Germplasm Acquisition

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INTRODUCTION

Plant genetic resources—varying from wild relatives of crops to farmers' varieties—form the raw materials of crop improvement programs. They have proven economic value to improve a wide range of traits, ranging from disease and pest resistances to improved yields and improved agronomic traits, and are critical to global food security. Their importance has long been recognized, and many national and international institutes have been set up to acquire, increase, store, distribute, and use them for crop improvement. This article briefly reviews the steps involved in the acquisition of germplasm, from the planning and conduct through the follow-up stages of germplasm collecting expeditions.

WHY COLLECT GERMPLASM?

Genetic resources, including landraces (farmer varieties) and wild relatives of our crops, are crucial to global food security. These resources are distributed worldwide, but with a concentration of diversity south of the tropic of Cancer (Fig. 1). The size and distribution of economic gains from yield increases in the major U.S. crops attributable to genetic improvements is impressive. Farmers have benefited from a 1% yield increase per year, half of this due to genetic improvements. Based on these assumptions, a one-time permanent estimation of the worldwide value to consumers of germplasm, as assessed by reduced food prices, is between \$8.1 billion and \$15.4 billion.[1] Although the United States enjoys 50–60% of these benefits, consumers in developing and transitional economies enjoy between \$6.1 and \$11.6 billion of the benefits. Whereas the ultimate goal of germplasm acquisition is crop improvement, a major subsidiary benefit is the availability of these collections for characterization studies (e.g., taxonomic studies) to aid breeders.

Germplasm may be acquired either by exploration or from existing germplasm collections. Exploration is a means of obtaining germplasm that does not exist in ex situ collections. For the major crops, relatively good coverage exists in some national programs and in the International Agricultural Research Centers (IARCs) of the Consultative Group on International Research (CGIAR). Examples are the International Rice Research Institute (IRRI) in the Philippines and the International Maize and Wheat Improvement Center (CIMMYT) in Mexico.[2,3] However, collecting needs remain, even in the major crops; and many minor orphan crops have major collecting needs.

HISTORY OF PLANT COLLECTING

Germplasm acquisition has a long history, with records of exchanges between cultures dating back thousands of years. International germplasm collecting expeditions in the 16th and 17th centuries were largely focused on exotic foods and ornamentals for botanic and university gardens. The Royal Botanic Gardens at Kew, England, established a widespread network of botanic gardens, resulting in the movement of enormous numbers of samples worldwide. Botanic gardens published new collections in seed lists that facilitated free worldwide exchanges of germplasm. The number of introductions brought into cultivation by botanic gardens exceeded 80,000.[4]

Private industry and gardening societies also collected, maintained, and exchanged germplasm, as did state and federal agencies. The early 19th century saw the development of major national collections, such as the All-Union Institute of Plant Introduction in St. Petersburg, Russia, later renamed the N.I. Vavilov All-Union Scientific Research Institute of Plant Industry (VIR). This institute, initiated by Nicolay Vavilov, sponsored collections worldwide and established an extensive system of national institutes to maintain, characterize, and use them. The U.S. Department of Agriculture (USDA) plant exploration program began formally in 1898 with the creation of the Section of Seed and Plant Introduction that evolved into an organized U.S. National Plant Germplasm System (NPGS). From 1898 to 2001, the USDA conducted 540 explorations, 80% to foreign countries.

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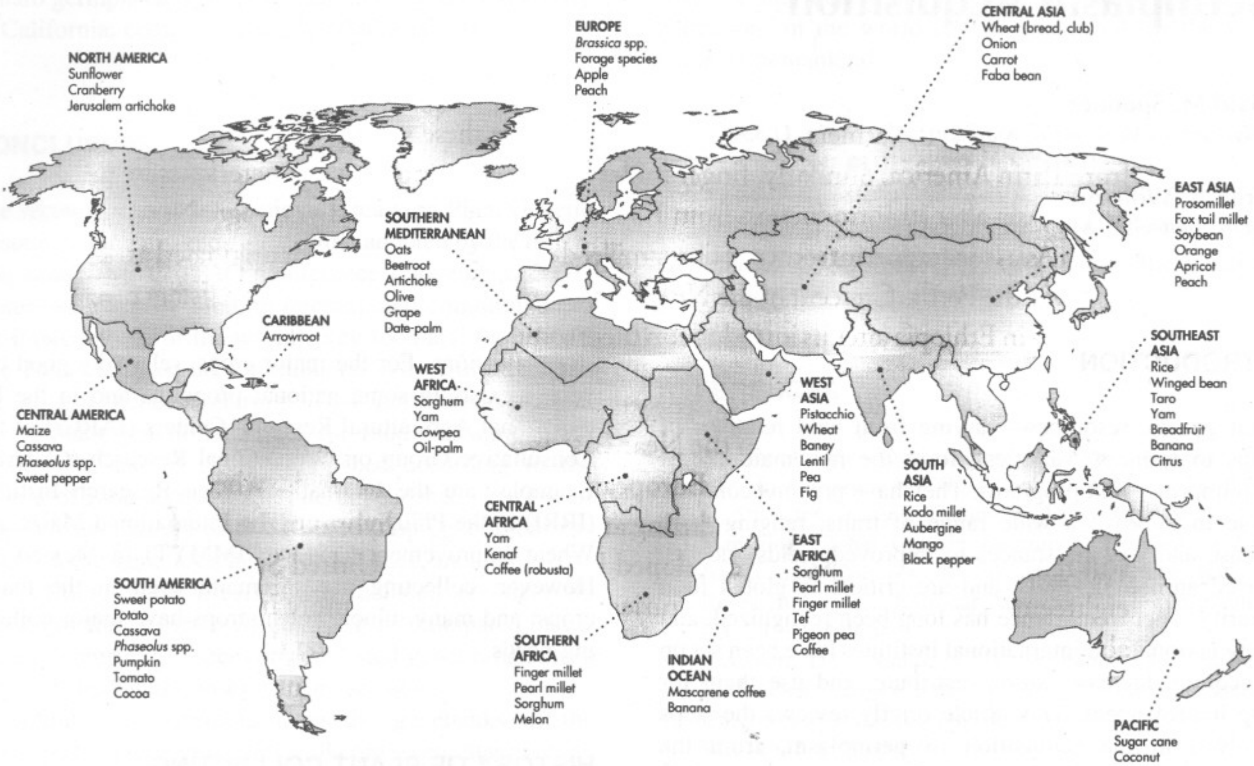

Fig. 1 Regions of diversity of major cultivated plants. (Figure from Ref. 2. Used with permission of the United Nations Food and Agriculture Organization.)

Explorations were made in every year except the war years, 1942–1945. Today the NPGS is the largest national germplasm system in the world, with 450,000 samples covering more than 10,000 species.[5] At least a quarter of the yearly distributions made by the NPGS are to scientists outside the U.S. National genetic resources programs are established in many other countries, and over six million collections are estimated to occur in ex situ genebanks worldwide.[2] In the future, the International Treaty on Plant Genetic Resources for Food and Agriculture (IT) will govern access to germplasm for Plant Genetic Resources for Food and Agriculture, which has been agreed to by country members of FAO and will enter into force upon ratification by the required number of countries. The implementation of the Treaty will determine the future ease of access.

ACCESS

In the initial stage of germplasm collecting, and continuing through the 1960s and 1970s, most germplasm was generally freely available. Exchange of plant genetic resources is now the subject of the IT, which was adopted by the FAO Commission on Plant Genetic Resources in November, 2001, and will become international law once it is ratified by 40 countries. The treaty establishes a multilateral system for the exchange of key crops and forage species. National laws of countries that are parties to the IT must be adjusted to conform. In some countries, national genetic resources programs are not yet established or their regulations have not yet been implemented. In others, access (including that required for plant exploration) has already been subject to new regulations. In order to address developing countries' concerns regarding benefit sharing, which is required by the new treaty, some developed nations are exploring the association of increased nonmonetary benefits, such as student training; the transfer of equipment, information; and technology; and other collaborative exchanges, with agreements on access.[6]

PLANNING AN EXPEDITION

Extensive background work is critical to the success of germplasm explorations, beginning with the definition of

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goals. Most explorations are initially intended to fill in gaps in current collections, as determined by taxonomic, ecological, or geographic criteria. Thus, an exhaustive search of available collections (national genebanks, international genebanks, and individual research collections) should be made before an exploration is contemplated. Some apparently available germplasm is not accessible because it is not increased, is diseased, or is otherwise restricted. Sometimes, discordant taxonomies of the same group make the task of comparing all sources of information difficult because of competing names and classifications (see an example in wheat at http://wheat.pw.usda.gov/ggpages/DEM/9IWGS/taxonomy.html and potato).[3] Searching for germplasm currently available in genebanks is simplified by the on-line availability of the germplasm in the genebanks of the CGIAR http://www.singer.cgiar.org/) and the U.S. NPGS http://www.ars-grin.gov/npgs/), but germplasm holdings of many smaller genebanks require direct correspondence with managers. The determination of all germplasm collections available is facilitated by indices of common collections held in common among genebanks,[7] although such indices are rare. Monographs (treatment of a particular group) and floras (treatment of all plants in a particular region) provide locality data, as well as identify regional herbaria. (An index of herbaria, *Index Herbariorum*, is available at http://www.nybg.org/bsci/ih/ih.html.)

Once the goals of an exploration have been identified, successful planning involves attention to access agreements, identifying and establishing contacts with knowledgeable in-country field collaborators, timing, logistics, and field equipment.[4,8,9] The new political climate can make access agreements difficult to obtain, and planning must begin well in advance. Agreements with host countries should clearly state details of the collection, export, increase, intended use, and distribution of germplasm. An experienced collaborator—ideally one who knows the logistics, culture, and crop—is essential. Timing of the expedition is crucial, especially for highly seasonable species for which differences in rainfall the prior or current year can drastically affect the growth of plants in a given year and the availability of germplasm. Germplasm collecting expeditions are expensive and time-consuming. Logistical challenges of some areas are often daunting, and investments in reliable equipment, especially vehicles, pay off. Field equipment needs vary according to the crop and terrain, but a geographic positioning system (GPS—determines latitude and longitude), altimeter (in mountainous areas), and maps are essential for reliable locality data. Some maps can be obtained only in country. Time must be allotted at the beginning of the exploration to purchase maps, visit herbaria, and meet local officials.

CONDUCTING THE EXPEDITION

Important considerations in the field include number of sites to visit, number of plants to sample, sampling techniques, and the number and type of propagules to sample from each plant.[4] These differ among species with different breeding systems and dispersal mechanisms. The number of collecting sites must be planned to maximize the amount of genetic variation sampled, within the constraints of time and funding. Marshall and Brown and others[4] proposed mathematical formulas for these that are useful when germplasm is common, as when collecting landraces. For many crops, populations are often so scarce that these theoretical calculations give way to the practicality of collecting sufficient germplasm of all populations encountered to ensure a successful germplasm increase, taking care to maintain populations intact in the wild. Collecting methodologies depend on a number of factors, including the biology of the targeted taxon and the objectives of the expedition. Different types of propagules, whether seed or vegetative, require different sampling and handling techniques in the field.

Local markets provide a relatively easy means of collecting landraces for many crops, and are important sources of information on the diversity of a crop in a given area. However, visits to local farmers provide better information on plant characteristics, uses, and cultural methods; higher quality germplasm; and varieties grown only for home consumption. Visiting farmers of different ethnicity is as important as visiting different ecogeographic regions.

Minimal data to be recorded when collecting germplasm should describe country, lower-level administrative units, locality, latitude, longitude, altitude, collector number, type of material (seed, vegetative, pollen, in vitro material), improvement status (wild, weedy, landrace), abundance, morphological description of the accession, and habitat. Additional data that may be collected include slope, aspect, landform, and various descriptors for soil, drainage, and vegetation. Such basic data collected in the field have been referred to as passport data (as used elsewhere in this volume). The more data collected the better, but the need for data must be balanced with time constraints and the need to visit additional sites. Some descriptors applying only to landraces include farmer name, cultural methods used by farmers, length and time of growing season, history of landrace, and traits perceived by the farmer and other users. Herbarium vouchers are also needed to document the collection, with enough duplicates to ensure that sets are left in the country and others left in recognized institutions upon return home. Collections ultimately are studied by a wide array of broadly defined prebreeding studies to guide the breeders in their use, as taxonomy, diversity screening, or resistance evaluations. Such studies vastly increase the value of collections, and can be greatly aided by the careful collection of the field data previously described.

CONCLUSION

Most agreements stipulate the deposition of duplicate germplasm and herbarium samples in the country, although others may state otherwise (e.g., collectors may be allowed to leave with all germplasm if the host country is provided with a sample of the first germplasm increase). Successful passage of samples through quarantine to the germplasm station is greatly facilitated by cleaning and processing samples properly. For example, herbarium specimens and fruits often harbor adult insects or larvae, so proper fumigation and seed extraction are crucial to successful introductions. Notes taken in the field are often scanty; it is best to write a complete report soon after the expedition, before facts are forgotten. Well-planned and conducted expeditions often merit publication in peer-reviewed crop-specific journals or journals devoted to germplasm collections and evaluations, such as *Genetic Resources Newsletter*, FAO. Such publication makes results of an expedition accessible to the world germplasm community. When published with cooperators, it generates goodwill and opens doors for continued collaboration.[10]

ARTICLES OF FURTHER INTEREST

Crop Domestication in Mesoamerica, p. 310
Crop Domestication: Fate of Genetic Diversity, p. 333
Crop Improvement: Broadening the Genetic Base for, p. 343
Genetic Resource Conservation of Seeds, p. 499
Genetic Resources of Medicinal and Aromatic Plants from Brazil, p. 502
Germplasm Collections: Regeneration in Maintenance, p. 541

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