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# Conservation of Tropical Root and Tuber Crops Agrobiodiversity: On farm True Seeds Production and Use as a Mean for Geographic Distribution of Allelic Diversity

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## Introduction

Root and tuber crops are important staple in numerous tropical areas where they play a role in food security. It is particularly so in Pacific regions. In Vanuatu, a volcanic archipelago of 80 islands in the South Pacific, root crops species are of different geographical origins. Taro (*Colocasia esculenta*) and yam (*Dioscorea alata*) were probably introduced by the first Melanesians some 3 000 years ago, whereas sweet potato (*Ipomoea batatas*), cassava (*Manihot esculenta*) and cocoyam (*Xanthosoma sagittifolium*) were introduced later by the first Europeans, or by the Polynesians. As they all result from clonal introduction, their genetic base is quite narrow (Lebot, 1992). Cultivars are mostly reproduced asexually which impedes their evolution.

South countries are now in a stage of dramatic environmental changes as well as changes of food habits (NSO, 2008). Climatic changes are especially extreme in those areas, leading to drought and floods (Allen and Bourke, 2000). Moreover, intense international exchanges favor the introduction of new pathogens (Fullerton and Tyson, 2004). All those changes are threatening the local agrobiodiversity and, consequently, food security. Indeed, the loss of global agrobiodiversity reduces the potential of adaptation to changes. In one other hand, farmers do not benefit of any improved material since selection and its distribution is very costly. Local research institute cannot assume these costs. The problem is that the local cultivars might no be adapted to future environmental conditions. Additionally, the accumulation of viruses leads to the diminution of yield or degeneracy. Thus, there is a real need for the creation of new planting material adapted to local conditions and to farmer's expectations.

One solution could be based on decentralized plant breeding (Lebot *et al.*,2005). It is hypothesized that farmers' autonomy for the regeneration of their planting material could be achieved through on-farm production of new genotypes via through seed production. This would imply that farmers are directly involved in breeding practices, as early at the crossing stage. This is however, an innovative approach for them as they are not very familiar with the sexual reproduction of those plants.

The present study was undertaken to question the feasibility of on-farm plant breeding. More precisely, we focused on two issues: i) the possibility of developing breeding techniques within farm management*, i.e*. to involve farmer's resources, time and interest in breeding and hybrid selection. ii) the practical ability to control the on-farm breeding process, which supposes a good understanding of plant sexuality and seedlings germination and growth

## Materials and methods

Field work was conducted between April and September 2009 in Vanuatu. We studied five crop species: sweet potato, taro, greater yam, cassava and cocoyam. Five villages were chosen for their proximity to the research station, their ease of access and representativeness of main climatic and

agronomic orientation, such as taro humid agrosystems and yam dry agrosystems, and various economic situations. They are located on three islands: Santo, Ambae and Malo. Volunteer farmers were involved in field trials and interviewed.

***In situ* diagnostic of the farms** was conducted through inquiries. Each lead farmer was interviewed to understand the relative importance of their cash crops versus subsistence agriculture, the main cultivated crop species, the fallow and cultivation duration. Other general socio-economic data about household and data about physical environment were also collected. The functioning and constraints of farms were then analyzed in order to understand possible differences in the adoption of breeding techniques.

Through inquiries, the knowledge of local farmers regarding the sexual reproduction of tuber and root crops was investigated in three villages. Forty farmers of different sex and age were interviewed about their traditional knowledge of flower, fruit and the occurrence of volunteer seedlings in each species. This helped us understanding to what extent the sexual reproduction principle, which they need to use for understand breeding, are new for them.

**The breeding efficiency** is the global efficiency of breeding from the production of seeds to the evaluation of hybrids. However, the time imparted for this study (6 months) did not enable us to assess the global breeding efficiency. Therefore, we tried to evaluate some of its components according to the availability of material. As the current knowledge on the sexual reproduction of tuber and root crops is incomplete, flowering and fructification were quantified. The germination, the growth and the vigour of the seedlings of the different species were also evaluated. We had no idea of the difficulties that farmers will encounter for producing seeds but also for growing them until the selection stage. For this reason, we combined on station trials at VARTC (Vanuatu Agricultural Research and Training center) and on-farm experiments for a better understanding of the constraints in the farm context.

We first evaluated the efficiency of the breeding stage, the seed production. Sweet potato was used as a model because of its fast growth. An open pollination polycross trial involving 39 accessions of sweet potato was lanted in April 2009 at the research station. Flowering and fructification were measured twice, weekly, from the 21$^{th}$ of June to the end of August. We also planted ten polycross plots (3 accessions) in three villages. We analyzed differences of flowering and fructification among accessions through ANOVA process, using Excel Stat® software.
A second trial set was conducted on-farm to measure the success and the kinetics of germination. Ten farmers were provided with seeds of taro, cocoyam, manioc or sweet potato. They were free to choose the sowing modalities. Germination rates were assessed one month later.

Then, the survival rate and growth of taro seedlings in individual pots and after transplantation in the field were measured on-farm. Taros were chosen because their seedlings are particularly sensitive. They were given to farmers in individual pots at the two-leaves stage. Farmers were free to decide when and where to transplant them. Measurements of surviving rates and growth were conducted one month later.

The last level of evaluation is the rate of eligible hybrids. This has been done at the research station for progenies of yam issued from open pollination (India X Vanuatu). The progenies (130 hybrids) have been evaluated in the first clonal generation mainly for tuber quality regarding oxidation, shape and yield.

**Results and discussion**

This study enabled us to identify three main kinds of constraints that may impede the development of the production of true seeds and their use for on farm plant breeding. First, at the farm level, second at the socio–cultural level and third at the plant biology level.

Our investigation revealed that all farms are not equally able or prepared to adopt on-farm plant breeding techniques. We observed significant differences in management strategies between farms, some being more oriented toward cash crops. This is also often linked with a rather high intensification of land use, the fallow period being shorter than the cultivation period. Those farms are less available for the experimentation of a new technique as shown by our on-farm

trials. Thus, it seems that less intensive and more subsistence-oriented systems must be targeted in priority for diffusing new techniques.

We also identified some social and cultural obstacles. Our inquiry shows that farmers are familiar with flowers of most species, but fruits and volunteer seedlings are unknown to most of them, except for cassava. Moreover, for this species, more than half of the farmers weed-out these volunteers because they consider that they are of poor quality. Thus, they hardly understand the interest of raising seeds, especially when they consider volunteer seedlings as weeds needing to be removed. This can explain partly why most farmers show little interest for breeding. This is reflected by the limited care and support provided by farmers for cultivating the seeds and seedlings they were given within our experiments..

This study highlighted the complexity of the sexual reproduction of root crops. However, there are differences among and within species.

In our sweet potato polycross plot, all accessions flowered, but there were differences of flowering abundance among them. Effectively, a previous inquiry based on farmers' knowledge in Vanuatu had shown that almost all local cultivars of sweet potato are flowering. This is also the case for cassava, but not for yam and taro for which more than thirty percent of the cultivars do not flower. Our polycross trials showed that the "sexual reproduction rates", which is the number of viable seeds produced per individual, is quite low for the sweet potato. Effectively, a mean of less than one viable seed is produced per individual, but important variations were observed between cultivars. Some produced more than seventeen capsules per individual, whereas others do not produce any capsule. Moreover, large differences have been observed between sites of study but also between farms. They seem to be due to differences of climate. The lack of rainfall in some areas seems to impede fructification.

This shows that improvements have to be conducted in order to maximize fructification. First, the choice of the "mother cultivar" must take into account the ability to produce seeds on top of the selection criteria. Secondly, the site for seed production and of the period of implantation must be chosen carefully. Previous studies showed that the "sexual reproduction rates" is also very variable among species. Greater yam presents a very low fructification in Vanuatu since it is dioecious and there are few female cultivars. In contrast, taro produces hundreds of seeds per infructescence (Ivancic and Lebot, 2000).

Also, germination rates and kinetics vary among species. Yam and taro usually germinated within two weeks, even if some dormancy has been observed for taro (one month) and their germination rate was quite high (45 % for yam, five hundred seedlings per infructescence for taro). In contrast, sweet potato seeds germinate poorly, between three and 15 %. Cassava showed a high dormancy. Without treatment, germination is less than 1 % within three months. Previous studies showed that a heat treatment is necessary to obtain a reasonable germination rate (Pujol *et al*., 2002).

Taro seedlings showed very different rates of survival and growth between farms because of the difference of farmer's practices. The rate of survival of the seedlings varied from 0 to 100%, (mean 60%), reflecting the level of care provided by farmers.

Measurements taken after a month showed that seedling mean height was around 2,6 cm (± 1,8), which shows that their growth is slow under farm conditions in most of the cases. As a comparison, a very meticulous farmer managed to obtain 6,5 cm with daily irrigation, which shows that much better results could be obtained with care.

The last level of technical evaluation in this study was the in yam hybrids evaluation. The experiment showed a very low proportion of good quality hybrids (5 %), presenting no or little oxidation. Similar results were observed in previous studies with taro progenies (Quero-Garcia 2004). For these species, on-farm selection is thus tedious because many hybrids have to be implanted for a low success. However, previous studies suggest that the choice of parents and crosses determines the quality of progenies, and this raises hope for the development of on-farm breeding. Preliminary work must be done in order to predict the good quality crosses.

Other crops (sweet potato, cassava and cocoyam) seem to produce progenies having a much more acceptable quality, according to our own observations.

**Conclusion**

We have reviewed the main constraints to the development of the on-farm production and use of true botanical seeds. We attribute them to land-use intensification, but also to socio-cultural factors. Moreover, the complexity of the sexual reproduction of these crops suggests that its control is quite difficult and more research is needed. In spite of these current constraints, the technique can be greatly improved. More research is needed for identifying adequate cultivars as genitors for improving the quality of progenies. Our results suggest that, at least for the sweet potato, the choice of the cultivar is critical for an abundant production of seeds. The cultivation techniques, such as fertilization or irrigation, must also be investigated for maximizing the production of seeds.

As it was shown in many other biodiversity conservation projects (Prain and Piniero, 1998), farmers hardly understand initially the benefits which can result for them. Some individuals, however, express much interest in innovative techniques. They do invest much time and energy in plant breeding and must be targeted in priority. Since the circulation of planting material is intensive in Vanuatu, even if few individuals are involved in plant breeding, diffusion will be efficient.

In most cases, middlemen could be identified in order to produce and raise seeds in nursery. Robust cuttings or planting material would then be distributed to farmers for selection. This could perhaps be achieved by delocalized stations of the Department of Agriculture or with the assistance of schools.

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