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Research Study 9

Twenty five years of international exchanges of plant genetic resources facilitated by the CGIAR genebanks: a case study on international interdependence

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Abstract

This discussion paper is submitted to the *Ad Hoc* Open-ended Working Group to Enhance the Functioning of the Multilateral System of Access and Benefit-sharing for its consideration. The paper analyses twenty five years of data concerning international movements of plant genetic resources for food and agriculture (PGRFA) facilitated by the genebanks hosted by seven CGIAR centres. The paper identifies global trends in the aggregate movements of PGR as facilitated by these genebanks, and the diversity of the resources transferred over time. It also presents data on individual countries concerning a combination of: a) the number of countries from which they have received germplasm (with the genebank as an intermediary) and b) the diversity of varieties, species and genera they have received. The paper also describes the corollary situation: that is, the number of countries to which germplasm originally collected (or improved) from a single country has been distributed around the world. The paper confirms that when provided the opportunity, through a system of facilitated access, countries will access and use a wide diversity of germplasm from a high number of other countries, sub-regions and continents as inputs into their agricultural research and development programs. This finding appears to be equally true for countries that are, and are not, centres of crop domestication and diversity. The paper's findings highlight the fundamental importance of facilitated access as the fundamental non-monetary benefit derived from the creation and functioning of the multilateral system of access and benefit sharing.

Introduction

1. Plant Genetic Resources for Food and Agriculture (PGRFA) are the basic building blocks of crop improvement and adaptation, and by extension, food security. As a result of the history of crop domestication and global dispersal and adaptation , all countries around the world are today highly dependent upon plant genetic resources located (or originally collected from) beyond each others' borders. Countries' interdependence on plant genetic resources has been described by a number of commentators (Crosby 1972, 1986; Diamond 1977; Mann 2011; Fowler *et al.* 2001; SGRP 2011; Halewood 2014), and predictions have been made of increased future interdependence as a result of challenges such as climate change (Lane and Jarvis 2007, Jarvis *et al.* 2010, Burke *et al.* 2009, Fujisaka *et al.* 2011; Ramirez-Villegas *et al.* 2013), and the evolution of food systems and diets (Khoury *et al.* 2014). Global appreciation of the policy significance of countries' interdependence on PGRFA arguably reached its zenith in 2001, when 'interdependence' was explicitly included in the text of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) as one of two criteria - the other criterion is relevance for food security - for including crops or forages in the multilateral system of access and benefit-sharing (ITPGRFA, article 11).

2. Through the multilateral system of access and benefit sharing (multilateral system), the ITPGRFA member states agree to create a global, virtual pool of the genetic resources of 64 listed crops and forages to be used for the purposes of conservation, training, breeding and research for food and agriculture. Member states undertake to provide facilitated access to one another (including natural and legal persons within their borders) on the understanding that, among other things, monetary benefits will be shared if recipients incorporate materials in new, commercialized PGRFA products that are not available to others for research, training or breeding. The multilateral architecture of access and benefit-sharing under the ITPGRFA was designed to reflect countries' current and future interdependence on PGRFA; the system was meant to minimize transaction costs that could otherwise multiply beyond acceptable limits,

given the high numbers of international exchanges of genetic resources that attend agricultural research, development and plant breeding.

3. In recent years, ITPGRFA member states have expressed concerns that the multilateral system has not been functioning at hoped-for levels: both in terms of generating financial benefits by users to share through the international benefit-sharing fund, and in terms of materials being made available to, and accessed through, the multilateral system. During its fifth session in September 2013, the ITPGRFA's governing body created the Ad Hoc Open Ended Working Group to Enhance the Functioning of the MLS (WG-EFMLS) with the mandate to develop a range of optional measures to: "a) Increase user-based payments and contributions to the Benefit-sharing Fund in a sustainable and predictable long-term manner, and (b) Enhance the functioning of the Multilateral System by additional measures." The WG-EFMLS met for the first time in May 2014, in Geneva. It met again in December 2014. Its primary focus for the first two meetings was on user measures; it will shift to access measures at its third meeting. This discussion paper is being submitted for consideration by the third meeting of the WG-EFMLS. By focusing on an issue at the heart of the multilateral system - the state of countries' interdependence on PGRFA – we hope it will help the negotiators as they consider options for revising the terms and conditions of that system. The paper not only confirms that countries are indeed interdependent, but presents new data that illustrates the extent and manner of that interdependence. It provides insight into the extent to which countries can and do take advantage of systems of facilitated access to global pooled crop and forage genetic resources, requesting and receiving diversity from all over the world to support their agricultural research and development.

Data sources and methods

4. We started by retrieving data that had been compiled regarding CGIAR genebanks' holdings, acquisitions and distributions in the CGIAR System-wide Information Network on Genetic Resources

(SINGER).[1] (There were no records in SINGER for two of the genebanks.) We then asked each of the genebanks if the data we had was accurate and if not, if they could provide updated data. In the end, we obtained data from seven genebanks to include in this study. The data from these seven genebanks alone provides convincing evidence of the high degree of countries' interdependence. However, as the Secretariat's information document 'Typology of Users of the Multilateral System and their Regional Distribution Including PGRFA under Development'[2] makes clear, our study does not include data from the centre that makes the highest number of distributions, that is CIMMYT (from its international maize and wheat collections). Had CIMMYT data been included, the final conclusions regarding the extend of international interdependence would have been even stronger.

5. Distribution data followed a standard format which gathers information according to the fields shown in Box 1 below.

Box 1. Fields of information included in the distribution data from CG genebanks	
CG Center	Transfer Year
Accession number	Recipient Country Code
Genus	Recipient Country Name
Species	Recipient Institute
Country of origin	Recipient Last Name
Biological Status	Recipient First Name
Recipient Code	Recipient User Type
Recipient Region	Transfer Date

Distribution records were available starting from 1973 for some genebanks included in the study, there were considerable inter-annual and inter-centre differences until 1985. Thereafter, the data and patterns were more uniform, which led to the decision to consider data from 1985 onwards. Since our focus was the germplasm sent to countries and within-country *r*ecipients, intra- and inter-CGIAR centre distributions were removed from the data as well as those transfers from CGIAR genebanks to the Svalbard Global Seed Vault, leaving the total numbers of samples set out in table 1 as the basis for our analysis. These centres' mandate crops (and their wild relatives) include key staples for worldwide food security, such as rice, tropical and dryland legumes and cereals, potato and other roots and tubers, banana and plantain and tropical forages (see Annex 1-table 1 for details on the collections hosted at all CGIAR centres).

[1] SINGER has been discontinued, with much of its data and functionality – minus distribution data – incorporated into Genesys (www.genesys-prg.org).
[2] IT/OWG-EFMLS-3/15/Inf.9, available at http://www.planttreaty.org/sites/default/files/OWGEFML3Si09.pdf

Table 1. Total number of samples sent to national recipients from the seven genebanks, 1985-2009

	AfricaRice	Bioversity	CIP	ICARDA	ICRISAT	ILRI	IRRI
N. of samples distributed	38963	13436	84380	246026	418934	30830	166681

6. Various measures of international PGRFA movements were explored: we considered the total number of samples distributed (a single sample consisting of ideally between 50-100 viable seeds or much less vegetative propagules, depending on the breeding system of the species (CGKB 2014)), the number of unique accessions distributed, and the number of species (the latter two providing a picture of the diversity, rather than the sheer volume, of the flows).

7. Further analyses qualified the international flows facilitated by the genebanks in terms of the number of countries from which the materials distributed were originally collected or improved, the number of recipient countries and types of recipient institutions, the number of genera and species distributed, and the type of materials exchanged. Countries were classified based on their development status according to the UN classification (UN 1996), in order to provide a picture of the contributions of transition economies, developing and developed countries to the exchange of germplasm facilitated through the CGIAR. All data handling and analyses were performed in R (R Core Team 2013).

Global flows of PGRFA, 1985-2009: volumes and diversity

8. Over the years from 1985 to 2009, germplasm conserved in the selected CGIAR genebanks has been made available to a broad range of users around the world, highlighting the heavy reliance of individual countries on genetic materials obtained from other countries via the system. According to the available data, over 999 250 samples of 262 872 unique accessions belonging to 1 470 different plant species were distributed during that period. Virtually all countries in the world have been involved in the exchanges: the materials listed in table 1 above were originally collected in, or provided by, *at least* 189 countries and distributed to *at least* 191 countries. The CG centres also distributed large amounts of germplasm through their breeding programmes (in 2009 alone, the breeding programmes of five centres for which we had data, provided 153 215 samples of improved materials), but these data are not as well documented and are not the focus of the present paper.

9. According to data available through the Genesys portal which gathers information on a number of national and international genebanks[3], the international *ex situ* collection hosted by the CGIAR centres currently include 714 063 accessions of their mandate crops and related genepools, originally collected from a vast number of countries (Annex 1-tables 1 to 3). The genebanks whose distributions are analysed here, currently host 445 785 accessions of 2848 species. Our data suggests that samples of roughly half the diversity held, has been distributed at least once by centres' genebanks.

10. During the time period analysed here, there appears to be have been a slight downward trend in the overall number of samples distributed, as already highlighted elsewhere (Halewood *et al.* 2013). A similar decline was observed in the diversity of the materials distributed, measured as number of unique accessions and number of species represented by the accessions distributed (table 2).

Table 2. Results of the models used for analysing trends in the overall flows over time (1979-2009).

Parameter / year	Estimate	P value	Method
N. of samples	-0.031	<2e-16	Generalized linear model with Poisson error distribution
N. of unique accessions	-0.065	<2e-16	Generalized linear model with Poisson error distribution
N. of species	-0.013	<2e-16	Generalized linear model with Poisson error distribution

11. This progressive trend has been attributed to the possibility that genebanks' responses to requests were becoming more targeted, as characterization and evaluation data became available (Halewood *et al.* 2013, Lopez Noriega *et al.* 2013), leading to breeders' and researchers making requests for smaller sets of materials. For those genebanks actively distributing sets of materials for international breeding and adaptation trials, the decline could also be due to decreases in the funding made available for these efforts. Yearly trends in number of samples and unique accessions received *per recipient country* (i.e. the "national" incoming flows rather than the global flows) show very small yearly increases; this counter-trend to the one observed overall in the global flows, may be explained by the fact that the number of recipient institutions within some recipient countries grew slightly over time (data not shown).

[3] https://www.genesys-pgr.org

Types of materials and frequencies of distribution

12. Over 50 per cent of the total germplasm distributed by CGIAR genebanks over the 25 years analysed are landraces or traditional cultivars, which are indeed predominant within those collections (Fowler *et al.* 2001, Genesys 2014); breeding and research lines constitute less than 20 per cent of the materials distributed, while advanced or improved cultivars are only 7 per cent of the distributions (figure 2). The decision about what materials they want to conserve long term in the centre's genebanks is made by each centre independently. The data here highlights that most centres favour materials which belong to their mandate crops' primary genepools, i.e. landraces and wild relatives. This strategy also reflects the fact that all centres with genebanks also have breeding programmes which actively exchange research, breeding and improved lines with partners worldwide, making the conservation of these sets by the genebank neither necessary nor efficient. The inclusion of research, breeding or advanced lines in the genebanks is generally an exception to this practice, when the properties or the use of a material justify it. This may be the case, for instance, of materials which have accumulated unique genetic properties (e.g. allele combinations), of those which are laborious to obtain again (e.g. inter-specific hybrids) or of those which are used as common benchmark varieties in evaluation trials (Daniel Debouck pers. comm.).

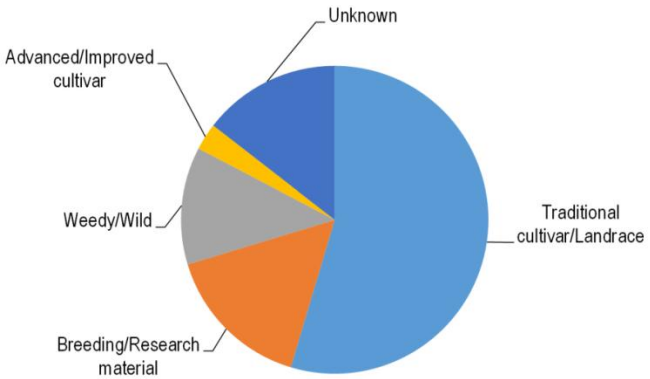

Figure 2. Proportion of the different types of germplasm distributed by the selected CGIAR genebanks based on unique accession data over the 1985-2009 period (germplasm categories from SINGER/Genesys).

13. Based on the number of samples per accession sent out to recipients, there appears to be enormous variation in the popularity of any single accession. Almost 60 per cent (59.7) of the accessions in the dataset have been distributed between two and ten times, while only 5.7 per cent (150 accessions) have been distributed more than 100 times. The latter more frequently transferred

accessions mostly come from ILRI, CIP and ICRISAT and have been distributed to an average of over 38 countries (sd = 20.5) (see Annex 1-table 4 for details on the top 50 most "popular" accessions of our dataset). More than half of these frequently distributed materials are improved lines, whereas it is landraces, wild relatives and to a lesser extent breeding materials which constitute the bulk of accessions transferred less frequently. Among the possible reasons for the "popular" materials to be more frequently requested (i.e. by a considerable number of institutions worldwide), is the fact that the work already undertaken on them (be it characterization, evaluation, improvement or any combination of these) makes their value for breeding and research better known. This, in turn, facilitates their use even in institutions and countries with limited capacities or infrastructure for carrying out the lengthy and costly pre-breeding procedures which lead to identifying and introducing interesting traits from non-adapted populations and wild relatives (FAO 2010).

Providers and recipients

14. Of the total 189 countries from which material distributed by the seven CGIAR genebanks was obtained, 112 are developing countries, 54 are developed and 23 have economies in transition. Of the total 191 recipients, 117 are developing countries, 19 are economies in transition and 56 are developed countries. Developing countries and countries with economies in transition will be considered together from now on, for the purpose of this study. Both developed and developing countries are net recipients, i.e. they receive more diversity than they contribute to others through international gene banks; while this "sink" behaviour is more evident for developed countries, which tend to harbour comparatively less genetic diversity in their territory, the majority of global exchanges of germplasm mediated by the CGIAR genebanks are south to south, i.e. occur between developing countries (figure 3).

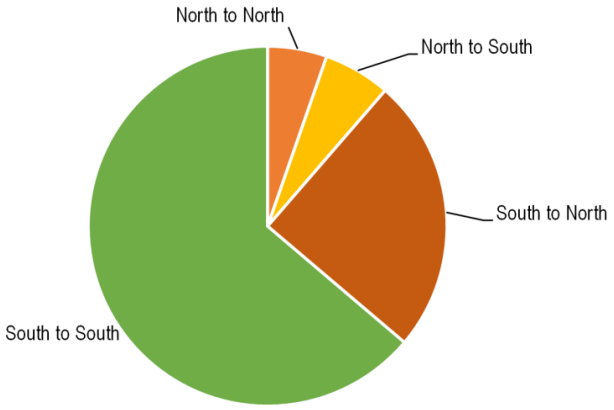

Figure 3. Number of unique accessions exchanged between developed (the "North") and developing and transition countries (the "South").

15. Fowler *et al.* (2001) and Smale and Day-Rubenstein (2002) also observed a predominance of developing countries and transition economies in their analysis of flows from six of the CGIAR genebanks and from the US NPGS between 1990 and 1999. So too did the CGIAR System-wide Genetic Resources Programme in its bi-annual reports to the Governing Body of the ITPGRFA (SGRP 2011). The following tables (3a and 3b) provide more detail on the amount, diversity and geographical coverage of the distributions facilitated by the international genebanks, for the top 25 provider and the top 25 recipient countries.

Table 3. a) Top 25 provider countries, number of samples (total number of transfers) and of unique accessions contributed to international flows, number of genera provided and of recipient countries (1985-2009); b) Top 25 recipient countries, number of samples (total number of transfers) and of unique accessions received, number of genera received and of provider countries (1985-2009).

a)

Provider country	Total samples provided	Unique accessions provided	Genera provided	Recipient countries
India	188911	48635	35	144
Peru	67899	16216	23	158
Ethiopia	40143	13683	94	120
United States	36652	6294	30	156
Iran	29829	9779	26	87
Turkey	29579	9634	29	83
Syria	26029	7487	27	78
Sudan	24262	3457	17	61
The Philippines	21626	4016	7	109
Côte d'Ivoire	20494	3037	4	78
China	18559	7225	21	125
Nigeria	16060	3462	27	126
Zimbabwe	15477	4500	19	62
Cameroon	15216	2942	13	67
Jordan	12328	3319	20	66
Morocco	12257	4106	34	69
Bangladesh	12092	3839	14	94
Indonesia	11696	3774	12	93
Uganda	11172	2565	13	103
Tunisia	10799	3523	22	74
Pakistan	10587	2950	23	99
Kenya	10509	2205	38	104
Algeria	9743	3522	24	65
Tanzania	8438	2132	37	96
Nepal	7725	2745	19	73

b)

Recipient country	Total samples received	Unique accessions received	Genera received	Provider countries
India	284454	115849	70	181
United States	45992	39963	97	178
China	33690	18664	48	151
Ethiopia	28863	17572	175	150
Australia	20218	17566	63	150
Japan	17628	12022	32	141
United Kingdom	17231	14283	89	144
Morocco	16362	14618	38	97
The Philippines	16332	8798	50	107
Tunisia	13399	9706	18	70
Iran	13083	12301	18	135
Austria	12703	12657	24	92
Italy	12345	10003	36	116
Syria	10598	8610	19	92
South Korea	10195	8423	26	137
Russia	9614	8636	12	92
Pakistan	9512	7901	64	139
Turkey	9295	7221	25	96
Canada	9160	7709	38	121
Indonesia	8965	8395	32	110
Peru	7953	4053	33	75
Egypt	7921	6685	54	126
Germany	7276	6253	63	130
Brazil	6903	6030	34	129
Thailand	6821	4899	27	103

16. Almost all the top providers listed above are developing countries or countries with economies in transition; many of them harbour important centres of origin, domestication or diversification of the crops included in the mandate of the genebanks considered in the study, as is the case for India (rice, millet), Peru (potato), Syria and Turkey (wheat and barley), China (rice) and a number of African countries (particularly for tropical forages). Many top recipients are *also* developing countries and again, many of them are centres of origin or diversity of crops or forages, indicating that even diversity-rich countries are not necessarily self-sufficient on the plant genetic resources needed to improve their crops. The difference in the amount of germplasm both provided and received by India and the following top providers stands out as very significant, indicating that India provides and receives massive amounts of germplasm. Interestingly, significant percentages of materials originally collected in or obtained from India that enter the flows end up going back to Indian recipients (59 per cent of the

samples and over 70 per cent of the unique accessions); this makes the country the largest recipient of materials that were originally obtained from within its own borders through the CGIAR-hosted collections. High percentages of "reabsorption" of their own materials through the CGIAR-mediated flows are recorded also for Tunisia and Morocco (48 and 42 per cent respectively), the Philippines (37 per cent), Iran and Jordan (30 and 25 per cent), and others to progressively decreasing extents. These trends highlight an additional benefit of germplasm deposited in these international collections in addition to access to diversity from hundreds of other countries, i.e. long term secure conservation and availability of quality material (and often value added characterization, evaluation data) from one's own territory. The latter benefit is potentially particularly relevant for those countries with limited capacity to establish and maintain national conservation programs for their local materials.

17. Differences exist not only in the amount but also in the types of materials provided by developed and developing countries: while developed countries provide an overall lower *quantity* of materials compared to developing countries, they contribute a proportionally higher share of materials where some formal research, pre-breeding or other form of improvement has been conducted; 27 percent of the materials 'distributed' by the seven studied CGIAR genebanks from developed countries were research materials and improved/elite lines (with a peak of 80 per cent for the United States); 14 per cent of the total samples distributed by the CGIAR genebanks from developing and transition countries was similarly improved. On the recipient side, the share of germplasm which carries some degree of research and improvement flowing into developing countries and transition economies is 30 per cent of the overall incoming materials, while it is 14 percent for developed countries.

18. In both developed and developing nations, public institutions (NAROs, genebanks and Universities) are by far the predominant recipients of CGIAR materials (figure 4). These public sector recipients are located in developing countries in over 75 percent of the cases . The share of samples sent out to commercial companies is only around 3 per cent of the total, and for this category too, the recipients are mostly (77 per cent) in developing countries.

19. The 25 countries that received the most samples from the seven studied genebanks received materials that were collected from, on average, 122 other countries. The 25 countries who have the most materials conserved in the seven studied genebanks (many are the same countries) had those materials distributed, on average, to 96 countries.

Recipient Type	Samples received	Percentage	Unique accessions received	Percentage
National Agricultural Research Centre	573456	57.39	374714	61.87
University	297034	29.73	161845	26.72
Genebank	53198	5.32	33967	5.61
Commercial company	32020	3.20	10985	1.81
Other	24739	2.48	13650	2.25
Non-governamental Organization	14821	1.48	7905	1.31
Regional Organization	2727	0.27	2054	0.34
Farmer	1255	0.13	528	0.09

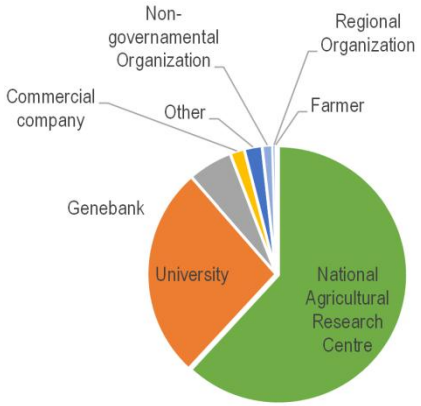

Figure 4. Types of recipients of CGIAR material, number of samples and unique accessions received (1985-2009) and percentages over the totals per category. The pie graph is based on unique accession data.

20. These findings are consistent with those of Smale and Day-Rubenstein (2002) who found that public sector actors were predominant among the recipients of germplasm from the US NPGS, another important worldwide facilitator of PGRFA for research and breeding.

Conclusion

21. The extent and diversity of the PGRFA flows described here, albeit only a small sample of the worldwide exchanges, provide a clear picture of the extent of countries' interdependence on PGRFA for crop improvement and ultimately food security. It confirms Duvick's (1984) description of modern agriculture as an interdependent network of seed and germplasm sources, in which very few countries or farming systems in the world do not rely to some degree on the international system that moves crop germplasm, breeding lines and improved varieties across international borders.

22. Analyses by other authors confirm these patterns, describing how crop improvement has benefited from access to a wide range of materials of different origins: Fowler *et al.* (2001) undertook an analysis of CGIAR data focusing on a different time frame and different measures than those presented here; Smale *et al.* (2002) use the case of spring bread wheat released by national programs in developing countries; Warburton *et al.* (2006) and Dreisigacker *et al.* (2005) look at synthetic hexaploids to illustrate the significance of access to wild relatives from centres of diversity in wheat improvement; Voysest *et al.* (2003) take the case of beans in Latin America. Additional studies have focused on the

case of those countries which are centres of crop diversity: Rejesus *et al.* (1996) find that in breeders in Western Asia, the Vavilov center for wheat, 45.6 per cent of the germplasm used by wheat breeders comes from international sources and was likely sourced in countries other than the breeder's; Evenson and Gollin (1997) document the dependence of Asian countries, including Vavilov center countries like India, Burma, Bangladesh, Nepal, Vietnam, on IRRI for rice germplasm of different provenance (65.0 per cent in India and 98.1 per cent in Vietnam).

23. As noted earlier, it is predicted that countries' dependence upon PGR from beyond their borders will increase in the future, as a result of climate change, population growth, increased demand for food and diversification of national diets across the world. It has also been noted how national or regional collections tend to harbour a different set of species and varieties, among which many underutilized species with promising potential to meet the above challenges, and which are not necessarily found in international genebanks (see Galluzzi and Lòpez Noriega 2014, and Thomas *et al.* (forthcoming) for examples from Latin America). As a result, the effective functioning of a globally coordinated system for access and benefit sharing, which include as many national collections as possible, will be more important than ever.

24. The ITPGRFA and its Multilateral System have arrived at a cross-roads. The WG-EFMLS will need to identify options to recommend to the Governing Body to increase the flow of financial benefits from users, and to increase the functionality of multilateral system overall. In so doing, it is critically important that the Working Group members are aware of the extent of countries' interdependence on PGRFA as illustrated by the global flows facilitated by the CGIAR genebanks (as presented in this paper) and by all other actors involved in conserving and sharing germplasm globally. The paper highlights that access to globally pooled genetic resources is a fundamentally important benefit that all countries have historically exploited when systems were set up to facilitate that access. The Working Group's efforts to improve the multilateral system must be guided by the absolute necessity of supporting and improving countries' ability to further exploit this benefit.

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Annex 1

Table 1. Current numbers of accessions held by the genebanks of the CGIAR system. Data from: Genesys, www.genesys-pgr.org (accessed on 20 November 2014)

Centre	N. of accessions held
Africa Rice	26098
Bioversity International	1516
CIAT	64721
CIMMYT	164320
CIP	16061
ICARDA	147076
ICRAF	2005
ICRISAT	119524
IITA	27232
ILRI	20229
IRRI	124052

Table 2. Genera represented in the genebank collections of all CGIAR centres (genera represented by less than 50 accessions are grouped as "other"), according to data deposited in Genesys (www.genesys-pgr.org). Numbers of accessions refer to those received and reported by centres over time, and may overestimate the current living material available for distribution in each genebank.

Collection	Genus	N. of accessions
Africa Rice	*Oryza*	131840
	Other	22
Bioversity	*Musa*	1525
	Ensete	4
CIAT	*Phaseolus*	36124
	Manihot	5458
	Stylosanthes	4276
	Desmodium	3561
	Centrosema	2874
	Aeschynomene	1209
	Macroptilium	1052
	Vigna	1050
	Zornia	967
	Brachiaria	601
	Panicum	563
	Galactia	561
	Calopogonium	553

	Rhynchosia	389
	Teramnus	372
	Chamaecrista	339
	Desmanthus	325
	Crotalaria	274
	Alysicarpus	259
	Pueraria	255
	Canavalia	215
	Dioclea	199
	Leucaena	198
	Indigofera	184
	Flemingia	179
	Uraria	176
	Arachis	171
	Clitoria	157
	Lablab	155
	Paspalum	155
	Tephrosia	153
	Phyllodium	139
	Cajanus	135
	Tadehagi	108
	Andropogon	93
	Pseudarthria	72
	Neonotonia	68
	Dendrolobium	62
	Sesbania	62
	Cratylia	52
	Other	926
CIMMYT	*Triticum*	103780
	Zea	27279
	Triticosecale	16004
	Hordeum	14221
	Aegilops	1316
	X Triticoaegilops	991
	Secale	438
	Tripsacum	156
	X Aegilotriticum	128
	Other	7
CIP	*Ipomoea*	7783
	Solanum	7112
	Oxalis	520
	Ullucus	435
	Tropaeolum	54

	Other	157
ICARDA	*Triticum*	37214
	Hordeum	31619
	Vicia	16151
	Cicer	14906
	Lens	12463
	Medicago	9418
	Pisum	6110
	Trifolium	5010
	Aegilops	4257
	Lathyrus	4184
	Astragalus	956
	Onobrychis	733
	Avena	593
	Scorpiurus	500
	Hippocrepis	319
	Trigonella	280
	Coronilla	251
	Lotus	246
	Hymenocarpos	223
	Melilotus	219
	Lupinus	134
	Elymus	81
	Hedysarum	81
	Brachypodium	78
	Secale	73
	Other	977
ICRAF	*Prosopis*	929
	Calycophyllum	390
	Guazuma	390
	Leucaena	80
	Gliricidia	55
	Desmodium	52
	Other	109
ICRISAT	*Sorghum*	37901
	Pennisetum	22200
	Cicer	20140
	Arachis	15440
	Cajanus	13289
	Eleusine	5957
	Setaria	1542
	Panicum	1306
	Echinochloa	749

	Paspalum	665
	Rhynchosia	290
	Other	45
IITA	*Vigna*	18237
	Dioscorea	3169
	Manihot	2984
	Glycine	1749
	Zea	798
	Musa	150
	Sphenostylis	145
	Other	0
ILRI	*Trifolium*	1649
	Vigna	1161
	Stylosanthes	1160
	Leucaena	801
	Sesbania	674
	Indigofera	669
	Brachiaria	663
	Alysicarpus	516
	Neonotonia	508
	Rhynchosia	501
	X Triticale	459
	Macroptilium	431
	Panicum	423
	Tephrosia	395
	Lablab	374
	Centrosema	323
	Teramnus	322
	Cenchrus	294
	Zornia	283
	Phaseolus	282
	Vicia	258
	Digitaria	255
	Medicago	252
	Acacia	248
	Pennisetum	245
	Crotalaria	237
	Paspalum	223
	Cytisus	220
	Chloris	194
	Glycine	192
	Galactia	188
	Desmodium	177

	Lathyrus	166
	Cajanus	164
	Urochloa	162
	Chamaecrista	160
	Aeschynomene	158
	Calopogonium	152
	Avena	147
	Gliricidia	141
	Eragrostis	136
	Cynodon	130
	Lotononis	130
	Setaria	130
	Pisum	126
	Clitoria	122
	Andropogon	109
	Desmanthus	107
	Echinochloa	93
	Pseudarthria	93
	Bothriochloa	89
	Senna	89
	Uraria	89
	Pueraria	76
	Lolium	75
	Sorghum	72
	Cassia	71
	Hordeum	71
	Festuca	64
	Argyrolobium	57
	Erythrina	57
	Lupinus	53
	Amaranthus	51
	Cymbopogon	51
	Hyparrhenia	51
	Dolichos	50
	Other	2160
IRRI	*Oryza*	124052
	Other	22

Table 3. Countries from which accessions held by CGIAR genebanks were originally collected or improved. Data from: Genesys, www.genesys-pgr.org (accessed on 20 November 2014).

Country code in Genesys	Country	n. of accessions in the CG genebanks
AFG	Afghanistan	4962
ALB	Albania	75
DZA	Algeria	3828
AGO	Angola	110
ATG	Antigua and Barbuda	116
ANT	Antilles	9
ARG	Argentina	3991
ARM	Armenia	1304
AUT	Austria	564
AZE	Azerbaijan	1723
BHS	Bahamas	4
BHR	Bahrain	2
BRN	Baker Island	215
BGD	Bangladesh	8009
BRB	Barbados	57
BLR	Belarus	324
BEL	Belgium	347
BLZ	Belize	376
BEN	Benin	1455
BTN	Bhutan	507
BOL	Bolivia	3289
BIH	Bosnia and Herzegovina	59
BWA	Botswana	1078
BRA	Brazil	14765
IOT	British Indian Ocean Territory	1
VGB	British Virgin Islands	55
BGR	Bulgaria	1570
BFA	Burkina Faso	2995
MMR	Burma	3550
BDI	Burundi	867
KHM	Cambodia	4885
CMR	Cameroon	5320
CAN	Canada	914
CPV	Cape Verde	22
CAF	Central African Republic	849
TCD	Chad	909
CHL	Chile	2431
CHN	China	15294
COL	Colombia	12829
COM	Comoros	8

COG	Congo	334
COD	Congo (Democratic Republic of the)	687
COK	Cook Islands	7
AUS	Coral Sea Islands	2172
CRI	Costa Rica	1543
CIV	Cote d'Ivoire	10018
HRV	Croatia	63
CUB	Cuba	980
CYP	Cyprus	1103
CZE	Czech Republic	556
DNK	Denmark	206
DJI	Djibouti	6
DOM	Dominican Republic	497
ECU	Ecuador	3934
EGY	Egypt	1831
SLV	El Salvador	562
GNQ	Equatorial Guinea	28
ERI	Eritrea	97
EST	Estonia	10
ETH	Ethiopia	22113
FLK	Falkland Islands (Islas Malvinas)	2
FSM	Federated States of Micronesia	7
FJI	Fiji	53
FIN	Finland	91
YUG	Former Yugoslavia	222
FRA	France	1136
GUF	French Guiana	20
PYF	French Polynesia	2
GAB	Gabon	100
GMB	Gambia	695
PSE	Gaza Strip	129
GEO	Georgia	1230
DEU	Germany	2357
GHA	Ghana	2006
GRC	Greece	3921
GRD	Grenada	50
GLP	Guadeloupe	62
GUM	Guam	9
GTM	Guatemala	4447
GIN	Guinea	1678
GNB	Guinea-Bissau	151
GUY	Guyana	156
HTI	Haiti	233
HND	Honduras	1476
HKG	Hong Kong	21

HUN	Hungary	1625
IND	India	44216
IDN	Indonesia	12087
IRN	Iran	21347
IRQ	Iraq	1652
IRL	Ireland	3
ISR	Israel	1663
ITA	Italy	2720
JAM	Jamaica	189
JPN	Japan	2555
JOR	Jordan	5023
KAZ	Kazakhstan	613
KEN	Kenya	4048
KIR	Kiribati	1
KGZ	Kyrgyzstan	226
LAO	Laos	15642
LVA	Latvia	32
LBN	Lebanon	2208
LSO	Lesotho	587
LBR	Liberia	3616
LBY	Libya	762
LTU	Lithuania	38
MAC	Macau	1
MKD	Macedonia	766
MDG	Madagascar	4296
MWI	Malawi	3214
MYS	Malaysia	4832
MDV	Maldives	23
MLI	Mali	4850
MLT	Malta	35
MTQ	Martinique	17
MRT	Mauritania	162
MUS	Mauritius	31
MEX	Mexico	77448
MDA	Moldova	94
MNG	Mongolia	232
MNE	Montenegro	43
MSR	Montserrat	11
MAR	Morocco	4989
MOZ	Mozambique	413
BUR	Myanmar	323
NAM	Namibia	1546
NPL	Nepal	5858
NLD	Netherlands	780
NCL	New Caledonia	11

NZL	New Zealand	117
NIC	Nicaragua	646
NER	Niger	4983
NGA	Nigeria	14636
NIU	Niue	4
PRK	North Korea	2592
NOR	Norway	29
OMN	Oman	324
PAK	Pakistan	5604
PLW	Palau	2
VUT	Palestine	3
PAN	Panama	1000
PNG	Papua New Guinea	991
PRY	Paraguay	1375
PER	Peru	14412
PHL	Philippines	9224
POL	Poland	426
PRT	Portugal	2381
PRI	Puerto Rico	364
REU	Reunion	1
ROU	Romania	572
RUS	Russia	3529
SUN	Russia	1259
RWA	Rwanda	874
KNA	Saint Kitts and Nevis	33
LCA	Saint Lucia	37
VCT	Saint Vincent and the Grenadines	54
WSM	Samoa	2
SMR	San Marino	3
SAU	Saudi Arabia	84
SEN	Senegal	3540
SRB	Serbia	99
SYC	Seychelles	3
SLE	Sierra Leone	1997
SGP	Singapore	6
SVK	Slovakia	105
SVN	Slovenia	8
SLB	Solomon Islands	56
SOM	Somalia	562
ZAF	South Africa	2138
KOR	South Korea	2153
ESP	Spain	3567
LKA	Sri Lanka	2740
SDN	Sudan	3528
SUR	Suriname	188

SWZ	Swaziland	276
SWE	Sweden	554
CHE	Switzerland	1102
SYR	Syria	10776
TWN	Taiwan	3075
TJK	Tajikistan	2275
TZA	Tanzania	4094
THA	Thailand	7870
TGO	Togo	2817
TON	Tonga	15
TTO	Trinidad and Tobago	201
TUN	Tunisia	4382
TUR	Turkey	16775
TKM	Turkmenistan	587
TUV	Tuvalu	1
UGA	Uganda	3532
UKR	Ukraine	1610
ARE	United Arab Emirates	4
GBR	United Kingdom	801
USA	United States	12969
UNK	Unkown	6870
URY	Uruguay	1229
UZB	Uzbekistan	987
VEN	Venezuela	4075
VNM	Vietnam	3787
VIR	Virgin Islands	17
YEM	Yemen	2816
ZMB	Zambia	2733
ZWE	Zimbabwe	5717

Table 4. Top 50 most popular accessions of our distribution dataset (based on how many samples of each accession have been distributed), with information on the distributing centre, genus, frequency of distribution, number of recipient countries, biological status and country of origin.

Accession number	Center	Genus	Freq. of distribution	N. of recipients	Biological Status	Country of origin
328	IRRI	Oryza	321	42	Landrace	The Philippines
CIP 985003	CIP	Solanum	312	76	Improved	Peru
10865	ILRI	Sesbania	268	66	Weedy/Wild	Unknown
104	ILRI	Desmodium	253	51	Improved	Australia
CIP 720088	CIP	Solanum	252	101	Improved	Argentina
4	ILRI	Stylosanthes	247	53	Improved	Colombia
69	ILRI	Macroptilium	247	59	Improved	Unkown

4918	ICRISAT	Cicer	246	13	Improved	India
5159	IRRI	Oryza	246	21	Landrace	The Philippines
30333	IRRI	Oryza	245	23	Landrace	The Philippines
6765	ILRI	Desmodium	240	50	Improved	Unkown
140	ILRI	Stylosanthes	232	49	Improved	Brazil
CIP 379706.27	CIP	Solanum	220	88	Improved	Peru
70	ILRI	Leucaena	219	55	Improved	Unkown
30416	IRRI	Oryza	213	41	Improved	The Philippines
ITC0249	Bioversity	Musa	213	50	Weedy/Wild	Unkown
75	ILRI	Stylosanthes	212	50	Improved	Venezuela
ITC0504	Bioversity	Musa	212	77	Improved	Unkown
ITC1123	Bioversity	Musa	212	67	Landrace	Unkown
599	IRRI	Oryza	210	18	Breeding/research	The Philippines
CIP 378017.2	CIP	Solanum	210	88	Breeding/research	Peru
CIP 720087	CIP	Solanum	209	91	Improved	Argentina
6756	ILRI	Macrotyloma	208	51	Improved	Unkown
7035	ICRISAT	Cajanus	207	16	Improved	India
CIP 374080.5	CIP	Solanum	203	67	Improved	Peru
CIP 800827	CIP	Solanum	199	70	Improved	United States
CIP 978001	CIP	Solanum	195	54	Breeding/research	Peru
4973	ICRISAT	Cicer	194	14	Improved	India
6984	ILRI	Medicago	179	37	Improved	Unkown
10320	IRRI	Oryza	178	30	Improved	The Philippines
12048	IRRI	Oryza	178	38	Other	Guinea
ITC0506	Bioversity	Musa	178	74	Improved	Unkown
27748	IRRI	Oryza	177	29	Landrace	Thailand
71	ILRI	Leucaena	176	43	Improved	Unkown
CIP 978004	CIP	Solanum	176	64	Breeding/research	Peru
66970	IRRI	Oryza	175	38	Improved	The Philippines
CIP 984001	CIP	Solanum	174	60	Breeding/research	Peru
167	ILRI	Stylosanthes	173	51	Weedy/Wild	Venezuela
147	ILRI	Lablab	169	42	Improved	Unkown
17159	ICRISAT	Cicer	169	7	Weedy/Wild	Turkey
5003	ICRISAT	Cicer	169	12	Improved	India
15036	ILRI	Sesbania	167	54	Improved	Uganda
6633	ILRI	Chloris	167	40	Improved	Unkown
11575	ILRI	Cajanus	163	50	Weedy/Wild	Unkown
15019	ILRI	Sesbania	163	53	Weedy/Wild	DR Congo
23364	IRRI	Oryza	163	29	Landrace	The Philippines
ITC0505	Bioversity	Musa	163	68	Improved	Unkown
CIP 980003	CIP	Solanum	159	54	Breeding/research	Peru
15632	ICRISAT	Cajanus	158	5	Weedy/Wild	India
312	ILRI	Desmanthus	157	42	Weedy/Wild	Belize