PLANT GENETIC RESOURCES

Keith G. Briggs
University of Alberta, Canada

Keywords: Domestication, agriculture, land races, wild relatives, *in situ*, *ex situ*, collections, genetic diversity and uniformity, disease resistance and epidemics, centers of origin, genetically modified organisms, intellectual property rights, farmers' rights, plant breeders' rights, CGIAR, IPGRI, Global Plan of Action, International Convention on Biodiversity, plant genes, genetic databases, genetic engineering

Contents

Summary

Plant genetic resources are the major biological resource on which humankind has relied for its very existence, and its dependence on plant-derived products will increase in the future, due to greater demand from an increasing global population. New uses will be found for plants and many new kinds of plants will be developed for their contribution to nutritional, medicinal, energy, shelter, fuel, amenity, and cultural uses. In the twenty-first century, an international recognition has developed that there is a need greatly to slow down the extinction of threatened plant species, and to collect and conserve from the wild genetic variability what will be needed in the future, and what is at risk due to changing land use patterns. Plant species from all parts of the world are important in this, so that international efforts are now being made to coordinate the collection, preservation, and germplasm-use efforts in all parts of the world. The Consultative Group on International Agricultural Research has taken the lead in these efforts as has the International Plant Germplasm Research institute. Of great importance to plant germplasm conservation is the establishment of the International Convention on Biodiversity, which has led to most nations being actively involved in developing consensus driven protocols about the ways and means by which plant germplasm issues will be looked after in the future. There is international agreement that increased investment in plant genetic resources and the facilities and human resources to manage them will be necessary, but there is less agreement on who should pay for this activity, or how.

On the technical side, new developments, both in breeding technologies and in greater movement of germplasm ownership away from primary producers into industry-based ownership, offer great potential for plant breeding to create new varieties that will meet the future needs of humankind in quantity and in new kinds of food and other products. The many technical changes in the world seed business are, however, causing uncertainty and disagreement on many fronts. The most important of these evolving issues are concerns about who owns plant germplasm, and who should receive the rewards from germplasm improvement, or have control of the resources, and how the reward should be apportioned. Issues also exist between developing countries, who are the historic source of much of the modern germplasm now found in the world's most important crops, and developed countries, who tend to own the new technologies and are in the best position to make commercial gain using plant germplasm resources.

A number of national policy issues, trade issues, intellectual property ownership issues, and freedom of access to germplasm issues are slowing down the development of a truly global and equitable approach to germplasm development and conservation. At the same time, novel genetic engineering techniques are creating many new opportunities for plant geneticists to improve the productivity, adaptability, and resistance to pests and diseases of crop plants in a way that could also reduce the negative impacts of production agriculture on the global environment, in a sustainable manner. Some of these new technologies are being resisted in some parts of society, as this sector believes that scientists' current safety checks to new genetically modified plants are unable to predict the long-term safeness of genetically modified organisms for health or for the environment. At the beginning of the new millennium, as plant geneticists envision dramatic new ways to put plant genetic resources to work to meet the needs of humankind, consumers will demand much more information, both on their food labels and through education, about the products they use on a daily basis. They will want to know the reasons why genetically modified plants will be necessary, and the details of the choices available for meeting the long-term food requirements of humankind. Given the support of governments and society, the crop producers of the world will once again demonstrate their ability to use new genetics, production technologies, and sustainable production practices to meet production needs. Any success in this will be based on the wealth of genetic resources already inherited by humankind.

1. Importance and Utilization of Plant Genetic Resources

1.1. Humankind's Dependence on Plants

The existence and survival of humankind on earth has always depended primarily on the food, fiber, fuel, shelter, medicinal, industrial, and other requirements derived from plant-based resources. This dependence has existed from the earliest stages of human life on earth, and will continue into the future. Humankind also depends on biological resources derived from animals, but animals themselves depend on plant-based food sources for their existence, again underscoring the importance of the plant genetic resource in the world ecosystem. The many roles of the entire plant genetic resource, cultivated and wild, in soil genesis, in nutrient and hydrologic cycling, in capturing energy from the sun and fixing carbon in the global ecosystem, including conversions to forms essential for the very subsistence of human life, are also primary. These other, broader, contributions of plants to the world ecosystem are not further reviewed in this article, which is restricted to consideration of plant genetic resources use for agri-food applications.

1.2. Domestication of Wild Plants, to Become the Elite Plants of Crop Agriculture

Recent estimates suggest that there may be over 750 000 plant species on earth, not including wild species not yet discovered. Some 500 000 of these grow on land, and around 195 000 of these are flowering plant species. About 5000 are currently cultivated for food, shelter, or medicinal use, but less than 300 of these are used for human food, around 0.1% of all available terrestrial plant species. As civilizations and their food systems evolved over time, a very small number of plant species rose to global prominence in providing most of the nutritional needs of today. Many different factors affect the success with which different species move into cultivation in different parts of the world. They include adaptation of the plant to local environmental conditions (e.g. plants adapted to tropical versus temperate conditions, high or low rainfall, short or long day-length, variable soil conditions, etc.), ease of cultivation, harvesting, and processing, freedom from destructive pests and diseases, contribution of caloric energy and protein requirements in relation to basic human dietetic needs, ease of transport and storage, cost of production, and suitability for different culinary needs in different cultural situations. The adaptability and accelerated adoption of new crops has also been influenced in recent years by the extent of crop breeding and production agronomic research applied to them. Before the application of scientifically based plant genetics, this work was done by farmers selecting, saving, and replanting seeds of the best producing plants for their needs, leading to strains adopted in the early stages of crop domestication known as "land races." Some of these still exist in some crops, but their origins are often not known.

As mechanized crop agriculture evolved, the characteristics required in modern crop varieties also evolved with it, resulting in development of preferred varieties responsive to the best management practices of a desired sustainable but profitable agricultural system. In particular, the demand for higher yielding varieties required a search for genotypes that would be fertilizer and moisture responsive, that had stronger straw strength (in cereals, for example) to bear higher grain yields without plants breaking or falling over (lodging), that were suitable for herbicide application to control weeds, that would resist pests and diseases, that would be suitable for mechanized conservation tillage production systems, and that would have product qualities suited to ever-changing market demands.

Plant breeders have learned over the years that when a new desirable trait is required in a crop species it is usually possible to find favorable genetic variation for the trait within the species, or in related species, so long as a large gene pool is available in which to search. If the trait cannot be found in related species it can often be found in other species not obviously related to the target crop. In these cases modern breeding could still move the gene(s) controlling the desired trait into the target crop with molecular cloning techniques or other species-bridging breeding techniques. For any specified crop, all species in the world (plant, animal, or microbial) might now become target sources for finding desired genetic variation for improving that crop, as breeders have demonstrated that genes from animals and microbes can also be manipulated to express at useful levels in plants.

Although there are a great many individual plant species that meet smaller and often local needs, the species that moved into greatest world prominence are those that met the greatest number of food needs in the widest range of world food systems. As a result of global movement of favored crops with travelers and immigrants around the world and, in more recent times, because of global trade in plant-derived commodities and food ingredients, only 50 species now account for most of the cultivated world crop acreage. Seventeen of these provide 90% of the world's food and occupy 75% of the tilled land on earth. Listed in order of greatest production, these crops are wheat, rice, corn, potato, barley, sweet potato, cassava, soybean, oat, sorghum, millet, rye, peanut, field-bean, pea, banana, and coconut. There is a very uneven distribution of these species, whether they be cereal grains, pulse crops, vegetables, fleshy fruits, or root crops, in how they meet the nutritional needs in the developed or developing world (see Table 1). These data, from FAO statistics of 1987, indicate that 50% of human digestible energy needs are provided by the cereals that are dominant in the list of major crops given above. This contribution is even greater in developing countries, where meat products are consumed at a lower level because of cultural custom, high cost or limited availability. The much higher dependency on plants as a source of essential protein in developing compared to developed countries is also very evident in these statistics. This difference also leads to a greater primary dependency on plant genetic resources in developing countries, although this trend is known to change as developing countries become more affluent and diversify their food demands towards greater use of meat products.

Source	**Digestible energy, %**			**Protein**		
	World	Dd.[a]	Developing	World	Dd.[a]	Developing
Plant products						
Cereals	50.2	26.4	57.7			
Pulses and nuts	3.9	2.4	5.6			
Roots and tubers	6.9	3.7	6.2			
Sugar	9.1	13.0	9.7			
Vegetable oils / fats	4.9	4.8	4.4			
Stimulants / alcohol	3.9	6.7	1.5			
Subtotal	83.7	68.3	91.4	65	44	79
Animal products						
Meat	7.6	15.3	3.1			
Milk and cheese	4.4	8.5	3.1			
Animal oils / fats	2.5	4.7	1.1			
Eggs	0.9	1.6	0.4			
Fish	0.9	1.6	0.7			
Subtotal	16.3	31.7	8.6	35	56	21
Total kcal person^{-1}d^{-1}	2630	3390	2350			
Total (M) person^{-1}d^{-1}	11.0	14.2	9.8			
Total protein (g person^{-1}d^{-1})				68	99	57

[a] Dd. = developed

Source: Reproduced with permission from L.T. Evans, *Crop Evolution, Adaptation and Yield* (Cambridge: Cambridge University Press, 1993), Table 2.2, p. 47. Data from the Fifth World Food Survey (FAO, 1987). Apparent discrepancies between world and component figures are due to the omission here of data for the centrally planned economies.

Table 1: Sources of digestible energy and protein in the world's diet, 1979–1981, as percentages of total diet and in those of developed and developing market economies

Most of the crops grown in a particular region for food are introductions from other centers of diversity, as indicated in Table 2.

Region	% of production accounted for by non-native crops
West central Asia	31
Indochina	34
Hindustan	49
Latin America	56
Chino-Japan	62
Africa	88
Euro-Siberia	91
Mediterranean	99
Australia	100
North America	100

Source: Reproduced with permission from D. Cooper, J. Engels, and E. Frison, E. 1994. A multilateral system for plant genetic resources imperatives, achievements, and challenges, *Issues in Plant Genetic Resources* (Rome: International Plant Genetic Resources Institute) No. 2, May (1994).

Table 2. Percentage of total regional food production based on crops originating in other regions of diversity

These revealing statistics about plant use just for world food needs do not include the less accessible statistics about plant use for medicine, shelter (e.g. forestry, timber, and derived products), fuel (wood), soil amelioration (e.g. green manure, legumes for nitrogen fixation), biological pest control, and amenities (e.g. horticultural uses, landscaping, cultural use, etc.).

Nor do they include data about plant use for environmental conservation or land reclamation. In the last part of the twentieth century there came a realization, however, that both the known plant species and those as yet undiscovered will continue to offer an irreplaceable resource of genetic material.

Plants will be used for many products and processes as yet unimagined, from food supply, through medicinal applications, to use as renewable energy sources, or for industrial stock. Existing plant genetic resources are a finite entity, and they are at risk from any loss of species or forms, since the extinction of any species is an irreversible event. When the species is lost, so is access to the individual genes from which it was constituted.

-
-
-

Bibliography

Asian Vegetable Research and Development Center (AVRDC) (1993). *Germplasm Collection, Evaluation, Documentation, and Conservation*, 95 pp. (Publication No. 93–398A. Compilation of lecture materials of a training course held in Bari, Joydebpur, Gazipur, Bangladesh, May 4–6, 1992). Shanhua, Taiwan: AVRDC. [Illustrates the technical detail involved in plant genetic resources activities, for one particular group of crop species.]

Consultative Group on International Agricultural Research (CGIAR) (1976). *Priorities Among Crops and Regions*. Rome: International Board for Plant Genetic Resources (IBPGR) [Also at *www.cgiar.org*. This site summarizes current goals, activities, and research projects of CGIAR, and has links to sites of related interest.]

CGIAR. www.cgiar.org/ipgri/ International Plant Genetic Resources Institute home page. [This site summarizes current goals, activities, and research projects of IPGRI, and has links to sites of related interest.]Convention on Biological Diversity (1992). www.biodiv.org [The official Web site source for information on the convention.]

Cooper H.D., Spillane C., Kermali I., and Anishetty N.M. (1998). Harnessing plant genetic resources for sustainable agriculture. *Plant Genetic Resources Newsletter* No. 114, 1–8. [A concise account of current and future approaches to plant genetic resources use.]

Crucible Group (1994). *People, Plants and Patents: The Impact of Intellectual Property On Biodiversity, Conservation, Trade, and Rural Society*, 118 pp. Ottawa: International Development Research Centre. [A straightforward account of the issues and options available.]

Evans L.T. (1993). *Crop Evolution, Adaptation and Yield*, 500 pp. Cambridge: Cambridge University Press. [This text offers a scientific systems approach to analyzing factors that influence crop yield, including the genetic capabilities and limitations of several different species during domestication.]

Fowler C. (1994). *Unnatural Selection: Technology, Politics, and Plant Evolution* (Vol. 6, *International Studies in Global Change*, ed. T.R. Burns and T. Dietz), 317 pp. Langhorne, PA.: Gordon and Breach. [A unique treatment of the subject that ties together biological, technical, political, economic, developmental, legal, and sociological aspects of humankind's use of plants.]

Frisvold G.B. and Condon P.T. (1998). The convention on biological diversity and agriculture: implications and unresolved debates. *World Development* **26**(4), 551–570. [Describes the convention and the consequences that flow from it.]

Harlan J.R. (1992). *Crops and Man*, 284 pp. Madison, Wisconsin: American Society of Agronomy; Crop Science Society of America. [Classic book written by one of the world's foremost experts on the subject. Easy reading and very informative.]

Hawkes J. G., ed. (1991). *Genetic Conservation of World Crop Plants*, 87 pp. (Reprinted from *Biological Journal of the Linnean Society* **43**(1).) London: Academic Press. [A collection of review papers by experts covering all aspects from collections, to agricultural applications and new molecular approaches.]

Hoyt E. (1992). *Conserving the Wild Relatives of Crops*, 52 pp. 2nd rev. edn. Rome: IBPGR. [Published in the era when international concern about loss of plant genetic resources first started to focus.]

Iwanaga M. (1993). Enhancing links between germplasm conservation and use in a changing world. *International Crop Science I* (ed. D.R. Buxton et al.), pp. 403–413. Madison, Wisconsin: Crop Science Society of America. [A comprehensive article describing different ways in which plant genetic resources are put to use.]

Oldfield M.L. (1989). *The Value of Conserving Genetic Resources*. Sunderland, Mass.: Sinauer Associates. [This university level text draws attention to the importance of conserving global biodiversity, and contains many examples of the application of genetic diversity for societal use. It offers an excellent summary of issues in the era predating the Global Plan of Action.]

Reaka-Kudla M.L., Wilson D.E., and Wilson E.O., eds. (1997). *Biodiversity II: Understanding and Protecting Our Biological Resources*, 551 pp. Washington, D.C.: Joseph Henry. [Written for lay and science readers alike, this book describes what needs to be done immediately "to preserve life on Earth."]

Shand H. (1997). *Human Nature: Agricultural Biodiversity and Farm-Based Food Security*, 94 pp.

Ottawa: Rural Advancement Foundation International (RAFI). [The book deals with the causes and consequences of loss of biodiversity, and emphasizes the need to develop suitable policy for biodiversity conservation. Political issues affecting agrobiodiversity are also considered.]

Smale M., ed. (1998). *Farmers, Gene Banks and Crop Breeding. Economic Analyses of Diversity in Wheat, Maize, and Rice*, 270 pp. (Papers presented at a conference hosted by Stanford University on behalf of CIMMYT, Palo Alto, August 1997; Natural Resource Management and Policy series.) Boston: Kluwer. [This text not only describes estimates of plant genetic resources value for several crops, it also breaks new ground by presenting new methodologies for this kind of analysis.]

Swaminathan M.S., ed. (1996). *Agrobiodiversity and Farmers' rights*, 303 pp. Delhi: Konark. [Describes the case for farmers' rights, and presents proposals as to how this could be achieved, especially for developing countries.]

Thormann I, Jarvis D.I., Dearing J.A., and Hodgkin T. (1999). Internationally available information sources for the development of *in situ* conservation strategies for wild species useful for food and agriculture. *Plant Genetic Resources Newsletter* No. 118, 38–50. [Lists all the important Web sites on this topic.]

Biographical Sketch

Keith Briggs is Professor Emeritus (cereal breeding and agronomy), University of Alberta. After serving as Chair for seven years, he retired and formed GrainTek, a services and consulting company. He has over 30 years national and international experience in the area of plant breeding, agronomy, research, teaching, and institutional management.