



SGRP

The SGRP is a partnership programme of the 15 Future Harvest Centres of the CGIAR.

ANNOTATED BIBLIOGRAPHY ADDRESSING THE INTERNATIONAL PEDIGREES AND FLOWS OF PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Information document submitted by the System-wide Genetic Resources Programme of the CGIAR to the Eighth Conference of the Parties to the Convention on Biological Diversity (COP 8) and the Ad Hoc Open-ended Working Group on Access and Benefit-sharing

Secretariat of the
CGIAR System-wide
Genetic Resources
Programme (SGRP)
International Plant Genetic
Resources Institute
Via dei Tre Denari, 472/a
00057 Maccarese
Rome, Italy
Tel: (39)0661181
Email: ipgri@cgiar.org
Fax: (39)0661979661
<http://www.ipgri.cgiar.org>



**FUTURE
HARVEST**

ANNOTATED BIBLIOGRAPHY ADDRESSING THE INTERNATIONAL PEDIGREES AND FLOWS OF PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Information document submitted by the System-wide Genetic Resources Programme of the CGIAR to the Eighth Conference of the Parties to the Convention on Biological Diversity (COP 8) and the Ad Hoc Open-ended Working Group on Access and Benefit-sharing

This bibliography was developed by Christine Frison, consultant, and Michael Halewood of the International Plant Genetic Resources Institute (IPGRI). IPGRI thanks the following individuals for their contributions: Cary Fowler, Jane Toll, Jan Engels, Toby Hodgkin, Samy Gaiji, Coosje Hoogendoorn, Robert Lewis-Lettington, Olivier Hanotte, Adam Drucker, Workneh Ayalew, Jean Hanson, Ruairaidh Sackville Hamilton, Mike Jackson, Graham McLaren, Melinda Smale, Reem Hajjar, Hari D. Upadhyaya, C.L.L. Gowda, Douglas Gollin, Thomas Carter, Ricardo Cardellino, Kent Nnadozie, Clive Stannard, Irene Hoffman, Sirkka Immonen, Jonathan Robinson, Roland von Bothmer, Kameswara Rao, Shawn Sullivan, Masa Iwanaga and Ilse Kohler-Rollefson.

For more information about this bibliography and or suggestions for additional entries, contact Michael Halewood, Policy Research and Support Unit, IPGRI, at M.Halewood@cgiar.org.

INTRODUCTION

The System-wide Genetic Resources Programme (SGRP) of the Consultative Group on Agricultural Research (CGIAR) has developed this annotated bibliography to assist the Conference of the Parties to the Convention on Biological Diversity (CBD) and the Ad Hoc Open-ended Working Group on Access and Benefit-sharing in analyzing technical issues associated with developing access and benefit-sharing mechanisms for plant genetic resources for food and agriculture (PGRFA). The first part of the bibliography includes literature that examines the international ancestry (pedigrees) of crops. The second part includes literature concerning international flows of germplasm that have occurred as a result of human activity.

Consideration of the international pedigrees and flows of PGRFA is perhaps most relevant *vis-à-vis* the development of access and benefit-sharing rules to identify the ‘origin’ of material as a prerequisite or ‘trigger’ for benefit sharing. The CBD defines the ‘country of origin of genetic resources’ as “the country which possesses those genetic resources in *in situ* conditions.” In turn, the CBD defines ‘*in situ* conditions’ as those “conditions where genetic resources exist within ecosystems and natural habitats and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties.” Pursuant to this definition, the CBD requires more than simply identifying the country of origin of a crop—it requires the identification of the country of origin of the distinctive properties of the crop.

Many of the articles in this bibliography, though not all, suggest directly or indirectly that it is difficult or impossible to determine the country of origin of crop varieties, and even more so their distinctive traits, given the long histories of human intervention and cooperation involved in their development. This information about the internationally complex origins of PGRFA is not new. It was clearly appreciated by more than 180 FAO Member Countries that adopted unanimously the International Treaty on Plant Genetic Resources for Food and Agriculture (the Treaty) at the FAO Conference in 2001. The Treaty created a multilateral system for access and benefit sharing that builds upon and complements the international historical development of PGRFA. The two specifically listed criteria in the Treaty for identification/inclusion of crops and forages in the multilateral system of access and benefit sharing are interdependence and importance to food security.

This bibliography does not include all of the relevant literature concerning this subject. Instead it includes a representative sample of the wider body of literature on the issue. SGRP may, in the future, publish a revised version of this bibliography with more entries.

PART I: INTERNATIONAL PEDIGREES

Brennan JP, Godden D, Smale M, Meng E. 1999. Breeder demand for and utilization of wheat genetic resources in Australia. *Plant Varieties and Seeds* 12(2):113–127.

This paper presents data concerning the international nature of the pedigrees of wheat varieties developed in Australian breeding programmes. It indicates that the principal sources of new genetic resource materials are international nurseries such as those maintained by the International Center for Agricultural Research in Dry Areas and the International Maize and Wheat Improvement Center (CIMMYT). These international nurseries represent 40% of the source of all materials introduced, compared with 29% originating from other Australian programmes, 14% from overseas national programmes, 15% from other origins and 2% from landraces.

Cassaday K, Smale M, Fowler C, Heisey PW. 2001. Benefits from giving and receiving genetic resources: the case of wheat. *Plant Genetic Resources Newsletter* 127:1–10.

This paper demonstrates that the public sector breeding of spring bread wheat varieties, with a particular focus on those developed by CIMMYT, involves numerous crosses of a large number of ancestors from a large number of countries.

(Spring bread wheat is sown on approximately 72 million hectares in the developing world.) For example, in 1997, for 30 major spring bread wheat varieties grown in eight developing countries:

- the average number of ancestors per variety was 1781;
- the average number of crosses between those parents was 1932; and
- the average coefficient of parentage¹ was 0.211 (which represents a high degree of genetic diversity).

The paper provides a brief introduction to the historical movement and flows of wheat. Wheat was domesticated approximately 9000 years ago in West Asia. By 6000 BC, it was introduced into East Asia. By 4000 BC, it had spread to South Asia and North Africa. In 1529, the Spaniards introduced wheat into Mexico.

Fowler C. 2000. Implementing access and benefit-sharing procedures under the Convention on Biological Diversity: the dilemma of crop genetic resources and their origins. In: GFAR/IPGRI. *Strengthening Partnerships in Agricultural Research for Development in the Context of Globalisation. Proceedings of the GFAR–2000 Conference, 21 April–3 May 2000, Dresden, Germany.* GFAR and IPGRI, Rome, Italy. pp. 106–155.

Revised and republished in *Jurimetrics* (see next entry).

Fowler C. 2001. Protecting farmer innovation: The Convention on Biological Diversity and the question of origin. *Jurimetrics: The Journal of Law, Science and Technology* 41:477–488.

1. Coefficient of parentage is an index used to determine the level of diversity between crosses. A coefficient close to 0 indicates a very high level of diversity. A coefficient close to 1 indicates a very low level of diversity (or a high level of genetic similarity between the parents).

This paper, first published in 2000 and revised in 2001, argues that it is very difficult to identify the country of origin of a crop variety, as defined in the CBD, given the high level of international interdependence evidenced in their pedigrees and the international flows of these resources. The paper notes that the historical information on food crops is not exhaustive, certainly not concerning their numerous distinctive traits and properties. To illustrate the difficulty, the paper provides the example of the pedigree of the 'Veery' line of wheat. 'Veery' is a product of 3170 different crosses involving 51 parents from at least twenty-six (source) countries. It would be extremely challenging, if not impossible, to trace back the contributions of those parents to the development of particular distinguishing characteristics and to a particular country.

Gollin D. 1998. Valuing farmers' rights. In: Evenson RE, Gollin D, Santaniello V, editors. *Agricultural Values of Plant Genetic Resources*. CAB International, Wallingford, UK. pp. 233–245.

The authors identify the 'end point progenitors' (including landraces and mutants) in the ancestries of the 1709 'improved' varieties and elite lines (developed in the 'formal sector') of rice, which were released between the 1960s and 1990s in 15 countries and three regions. For each of the 15 countries, they compared the total number of landraces (in the ancestries of all of the varieties released in that country) with the total number of landraces that came from outside the country. The extent of 'borrowing' of landraces from other countries was very significant.

In Bangladesh, 34 modern varieties were released, which could be traced back to 233 progenitors (including landraces). Only four of the landraces, or less than 2% of the total, were from Bangladesh, 80% or more of the landraces in the ancestries of the varieties released in the following countries were from outside those same countries: Brazil, Burma, China, Indonesia, Nepal, Nigeria, Pakistan, The Philippines, Sri Lanka, Taiwan, Thailand and Vietnam. Of the 15 countries studied, only two contributed more than 20% of the end point progenitors of the varieties released—the United States with 67% and India with 40%. The authors conclude that many countries representing major centres of origin might actually be the countries that 'borrow' the most foreign genetic resources in the form of 'improved' or 'modern' varieties.

Harlan JR. 1992. *Crops and Man* (2nd ed.). American Society of Agronomy, Madison, Wisconsin, USA.

The book examines the co-evolution of crops from wild plants and economies that existed prior to agriculture. Harlan summarizes archeological and other evidence concerning the historical development of crops and their spread, through human influences, around the globe. With respect to the issue of determining the geographic origin of crops, Harlan rejects the Vavilovian concept of 'centres of origin' as "too simplistic" and asserts that it is necessary to examine each crop separately, because there are a variety of geographical patterns that depend on the history and distribution of each crop. He states: "Some had centers of origin; some did not. Some were domesticated at least several times, others only once. Some spread early and developed secondary centers; some spread recently and can be traced to their origins by historical data. Each crop was shaped and molded throughout its history by human activity, by uses, preferences, cultural practices

and by continuous adjustment to the environment provided, including climate, soils, agronomic management, diseases and pests. Space, time and variation are all part of the geography of crop plants and fundamental to the collection and preservation of crop genetic resources.” (page 155)

Johnson NL, Pachico D, Voysest O. 2003. The distribution of benefits from public international germplasm banks: the case of beans in Latin America. *Agricultural Economics* 29:277–286.

This paper provides genealogical data for the 205 bean varieties that were bred by the International Center for Tropical Agriculture (CIAT) between 1976 and 2000 and subsequently distributed, upon request, to countries in Latin America and the Caribbean (LAC). The paper then provides a breakdown of the percentage of ancestors in the pedigree of those varieties that are foreign to the LAC countries in which they were released. Only in two of the 18 countries (Dominican Republic and Colombia) did local material contribute more than 50% of the genetic material to the released varieties. In all of the other countries, more than 50% was from other countries. Five countries (Venezuela, Bolivia, Panama, Cuba and Haiti) depended upon more than 90% of the genetic material contributed from other countries.

The CIAT bean collection includes 31 000 accessions from 65 countries. From 1973 to 2000, CIAT distributed 307 000 samples from this collection to 96 countries.

Smale M, Reynolds MP, Warburton M, Skovmand B, Trethowan R, Singh RP, Ortiz-Monasterio I, Crossa J. 2002. Dimensions of diversity in modern spring bread wheat in developing countries from 1965. *Crop Science* 42:1766–1779.

This paper presents data on the genetic bases of ‘modern’ cultivars of spring bread wheat (*Triticum aestivum* L.) in the developing world since 1965, concluding that genetic uniformity is not likely to have increased among the spring bread wheat cultivars grown in the developing world. In 1997, approximately 86% of the spring bread wheat area in developing countries (excluding China) was sown to CIMMYT-related wheats, that is, those that have at least one CIMMYT ancestor. In developing countries, national programmes cross CIMMYT lines with their own materials before releasing the line. This indicates that genetic diversity in their cultivars is at least as important as that in CIMMYT lines. It also contributes to the maintenance and promotion of diversity. The open exchange of numerous and diverse materials among wheat breeding programmes in the world and inventive uses of those materials by national programmes has contributed to this positive finding.

The average number of parental crosses in pedigrees of released varieties was 960 in 1990 and 1932 in 1997. The average number of landraces (or farmers’ varieties) included in the pedigrees of those varieties was 45 in 1990 and 50 in 1997.

Srinivasan CS, Thirtle C, Palladino P. 2003. Winter wheat in England and Wales, 1923–1995: what do indices of genetic diversity reveal? *Plant Genetic Resources: Characterization and Utilization* 1(1):43–57.

This paper examines changes in the genetic diversity of the winter wheat crop in England and Wales over 72 years from 1923 to 1995 and demonstrates that (1) the

overall levels of genetic diversity across varieties in farmers' fields have remained generally constant and (2) the geographic sources of parents over the last five generations of crosses of those materials have been relatively narrow, that is, France, United States, Canada and Australia (and CIMMYT). For each generation back, the proportion of material of unknown geographical origin increases from 4% on average for the first generation to approximately 38% for the fifth generation.

Examples are given for several wheat varieties, such as 'Apollo', where at the first expansion level (or generation), 50% of the parents are from the United Kingdom and 50% from Germany, whereas at the fifth expansion level, the share is the following: 12.52% from France, 9.39% from CIMMYT, 3.13% from the United States, 6.25% from Belgium, 3.13% from Germany, 6.26% from Canada, 3.13% from the United Kingdom/France and 56.25% are not known. The average contribution from CIMMYT remains considerable in the five expansion levels; approximately 10%.

Zhou X, Carter TE Jr, Cui Z, Miyazaki S, Burton JW. 2000. Genetic base of Japanese soybean cultivars released during 1950 to 1988. *Crop Science* 40:1794–1802.

This article identifies 74 ancestors in the pedigree of 86 publicly bred Japanese soybean cultivars registered from 1950 to 1988. Sixteen of the 74 ancestors originated from abroad. They came from the United States (6), China (7), Korea (2) and Sakhalin Island (1). The Chinese and American soybean breeding programmes are less independent, with increasing numbers of crosses between Chinese and American cultivars.

PART II: INTERNATIONAL GERMPLASM FLOWS

CIMMYT. 1995–6.. World Wheat Facts and Trends 1995/1996. Understanding global trends in the use of wheat diversity and international flows of wheat genetic resources [online]. Available from: http://www.cimmyt.org/Research/economics/map/facts_trends/wft9596/htm/wft9596contents.htm. Date accessed: 08 December 2005.

This paper provides a description of the origins of wheat and wheat germplasm flows. It contains a flow chart on germplasm flows and deals with measuring genetic diversity, genetic variation among major bread wheats in the developing world and valuing genetic resources and diversity. The paper also includes data on wheat production, trade and utilization and compiles selected wheat statistics region by region.

Regarding pedigree complexity, the paper provides an example of the ‘Sonalika’ wheat variety (released in India in 1966), which has 17 generations in its pedigree and a total of 420 parental combinations. The HD 2285 cross (released in India in 1983) has 23 generations in its pedigree and a total of 3295 parental combinations. The Veery cross (released in Mexico in 1977) has 23 generations in its pedigree and a total of 3169 parental combinations. Another table shows pedigree complexity of widely grown CIMMYT bread wheats from 1952 to 1992, including the cultivar ‘Jupateco F’ (released in 1973), which has 19 generations, 96 different parental combinations and 40 different landraces in its pedigree; the cultivar ‘Ciano T’ (released in 1979), which has 21 generations, 160 different parental combinations and 62 different landraces in its pedigree; and the cultivar ‘Veery’ (Serim8) (released in 1982), which has 23 generations, 127 different parental combinations and 47 different landraces in its pedigree.

Day Rubenstein K, Smale M. 2004. International exchange of genetic resources, the role of information and implications for ownership: the case of the U.S. National Plant Germplasm System. EPTD Discussion Paper no. 119. Environment and Production Technology Division, International Food Policy Research Institute (IFPRI), Washington DC, USA. Available from: <http://www.ifpri.org/divs/eptd/dp/papers/eptdp119.pdf>. Date accessed: 08 December 2005.

This paper analyzes flows of germplasm facilitated by the US National Plant Germplasm System (NPGS). It shows that domestic and international demand for genetic resources is high and increasing and that developing countries make more intensive use of these resources than developed countries.

The NPGS holds over 450 000 accessions. The NPGS sent out 30 493 samples of maize and 154 962 samples of wheat between 1987 and 1998 to 191 countries and 45 territories, departments or commonwealth associations outside the USA. For the purposes of comparison, CIMMYT sent 20 540 samples of maize and approximately 40 000 samples of wheat during the same period. Between 1990 and 1999, 26% of samples distributed by the NPGS were sent to foreign countries, including 12% to developing countries. Public institutions received 58% of these samples, out of which 74% went to publicly funded institutions in the United States. Only 22% went to non-profit institutions, out of which 80% were sent to non-profit, non-governmental organizations outside the United States. Commercial recipients received 18% of all samples sent by the NPGS (23% to commercial users in the United States against 6% to commercial users abroad). Cultivars were

the germplasm type most requested (47% of the distributed material); landraces accounted for 19%; and advanced breeding material accounted for 12%. Developing countries requested cultivars for 51% of the samples; advanced material for 29%; genetic stock for 36%; landraces for 21%; and wild relatives for 18%. Users from developing countries and transitional economies used more cultivars, advanced materials and genetic stocks than users from developed countries, who requested more samples of landraces (31%) and wild relatives (31%). Developing countries used most of the NPGS samples to evaluate for specific traits (45%), whereas research purposes accounted only for 15%. In contrast, developed countries used 35% of the samples for basic research and 32% of the samples for evaluation of specific traits.

Dudnik NS, Thormann I, Hodgkin T. 2001. The extent of use of plant genetic resources in research—a literature survey. *Crop Science* 41:6–10.

This paper assesses the level of use of *ex situ* conserved plant genetic resources in crop genetic research and sheds some light on the sources of materials—and the international transfers of these resources—that were used as the basis of this research. The authors analyze reports from four internationally recognized journals—*Crop Science*, *Euphytica*, *Plant Breeding and Theoretical and Applied Genetics*—that were published in 1997. Of the material used in the published reports, 80% came from seven CGIAR genebanks and other national collections based in 27 countries and was sent mainly to national research centres and universities. The studies were developed by 249 different institutions in 41 countries and seven CGIAR centres. Overall, 74% of the institutions were located in developed countries, 6.4% by the CGIAR and just less than 20% of the institutions were in developing countries. Of these, 57% of the institutions in developed countries were universities, 40% were national research centres and 3% represented private industries. In developing countries, 65% of the institutions were national or other research institutes, 30% were universities and three were private corporations (5% of the total), which were located in Brazil.

Fowler C, Hodgkin T. 2004. Plant genetic resources for food and agriculture: assessing global availability. *Annual Review of Environment and Resources* 29:143–179.

This article underscores the importance of international interdependence on PGRFA and argues that the conservation and use of PGRFA would be enhanced by, among other things, improving the efficiency in exchange of genetic resources and related information.

The paper notes the dramatic increase in the number of genebanks from the early 1970s. Over the same period of time, the number of accessions increased from a few hundred thousand to 6.2 million in 1996, with the largest proportion being held in genebanks in Europe and Asia. It is difficult to comment on the proportion that is unique or, conversely, the extent of duplication of materials held in other genebanks.

Annually, the CGIAR genebanks distribute 60 000 samples of material, originally collected from 170 countries. Almost all countries are net recipients of materials each year from the CGIAR genebanks. During the 1990s, the United States

distributed approximately 16 300 samples of ten crops annually to other countries and approximately 45 000 samples to recipients within the United States. India provides approximately 46 000 samples, 65% internally and 35% internationally. Many national genebanks, particularly in Africa, the Near East, Asia and the Pacific, do not distribute materials outside their national borders.

The authors cite Gollin (1998, above) with respect to international 'borrowing' by a number of countries of landraces and other end point progenitors in the pedigrees of released varieties that have been improved within their borders. They highlight the fact that, for example, out of 386 total landrace progenitors in all released improved varieties of rice in Sri Lanka, 64 came from Sri Lanka and 322 were 'borrowed' from other countries. Pakistan has borrowed all of its 195 landrace progenitors in all released varieties of rice.

One of the major obstacles to increased use of materials in genebanks is a lack of information about the accessions held, which makes it difficult for would-be users to know what is available and useful to them.

Fowler C, Smale M, Gaiji S. 2000. Germplasm flows between developing countries and the CGIAR: an initial assessment. In: GFAR/IPGRI. *Strengthening Partnerships in Agricultural Research for Development in the Context of Globalisation. Proceedings of the GFAR-2000 Conference, 21 April-3 May 2000, Dresden, Germany.* GFAR and IPGRI, Rome, Italy. pp. 86-105.

This paper demonstrates the high interdependence between countries in terms of plant genetic resources for food and agriculture by analyzing germplasm flows between developing countries and the International Agriculture Research Centres (IARCs) of the CGIAR.

From 1972 to 1990, 14 selected developing countries provided 123 979 samples for inclusion in the IARC genebanks. During this same period of time, the IARC genebanks distributed 528 452 samples to those same countries. The IARCs also released 678 improved varieties in those countries.

Until March 2000, 63-99% of samples from the IARC genebanks were distributed to developing countries. During this same 20-year period, 1-37%—depending on the crop—was distributed to developing countries. For example, CIMMYT distributed 1.2 million seed samples of bread wheat, durum wheat, triticale, barley and other lines from 1994 to 2000. Of the total, 71.3% was distributed to developing countries. The paper shows that germplasm flows are largely facilitated by a multilateral system of access to plant genetic resources for food and agriculture.

FAO. 1998. *The State of the World's Plant Genetic Resources for Food and Agriculture.* FAO, Rome, Italy.

The book is a synthesis of information on the state of the world's plant genetic resources for food and agriculture. It is based on, among other things, 154 country reports. The introductory chapter includes a discussion of the 'Origins of PGRFA and the Interdependence of Countries on PGRFA'. This section includes the following examples of international flows of PGRFA over the history of the domestication of

a number of crops: the development of secondary centres of diversity of common bean, maize and cassava in sub-Saharan Africa since they were introduced from Latin America; development of important characteristics in finger millet in south Asia after it was introduced from East Africa thousands of years previously; farmers all over the world rely on hybrid maize developed by farmers in the USA in the 18th and 19th centuries; rye and oats may have been domesticated in northern Europe after having been introduced there as weeds from the Mediterranean and Near East. The report states that over two-thirds of developing countries rely on crops that originated in other parts of the world for more than half of their crop production. The report cites the case of Brazil in particular, which relies on just three cereals, which originated in other parts of the world, for almost half of the calories consumed by its population.

Halewood M, Gaiji S, Upadhyaya HD. 2005. Germplasm flows in and out of Kenya and Uganda through the CGIAR: a case study of patterns of exchange in developing national policies [online]. Available from: http://www2.merid.org/bellagio/4E-Kenya_Uganda_Germplasm_Flows.pdf. Date accessed: 08 December 2005.

This paper analyzes the germplasm flows in and out of Kenya and Uganda that were facilitated by the genebanks of the IARCs of the CGIAR over 20 years up to 2004. The germplasm flows were carried out within the relatively open framework of facilitated access to materials held by those same centres. The study focuses on pigeon pea, finger millet, sorghum, banana (*Musa*), beans (*Phaseolus*), tropical forages and groundnuts.

As an absolute minimum, the countries got back at least as many unique accessions originally collected from other parts of the world as they provided (tropical forages). At the other end of the spectrum, they got back from the rest of the world eight times more unique accessions of pigeon pea, *Musa* and beans than they provided. On average, of the total number of accessions sent to Uganda and Kenya, 88% was originally collected elsewhere (12% was originally collected from Kenya and Uganda, stored in the international genebanks and samples were sent back upon request). This degree of reliance on 'foreign' material was the same for those crops for which Kenya and Uganda were considered to be part of a centre of diversity (that is, pigeon pea, finger millet, sorghum and *Musa*) as for those crops and forages for which they were not a part of a centre of diversity (beans, tropical forages and groundnut). The degree of dependence was also the same for crops not included in Annex I of the ITPGRFA (that is, tropical forages and groundnuts) as for those that were included in the list.

Hodgkin T, Rao VR, Cibrian-Jaramillo A, Gaiji S. 2003. The use of *ex situ* conserved plant genetic resources. *Plant Genetic Resources: Characterization and Utilization* 1(1):19–29.

By analyzing surveys of distribution of germplasm from genebanks and surveys of recipients/users of this germplasm, this paper investigates the patterns of use of *ex situ* material held around the world. There is substantial use of *ex situ* materials. However, considerably more information needs to be gathered, using methodologies that facilitate comparing data more efficiently, in order to develop a more complete picture.

Over 25 years, from about 1978 to 2003, 81% of the material transferred from the CGIAR genebanks went to developing country users. The largest blocks of recipients of materials held in the CGIAR genebanks have been the National Agricultural Research Systems (NARS) and universities. The private sector has been the smallest recipient by far. The pattern of distribution from national genebanks has generally been the same, with only a miniscule proportion going to the private sector. Developing countries tend to request improved materials, while developed countries tend to request landraces and wild relatives. Flows of material between regions have proven to be very important for some crops. For groundnut, 60% of transfers from the CGIAR genebanks involved movement to a region different from that where it was collected.

Some of the best data on the uses of distributed germplasm are available with respect to China. A survey of distributions of samples of ten crops showed that 61% of the samples distributed were advanced lines and cultivars while 22% were landraces, 4% were wild relatives and 2% genetic stock. There were some exceptions; 60% of the distributed citrus material and soybeans were wild relatives and landraces.

Kloppenborg J Jr, Kleinman DL. 1987. Analyzing empirically the distribution of the world's plant genetic resources: the plant germplasm controversy. *Bioscience* 37(3):190-198.

This paper demonstrates that every region in the world depends substantially on genetic resources coming from other parts of the world. The authors used the UN Food and Agriculture Organization's 1983 global production statistics for the 20 most produced crops in the world, allocated these data to regions and then calculated the proportion of production that is accounted for in each region by crops whose primary centres of diversity are elsewhere.

According to these calculations, the least interdependent regions in the world, including the Indo-Chinese and west central Asiatic regions, are 33% and 31% dependent, respectively. Africa is 88% dependent. The Mediterranean is 98% dependent. Australia and North America are 100%. The paper provides further details with respect to dependency. Africa depends to the extent of 2.4% on the Chino-Japanese region; 22.3% on the Indo-Chinese region; 1.5% on the Hindustanean region; 4.9% on the west central Asia region; 0.3% on the Mediterranean region; 12.3% on Africa; 0.1% on the Euro-Siberian region; and 56.3% on Latin America.

Pachico D. 2001. Implementing farmers' rights in genetic resources: approaches to benefit sharing. *Biopolicy* 4: paper 1 [online]. Available from: <http://www.bioline.org.br/abstract?id=py01001&lang=en>. Date accessed: 08 December 2005.

This article analyzes the hypothetical consequences of applying property rights regimes to vest rights in landraces (or farmers' varieties) of common beans (*Phaseolus vulgaris* L.). The author assumes that countries would receive royalties proportional to their share of the total diversity of bean landrace genetic diversity worldwide. They would pay out according to the number of hectares of beans they actually grow. Based on this model, the paper estimates that the United States and Canada would pay US \$2.9 million annually. However, Europe would have a net

income of US \$1.5 million because it grows relatively few beans but is a secondary centre of diversity for beans. Africa would have to pay more than any other continent, a total of US \$7.4 million per year. East and South Asia and West Asia/North Africa would also have to make payments of US \$1.8 and \$0.9 million annually. As far as individual countries are concerned, the paper identifies Brazil as the country that would have to pay the most, based on its high production and low level of local landraces—it would have to make a net payment of US \$19.2 million. The paper acknowledges that the dollar figures are based on a number of assumptions about market values. The overall principles established, however, remain constant. Many countries and regions—both developed and developing—would end up making net payments for their access to bean germplasm and Africa would have to pay the most by far.

Palacios XF. 1997. Contribution to the estimation of countries' interdependence in the area of plant genetic resources. Background Study Paper no. 7, REV.1 [online]. Available from: <http://www.fao.org/ag/cgrfa/docs.htm#bsp>. Date accessed: 08 December 2005.

This study assesses the degree of dependence of a country's main food crop on genetic diversity in areas of origin and in areas of primary diversity located elsewhere. The study is conducted for six regional groups of countries that were divided into sub-regional groups. The importance of the crops is calculated on the basis of calorie intake from the crop and its derivatives. Thirty-five main crops were identified and the determination of regions of diversity for these crops was based on their geographic distribution. The degree of regional and national dependence on crops that have their centres of diversity in other parts of the world was then determined.

Countries from all regions are dependent on crops originating from other countries. For example, for Africa, the degree of dependence of countries in Central Africa is between 67% and 94%; it is between 28% and 98% in East Africa; 51% and 98% in southern Africa; 13% and 81% in West Africa; and 85% and 100% in the Indian Ocean region.

Rejesus RM, Smale M, van Ginkel M. 1996. Wheat breeders' perspectives on genetic diversity and germplasm use: findings from an international survey. *Plant Varieties and Seeds* 9(3):129–147.

This paper presents survey results concerning wheat germplasm use and diversity. The respondents were from 107 countries (38 developed and 69 developing). The authors concentrate their analysis on the diversity maintained in the national breeding programmes 'crossing blocks.' Crossing blocks are the nurseries that contain the parental stock that plant breeders use in their crossing programmes.

All countries give top priority within their crossing blocks to their own advanced lines. On average, they constitute 35% of the crossing blocks of developing countries and 46% of developed countries. For developed countries, the second most important materials in their crossing blocks are nationally released varieties (18%) and then advanced lines from other countries (12%). For developing countries, however, the second most important source of material is CIMMYT's

international nurseries (an average of 25% as opposed to just 10% for developed countries). As a result of their reliance on CIMMYT nurseries for a quarter of their crossing blocks, developing country crossing blocks are likely to be more “genetically diverse in terms of types and geographical origin of parent materials” than those used in developed countries. To illustrate the international nature of the pedigrees of the CIMMYT materials, the paper provides examples of a few CIMMYT-bred wheats. ‘Ciano T’, which was released in 1979, has a maximum of 21 generations for 160 crosses in its pedigree and contains 62 different landraces. ‘Veery’ (Serim8), which was released in 1982, has a maximum of 23 generations for 127 crosses in pedigree and contains 47 different landraces in its pedigree. ‘Sonalika’s ancestry has been traced back to the nineteenth century with landraces from 17 countries and crosses by wheat breeders from 14 countries. Landraces and advanced lines in ‘Sonalika’s pedigree come from six continents and most of the world’s wheat-producing countries.

SGRP. 2006. Developing access and benefit sharing regimes: plant genetic resources for food and agriculture. SGRP, Rome, Italy. Available from: http://www.ipgri.cgiar.org/policy/ABS_brief.pdf. Date accessed: 28 February 2006.

The brief synthesizes and reiterates a number of the points raised in existing literature regarding the international pedigrees and flows of plant genetic resources for food and agriculture. The brief cites evidence that the same case can be made for both crops and forages that are and are not specifically listed for inclusion in the multilateral system of access and benefit sharing (MLS) created by the International Treaty on Plant Genetic Resources for Food and Agriculture. The brief encourages delegates to negotiate for an international regime regarding access and benefit sharing under the CBD to leave space for either: a) the expansion of the MLS to include a wider range of crops and forages, or b) the development of regional agreements for exchange of non-Annex 1 materials.

Smale M. 1996. Understanding global trends in the use of wheat diversity and international flows of wheat genetic resources. Economics Working Paper 96–02. CIMMYT, Mexico. Available from : http://www.cimmyt.org/english/docs/eco_wpaper/ewp96_02.pdf. Date accessed: 08 December 2005.

This working paper identifies the centres of origin and diversity for bread wheats. It explains how worldwide germplasm flows shaped the evolution and development of cultivated bread wheats. It measures genetic diversity in wheats and provides data on genetic variation among the major bread wheats grown in the developing world. It includes a description of germplasm flows between 1500 and 1900, highlighting the complexity of segments of pedigrees from wheat cultivars—for example, ‘Sonalika’, ‘II8156’, ‘Veery’ and ‘Gerek 79’. The segment of ‘Sonalika’ shows bread wheat ancestries that date back to 1842 and come from all continents.

The paper contains tables that analyze the characteristics of the top ten bread wheat cultivars in the developing world in 1990 (‘Sonalika’, ‘HD2329’, ‘Veery’, ‘HD2285’, ‘WH147’, ‘II8156’, ‘Gerek 79’, ‘Klein Chamaco’, ‘Bluebird’ and ‘Lok1’). For example, India released the cross HD2329 in 1985, which has 22 generations, 153 different parental combinations and 58 different landraces in its pedigree. Argentina released

the cross Klein Chamaco in 1978. It has 21 generations, 141 different parental combinations and 47 different landraces in its pedigree.

Other tables show the pedigree complexity of 13 leading CIMMYT bread wheat varieties grown in developing countries between 1952 and 1992 and suggest a growing pedigree complexity in the more successful CIMMYT wheats grown by farmers in developing countries over time. The Yaqui 50 cross, which was released in 1950, contains 8 generations in its pedigree, 20 different parental combinations and 12 different landraces traced in its pedigree. 'Ciano T', released in 1979, contains 21 generations in its pedigree, 160 different parental combinations and 62 different landraces traced in its pedigree. 'Veery' (Serim8), which was released in 1982, contains 23 generations in its pedigree, 127 different parental combinations and 47 different landraces traced in its pedigree. The distribution of landraces by genetic contribution (Gini coefficient for landrace contribution) is most unequal for 'Ciano 79' and most equal for 'Yaqui 50'.

Another table analyzes pedigree complexity by geographic sources of 800 parental lines and by wheat varieties released by developing countries from 1960 to 1990. The average number of generations and parental combinations in pedigrees increases every decade. For example, from 1960 to 1969, a sample set contained an average of 16 generations and 214 parental combinations in their pedigrees; from 1970 to 1979, they contained an average of 19 generations and 739 parental combinations in their pedigrees and from 1980 to 1989, they contained an average of 22 generations and 2 084 parental combinations in their pedigrees. The average number of distinct parental combinations also increases over time as does the percentage of reused parental combinations, increasing from 64% to 90% over the same periods and for the same lines.

Smale M, Day Rubenstein K. 2002. The demand for crop genetic resources: international use of the U.S. National Plant Germplasm System. *World Development* 30(9):1639–1655.

This case study of the NPGS shows that developing countries benefit from the sharing of germplasm and that the demand for genetic resources exchange is likely to increase, especially in developing countries.

The survey focuses on the distributions of samples of accessions of ten crops (barley, bean, cotton, maize, potato, rice, sorghum, soybean, squash and wheat) that were held by the NPGS. Over the ten-year period under review (1990–1999), the NPGS distributed 163 000 germplasm samples to 191 countries at no charge. Developing countries accounted for 46% of the demand, while 37% of requests for germplasm came from developed countries and 17% from transitional economies. Of the samples distributed outside the United States, 76.6% were sent to non-commercial organizations; 12.8% were sent to genebanks or genetic resources units; 5.6% were sent to international agricultural research centres; and 4.5% to commercial companies. Developing country survey respondents estimate that 16% of the material requested has already been used in breeding programmes, that another 52% of the material is still being evaluated and that 10% of the material has been useful in other ways. Moreover, 70% of respondents/users in the developing country surveys estimated that they will increase their requests to the NPGS in the next decade, as compared with only 48% for respondents/users from developed countries.

Srinivasan CS. 2003. Exploring the feasibility of farmers' rights. *Development Policy Review* 21(4):419–447.

This paper identifies challenges associated with the development of *sui generis* forms of intellectual property protection for landraces (or farmers' varieties). In this context, the paper highlights the fact that by going back five generations in the pedigree of 'Sonalika', one finds 31 parental crossings involving parents from 15 different countries. In this context, it is very difficult, if not impossible, to ascertain the actual contributions made by each parent to the extant variety. The paper proposes alternative means to recognize the historic contributions of farmers and to provide them with incentives for further conservation and use of diversity.

