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The distribution of benefits from public international germplasm banks: the case of beans in Latin America

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Abstract

The unrestricted international flow of genetic resources from international genebank collections is the source of perhaps one of the greatest impacts of international agricultural research. This paper examines the distribution across countries in Latin America of benefits generated from bean genetic resources held by the International Center for Tropical Agriculture (CIAT). The genealogies of commercial bean cultivars released since 1976, containing materials from the collection, are analysed to calculate for each country the source of the genetic resources used. All countries in the region are shown to be heavily dependent on imported genetic resources for their commercial cultivars. From the available information on the economic impact of these improved bean varieties, the share of economic productivity benefits associated with imported germplasm by country of origin is calculated. The benefits received by each country from improved bean germplasm are compared with the contribution of that country's germplasm to other countries. Some of the patterns in the flow and use of genetic resources are analysed.

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Keywords: Genetic resource conservation; Crop varietal improvement; Beans; Latin America

1. Introduction

Large increases in crop productivity have been achieved through the sciences of plant genetics and breeding, including breakthroughs like hybrid maize and semi-dwarf wheat and rice. Improved crop varieties associated with International Agricultural Research Centres (IARCs) have generated economic benefits worth billions of dollars (Evenson and Gollin, 2003). These benefits derive from the application of advanced scientific methods in plant breeding. However, they also depend on the availability of germplasm with desirable traits that can be combined to produce a plant more productive than its parents.

It has been estimated that up to one-half of the gains in US agricultural yields during 1930–1980 can be attributed to genetic resources (OTA, 1987).

Much of the germplasm used for crop improvement comes from collections that are the result of decades of collecting and conserving materials from around the world. In the past, collection and exchange of germplasm was relatively unregulated, except for basic phytosanitary requirements. Recently, interest in intellectual property rights to genetic resources has led to international conventions that assign ownership of materials to their country of origin and regulate their exchange.¹ While it is important that countries recog-

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¹ See, for example, the Convention on Biological Diversity (<http://www.biodiv.org/>) or the International Treaty on Plant Genetic Resources for Food and Agriculture (<http://www.fao.org/ag/cgrfa/itpgr.htm>).

nise the economic value of their genetic resources, there is a danger that unilateral attempts to appropriate these benefits could end up restricting the flow of germplasm. The consequences of an interruption in the flow of genetic materials would depend on how important imported materials are to the production of improved varieties released by individual countries.

This paper estimates the importance of international exchange of genetic material via genebanks for the case of beans in Latin America and the Caribbean (LAC). The magnitude of inter-country gene flows is documented on the basis of the genealogies of improved bean varieties released in LAC between 1976 and 2000. The economic value of the gene flows is calculated by apportioning the estimated benefits generated by the improved varieties—in the form of the value of increased bean production—among their ancestors according to their contribution of genetic material. The results of the analysis show how individual countries both benefit from and contribute to the international exchange of germplasm.

The remainder of the paper is organised as follows. Section 2 describes bean germplasm conservation activities and the exchange and improvement efforts that led to the release of improved varieties. Section 3 presents the results of a genealogical analysis of improved cultivars, including a gene borrowing–lending matrix. In Section 4, the economic benefits associated with the exchange of genetic material are estimated. Section 5 discusses the main findings and their implications for research and for genetic resource conservation and use.

2. Conservation and use of bean genetic resources in Latin America

2.1. Conservation of bean genetic resources

Common bean (*Phaseolus vulgaris*) is a non-centric crop, with multiple domestication sites throughout Middle and Andean South America. The genetic resources of the common bean consist of two major gene pools, one Mesoamerican and one Andean. Wild ancestors and common bean land races from these two sources form the base of today's cultivated beans.

A significant portion of the world's bean genetic diversity is conserved in the genebank of the Inter-

national Center for Tropical Agriculture (CIAT) in Cali, Colombia. The CIAT genebank currently has over 31,000 accessions of *Phaseolus* beans designated to the Food and Agriculture Organisation (FAO) of the United Nations.² CIAT's is the largest collection of bean genetic resources in the world, accounting for 15% of total accessions in *ex situ* conservation. In addition to land races and other collected materials, the genebank also includes pure lines, breeding lines and improved varieties.

The collection includes materials from 65 countries. The national origin of an accession is defined as the country that provided the material to the genebank. Main contributors to the genebank include Mexico (4706 accessions), Peru (2361), Guatemala (2209) and Colombia (1380). The USA has contributed over 10,000 accessions, though in many cases the USA is the source rather than the country of origin.

Since 1973, over 307,000 accessions have been distributed by the germplasm bank to 96 countries to be used in bean research and development programs.³ The top five recipients were Colombia (16.2%), USA (9.1%), Guatemala (8.6%), Brazil (6.2%) and Mexico (6.0%). Excluding materials used in CIAT, 60% of distributed materials went to national research systems (NARS) and 33% went to universities, with the remainder going to non-governmental organisations (NGOs), commercial companies, individual farmers, other genebanks and other Centres of the Consultative Group on International Agriculture (CGIAR). Forty-four percent of the materials distributed by the germplasm collection were used for breeding. The remainder were used for basic and applied research (41%), agronomy (14%) and training purposes (1%). CIAT scientists are much more likely to use materials

² 'Designated germplasm' refers to a 1994 agreement between the Centres of the Consultative Group on International Agricultural Research (CGIAR) holding germplasm collections and the FAO. Under the agreement, the Centres agree to hold the collections in trust for countries and for the world farming community, and to distribute the samples from the collections under a materials transfer agreement. In order to identify exactly which materials are covered under the agreement, CGIAR Centres must provide the FAO with a complete list of the accessions in their collections. The list is updated biannually as new materials are designated and materials that are no longer available are de-designated. A complete list of all designated germplasm is available at <http://www.singer.cgiar.org/>.

³ Statistics from this paragraph come from databases maintained by CIAT's Genetic Resources Unit (GRU).

for breeding than are scientists from external institutions.

2.2. *Bean improvement in Latin America*⁴

Since domestication, bean farmers have been continuously improving bean varieties through a process of selection and exchange of materials. The pace of change accelerated in the 1930s when the first organised bean improvement efforts began in Colombia and Brazil. In the 1950s, Mexico initiated one of the region's strongest improvement programs, with support from the Rockefeller Foundation Agricultural Program. Subsequently, several more countries, including Chile, Peru and Guatemala, established breeding programs. Important regional and international bean improvement efforts include the formation of the Instituto Interamericano de Cooperación para la Agricultura (now Instituto Interamericano de Ciencias Agrícolas)–Organización de Estados Americanos (IICA–OEA) program (1962–1975); the founding of the CIAT Bean Program in 1974; and the establishment of the USAID-funded Bean/Cowpea Collaborative Research Support Project (CRSP) in 1980. While breeding and improvement activities can be carried out by a variety of organisations including national agricultural research programs, universities, private companies or international organisations, only national programs can officially release varieties.

Until the 1960s, the principal method of varietal development was through selection, a process in which individual plants with desirable characteristics are identified and multiplied. While intra-regional selection produced steady gains in productivity, major productivity increases were often achieved through the introduction of landraces from other regions. Inter-regional exchange of genetic material has been going on for thousands of years, and the establishment of the germplasm collections was designed to systematise, facilitate and accelerate the process. Between 1950 and 2000, 300 varieties developed through selection were released in 19 countries of LAC (Voysset, 2002b). The majority (190) were released before 1976. Approximately, two-thirds were local releases and one-third were introduced from other countries.

Varietal improvement through selection continues to occur; however, in Latin America the main focus of improvement programs is now on the production of hybridised or bred materials. In breeding, promising parent plants are deliberately crossed to produce progeny that combine the desirable characteristics of the parents. Since there is a great deal of variability in the first generation of offspring, a process of selection is carried out among successive generations where the most promising materials of each generation are identified and replanted until a genetically uniform “finished” line is obtained. During the 1950s, only two countries, Mexico and Colombia, released bred varieties (Table 1). During the 1990s, 18 countries released a total of 181 bred varieties. A total of 353 bred varieties were released in Latin America between 1950 and 2000.⁵ The dramatic increase in both releases and releasing countries between the 1970s and 1980s coincides with the establishment of CIAT's bean program and the consolidation of the CIAT genebank.

3. The contribution of CIAT's genebank to international exchange of genetic resources

Of the 411 varieties released in Latin America since 1976, 243 (59%) contain material from CIAT's germplasm collection (Table 2). Thirty-eight of the CIAT-related varieties were improved by selection, and 205 are bred varieties (also known as crosses) whose parent(s) came from the genebank. In some cases, national program breeders made the crosses; however, in most cases the varietal development was also done at CIAT, and national programs received elite lines which they finished and released (Johnson et al., 2003).

All of the genebank varieties improved by selection were released in countries other than their country of origin,⁶ however, bred varieties may contain material

⁵ It should be noted that these are not all unique releases in the sense that the same variety may be released in several countries under different names.

⁶ In this paper, the use of genebank accessions in their country of origin is not treated as a contribution of the genebank since, in principle, these materials could have been locally available to national breeders. In fact, breeders often obtain material from their own countries via the genebank, so we likely underestimate the actual contribution of the genebank.

⁴ Material for this section comes from Voysset (2002a–c).

Table 1

Number of bean varieties of hybrid origin released in Latin America, 1950–2000^a

Country	1950–1959	1960–1969	1970–1979	1980–1989	1990–2000	Total/country
Colombia	2	8	5	2	10	29
Mexico	3	2	6	14	16	41
Peru	–	2	2	4	14	22
Brazil	–	–	8	39	41	89
Chile	–	–	7	5	12	24
Guatemala	–	–	3	4	8	15
El Salvador	–	1	–	2	4	7
Nicaragua	–	–	–	9	6	16
Argentina	–	–	–	11	19	30
Bolivia	–	–	–	8	7	15
Cuba	–	–	–	12	4	16
Costa Rica	–	–	–	7	5	12
Honduras	–	–	–	3	6	9
Panama	–	–	–	1	4	5
Puerto Rico	–	–	–	1	4	5
Venezuela	–	–	–	1	4	5
Ecuador	–	–	–	–	8	8
Dominican Republic	–	–	–	–	5	5
Total	5	13	31	123	177	353

^a Source: Voysest (2002c, 3 pp.).

Table 2

Number of bean varieties released in Latin America, 1976–2000^a

Country/region	All varieties	CIAT ^b genebank varieties		
		Selection	Bred varieties	All
Brazil	110	3	34	37
Mexico	>50	–	11	11
Argentina	31	1	28	29
Chile	17	1	5	6
Guatemala	17	1	13	14
El Salvador	8	–	6	6
Honduras	10	1	9	10
Nicaragua	15	–	14	14
Costa Rica	12	–	12	12
Panama	10	3	5	8
Cuba	18	3	14	17
Dominican Republic	11	1	3	4
Haiti	4	–	4	4
Bolivia	17	7	9	16
Colombia	18	1	13	14
Ecuador	15	2	8	10
Peru	42	13	12	25
Venezuela	6	1	5	6
Total	411	38	205	243

^a Source: Voysest (2001, Table 5).^b International Center for Tropical Agriculture.

from several countries, including the releasing country. One way to assess the genebank's contribution to bred varieties is to look at the number of countries whose genetic material was used to create them. Analysis of the pedigree data⁷ shows that a total of 179 genebank accessions from 31 countries were used as parents in the crosses that led to the 205 released varieties (Table 3). Argentina has released the largest number of crosses using material from the genebank: 28 varieties were released that included 66 genebank parents from 20 countries. Brazil released 34 varieties containing 55 genebank accessions from 17 countries.

Another way to assess the genebank's contribution is to look at how much of the genetic material in bred varieties is of foreign origin. To calculate the origin of genetic material in a cultivar, we assume that each parent supplies 50% of the genes.⁸ This implies that

⁷ Released varieties and their pedigrees were obtained from published CIAT sources (Voysest and Dessert, 1991, 2000), circulars and bulletins, the CIAT Bean Program database (Rodríguez et al., 1995), personal communications with bean breeders, and other sources (McClean and Myers, 1990).

⁸ We also implicitly assume that genetic drift and selection did not cause significant change in genetic composition, and that parents used in crosses were homozygous and homogeneous.

Table 3

Origin and number of genebank accessions used in the development of 205 CIAT^a cultivars through hybridisation in Latin America, 1976–2000^b

Country	Number of bred releases with genebank material	Number and origin of the genebank accessions used in bred releases	
		Accessions	Donor countries
Argentina	28	66	20
Bolivia	9	50	15
Brazil	34	55	17
Chile	5	11	8
Colombia	13	25	6
Costa Rica	12	38	12
Cuba	14	34	11
Dominican Republic	3	11	6
Ecuador	8	14	6
El Salvador	6	26	13
Guatemala	13	29	11
Haiti	4	17	10
Honduras	9	23	11
Mexico	11	48	13
Nicaragua	14	24	10
Panama	5	21	11
Peru	12	28	13
Venezuela	5	18	8

^a International Center for Tropical Agriculture.

^b Source: Voysest (2001, Table 8).

each grandparent supplies a quarter of the genes, each great-grandparent an eighth, and so on. Pedigrees of each released bean variety were traced back to ancestors in the genebank or to genotypes for which no further genealogical relationships could be discovered. The result of this analysis is a borrowing–lending matrix where the rows are recipient countries and the columns are donor countries. Each cell of the matrix contains the proportion of genetic material in varieties released in recipient country r that came from donor country d , which we denote as $p_{r,d}$. The total proportion of imported genetic material in country r (P_r) can be calculated as $\sum_d p_{r,d}$, where d represents the countries that supplied genetic material to country r . Table 4 shows the total proportion of imported material per country (P_r), as well as the individual contribution to each country of each of the top five donors to the region.

Only in Colombia and the Dominican Republic did local germplasm contribute half or more of the

genes of the new varieties (Table 4). At the opposite extreme are Venezuela, Bolivia, Panama, Cuba and Haiti, where local material accounted for less than 10% of genetic content of released varieties. Keeping in mind that just over a third of selected varieties were of non-local origin, the introduction of bred varieties appears to have significantly increased the amount of imported material in countries' gene pools.

Of the 31 donor countries or regions that supplied genetic material, 11 accounted for over 80% of the total genetic material (Voysest, 2001). Colombia was the country with the greatest genetic contribution—17% of the material in released varieties in other LAC countries is of Colombian origin. Colombian germplasm is particularly important in countries such as Ecuador, Peru, Chile and the Dominican Republic, where beans with large- and medium-sized seeds characteristic of the Andean gene pool are preferred. In regions where small seeds are preferred, germplasm from Mesoamerica made the greatest genetic contribution.

The presence of US germplasm and the absence of Peruvian germplasm as important sources of genes was quite a surprise. Peru is a major centre of bean genetic diversity; however, this diversity appears not to have been widely used in the production of improved varieties. In contrast, materials developed in the USA have been widely used in developing new cultivars. The explanation is likely related to the greater commercial importance of Mesoamerican versus Andean beans, and the fact that some US accessions are well-known sources of resistance to important bean pests and diseases.

These findings may overstate the importance of some countries' germplasm because it does not distinguish between bred accessions and landrace accessions. For example, 32 of the 179 genebank accessions used to develop bred varieties are actually bred varieties themselves. Thirteen are considered Colombian by virtue of being bred there; however, they contain material from Peru, Italy, Japan and the USA. There are strong arguments for considering these materials as varieties rather than breaking them down into their components, since it would be virtually impossible to recreate them from the parent material alone (Voysest, 2002c). These cases demonstrate that the assignment of national origin to genetic resources is not a simple matter, yet its implications for exchange

Table 4

Proportion of imported genetic material in released varieties in selected Latin American and Caribbean countries, and country of origin for the five most important donor countries, 1976–2000^a

Recipient	Proportion of foreign genes (P_r)	Donor				
		Colombia	Mexico	Costa Rica	El Salvador	USA
Brazil	0.764	0.085	0.109	0.136	0.135	0.101
Mexico	0.568	0.100	–	0.083	0.057	0.049
Central America						
Costa Rica	0.841	0.089	0.293	–	0.282	0.035
El Salvador	0.815	0.042	0.137	0.152	–	0.031
Guatemala	0.749	0.091	0.209	0.166	0.101	0.024
Honduras	0.726	0.000	0.212	0.111	0.076	0.036
Nicaragua	0.766	0.009	0.145	0.150	0.219	0.013
Panama	0.950	0.375	0.176	0.023	0.023	0.065
Andean zone						
Bolivia	0.973	0.151	0.138	0.058	0.005	0.166
Colombia	0.255	–	0.048	0.000	0.005	0.106
Ecuador	0.625	0.438	0.031	0.000	0.000	0.062
Peru	0.631	0.199	0.060	0.026	0.000	0.104
Venezuela	1.00	0.125	0.050	0.150	0.200	0.100
Southern cone						
Argentina	0.905	0.159	0.960	0.073	0.084	0.172
Chile	0.700	0.200	0.025	0.075	0.025	0.100
The Caribbean						
Cuba	0.929	0.072	0.205	0.131	0.125	0.034
Dominican Rep.	0.500	0.229	0.021	0.125	0.021	0.021
Haiti	0.938	0.125	0.113	0.164	0.180	0.010

^a Source: Voysest (2002a, pp. 2, 4).

and benefit-sharing mechanisms are potentially very significant.

4. Estimating the economic value of germplasm exchange

In order to generate economic value, it is not sufficient that genetic material be incorporated into released varieties. Those varieties must also be adopted by farmers and contribute to increases in productivity. Johnson et al. (2003) estimate that in 1998, 49% of bean area in Latin America was planted to varieties associated with CIAT and the genebank, ranging from 16% in Peru to 85% in Costa Rica (Table 5). In 1998, the annual value of increased production associated with the varieties was estimated to be 177.5 million US\$ (mUS\$), and the cumulative value of increased production due to improved varieties between 1970

and 1998 was over a billion dollars (Table 5).⁹ (For a detailed description of how these estimates were obtained, see Johnson et al., 2003; Johnson, 1999.)

The magnitude of the economic benefits generated by improved crop varieties is largely determined by the contribution of science, in the form of conservation, breeding, and dissemination programs. These programs have an effect on both the number and the quality of varieties released (Evenson and Gollin, 1977, 2003). In this study, we do not attempt to distinguish the relative contributions of breeders versus genes to the productivity of improved varieties. Rather we focus on the benefits associated with exchange

⁹ These estimates are based on estimated yield gains alone and do not include other benefits of crop improvement such as disease resistance. In the case of beans, disease resistance has been an important characteristic of improved varieties in many areas, especially Central America (Johnson and Klass, 1999; Mather et al., 2002).

Table 5
Impact of CIAT^a-related bean varieties in selected countries of Latin America^b

	Area planted to beans, 1998 (000 ha)	Percentage in CIAT-related varieties, 1998	Estimated yield gain over local varieties, 1998 (t/ha)	Incremental production due to CIAT-related varieties, 1998 (000 t)	Value of increased production, 1998 (mUS\$)	Cumulative value of incremental production due to CIAT-related varieties, 1970–1998 (mUS\$)
Costa Rica	39	85	0.10	3.3	1.5	35.63
Guatemala	123	40	0.23	11.3	7.4	79.12
Nicaragua	154	30	0.23	10.4	3.5	45.37
Honduras	83	45	0.11	4.2	1.4	21.44
El Salvador	85	25	0.29	6.1	2.3	19.41
Panama	11	40	0.25	1.1	0.7	7.86
Brazil	3307	51	0.17	279.2	125.9	766.72
Argentina	285	77	0.24	53.3	28.8	134.59
Colombia	138	10	0.20	2.8	1.9	12.93
Bolivia	12	82	0.25	2.7	920.8	2.87
Ecuador	62	20	0.13	1.7	0.9	8.31
Peru	73	16	0.35	4.0	2.9	19.57
Total	4372	49	0.21	380	177.5	1153.82

^a International Center for Tropical Agriculture.

^b Source: Johnson et al. (2003, 268 pp.) and Johnson (1999, 15 pp.).

of genetic material, recognising that the countries that invest in breeding, improvement and dissemination activities will almost certainly appear to benefit relatively more than those that do not.

Economic impact data are available by country rather than by variety; however, through expert opinion we were able to eliminate the released varieties that were known to have experienced little acceptance by farmers. The borrowing–lending matrix was re-calculated for the remaining economically important varieties, i.e., excluding varieties that were not accepted by farmers and therefore did not contribute to the economic benefits. If we assume that all genes contribute equally to the productivity of a variety, we can calculate the estimated economic value associated with use of imported genetic material in country r (V_r) as $B_r P_r$, where B_r is the total economic value attributed to improved varieties in country r and P_r the percent of imported genetic material that those varieties contain, as calculated in the revised borrowing–lending matrix. The value of the contribution of country d to country r ($v_{r,d}$) can be calculated as $B_r P_{r,d}$.

On a regional basis, an estimated 72% of the benefits of improved varieties—827 mUS\$ ($\sum_r V_r = \sum_r B_r P_r$)—can be attributed to non-local germplasm.

The reason that it is so high that many of the largest bean producing countries, such as Brazil and Argentina, are big users of both CIAT-related varieties and imported germplasm. Mexico's germplasm has made the biggest economic contribution to varietal development in other countries (168 mUS\$ = $\sum_r v_{r,\text{Mexico}}$), followed by El Salvador (121 mUS\$), Costa Rica (103 mUS\$) and the USA (99 mUS\$) (Table 6). European and African countries also made important contributions to germplasm development in LAC.

Brazil was the biggest beneficiary of international germplasm exchange (538 mUS\$ = $\sum_d v_{\text{Brazil},d}$), followed by Argentina (115 mUS\$) and Guatemala (53 mUS\$). Six countries are net beneficiaries and six are net donors. Brazil and Argentina continue to be the largest net beneficiaries of international germplasm flows. El Salvador, Colombia and Costa Rica are the biggest net contributors.

One of the principle motivations for assigning rights to genetic materials is to reward those who develop and conserve them. Many advocates of a system of 'farmers rights' over genetic resources are motivated by the belief that a system of royalty payments based on use of germplasm could result in significant transfers of income from developed to developing countries

Table 6

Value and distribution of cumulative benefits from improved bean varieties associated with the CIAT^a genebank, 1970–1998 (in 1990 mUS\$)

Beneficiary country	Value contributed to LAC ^b via genebank (not including own country)	Value received from other countries via genebank	Net benefit from CIAT genebank
Brazil	22.47	538.24	515.76
Mexico	167.87	n.a.	
Central America			
Costa Rica	103.27	28.75	–74.52
El Salvador	120.87	15.78	–105.09
Guatemala	50.40	53.49	3.09
Honduras	18.05	15.57	–2.49
Nicaragua	50.91	31.49	–19.42
Panama	0.00	7.37	7.37
Andean zone			
Bolivia	0.00	2.87	2.87
Colombia	83.13	3.43	–79.70
Ecuador	15.77	4.99	–10.78
Peru	8.07	10.39	2.32
Venezuela	23.53	n.a.	
Southern cone			
Argentina	0.00	114.94	114.94
Other countries/regions			
Dominican Republic	15.09	n.a.	
USA	98.80	n.a.	
Canada	2.29	n.a.	
Europe	27.55	n.a.	
Africa	12.81	n.a.	

^a International Center for Tropical Agriculture.^b Latin America and the Caribbean.

(Pistorius, 1997; RAFI, 1997). The results of our analysis do not strongly support this claim, however. While some countries such as El Salvador, Colombia and Costa Rica clearly stand to benefit from such a system in the case of beans, many others would have to pay, and a significant portion of the payments would go from LAC to developed countries. Pachico (2001) found that in the case of bean producing countries in Africa, the monetary outflow would be even greater. Furthermore, with the exception of Colombia—a special case because of the numerous international bean improvement activities carried out there—all countries benefit more from their own use of imported genetic materials in production than they would from, say, a 10% royalty on the use of their materials in other countries. The implication is that developing countries are likely to be hurt rather than helped by a significant disruption in the international exchange of germplasm.

5. Discussion and conclusions

This paper documents the contribution of the exchange of genetic material via CIAT's genebank to the development of improved bean varieties in Latin America. No country can claim complete reliance on its own genetic resources, and all countries made significant use of the genetic resources of other countries. Of the 18 countries studied, 11 received over 70% of the genetic material in their released varieties from other countries. Even Colombia, Mexico and Brazil—countries with strong breeding programs and abundant genetic resources—show a significant use of foreign germplasm. Similar levels of dependence on imported material can be found in other crops such as maize, wheat and rice (Smale et al., 1996; Evenson and Gollin, 1977).

These international gene flows are associated with significant economic value in the form of increases

in bean production due to improved varieties. Over 70% of the value of increased bean production due to the use of improved varieties in LAC was attributed to imported germplasm. Brazil and Argentina are the biggest beneficiaries of imported germplasm, not only because their use of imported genetic material is high, but also because they are large bean producers. Germplasm from Mexico, El Salvador, Costa Rica and the USA generated the highest economic benefits in other countries. While their contributions to other countries are important, with the exception of the special case of Colombia, countries benefit more by using imported material in bean production than they would from charging a 10% royalty on the use of their materials in other countries. This suggests that individual countries and the region as a whole would suffer if free exchange of genetic material were interrupted. Any system of royalties would also have to recognise the important contribution of crop improvement programs to the number and quality of varieties released.

The issue of national origin of genetic resources raises difficult questions about how to assign rights and responsibilities regarding collection, conservation and exchange of materials that have evolved over time and space. For example, this study found Colombia, El Salvador, Costa Rica and the USA to be important contributors to genetic diversity in other countries, yet there is no scientific evidence to support the domestication of beans in any of those countries (Gepts et al., 1986; Gepts and Debouck, 1991; Khairallah et al., 1992; Debouck, 2000). Conversely, recent evidence suggests that Bolivia may have been an important domestication site (Beebe et al., 2001), yet no Bolivian accessions were used in the improved varieties studied here. The implication is that since important modifications and/or uses of genetic materials often occur outside their centres of origin, management of genetic resources is a global concern.

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