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# GUADELOUPE, F. W. I., 21 - 24 APRIL 1992

EDITED BY

MARTEN SØRENSEN

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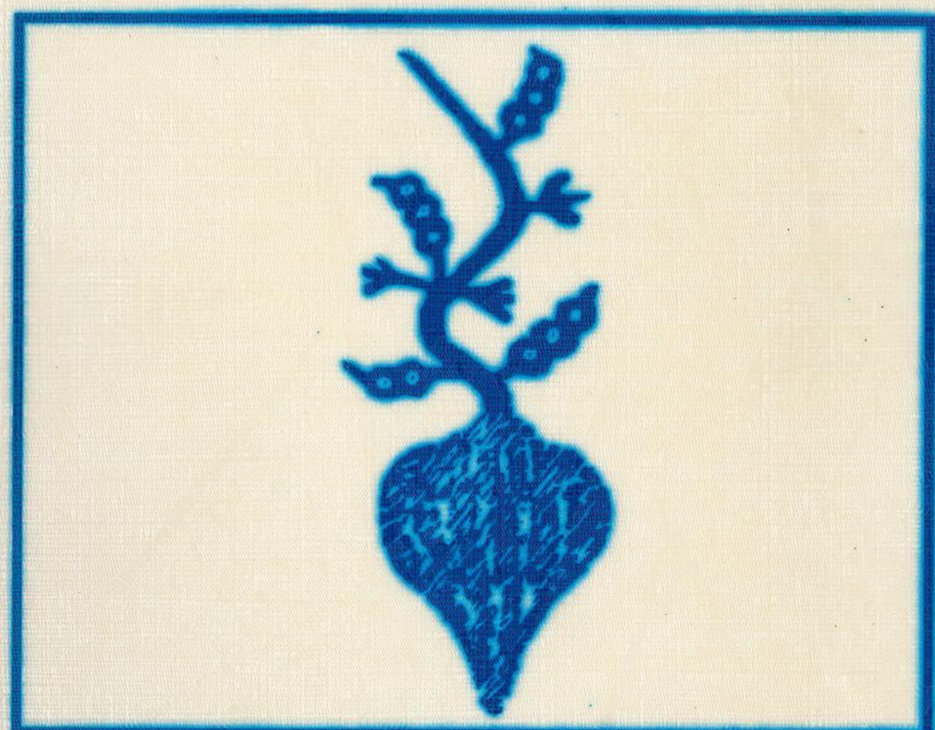

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# INTRODUCTION TO THE CONSERVATION OF GENETIC RESOURCES OF AMERICAN TUBER LEGUMES (*PACHYRHIZUS*)

D.G. Debouck

## INTRODUCTION

Due to changes in patterns of food production and consumption in recent years, and pressures on natural vegetation by encroaching agriculture, overgrazing, urban and industrial expansion, many plant genetic resources have become endangered in several parts of the world. This is the case for Latin America where it is calculated that up to 1 million hectares of tropical forests by a conservative estimate might be converted yearly to shifting agriculture, pasture land and other land uses (Gámez, 1989; Mather, 1990; World Resources Institute, 1990). Loss estimates for crop cultivars in Latin America are even more difficult because of the lack of censuses and detailed agricultural statistics at individual crop level, but the success of introduced food crops such as rice, wheat, pea, soybean, cabbage can hardly be denied, making some traditional crops to become marginal (Martínez Alfaro *et al*. 1992).

A group of crops from the Neotropics that has suffered particularly from genetic erosion and neglect is the one of the American tuber legumes of the genus *Pachyrhizus* Rich. ex DC., also known as yam beans (Vietmeyer, 1986). This genus of the subtribe Diocleinae within the Phaseoleae- Papilionoideae-Leguminosae (Lackey, 1977, 1981) includes probably five species (Sørensen, 1988) (six according to Lackey, 1981), of which two species *P. erosus* (L.) Urban and *P. tuberosus* (Lam.) Sprengel were domesticated in Central America and western upper Amazonia respectively, and one species *P. ahipa* (Wedd.) Parodi probably in the Peruvian and Bolivian Andes (Sørensen, 1988) (see Table 1).

A very common use of yam beans in Central America is that of eating the peeled roots raw with salt and lemon juice (León, 1987; National Research Council, 1979). Roots can also be boiled retaining their crunchy texture or fried (National Research Council, 1989). Green leaves and stems can also be used as green manure; nitrogen fixation ability has been reported (Kjær, 1992). Compounds with insecticidal properties (probably rotenone and others: Sørensen, 1990) are present in leaves, stems, ripe pods and seeds and are reported to be toxic to humans (National Research Council, 1979; Yamaguchi, 1983); alternatively, these plant parts can serve as means of biological control (Esquivel *et al.*, 1992), but poorly exploited so far. Yields for *P. erosus* have been reported reaching up to 80 t/ha in Mexico, Indonesia and the Philippines (National Research Council, 1979). These yields are interesting, and they could be even higher, once hybrid vigour is commercially fully exploited (Sørensen, 1990). Although mineral and vitaminic composition is not particularly outstanding (Sørensen, 1990), starch quality has been reported as good because of high digestibility (National Research Council, 1989). In spite of a historic decline in its Andean native country (Brücher, 1989; Herrera, 1942; Parodi, 1966; Yacovleff, 1933) that lead a certain number of scholars (e.g. Estrella, 1988) even up to mistake it for *yacón, Polymnia sonchifolia* Poepp. & Endl. (Asteraceae), *P. ahipa* might have an impressive potential in other countries such as Portugal (M. Sørensen, pers. comm. 1993). Yam beans thus offer several opportunities as vegetables, as sources of chemicals, as food for cattle feeding, as means for soil protection and improvement.

**Table 1.** Primary range of the five species of *Pachyrhizus* in the Americas according to Sørensen 1988 (see additional comments in the text).

| Species | Cultigen | Wild form | Primary range | Altitude |
|---|---|---|---|---|
| *P. erosus* | yes | yes | western-south Mexico to NW Costa Rica | 0-1,700 |
| *P. tuberosus* | yes | yes | Ecuador to N Peru, western Amazonia | 0-1,500 |
| *P. ahipa* | yes | unknown | scattered in Peru and Bolivia | 1,500-2,500 |
| *P. panamensis* | no | only | Panama and SW Ecuador | 0-800 |
| *P. ferrugineus* | no | only | Mexico to Colombia | 0-1,600 |

**An important past use**

Yam beans were domesticated quite early in pre-Columbian American agriculture. The jicama *P. erosus* was probably cultivated by the Old Empire Maya (300-500 A.C.) (Lundell, 1939; Wiseman, 1978), although not confirmed afterwards (Turner II and Miksicek, 1984). As the later authors mentioned it, archaeological material of yam bean could be rare because of ways of consumption and production (inflorescences are frequently pruned off for higher root yield: Sørensen, 1990) and also because plant material could be prone to rotting in tropical conditions. Pollen has been rarely considered by archaeologists. Interestingly enough, the Mayan name for yam bean (jícama in Spanish, see Table 2) is *chicam* (Patiño, 1964; Torres, 1985). According to the former author that word may specifically refer to the act of chewing the root. Torres (1985) mentioned in addition the consumption of the dried root by pre-Columbian Mexican Indians. *P. erosus* is also described by Brother Francisco Ximénez when writing about native plants of Guatemala around 1722 (Ximénez, 1722).

**Table 2.** Vernacular names of cultivated *Pachyrhizus* species in the Americas showing their antiquity and early distribution (see additional comments in the text).

| Species | Name | Language | Place | Source |
|---|---|---|---|---|
| *P. erosus* | catzotl | nahua | Mexico | 1 |
| | chicam | maya | Mexico | 1 |
| | jícama, jícama de agua | mestizo | Mexico | 1,2,3 |
| | nupe, nupera | cumana | Venezuela | 2,4 |
| *P. tuberosus* | yaspo | huitoto | Peru | 5 |
| *P. ahipa* | asipa | quechua | Peru | 6 |
| | villu, huitoto | aymara | Peru | 6,7 |
| | ajipa | quechua | Bolivia | 8 |

Sources:

1 = Torres 1985, 2 = Patiño 1964, 3 = Martínez 1979, 4 = Pittier 1926, 5 = Soukup 1986, 6 = Yacovleff 1933, 7 = Brücher 1989, 8 = Cárdenas 1989

In western South America where conditions for preserving such archaeological plant material are better, *Pachyrhizus*, probably *P. tuberosus* (the possibility that all archaeological material belong actually to *P. ahipa* cannot be excluded however: see Sørensen, 1990), has been found in at least four Preceramic sites (around 2,000 B.C.) on Central Peru coast (Cohen, 1978; Engel, 1966; Grobman and Bonavia, 1978; Quilter *et al.*, 1991).

Earlier dates, i.e. 4,000 B.C., have been proposed (Engel, 1987) but as stated elsewhere (Hawkes, 1989) many of these records have to be re-checked as to species. Abundant pictural representations on Nazca pottery (Lumbreras, 1974; Yacovleff and Herrera, 1934) would indicate that yam beans were an important part of the diet on the Peruvian coast and could let us to assume the same use as today.

This important past use contrasts with, as stated above, the presence of toxic compounds in almost all parts of the plant except for the tuberous root (National Research Council, 1979). Domestication of yam beans, in contrast with that of many other crops (potatoes, pulses), would thus have induced little changes from the wild ancestors in that nutritional perspective, suggesting either detoxification practices in order to use pods and seeds or skillful knowledge about harmless parts of the plant, i.e. the roots, or at certain periods, e.g. unripe pods. Many of these aspects are still largely to be considered as they may affect the kind and amount of genetic diversity to be conserved across gene pools.

## Keeping the options alive

### Approach to the conservation of yam bean genetic resources

A noteworthy past diffusion in the Americas with some recent prospects for export as well as a wide and successful acceptance in western Africa and southeast Asia would incite to a prompt, cost-efficient and relevant conservation of genetic resources of yam bean. As for other plant genetic resources, when dealing with their conservation, one of the first questions to be addressed is regarding the amount and quality of genetic variation worth conserving. Indeed, particularly when the *ex situ* conservation approach is preferred (keeping germplasm outside its original habitat, e.g. through germplasm banks, living collections) one of the purposes of the conservation effort is to keep genetic variability in order to allow genetic progress in future breeding activities. It is thus of paramount importance to know the genetic structure of the gene pools, i.e. how the genetic diversity is distributed among the different biological entities and where that diversity is geographically located. That knowledge will be assembled through ecogeographic surveying (Anonymous, 1985) and through the coupling of limited field exploration with measures of genetic diversity by biochemical/molecular markers such as seed storage proteins, isozymes, RFLPs, DNA minisatellite (see Gepts, 1990; Hamrick and Godt, 1990; Schaal *et al.*, 1991, respectively for reviews). The matter of genetic diversity structure is also worth investigating in symbionts such as *Bradyrhizobium* which is reported as

infective of yam beans in certain soil types (Kjær, 1992). Once these basic data have been gathered it is possible to orient specific germplasm collection, conservation, evaluation efforts towards specific sets of biodiversity in specific areas etc.

These questions are also fully relevant in the case of *in situ* conservation approach (keeping germplasm inside its original habitat, e.g. through national parks, genetic reserves), the main purpose of which is to preserve the evolutionary potential of the species. The later methodology would be efficient only if one knows where the critical amounts of genetic diversity are located.

How to conserve? Once basic information about genetic diversity in the target material has been gathered more insight could be given about procedures of germplasm conservation, generally, through a blend of *ex situ* and *in situ* methods or groups of methods. While *ex situ* conservation permits easy access, utilization and exchange of germplasm (Plucknett *et al.* 1987), it generally prevents any further evolution of the genetic material the variability of which can be seen as 'frozen'. On the other hand, *in situ* conservation allows under certain conditions the continuing evolution of the genetic material in contact with selective pressures from original environments, pests, diseases, etc. (Prescott-Allen and Prescott-Allen, 1982). In addition, certain materials better fit with one group of conservation methods than the other, e.g. wild relatives of perennial fruit trees with recalcitrant seeds might be better preserved through *in situ* conservation (Anonymous, 1985). There are thus specific reasons for preferring one methodology to the other, and specific advantages, problems and costs are linked to each of them.

That choice is rarely a permanent one. As more materials are becoming endangered in the field unique sets of genetic diversity are progressively secured in gene banks. On the other hand, materials kept in gene banks may in the case of cultivated types be re-distributed to farmers or in the case of wild forms serve in habitat restoration.

But, and particularly because of the high costs of conservation (direct ones in the case of *ex situ* conservation, and indirect ones in the case of *in situ* conservation) the dynamic approach to conservation cannot be certified as fully efficient if distribution of genetic diversity among the different biological entities, and within each of them along space and time gradients, is not properly known. The jumping into germplasm rescue has often been practiced even recommended prior to studies of the patterns of genetic diversity along physical gradients or in relation to biological parameters because of the imminent danger of definitive loss; it should not become a habit, however, because conservation

possibilities especially through the *ex situ* methods are not always unlimited and cheap. But there are, obviously, imperative reasons for action, e.g. the rapid disappearance of *P. ahipa* cultigens in the southern Andes according to Brücher (1989) or of *P. tuberosus* cultivars on the western slopes of the Ecuadorean Andes according to M. Sørensen (pers. comm. 1992). Finally, since *Pachyrhizus* gene pools are spread over several Latin American countries (see Sørensen (1988), and below, about geographic distribution) in order to share costs advantage should be taken of the existing regional plant genetic resources networks such as REMERFI (Red Mesoamericana de Recursos Fitogenéticos) for Central America and REDARFIT (Red Andina de Recursos Fitogenéticos) for the Andean region.

All *Pachyrhizus* species are reported self-compatible (Kalin Arroyo, 1981) and autogamous (Sørensen, 1990). The amount of outcrossing across species and genotypes is, however, still to be established as well as whether or not all genotypes of the different species have orthodox seeds (*Pachyrhizus* is supposedly with orthodox seed storage behaviour: Ellis *et al*. (1985)). These are indeed requisites to be filled prior to the launching of a major *ex situ* conservation programme which seems to be a feasible conservation method for this group of crops in addition to the specific advantages of certain *in situ* conservation efforts. Finally, prior to germplasm movements seed-transmitted diseases should also be investigated. The possibility of collecting strains of *Bradyrhizobium* together with seed germplasm for *ex situ* conservation is worth considering if the receiving germplasm bank(s) is (are) properly equipped to deal with that additional variability.

## Germplasm priority conservation actions across the species

### *P. erosus* (L.) Urban

This species is perhaps the one that has experienced the widest cultivation outside the Americas (see Sørensen (1990) for records of cultivation in Africa, southeast Asia and the Pacific) since 1492, and thus a wide range of genetic diversity might be kept through cultivation. Its recent success in the United States (National Research Council, 1989; Yamaguchi, 1983) may lead, however, to a progressive disappearance of less productive landraces in its original nuclear area: the Mexican Bajio, the Peninsula of Yucatan, and southeastern Guatemala. In Guatemala the yam bean *P. erosus* has indeed been reported (Standley and Steyermark, 1946) as cultivated in the departments of Peten, Chiquimula

and Jutiapa. A survey of still existing landraces is thus necessary with the help of biochemical/molecular markers to assess patterns of genetic diversity since little variation is expressed in the phenotype, with the exception of leaflet outline (Sørensen, 1988), and where necessary with additional collecting of germplasm for *ex situ* conservation. An appraisal of the founder effect which is a modification of genetic diversity as a result of domestication with an assessment of genetic diversity across wild forms, escapes from cultivation, landraces, and 'improved' cultivars, is also needed, as this will target germplasm collecting towards the most diverse material. In four cultigens of another American genus of edible pulses (Gepts *et al.*, 1986; Maquet *et al.*, 1990; Schinkel and Gepts, 1988; Schmit and Debouck, 1991) a strong founder effect between the wild and the cultivated forms has been demonstrated. Thus, the wild forms represent in this case the true reservoir of variability for future crop improvement and evolutionary potential of species. If such an effect is evidenced in yam bean a systematic plotting of all wild populations should be undertaken particularly from Jalisco, Mexico, down to Guanacaste, Costa Rica (Sørensen, 1988) with indications to where genetic reserves should be established and, if not possible, germplasm collecting and *ex situ* conservation. Whether germplasm collecting should be extended to include the Antilles (it is reported from Cuba: Esquivel *et al.*, 1992) is not clear till we know the extent of original diversity present there in comparison to the one on mainland.

***P. tuberosus* (Lamarck) Sprengel**

The approach recommended above for the conservation of yam bean or jicama genetic resources is largely applicable to this species, also called the potato bean. A survey for landraces is needed throughout its nuclear area, mainly Ecuador (all tropical rainy departments on both sides of the central Cordilleras but perhaps not the Amazonian Ecuador: Renner *et al.*, 1990!) and northern Peru (departments of Piura, Amazonas, Loreto, San Martin, and Cuzco). On the basis of their ecological characteristics other potential areas for landraces might include the departments of Putumayo and Caqueta of Colombia, Acre of Brazil and Beni of Bolivia. According to Brücher (1989), it might already be extinct in Paraguay while it was still cultivated there at the beginning of this century (Sørensen, 1988). This fact, if proven, would indicate some urgency of conservation actions for this species, a priority also recognized for Ecuador by Castillo T. (1991). The existence of a wild ancestor for the potato bean is still unclear, although the

herbarium specimen *Y. Mexia 6717* was reported as 'Habilla del monte' (transl. 'little pulse from the bush') growing in open woods in the Cotopaxi department of Ecuador (M. Sørensen, pers. comm. 1992). Obviously much more ecogeographic surveying in the field is needed in conjunction with measurements of genetic diversity by molecular markers.

***P. ahipa* (Weddell) Parodi**

As stated above, all available records (Brücher, 1989; Herrera, 1942; Parodi, 1966; Yacovleff, 1933) point to a quick disappearance of landraces of this cultigen in its nuclear area, Peru and Bolivia. It should thus be a priority for ecogeographic surveying and germplasm collecting (also stressed by Brücher, 1989) because of its interesting agronomical attributes such as erect growth habit and earliness (Sørensen, 1990; Yamaguchi, 1983) that could perhaps help to the germplasm enhancement of other species through widecrossing (Sørensen, 1990). Possible places to be visited are: valleys between 1,500 m and 2,500 m a.s.l. of rivers Marañon, Mantaro, Pampas, Apurimac and Urubamba in Peru, and the Yungas of La Paz and of Cochabamba, Bolivia (Cárdenas, 1989; Weddell, 1857). As the crop has been seen in the past in Jujuy, Argentina (Parodi, 1966), checks in Tarija, Bolivia, might be fruitful too. The structure of its gene pool deserves additional research since no wild ancestral form has been identified so far (Sørensen, 1988).

***P. ferrugineus* (Piper) Sørensen**

This wild species, formerly called *Calopogonium ferrugineum* by Piper and *Pachyrhizus vernalis* by Clausen, is distributed from Chiapas and Quintana Roo, Mexico down to Panama and Chocó in Colombia (Sørensen, 1988). Ecogeographic surveying in the field coupled with genetic diversity assessment with biochemical/molecular markers is needed in order to determine its exact geographical range, its status in the field (as endangered, rare, etc., following accepted standards: Munton, 1987), practicalities and needs for *in situ* and *ex situ* conservation. The possibility of establishing national parks along the Isthmus which include populations representing unique diversity should be considered.

***P. panamensis* Clausen**

A wild species distributed in deciduous neotropical forest around the Canal Zone of Panama, in Santa Marta in Colombia and in the provinces of Guayas and El Oro in

Ecuador (Sørensen, 1988). Limits of its distribution are still poorly understood, namely towards northwestern Ecuador and western Panama. Genetic diversity assessment is also needed as to advise on where *in situ* conservation facilities should be established. Genetic distances with *P. tuberosus* and *P. erosus* through widecrossing should also be clarified.

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