New Directions for Collecting and Conserving Peanut Genetic Diversity

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ABSTRACT

Existing strategies for collecting and conserving peanut genetic diversity need to be reassessed and updated in light of recent collecting efforts, technological advances, and the new political climate affecting international germplasm access and exchange. In the Americas, important taxonomic and geographical gaps in the collections still need to be filled before the full extent of peanut genetic diversity, both wild and cultivated, can be known from the crop' s hemisphere of origin. Moreover, reports of peanut genetic erosion in Asia and Africa need to be investigated and addressed. The current global trend to implement national legislation regulating access to genetic resources presents new challenges for organizing and conducting plant explorations in other countries, making international partnerships more important than ever. The use of innovative new tools and methods for assessing, locating, and conserving crop genetic diversity, such as Geographical Information Systems and on-farm conservation, has recently increased. These new tools, methods, and partnerships are proposed as key elements for an updated strategy to help ensure that the unfinished work of collecting and conserving peanut diversity can be successfully continued into the 21st century.

Key Words: Genetic erosion, germplasm collecting, GIS, on-farm conservation.

Until recently, the task of collecting and conserving peanut genetic resources was a relatively straightforward undertaking. In essence, the collector's task consisted of visiting one of the many uncollected areas where peanuts or their wild relatives were believed to occur, obtaining properly documented samples of seeds or plants, and then depositing the germplasm in gene banks. Prioritization was based primarily on geographic gaps in existing collections, often at the level of an entire country. Legal requirements for collecting were usually minimal and international partnerships sometimes did not extend beyond a host country scientist's participation in the collecting mission. To date, conservation of the collected material has been exclusively *ex situ*, usually in genebanks located outside the host country. Despite the fact that half of each collected accession was shared routinely with the host country authorities, oftentimes little attention was devoted to its conservation or use there, frequently resulting in the eventual loss of the germplasm in the host country.

Today, peanut germplasm collectors find that the situation described above has changed dramatically due to the progress made in germplasm collecting, recent scientific and technological advances, as well as a radically new political climate regarding international access to germplasm. The collecting strategies that were once so successful are no longer adequate to address the new demands and opportunities that define the current situation regarding acquisition and long-term conservation of peanut genetic diversity. An updated and refocused strategy needs to be adopted that will enable peanut conservationists to address new priorities, overcome new

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constsraints, and take advantage of new opportunities.

Recent Progress

In the second half of the 20th century, tremendous progress was made in the exploration, conservation, and description of *Arachis* genetic diversity, both cultivated and wild. Beginning in the late 1940s, W.C. Gregory, A. Krapovickas, and colleagues initiated systematic peanut explorations in South America; and these were continued by them, their students, and associates over the following decades in a collaborative and coordinated effort. As a result, wild species of *Arachis* were comprehensively collected throughout their native range in South America, with numerous new species discovered as the more remote corners of the continent were penetrated by collectors (Valls *et al.*, 1985; Simpson, 1991). Numerous collecting missions to Argentina, Brazil, Bolivia, Paraguay, and Uruguay greatly expanded the number of species known and made their germplasm available to conservationists, breeders, and other researchers. At the same time, comprehensive collections of cultivated peanut landraces were being assembled from throughout the crop's prehistoric range, focusing on areas of highest diversity such as Bolivia, Peru, Ecuador, Brazil, Paraguay, Mexico and Guatemala, as well as other countries.

One of the most significant outcomes of this broad collecting effort was the publication of a new monograph of the genus *Arachis* (Krapovickas and Gregory, 1994) in which 69 species are described, including six botanical varieties of *Arachis hypogaea* L. The monograph represents a major milestone for the study and conservation of peanut genetic resources, and provides a sound scientific foundation upon which future work can be based. Large peanut collections maintained at national genebanks in Argentina, Brazil, U.S., and other countries, together with the international collections maintained at ICRISAT and CIAT, together are conserving *Arachis* germplasm accessions numbering in the tens of thousands (including duplicates). Computer technology now plays a key role in efficiently managing the large amount of information associated with these accessions. Thanks to the recording of the precise locations and other information corresponding to the specimens collected, and to the computerized (and in some cases Web-enabled) documentation systems now employed by the main genebanks where *Arachis* germplasm is deposited, the analysis of the geographical, taxonomic, and climatic distributions of the accessions has been greatly facilitated. Such analyses are crucially important for the identification and prioritization of gaps in the collections and also for identifying high priority areas such as regions of high diversity or marginal environments where desirable traits are likely to be found.

While the *ex situ* conservation of *Arachis* diversity has improved, the situation *in situ* has taken a very different tack. Genetic erosion, the loss of *Arachis* diversity in farmers' fields and in the wild, is accelerating in concert with the sweeping social and economic changes, urbanization, modernization, and habitat destruction that is taking place in those developing countries where wild and cultivated peanuts are most diverse. Consequently, the urgent need to rescue the under-collected and undiscovered elements of the peanut's gene pool continues to increase. The identification, assessment, and prioritization of these outstanding gaps are critically important for the strategic planning of future collecting and conservation efforts.

Remaining Gaps

Despite the impressive achievements of the last half century, many fundamental questions remain unanswered regarding the origin, extent, and distribution of *Arachis* genetic diversity. These questions are of vital importance for peanut genetic resources conservation and use, and their answers will depend upon a coordinated effort to fill remaining gaps in the collections. For example, the most recent explorations in eastern Bolivia (Williams, 1989; Simpson, 1991) recovered wild species from the section *Arachis* that were new to science. These discoveries led researchers to believe that further explorations in that area are likely to discover other new species, possibly recovering one or more of the elusive progenitors of the cultigen. Northwestern Paraguay is another large, under-collected area that undoubtedly contains wild *Arachis* populations of great interest for peanut science. With regard to cultivated peanuts, the vast area of South America represented by northern and western Brazil, Colombia, Venezuela, and the Guyanas still awaits systematic exploration. In Central America, the countries from Honduras to Panama have likewise been unexplored for peanut landraces. Known areas of traditional peanut production in Mexico, Bolivia, and eastern Ecuador also remain uncollected. Some of these gaps are reflected by the numbers of accessions of *A. hypogaea* currently maintained by the U.S. Nat. Plant Germplasm System (NPGS), as shown by country in Figs. 1 and 2, based on information available on GRIN as of June 2000. Important collections from tertiary areas of peanut diversity in Asia and Africa are maintained at ICRISAT, which has an international mandate to collect, conserve, and distribute peanut genetic resources and maintains the world's largest *ex situ* repository for *Arachis* germplasm. Despite it's global mandate, the bulk of the ICRISAT germplasm accessions were obtained from the Indian subcontinent and a few African countries (Upadhyaya *et al.*, 2001), and this trend is duplicated in the NPGS accession obtained from those continents (see Figs. 3 and 4). It is evident that there remain some important gaps to be filled in numerous African and Asian countries where sampling has been inadequate. In China and in southeast Asia, primitive varieties, including the rare botanical variety *hirsuta*, evolved independently following their early introduction from the Americas and have thus diversified and become uniquely Asian landraces, a large number of which are not yet represented in any international germplasm collection.The recent government-sponsored modernization, expansion, and intensification of peanut production in India and China, including widespread promotion and adoption of improved cultivars, is causing many traditional Asian landraces to be abandoned and perhaps lost if efforts to collect them and conserve them are not made soon.

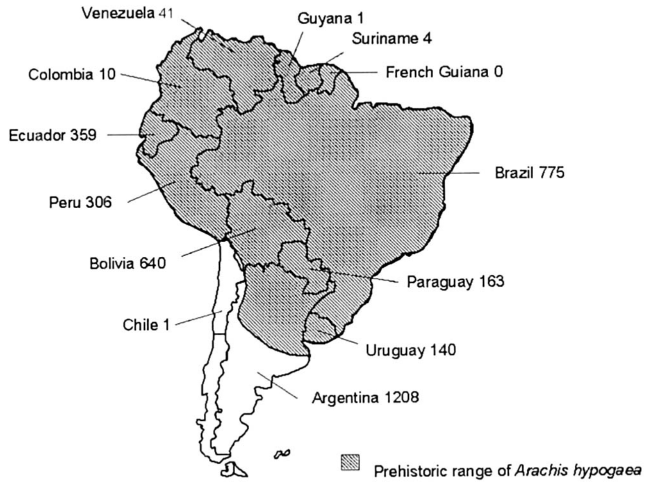

Fig. 1. Number of germplasm accessions, by country, of *Arachis hypogaea* from South America, maintained in the U.S. Nat. Plant Germplasm System as of June 2000 (Source: GRIN).

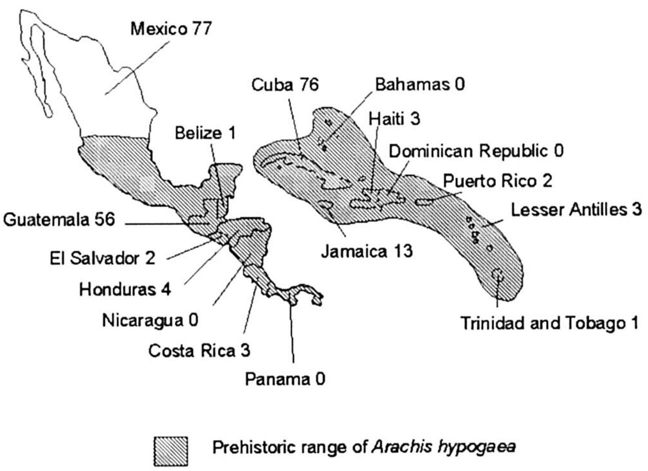

Fig. 2. Number of germplasm accessions, by country, of *Arachis hypogaea* from Mexico, Central America, and the Antilles, maintained in the U.S. Nat. Plant Germplasm System as of June 2000 (Source: GRIN).

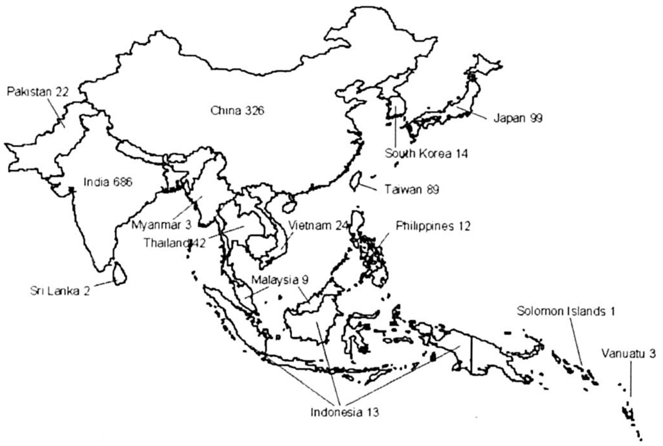

Fig. 3. Number of germplasm accessions, by country, of *Arachis hypogaea* from the Indian Subcontinent, China, and Southeast Asia, maintained in the U.S. Nat. Plant Germplasm System as of June 2000 (Source: GRIN).

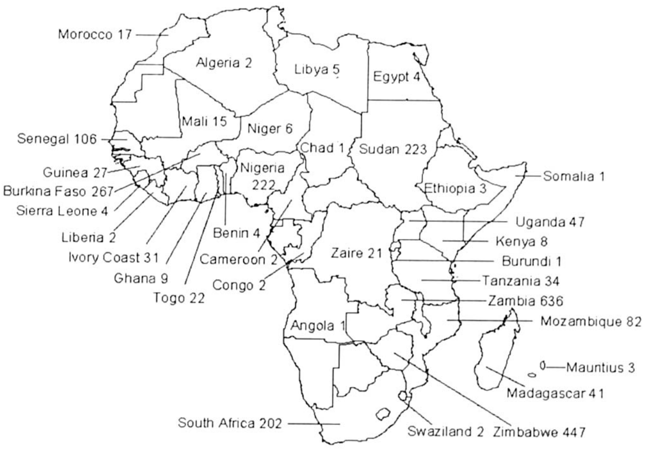

Fig. 4. Number of germplasm accessions, by country, of *Arachis hypogaea* from Africa maintained in the U.S. Nat. Plant Germplasm System as of June 2000 (Source: GRIN).

New Constraints

In addition to the accustomed scarcity of money, trained personnel, and institutional support that have long been limiting factors for peanut genetic resources exploration and conservation, researchers are now also faced with an entirely new set of legal regulations that must be complied with before further international collaborations involving access and exchange can be implemented. In an effort to promote the conservation, sustainable use, and equitable sharing of benefits derived from genetic resources, the Convention on Biological Diversity (CBD), adopted internationally in 1994, recognized national sovereignty over genetic resources and proscribed national regulation of access to those resources. Consequentially, cumbersome regulations governing access and exchange of genetic resources recently have been put into effect in many countries. While this important topic is the subject of another contribution to this symposium (Williams and Williams, 2001), suffice it to say here that new legislation in several countries already has placed a significant constraint on international exchange and conservation of peanut genetic resources. One of the immediately tangible effects of the recent access legislation has been an abrupt decrease in internationally supported peanut explorations, as the formal mechanisms for complying with the new requirements are still in the process of being worked out in many countries. Ironically, these new obstacles to international collaboration are especially pronounced in the Latin American countries where the peanut's greatest diversity occurs, yet where, in many cases, the national capacity to conserve and use these genetic resources is still lacking.

New Opportunities

Looking beyond the initial frustration felt by most researchers seeking access to foreign germplasm, the evolving regulatory scenario is, in fact, a double-edged sword. The new regulations present not just obstacles, but also opportunities for genetic resources conservationists. As a condition of access, foreign scientists are required now to detail the nature and purpose of the proposed activity and specify how the benefits derived from the research and the use of genetic resources will be shared equitably with the host country. While more or less informal benefit sharing with the host country has typically been an important element of international genetic resources collaborations in the past, the new legal scenario provides the mechanism by which future benefit sharing will be documented and duly recognized by all parties. Furthermore, the host country's commitment to share the responsibilities associated with the conservation and use of their sovereign genetic resources becomes explicit within the context of their new legislation. This recognition of responsibility by the countries themselves will serve to strengthen their national commitment and capacity to conserve and use their own genetic resources, and to engage in effective partnerships with other countries. Moreover, the legal access agreements between cooperating countries will help formalize and promote international partnerships on *Arachis* conservation. Such partnerships are indispensable for achieving effective, long-term conservation, both *ex situ* and *in situ*, and will broaden the overall benefits derived from the use of peanut genetic resources.

New Tools and Approaches

In the past few years, powerful new tools have become available that significantly enhance our capacity to integrate and enhance massive and diverse data sets (Greene and Guarino, 1999). The present availability of digitized data on *Arachis* diversity, distribution, taxonomy, characterization, and evaluation, together with other information on relevant human and physical, biotic, and abiotic variables, makes it possible for researchers to use Geographic Information System (GIS) technology to more effectively study, locate, and conserve *Arachis* genetic resources (Guarino *et al.*, 2001). Because of its ability to integrate different kinds of georeferenced data, GIS technology enables researchers not only to precisely map the distribution of different taxa but also to analyze the distribution of *Arachis* diversity and to correlate that diversity with other variables such as climate, topography, and soils, as well as relevant socioeconomic information such as demographic growth, agricultural activity, urban expansion, market access, development projects, ethnic diversity, etc. In the case of wild *Arachis* species, GIS applications such as FloraMap (Jones and Gladkov, 1999) can predict effectively the potential distribution of poorly known species based on climate. Figure 5 illustrates a predicted distribution of *A. batizocoi* Krapov. and W.C. Gregory produced by FloraMap based on a probability surface calculated from the climates of existing accessions of the species. This prediction then can be analyzed in conjunction with other factors, such as existing protected areas, threats of genetic erosion, etc., to target priority areas for future collecting efforts and identify suitable locations for *in situ* conservation of natural populations. Similar GIS analyses can be applied to cultivated peanut diversity and assist in predicting areas where new sources of cultivated diversity are most likely to be encountered and where on-farm (*in situ*) conservation efforts for peanut landraces would be most effective. The capacity of the GIS to integrate, analyze, and correlate huge amounts of relevant data makes it an invaluable new tool for planning effective peanut collecting and conservation activities.

Genetic resources conservationists now generally recognize that *ex situ* storage of germplasm ideally should be complemented by conservation of corresponding populations *in situ*, that is, in the same environments where they were collected and/or where they developed their unique traits. One of the great advantages of *in situ* conservation is that, unlike germplasm stored in genebanks, the ongoing evolutionary dynamic of the conserved populations is not interrupted and populations of sufficient size can be maintained so that the full range of genetic diversity they contain is conserved. *In situ* conservation for wild species takes place in the ecosystems where they occur naturally and, in the case of cultivated landraces, in the fields and traditional agroecosystems of the farmers that developed and use those varieties. While the need to promote *in situ* conservation and coordinate it with *ex situ* conservation has been recognized for some time, the ways and means for implementing this complementary conservation strategy have been slow in coming in the case of peanuts. Aside from Brazil, where natural populations of wild *Arachis* have been designated for *in situ* conservation and are periodically monitored (J. F. M. Valls, pers. commun.), no other countries have taken specific actions to conserve *Arachis* genetic diversity, either wild or cultivated.

Collaborative projects involving national partners, USDA, and the Int. Plant Genetic Resources Inst. (IPGRI), are currently underway in Paraguay and Bolivia to use GIS to map the distribution of wild *Arachis* diversity. The distribution of the wild peanut diversity is being compared with existing protected areas and variables contributing to the threat of genetic erosion to propose national action plans for *in situ* conservation of wild *Arachis* in those countries. Similarly, cultivated landrace diversity in Ecuador and Guatemala is being analyzed using GIS to develop recommendations for key areas where on-farm conservation efforts would be implemented most effectively. IPGRI is conducting a global project in several countries around the world to strengthen the scientific basis of *in situ* conservation of crop diversity on-farm, in which traditional farmers become active participants in national efforts to conserve agrobiodiversity (Jarvis and Hodgkin, 1998). In fact, the Peruvian component of this project, although still in its initial stage, includes peanut as one of the target crops being studied in the Amazonian lowland portion of that country. One of the principal objectives of the study is to document how and whyAmerindian farmers are able to maintain a diverse assemblage of peanut landraces and consciously manage this diversity as an integral part of their traditional farming system. Another objective is to find ways to enhance the usefulness of the local landraces, including through participatory breeding programs, so that the farmers will be less inclined to abandon their diverse traditional landraces in favor of genetically uniform introduced varieties, and to involve and incorporate the farmers into the Peruvian national genetic resources conservation effort. The experiences and recommendations that are beginning to come out of these innovative projects will be directly applicable to other programs seeking to promote *in situ* conservation of peanut diversity on-farm.

Elements of a New Strategy

Arachis germplasm collectors and conservationists have long recognized that their task was far too complex and demanding for any one institution or even country to manage alone. Thanks to the efforts of those collectors, fruitful international collaborations became the hallmark of peanut exploration activities (Simpson, 1991). Faced with daunting new challenges, and armed with powerful new information and analytical tools, the tradition and past successes of international collaboration can serve as the foundation upon which a complementary conservation strategy for *Arachis* can be developed and successfully implemented. Now that nations are, in effect, requiring that formal research partnerships be established before access to germplasm is granted, this becomes an opportunity (and possibly the last chance) for developed countries to enter into broad scientific collaborative agreements with their counterparts in the host countries that will provide an ongoing framework for sharing not only germplasm but also information, technology, and conservation responsibilities among the partner countries.

International partnerships involving developing countries where peanuts and their wild relatives are most diverse is the most logical approach for achieving long-term germplasm conservation and use because the partners agree to share the associated burdens as well as the benefits. Through formal partnerships, common research and conservation priorities can be defined, activities can be coordinated, comparative advantages and strengths can be brought to bear, costly duplications of effort can be avoided, and scarce financial and human resources can be used to their greatest advantage towards achieving the common goal.

A complementary conservation strategy is one that employs, in a coordinated fashion, numerous techniques and approaches, both *ex situ* and *in situ*, to protect the greatest possible amount of genetic diversity within the crop's genepool, and make the germplasm and associated information available to breeders, farmers, and other users. Typical *ex situ* conservation methods for *Arachis* include cold storage for orthodox seeds; greenhouse, screenhouse, and field collections for whole plants; slow growth *in vitro* for tissues of recalcitrant materials, and cryopreservation for long-term storage. *In situ* conservation for wild *Arachis* consists of managing specific populations located within protected areas and periodic monitoring of known populations occurring on unprotected lands. *In situ* conservation of cultivated peanut diversity is almost entirely in the hands of the farmers. In many

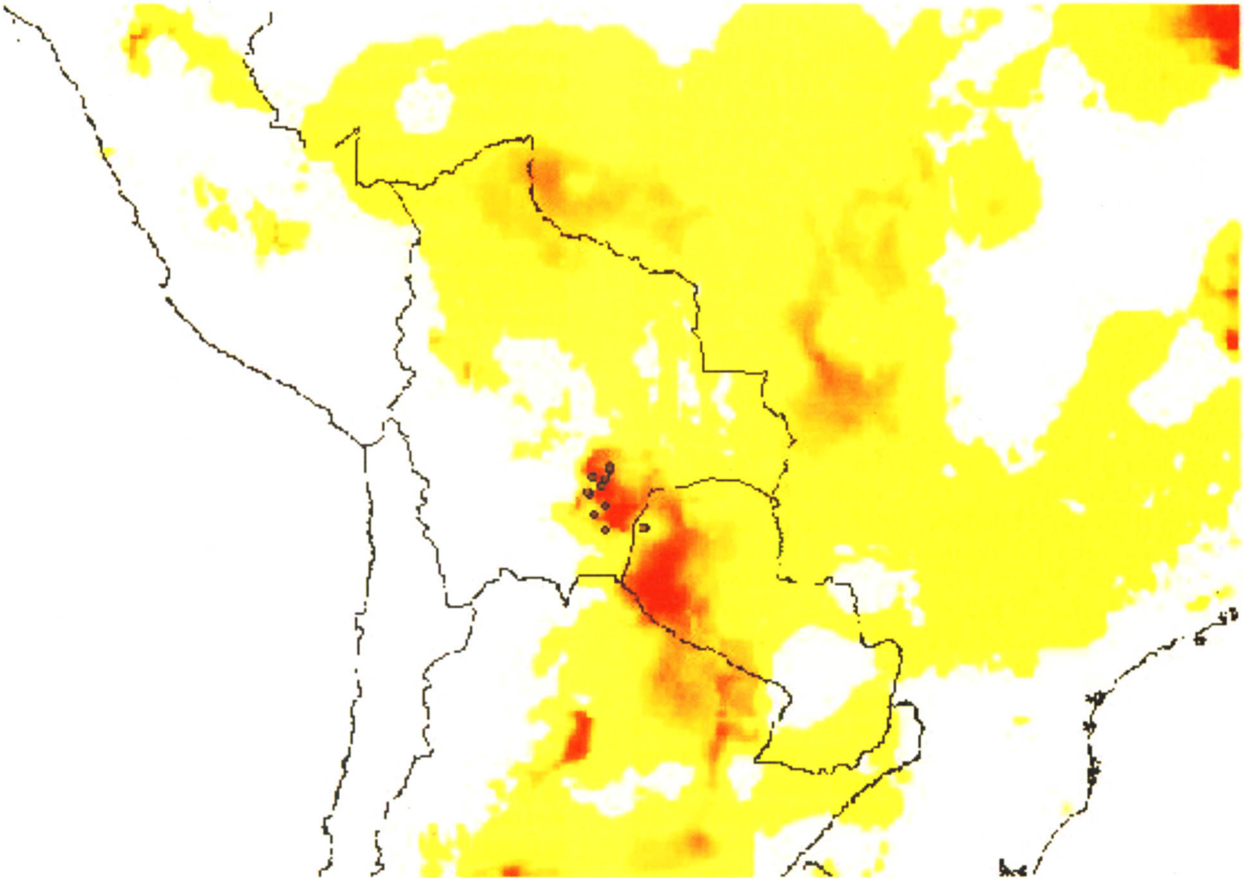

Fig. 5. FloraMap predicted distribution of *Arachis batizocoi* based on the climate probability surface calculated from locations of existing accessions, indicated by dots.

traditional communities, local varieties continue to be used and perpetuated on-farm as essential components of the local culture and farming system. Under these conditions, periodic monitoring may be all that is required of researchers unless intervention becomes necessary in the event that the local varieties are found to be in danger of being lost or abandoned.

One of the main advantages of a complementary conservation strategy is that the different conservation methods act as a sort of security backup for one another, although the germplasm conserved *in situ* continues to evolve in response to its environment while the sample stored *ex situ* remains comparatively static. This means that the most cost effective and biologically sound techniques can be employed in accordance with the particular conservation requirements of the different species and varieties in the genepool. For example, accessions of certain wild species that produce very few or no seeds in northern latitudes are precariously maintained in the U.S. national collection as a few individual plants laboriously kept alive in a greenhouse at great expense. These same accessions could be much more economically maintained and increased in their native country within the framework of a cooperative agreement. Similarly, numerous accessions of long-lived peanut landraces from the tropics are nearly impossible to properly characterize or increase in the U.S. Those accessions could be easily and economically multiplied, characterized and even used in U.S.-directed breeding programs through the auspices of a collaborator in a tropical country. When accessions become lost for whatever reason, either *in situ* or *ex situ*, in one country or another, these materials can be repatriated, replenished, or reestablished by drawing upon one of the alternative repositories. This already has taken place informally in a number of isolated instances, but could be readily coordinated and facilitated within the context of the complementary conservation strategy. Another key element of the new strategy is the standardization of information about the conserved germplasm in the various repositories and countries. Modern genebank data management systems, such as GRIN and pcGRIN, are essential for the exchange and analysis of relevant information, as well as for proper coordination of the complementary conservation activities. Through the collaborative efforts of USDA and IPGRI, the pcGRIN database management software has been developed and is freely available to genebanks and national programs in developing countries that lack a modern computerized system to properly manage their germplasm accessions and associated information. pcGRIN is already in the process of being adopted by many national programs and other institutions in Latin America and the Caribbean, and software and training courses soon will be offered to interested genebank managers on other continents. The widespread adoption of compatible germplasm data management software will greatly facilitate the exchange and management of information that is essential for the implementation of an effective complementary conservation strategy.

At this writing, the future of peanut genetic resources continues to hang very much in the balance. The need to collect, study, and conserve the remaining, unknown portions of the peanut's genepool is still of utmost importance not only for peanut scientists but also for humankind as a whole. Failure to discover suitable means to continue these exploration and conservation efforts could have disastrous long-term repercussions for peanut improvement. Fortunately, exciting new tools and opportunities still exist with which our exploration and conservation goals can be achieved and sustained. Although the new political reality will require a marked change in the way collecting and conservation is approached, these new opportunities should be pursued through the implementation of a complementary conservation strategy within the context of international cooperative partnerships. In this way, and only in this way, can the universal goals of studying, utilizing, and conserving peanut genetic resources be achieved so that the needs of breeders, farmers, and consumers can continue to be satisfied well beyond the 21st century.

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