Chapter 21: Collecting vegetatively propagated crops (especially roots and tubers)

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Abstract

Many of the developing world's poorest farmers and food-insecure people are highly dependent on root and tuber crops (RTCs) as a supplementary, if not principal, source of food, nutrition and cash income. Hence, the development and utilization of genotypes that can withstand abiotic and biotic pressures are the keys for sustainable production. Genes for such traits are often available in wild species and landraces; therefore, their genetic resources need to be collected, documented, characterized, evaluated and preserved. This paper supplements the original 1995 chapter by summarizing recent technical guidelines for collecting both wild and cultivated roots and tubers. The sampling procedures are discussed with particular attention given to the involvement of local communities in the case of cultivated species. To be of value, accessions should be well documented, an issue that is discussed, and guidelines are provided. Techniques of handling vegetative material in the field are summarized and the concept of *in vitro* collecting presented. Future challenges and needs in the areas of report preparation, germplasm conservation, research (characterization and evaluation) and information exchange are briefly discussed.

Introduction

Root and tuber crops are plants that are grown for their modified, thickened roots or stems, which generally develop underground (Bradshaw 2010). These organs are rich in carbohydrates and are commonly used as a dietary staple, livestock feed, raw material for the production of industrial products such as starch and alcohol, or processed into various food products.

The 1995 version of this chapter lists the most important root and tuber crops. This list has not changed. Those cultivated on a global scale include potato (*Solanum tuberosum*), cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), yams (*Dioscorea* spp.) and taro (*Colocasia esculenta*). Others that are of regional, national or local importance include, in total, over a dozen dicot and monocot families, most of which originated in tropical or subtropical areas. While they are mainly used as sources of carbohydrates, many minor root and tuber crops, such as turmeric (*Curcuma longa*) and arrowroot (*Maranta arundinacea*, *Tacca leontopedaloides*), are used in folk medicine and as spices (Sastrapradja et al. 1981).

This chapter is a synthesis of new knowledge, procedures, best practices and references for collecting plant diversity since the publication of the 1995 volume *Collecting Plant Diversity; Technical Guidelines*, edited by Luigi Guarino, V. Ramanatha Rao and Robert Reid, and published by CAB International on behalf of the International Plant Genetic Resources Institute (IPGRI) (now Bioversity International), the Food and Agriculture Organization of the United Nations (FAO), the World Conservation Union (IUCN) and the United Nations Environment Programme (UNEP). The original text for Chapter 21: Collecting Vegetatively Propagated Crops (Especially Roots and Tubers), authored by Z. Huaman, F. de la Puente and C. Arbizu, has been made available online courtesy of CABI. The 2011 update of the Technical Guidelines, edited by L. Guarino, V. Ramanatha Rao and E. Goldberg, has been made available courtesy of Bioversity International.

All these crops are vegetatively propagated. There are many different types of plant material that can be used to propagate crops vegetatively, definitions and examples of which are given in the 1995 version of this chapter.

Collecting material

Site selection

In addition to the plant material used for propagation, the selection of the site where the plants are to be collected is very important. Selecting sites only along roads should be avoided. Selected sites should be well spread throughout the occurring (wild species) or the production (cultivated species) zones of the species. Some collecting sites should be also selected in the marginal production areas where rare varieties may be found, following Bressan et al. (2005), Clausen et al. (2005) and Pillai et al. (2000). With yam, for example, marginal areas include arid zones affected by drought, lowland rich regions and mountainous zones with gravelly soils normally not suitable for the production of this crop but where particular varieties adapted to these abiotic constraints are cultivated.

Documentation

To be of value, collected accessions should be well documented. For this, it is important to prepare a documentation sheet adapted to the species considered. Bioversity International has developed such collecting sheets for many crops (including roots and tubers). These sheets included in the crop descriptors, can be used as models. Multi-crop passport descriptors (Alercia et al. 2001) also exist and can be used. Descriptors for farmers' knowledge of plants have also been recently developed by Bioversity International to provide a standard format for the gathering, storage, retrieval and exchange of farmers' knowledge (Bioversity and The Christensen Fund 2009). Labelling (markers, plastic labels, etc.) and field handling materials (bags made with net, for example, for better airing) should also be prepared. Collecting sites should be georeferenced (latitude, longitude, altitude) using GPS.

Sampling

In a traditional farmer's field of a root or tuber crop, there will be a mixture of many different genotypes (e.g., Jackson et al. 1980), each being the result of intensive selection by farmers over many generations. Random sampling of such a field, the usual method for sexually reproducing species, is not appropriate, as it will over-represent abundant clones at the expense of rare ones. In regions such as West Africa, where there is a good association between names and diversity for some crops (yam, taro, cassava, etc.), a two-step procedure involving farmers at both the community and individual level is recommended.

First, an exhaustive inventory of the farmer-named varieties or morphotypes is made at village level and in groups of 40 to 60 farmers (depending on the size of the community) of different ages as older farmers have a better knowledge of the ancient varieties, while young farmers will be more knowledgeable about the novel varieties and uses. To carry out a correct inventory, an understanding of the folk nomenclature is sometime a prerequisite. A typical example is related to yam with the sociolinguistic group Yom in northern Benin. In that ethnic area, where single-harvest and double-harvest varieties of guinea yam (*D. cayenensis* and *D. rotundata*) and varieties of water yam (*D. alata*) are known under the generic names of "assina", "noudouosse" and "kpatanga", respectively (Dansi et al. 1997), a diversity inventory generally erroneously yields three varieties (instead of 20 to 60), which are nothing more than these three types of yam, if a detailed listing under each category is not requested from farmers.

Second, collect three to four propagules of each listed variety per site (e.g., village). Generally, at tuber-collecting time for some crops, such as potatoes and yam, there will be no above-ground parts visible to identify the variety or look for any morphological variation. Moreover, when farmers harvest the tubers, they gather them (mixed or separated) in barns. It is recommended that the propagules be collected from different farmers, and when possible, experienced farmers should be asked, in groups, to confirm the identities of the propagules before numbering them (e.g. collector number) and recording data on them. With species like yam, where two harvests are possible, the use of the terms "early-maturing" and "late-maturing" to distinguish single-harvest and double-harvest varieties should be avoided as it creates confusion: farmers differentiate early-maturing and late-maturing cultivars within the single-harvest and the double-harvest classes of yam. This process should be repeated at each sampling site.

Farmer's knowledge

Local knowledge is crucial to the sampling process, just as it is crucial in deciding when and where to sample in the first place. Most farmers are aware of the extent of variation in their field, village and district, i.e., the number of distinct cultivars available in a given area, their names, appearance and characteristics. Documentation of varieties by individual farmers is good, but for accurate data collection, it is recommended that the documentation exercise be carried out with farmers in groups in order to avoid incorrect information. At each collecting site, the distribution and extent of each listed variety are among the crucial information to be documented; its compilation at the national level will indicate where and how common each farmer-named variety is across the country. This can easily be assessed using the Four Squares Analysis (FSA) approach described by Brush (2000), Tuan et al. (2003) and Dansi et al. (2008; 2010). At the community level, and based on two parameters (number of households and cultivated area), this method of participatory analysis helps to classify existing varieties into four groups: varieties cultivated by many households on large areas (++), varieties cultivated by many households on small areas (+ -), varieties cultivated by few households on large areas (- +) and varieties cultivated by few households on small areas (- -) (see table 21.1). To do this, varieties are individually taken and evaluated by farmers (in groups) using the first parameter (number of households). For this parameter, farmers are asked to indicate for each variety whether it is produced by many or few households. The same evaluation process is repeated for all the varieties for the second parameter (cultivated area). By combining the results of the two parameters, varieties can be classified into the different quadrants, and the results can immediately be presented to the farmers for comments and validation. Table 21.1 and figure 21.1 present, as examples, the results recently obtained on yam (*Dioscorea rotundata*) at Igboloudja (District of Ogou, Department of Plateau), a village of southern Togo (Dansi, unpublished).

Four-cell/square analysis is a powerful participatory tool to understand the amount (richness) and distribution (evenness) of crop diversity at the community level and socioeconomic rationale of them for community-based conservation actions. At the same time, this can be used to make decision as to which varieties to collect on priority basis. In the above example, the collector may assign higher priority to collect the varieties that are rare (occurring in the right hand bottom quadrant) as these are cultivated by few households and in small areas and hence are greatly threatened with genetic erosion. It is important to note that the time required to do the FSA depends on the number of varieties. Generally, the time available to collectors in any given location or site is relatively short, so to avoid wasting time, the process should be well understood by the collectors (some level of training in using the methodology is therefore required) and well explained to the local community.

In vitro collecting

Chapter 24 of the Technical Guidelines describes the concept of *in vitro* collecting, gives general guidelines and provides some examples. Two further examples are worth mentioning here, specifically that focus on root and tuber crops. The *in vitro* collecting method developed at the International Center for Tropical Agricultural (CIAT) for cassava consists in taking actively growing vegetative buds or terminal stem cuttings from branches without flowering buds. Explants of 1.0cm to 1.5cm are immersed in 70% ethanol for 5–15 minutes and then surface-sterilized by immersion in a 0.5% solution of calcium hypochlorite for 5 minutes. Finally, they are rinsed with cool boiled water. Explants are inoculated into semisolid culture medium (MS or 4E) containing an antibiotic such as rifampicin in a small wick of filter paper. In contrast, the *in vitro* methods tested at the International Potato Center (CIP) for sweet potatoes have so far not produced high rates of survival of the cultures. A simple method that has been partially successful consists of taking cuttings containing one node with axillary buds; they are surface-sterilized and introduced into a test tube containing 1ml of antibiotic solution (100ml distilled water + 0.025 g streptomycin). Particularly high losses due to contamination have been noticed in sweet potatoes with thin or very pubescent stems.

Table 21.1: List, Distribution and Extent of Yam (*Dioscorea rotundata*) Landraces Recorded at Igboloudja (South of Togo)

Double-harvest varieties	**Households**	**Cultivated Areas**	**Single-harvest varieties**	**Households**	**Cultivated Areas**
Afo	+	–	Arèkpè	–	–
Akoko	–	–	Bodé	–	–
Amoula	–	–	Gnarabo	–	–
Awonté	–	–	Karatchi	+	+
Dendi	–	–	Kôlor	–	–
Digbiri	–	–	Korodjo	–	–
Dôdô	–	–	koukou	+	+
Ewourou	–	–	Koukou foulani	–	–
Fananan	+	+	Kpakata	–	–
Gnidou	+	+	Tchabigara	–	–
Kangni	–	–	Tchakatchaka	+	+
Kodjéwé	–	–	Tchôkôyôkôtô	–	–
Laassiri	–	+			
Labôkô	+	–			
Lafia	+	+			
Lèkè	–	–			
Loumon	–	+			
Modji	+	+			
Oboti	–	–			
Ôkpè	–	+			
Sotouboua	+	+			
Tédji	–	–			
Yobèrè	–	–			

COMMON VARIETIES **Varieties cultivated by many households on large areas (++)**	**COMMON BUT THREATENED VARIETIES** **Varieties cultivated by many households on small areas (+ –)**
Fananan Gnidou Karatchi Koukou Lafia Modji Tchakatchaka Sotouboua	Afo Labôkô
RARE BUT NOT THREATENED VARIETIES **Varieties cultivated by few households on large areas (– +)**	**RARE VARIETIES** **Varieties cultivated by few households on small areas (– –)**
Laassiri Loumon Ôkpè	Akoko * Amoula* Arèkpè Awonté Bodé Dendi* Digbiri Dôdô Ewourou* Gnaranbo Kangni Kodjéwé Kôlor Korodjo Koukou foulani Kpakata Lèkè Oboti Tchabigara Tchôkôyôkôtô* Tédji Yobèrè

Note: Newly introduced varieties are marked with an asterisk.

Figure 21.1: Diagrammatic representation of the classification of yam varieties into the four quadrants after the participatory evaluation at Igboloudja (south of Togo)

Future challenges/needs/gaps

Conservation of collected germplasm in the field

Various approaches exist for the conservation of the collected germplasm, among which is the field genebank. In field genebanks, the plant genetic resources (PGR) are kept as live plants that undergo continuous growth and require continuous maintenance. Field genebanks provide an easy and ready access to the PGR for characterization, evaluation or utilization (Saad and Ramanatha Rao 2001). However, a field genebank is generally expensive to maintain and has high levels of risk from natural disasters and adverse environmental conditions like drought, floods or attacks from pests and diseases (Engels and Visser 2003). When field genebank conservation is the only feasible option, careful planning and field management can help to mitigate the risks.

For cultivated species like cassava, taro and yam, in which synonymies are frequent, accessions of the same vernacular name may be planted side by side to facilitate observations. Before planting, some collected materials may be cleaned through treatment with a complex of insecticide, nematicide and fungicide to avoid attack by and /or propagation of pests and diseases. It is recommended that a minimum of five plants be maintained for each accession, as well as duplicate field genebanks in more than one site or an *in vitro* genebank as a safety backup (Reed et al. 2004). Best practices for establishing and managing a field genebank are described by Reed et al. (2004). Recently, the Global Crop Diversity Trust assisted many countries in regenerating and safely duplicating their root and tuber crop germplasm in another genebank, such as the one at the International Institute of Tropical Agriculture (IITA).

Information exchange

Effective sharing of information about the collected germplasm is important. For this, Bioversity and its partners have published several descriptor lists (www.bioversityinternational.org) to standardize the way plant resources should be documented. For *Allium*, banana, carrot, potato, sweet potato, taro, *Xanthosoma* and yam, such descriptors exist free of charge and should be used. Recently, FAO has developed a database named HORTIVAR (www.fao.org/hortivar/index.jsp) in which information on the performance of cultivars can be compiled for public use. Writing and publishing a comprehensive report on a collection mission – as Pillai et al. (2000) have done on taro, Adair et al. (2006) have done on *Allium*, and Nair and Sekharan (2009) have done with *Saccharum* – is recommended.

Morphological and genetic characterization

Morphological characterization should be carried out to identify morphotypes and cultivar groups. For the cultivated species in which synonymy exists, complementary participatory characterization and classification is recommended for correct establishment of the equivalence between vernacular names.

Some species, like yam, that are polyploid, require cytogenetic characterization by chromosome count and flow cytometry (Dansi et al. 2000, 2001, 2005).

When possible, molecular characterization should be also done for diversity assessment and duplicate identification. Details on the use of molecular markers in the management of PGR can be found in Karp et al. (1997) and Spooner et al. (2005), as well as for some species, such as cassava (Raji et al. 2009, yam (Siqueira et al. 2011) and taro (Mace et al. 2006). There are numerous specific publications in the literature that can serve as guides.

Conclusion

There are not many countries that have perfect germplasm collections of their root and tuber crops. Many root and tuber crop species are neglected, underutilized, absent or poorly represented in both national and international genebanks. Apart from the commonly cultivated species, the genetic variability of many root and tuber crops is seriously endangered, mainly due to environmental degradation and changes in agricultural practices. Their diversity can be preserved and used only if it is collected in time.

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Internet resources

Descriptors for farmers' knowledge: www.bioversityinternational.org/nc/publications/publication/issue/descriptors_for_farmers_knowledge_of_plants.html

HORTIVAR (Horticulture Cultivars Performance Database): www.fao.org/hortivar/index.jsp

Multi-crop passport descriptors: www.bioversityinternational.org/nc/publications/publication/issue/faoipgri_multi_crop_passport_descriptors.html