and late planting (a valued feature because in West Africa's erratic climate the rains are often tardy). Also, there are some types that mature much more quickly than common rice. Planted out in emergencies when food stocks are getting low' these can save lives.

PROSPECTS

What actually happens in the future to this interesting African crop will depend on individual initiatives, most of them within Africa itself. Part of the problem is its lack of prestige.

Everywhere, consumers have fallen in love with processed Asian rice. If someone now makes a processed (that is, parboiled) product out of African rice, that alone may return it to high favor. Indeed, it may rise to become a gourmet food of particular interest because of its ancient and historic heritage.

Part of the problem, also, is lack of supply. Thus, if such specialty markets develop, it seems likely that African rice will survive as a commercial crop. Then, with selection and breeding, its various cultivars can almost certainly be made to compete with Asian rice in most African locations. There is evidence, for example, that certain types already match the productivity of Asian rice, and in the yield figures there is considerable overlap between the best African and the poorer Asian ones. This is remarkable considering the 5,000 years of intense effort that has been invested in improving Asian rice.

Even if the local rice never thrives as a commercial crop, it will likely continue as a subsistence crop in West Africa. However, whether this is a lingering decline for a few more decades or a robust return to massive use depends on the responses of scientists, administrators, and others. Even in its current neglected form the plant has something to offer, but just a small amount of support, promotion, and practical research seems likely to bring dramatic improvements.

The problems of shattering and brittle grain can undoubtedly be overcome by careful scrutiny of the types already spread across West Africa. A small cash prize might well produce appropriate genotypes almost overnight. The same could happen for white-skin types, which many people would find more appealing than the main type of today. Even now, not all the varieties are red-skinned. In Guinea, Senegal, and the Gambia, for example, white types are said to be already available.

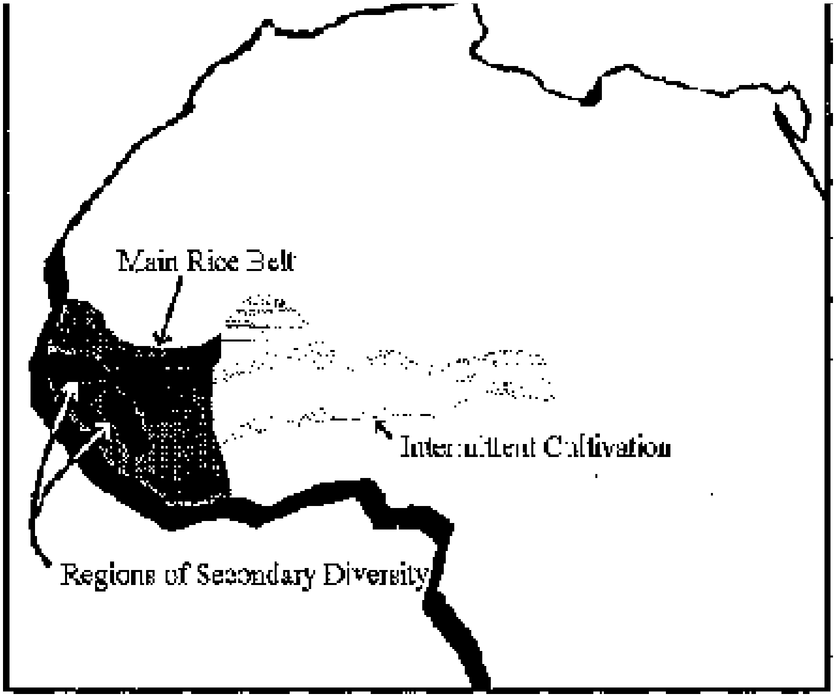


FIGURE: Rice was cultivated in frica long before any navigator from Java or Arabia could have introduced their kind of rice to Madagascar or the East African Coast. The Native rice was grown first in the central Niger delta, and later in the Gambia, Csamance, and Sokoto basins. African rice is now utilized

particularly in the central Niger floodplain, the coastal zone between Senegal and Sierra Leone, and the mountainous areas of Guinea and the Ghana/Togo border.
The primary center (small map) shows the distribution of the wild form. The secondary centers are where notable arrays of cultivated types occur. The main rice belt is the zone where African rice is cultivated the most.

Africa

Although no one can be certain of what will happen with this crop in the coming decades, the prospects for doubling its production and overcoming its various technical limitations are good. Technical improvements, such as those just mentioned, could give it a solid future. It is now known only in West Africa, but eventually it might also find a place elsewhere. Although only a few

African countries grow even Asian rice in a major way, it is the continent's fourth biggest cereal (after maize, pearl millet, and sorghum) in terms of area planted. And demand is ever rising as population, standards of living, urbanization, international travel (with its exposure to new cuisines), and the search for easy-to-prepare foods increase. At present, West Africa absorbs a quarter of the world's rice exports.

Humid Areas On the face of it, African rice is at its biggest disadvantage in the humid lowlands. This is prime country for growing Asian paddy rice. whose current competitive edge makes it clearly the crop of choice. In addition, in this zone farmers and governments often invest in irrigation facilities, and to recoup their vast expenditures they must grow the highest yielding, highest selling crop. As a result, it is in this zone that African rice has suffered its most precipitous decline.

On the other hand, even here there seems to be a small but vital place for African rice. A recent survey in southern Sierra Leone, for example, found that even where Asian rice predominates farmers still retain one or two ultra-quick traditional types as "hunger- breakers." And, faced with a worsening hungry season caused by economic recession or other factors, many farmers say they would revert to the short-duration African-rice varieties, if only they could find sources of seed.

Dry Areas For the truly arid zones African rice is not a suitable crop, but on moderately watered sites (for example, where annual rainfall is at least 760 mm) or seasonally flooded sites its prospects seem good. The fact that some varieties mature 10-20 days before their principal Asian-rice rivals is significant in drylands where precipitation is often erratic. In northern Sierra Leone, for example, the rainy season in recent decades has been terminating early and with unusual abruptness. For this reason alone, farmers are cultivating

African rice on at least some portion of their land. With it, they are assured of a harvest.

Upland Areas In West Africa's highlands where this type of rice is still an important grain producer, it will continue to be important as

Other Regions

For lands beyond Africa, prospects are slight. There, African rice offers few benefits over the

Asian species and may not adapt well. Although it might have a future as a small specialty crop, more likely it will become an accursed weed, especially in rice fields.

USES

African rice can be used for all the same purposes as Asian rice. It is thus extremely versatile. There are, however, some specialized local uses. West Africa's Mandingo and

Susu people, for instance, use rice flour and honey to make a sweet-tasting bread, so special that it is the centerpiece of ceremonial rituals. Rice beer is popular throughout West Africa, and in Nigeria a special beer (called betso or buza) is made from rice and honey.

Also, in Ivory Coast there is a project to use African rice as a component of baby foods.

NUTRITION

Both rices are principally carbohydrate sources. However, in practice African rice's nutritional quality is greater than that of Asian rice.

This seems to be not because of any inherent difference but because it is more difficult to polish. Asian rice is invariably polished to a greater degree, and therefore more of its nutrients (especially the important vitamin, thiamine) are lost.

AGRONOMY

As with Asian rice, African rice is grown in three major ways: dryland (or upland), paddy, and "floating."

Dryland -About 40 percent of the rice production in Africa's 15 major rice-producing countries relies on rain as the only source of water. Almost all of that area employs the Asian species, but West Africa still grows a small but significant amount of dryland African rice. Indeed, in certain parts of Ghana and Togo it is the chief staple.

The dryland form thrives in light soils wherever there is a rainy season of at least 4 months and minimum rainfall of 760 mm. It is often interplanted with millets, maize sorghum, beniseed, roselle, cowpea, cassava, or cotton. Today's varieties mature in 90-170 days.

Yields average 450-900 kg per hectare, but can go as high as 1,680 kg per hectare.

Paddy -Only about one-sixth of Africa's rice is produced using irrigation and 60 percent of that is in just one country - Madagascar. Swamp rice, however, is being increasingly cultivated in former mangrove areas of the Gambia, Guinea-Bissau, Guinea, and Sierra Leone. Essentially all of it at present is the Asian species.

African rice can also be grown in the same way. It can be seeded into damp soil or transplanted to fields under water. These types mature in 140-220 days. The yield ranges from 1,000 to 3,000 kg per hectare .

Floating - In the River Niger's inland delta in Mali, farmers grow various forms of floating African rice. These plants lengthen prodigiously to keep their heads at the surface of the floodwaters, where they flower and set seed. One type (songhai tomo) can grow in water more than 3 m deep.

Floating varieties can utilize deeply inundated basins where nothing else can be raised. They are often harvested from canoes. They ripen in 180-250 days. Yields range from 1,000 to 3,000 kg per hectare, depending on the amount of rainfall early in the growing season and on the eventual depth of the subsequent floods.

HARVESTING AND HANDLING

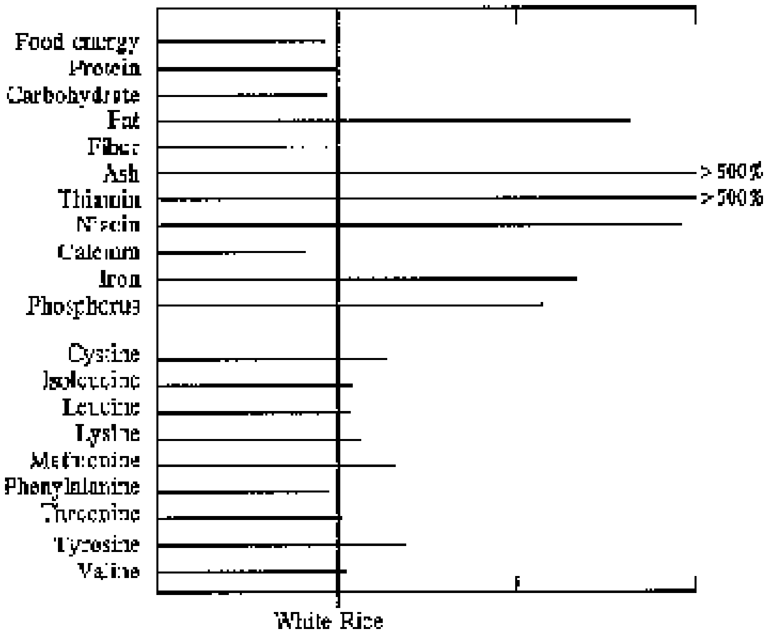
African rice is handled like its more famous Asian cousin, but (as noted) its grains tend to split, and so greater care must be taken. Also, it is more difficult to hull.

As is to be expected with such a neglected crop, yields are variable and uncertain. However, there are hints that they are not as low as commonly claimed. For example, five years of experiments at two sites in Ivory Coast found that 16 populations of African rice (selected for their productivity) compared favorably with three top varieties of Asian rice. Despite their natural lodging and spontaneous shattering, the best African rice varieties (BG 141 and BG 187) gave average and remarkably stable yields of 1,500-1,800 kg per hectare (depending on the site) as did their Asian counterpart (Moroberekan), the traditional upland variety promoted in Ivory Coast.

NUTRITIONAL PROMISE

Main Components		**Essential Amino Acids**	
Moisture (g)	5	Cystine	2.6
Food energy (Kc)	358	Isoleucine	4.7

Protein (g)	7.6	Leucine	8.8
Carbohydrate (g)	81	Lysine	4.1
Fat (g)	1.9	Methionine	3.1
Fiber (g)	0.5	Phenylalanine	5.1
Ash (g)	3.8	Threonine	3.7
Thiamin (mg)	0.39	Tyrosine	4.6
Niacin (mg)	5.0	Valine	6.4
Calcium (mg)	25		
Iron (mg)	2.0		
Phosphorus (mg)	263		



FIGURE

A glance at this chart shows that whole-grain African rice is at least as rich as white (i.e., Asian) rice in most nutrients. In some vitamins and minerals it is far superior.

Rice in Sierra Leone

Recently, researchers surveyed the distribution and use of rice in Sierra Leone. Following is their account of their findings. It is probably indicative of the situation throughout much of West Africa.

In visits to just over 500 farmers in all parts of Sierra Leone, we found that 245 types ("varieties") of rice were in use. Of these, 24 were African rice.

Although it generally yields less than Asian rice, African rice survives - and may even be making a modest comeback in some areas, especially in the drier northwest. There are a number of reasons for this. Compared with Asian rice, African rice:

· Seems to manage better on extremely impoverished soils.

· Competes better with weeds. Indeed, farmers pressed by labor shortages leave the crop to fend for itself. African rice will yield something even where Asian rice is choked out of existence by weeds. This is important because for small-scale rice farmers labor shortage is the most pressing constraint.

· Matures quicker. Nearly all the samples we collected matured in 100-125 days and are therefore among the quickest ripening rice cultivars in the country. (The average for dryland Asian rice in our sample was 130-140 days, and for wetland, 160-170 days.)

· Is preferred by many of the people. Several informants believed that African rice is nutritionally superior. They say that it is "heavy in the stomach" and keeps hunger at bay far longerthan the average Asian rice. Also, they often told us that it tastes "sweeter." And they said it keeps well after cooking. This is particularly important because many people prepare food only once a day, but members of the family drop by to eat at any time.

In northwestern Sierra Leone, however, Asian rice is preferred. People in this area complained that African rice is difficult to husk and that cleaning off its tough red bran takes a lot of work. Women in particular complained of the extra workload it imposes.

On the other hand, in other parts of the country redness was an important advantage. For example, Mende people in the south and east look on the red tinge (found on incompletely milled grains) as a guarantee that the sample is not a foreign rice. Rice soaked in palm oil plays a major part in their rituals, and it is unthinkable for them to use an Asian wetland variety.

In their fields, Sierra Leone farmers draw no distinction between Asian and African rices. Both species go by the same name: mba (Mende) or pa (Temne). The fields are very mixed from a genetic point of view. The farmers prefer it that way and, seemingly, they deliberately foster diversity because most of them know how to rogue out undesirable types and would do so if they wanted to.

We noticed that the African and Asian species appear to have hybridized in many places. A number of the most popular Temne rices, for example, are in fact intermediate types judged by ligule form, grain shape, and panicle type). Certain named landraces seemed to be neither Asian nor African rice and may be assigned to either or both species.

Paul Richards, Serrie Kamara, Osman Bah, Joseph Amara, Malcolm Jusu

LIMITATIONS

In its present state, African rice certainly has limitations, including those listed below:

· Lodging. The plants tend to have weak stalks, and late-season windstorms can sometimes topple them.

· Shattering. Today's plants tend to drop the seed as it matures.

· Splitting. The seed tends to break in half if handled roughly.

· Color. Although the grain itself is always white, most types have red husks.

· Processing. To remove the husk is laborious.

· Weediness. In West Africa, extensive genetic interaction occurs between African rice's wild and cultivated races. The mixed populations that build up can be extremely complex. The weedy results infest the rice fields and can be serious pests.

· Diseases. Compared to Asian rice, it can be more susceptible to numerous fungi as well as to the parasitic plant striga and to a brown spot of unknown cause.

Although these limitations collectively add up to a fearsome combination, they mainly reflect the neglect this crop suffers from. All are now circumvented by people who grow and use African rice; research can undoubtedly reduce their severity if not overcome them entirely.

Moreover, several of these limitations are also characteristic of competing grains.

NEXT STEPS

African rice must be kept from dying out as a crop. It deserves research, development, greater promotion, and support. At the very least it has genes of potential value to its near relation, the world's second biggest food crop. Actions to be taken include the following:

Friends of African Rice A good start could be made by an organization of volunteers - both professionals and amateurs - who join together in a cooperative spirit to explore, protect, promote, and provide samples of this millennia-old resource. They might also collect the legends that come with the various types before they, too, die.

Information Exchange Researchers are now working on rice in Senegal, Mali, Ghana, Ivory Coast, Burkina Faso, Cameroon, Liberia, Nigeria, Sierra Leone, and other countries. An international center, the West African Rice Development Association, specializes in the crop. And two French institutes, Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) and Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres-Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement (IRAT-CIRAD), also have rice programs in Africa. All but one of these organizations work almost exclusively on Asian rice, but the presence of their expertise means that there are good opportunities to advance the development of its African relative. One way to stimulate interest within the international scientific community is to collect all available research data and publish a detailed monograph on African rice.

Food Processing As noted earlier, the availability of precooked products made from African rice might do much to halt its decline and, indeed, to turn it around. Innovation, ingenuity, and marketing skill could be employed to return this food to prominence. It might well start out as a specialty product, selling at a premium to hotels for tourists and to those people dedicated to African traditions.

Seed Supply In many areas the amount of seed in circulation is so low as to render the species nonviable. It is important to keep up a supply of seed. Then, at least, the farmers who want to keep growing African rice won't be excluded as is now apparently happening in Sierra Leone.

Germplasm Samples of African rice have been gathered by various organizations, notably the International Plant Genetic Resources Institute (IPGRI), ORSTOM, and IRAT-CIRAD. This has been stored for purposes of conservation and possible plant breeding.

For all that, however, many interesting types undoubtedly remain to be collected across the vastness of West Africa.

Agronomic Studies Since little hard data on this crop exists, it would be useful for students of agronomy to take up the many challenges of "filling in the map." Examples include the following:

· Selecting nonshattering genotypes or developing techniques to overcome shattering.
· Testing strains for salt tolerance.
· Locating types for drought avoidance.
· Measuring cell sap osmotic adjustment.

· Testing the plant's storage capacity and dormancy requirements.
· Reducing broken grains. Certain strains of Asian rice also suffer this problem and recent research has shown that providing adequate nitrogen fertilizer largely overcomes it.
· Research in deep-water rice is vital and long overdue. The resources available - climate, water, and growing area - along with proper research could perhaps triple production of deep-water rice in the Niger's inland delta.

This is one area of research that can do something toward reducing hunger in one of the regions of Africa most in need of help.

Genetic Improvement Although the current African types shed grain more readily than the Asian ones, some improvements have been bred into dryland varieties. Additional research emphasizing seed shattering could make a big difference.

Because the gene for nonshattering is recessive, the selection of nonshattering types should be rapid, and true breeding should be immediate. Other improvements might include selection for resistance to disease. This resistance exists in the various genotypes, and the major problem is not to lose these local types as Asian rice spreads even further. For the uplands, any form of rice must resist blast and sheath blight. All types must also resist rice yellow-mottle virus; some local cultivars already do.

For areas dependent on seasonal flooding, varieties must resist lodging and respond to fertilizer; the transplant types must tolerate widely varying periods of growth in the nursery (while farmers await the onset of the unpredictable natural flooding).

Researchers are at present "mapping" the chromosomes of both African and Asian rice, identifying the portions that control various features of the plant.

This powerful modern technique will "jumpstart" the genetic improvement of African rice. Perhaps it could also facilitate the transfer of useful genetic material between the two.

SPECIES INFORMATION

Botanical Name Oryza glaberrima Steudel

Synonym Oryza barthii ssp. glaberrima

Common Names
English: African rice, glaberrima rice
French: riz pluvial africain, vieux riz, riz africain, riz flottant
Cameroon: erisi (Banyong)
Guinea: Baga-male, male, riz des Baga
Mali: Issa-mo (river rice), mou-ber (great rice)
Sierra Leone: kebelei, mba, mbei (Mende), male (Kiss)), Kono,

pa (Temne)

Description

African rice is an annual grass that grows generally between 66 and 120 cm tall. It is highly variable. The dryland types have smooth, simple culms that can form roots at the lower nodes and are simply branched up to the panicle (flower cluster). The floating types can form branches and even roots at the upper nodes. The panicles are stiff, smooth, and compact. The flowers are self-fertilizing; however, some inter- and intraspecific cross-pollination occurs.

From a distance, Asian rice and African rice are similar in appearance. However, African rice has diminutive ligules (small, thin membranes found at the base of the leaf where it joins the stem). Its compact panicles have less branching. Its spikelets lack awns. It is completely annual and dies after setting seed. Asian rice, on the other hand, continues growing so that late in the season the two can look strikingly different.

Distribution

African rice is important mainly throughout the southwestern region of West Africa, but it can be found as far east as Lake Chad, especially in the lands of the Sahel that are seasonally flooded by the Niger, Volta, and other rivers.

It has apparently been introduced to India. Also, it may have been taken to Brazil by seventeenth-century Portuguese explorers. Somehow it has also reached El Salvador and Costa Rica.

African rice to world attention.

Cultivated Varieties

Many cultivars of African rice have been obtained by natural crossings and inbreeding, giving forms with compact panicles and heavy grains. In particular, there are numerous swamp varieties suited to different soil and drainage conditions.

Amelioration des conditions de production du riz flottant au Mali (periode 1963-1973). L'Agronomie Tropicale 31(2):194-201.

In northern Mali alone are found about 30 cultivars of the floating type.

Examples of upland varieties of African rice are ITA 208, IRAT 112, Mutant 18, IRAT 104, and ISA 6.

In Upper Gambia, Guinea, and Senegal (Casamance) can be found a special group of African-rice genotypes with enhanced recessive characters such as white husks, spikelets persisting to maturity, and vegetative and floral organs without anthocyanins. These seem to indicate a secondary region of diversity and may be particularly valuable genetic resources.

Could African Rice Go High-Tech?

The world's rice research is overwhelmingly focused on Asian rice, but the remarkable developments now emerging from laboratories may bring big advances to African rice, on the side. Following are examples.

Gene Mapping. Molecular biologists have recently "marked" the locations on rice chromosomes where genes for certain genetic attributes are carried. These markers can be used to track the genes for those traits. The ability to determine whether a desired gene is present or absent in any sample bestows enormous power. It can, for instance, help find a desired gene in wild as well as cultivated species, it can find a "hidden" gene in a given plant where the gene's outward effects are masked, and it vastly simplifies the sorting of thousands of crossbred specimens - something that formerly could take a lifetime of tedious effort.

Gene markers based on restriction-fragment length polymorphisms (RFLPs) are being developed for both Asian and African rices. For instance, in 1988 a team at Cornell University found markers for various traits on the set of 12 chromosomes that (in both species) carries all the genetic characteristics. That first map had 135 genetic landmarks; later versions have more than 300.

A particular strength of this new work is that breeders can now work with very young seedlings. In other words, they can tell whether a certain gene is present without waiting months for the plant to mature. This can cut the time needed to breed a new variety - usually 10-12 seasons - in half.

Although the genomes (chromosome sets) of both African and Asian rice have been mapped, the rest of the effort has so far been solely on Asian rice. Nonetheless, most results from Asian rice are likely to be easily transferable. The genome is relatively small, containing only a tenth as much DNA as maize.

Test-Tube Reproduction. Although until recently no grass had been cloned using tissue culture, today Asian rice, maize, sorghum, and vetiver have succumbed. African rice has so far not been cultured in the test tube but, given the new insights, it seems a likely candidate for this powerful procedure.

Several teams have managed to regenerate fertile rice plants from protoplast-cells from which the wall has been removed. This makes it even easier to fiddle with rice genes.

Already, DNA from bacteria has been transferred into rice protoplasts. Mature plants, grown from these protoplasts, have transmitted the implanted DNA to their offspring.

High-Lysine Forms. In the early 1990s, U.S. Department of Agriculture researchers discovered Asian rice plants with both high protein quality and high protein levels. This has raised hopes that extremely nutritious varieties can be bred for the first time.

To find these new forms, Gideon W. Schaeffer, Francis T. Sharpe, Jr., and John Dudley gave small clumps of rice cells a lethal dose of Iysine (an amino acid vital for good health) in a laboratory dish. Only a tiny fraction survived the treatment. Those few cells, however, could allow more Iysine than normal to be made. The scientists grew them into whole rice plants and found that the resulting high-lysine plants are true genetic mutants and therefore suitable for breeding new commercial varieties. Some of the crossbreeds have succeeded in producing seed of nearnormal weights and good fertility but with greatly enhanced nutritional quality.

The high-lysine trait is apparently controlled by a single recessive gene. The scientists have begun isolating this gene so as to provide it to genetic engineers for incorporation into the world's Asian-rice crop. The work would likely be easily transferable to create high-lysine forms of its African cousin.

Hybrids. Both the male and female parts on rice flowers are normally fertile, but researcher J. Neil Rutger of the U.S. Department of Agriculture has found that growing certain rice plants in 1 5-hour daylight makes them essentially female. The plants never develop fertile pollen. This may provide a cheap and easy way to boost rice yields to a much higher level than at present. Because the modified plants cannot pollinate themselves, they are ready- made for pollination by other plants. Any pollination, therefore, produces hybrids, which are often known to produce robust and high-yielding plants. This process has not yet been tested on African rice, but Rutger believes that it might well work.

Asaf Hybrids. Recent decades have seen several dozen research papers on the genetic and morphological results of crossing Asian rice with African rice. Most have emerged from laboratories in Japan, Taiwan, and China. The driving force behind them appears to be the attempt to raise the yield of Asian rice by forming hybrids.

At least in principle, crosses between African rice and Asian rice might improve the yield of either or both. Although the botanical literature stresses their incompatibility, the two are genetically close. Both are self-pollinating diploids (2n=24) and possess the same genome, which rice geneticists call AA.

Environmental Requirements

Daylength Varies from neutral to strongly sensitive, depending on variety. However, most dryland types now in use are sensitive to photoperiod. They flower with the advent of the dry season. On the other hand, most floating types (at least in northern Mali) show little sensitivity to daylength.

Rainfall Some upland varieties can produce adequately with precipitation as low as about 700 mm.

Altitude From sea level to 1,700 m.

Low Temperature Average temperatures below about 25°C retard growth and reduce yields. Below about 20°C these effects are pronounced.

High Temperature African rice does well at temperatures above 30°C. Above about 35°C, however, spikelet fertility drops off noticeably.

Soil Type Some cultivars apparently can outperform Asian rice on alkaline sites as well as on phosphorus-deficient sites. Not unexpectedly, however, the crop performs best on alluvial soils.

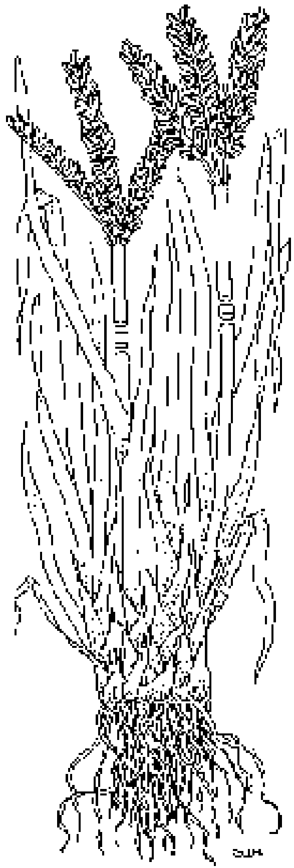
Related Species

At least two of African rice's close relatives are regularly gathered for food, often in sufficient abundance to appear in the markets.

Oryza barthii (Oryza breviligulata) is an annual that commonly occurs in seasonally flooded areas from Mauritania to Tanzania and from the Sudan to Botswana. It is the wild progenitor of cultivated African rice. It can form meadows in inundated areas. Its grain falls off so easily that it must be carefully collected by hand. (People use a basket or calabash, and sometimes they tie the stalks in knots to make harvesting easier.) It tastes good and is sometimes sold in markets. However, wherever rice is cultivated, this plant is regarded mostly as a weed to be eradicated. Certain strains of this species are immune to bacterial blight of rice (Xanthomonas), which could give them a valuable future as genetic resources.

Oryza longistaminata is a common wild rice found throughout tropical Africa as far south as Namibia and Transvaal, as well as Madagascar. Unlike the other species, it is a perennial with rhizomes. It is tall and outcrossing. It usually grows in creeks and drainage canals and reproduces by suckers, often setting few seeds. Nonetheless, these meager grains are sought in times of shortage.

FIGURE



FIGURE