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PROSPECTS AND CHALLENGES OF BIODIVERSITY IN SMALL-HOLDER SYSTEMS

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ABSTRACT

There is a wide diversity of cultivated banana (*Musa* spp.) found growing in small-holder systems around the world. The main types of bananas that are important for small-holders differ from region to region. Diversity is important for small-holders for many reasons. Diversity-rich production systems help to ensure a continuous supply of food throughout the year, losses due to pest and disease attack or unfavourable environmental conditions are reduced and a diverse range of products with different uses can be produced in a small area. Most importantly, diversity-rich production systems are sustainable, flexible and adaptable to change. Several challenges exist in ensuring the maintenance of diversity in small-holder systems. These include the need to combine increased production in the face of growing population pressure. with the need to conserve diversity for the future. To address these challenges, strategies have to be developed which allow improved, high yielding varieties to become part of the farming systems without replacing traditional varieties. At the same time conservation strategies, which combine *In situ* and *Ex situ* approaches in a complementary manner must be developed. This paper reviews the various methods of conservation available and emphasises the need for farmers, as the main users, custodians and beneficiaries of diversity, to be fully involved in the development of any such strategies.

Key Words: Banana, conservation, *Ex-situ, In-situ*

RÉSUMÉ

Il y a une large diversité des bananes cultivées (*Musa* spp) trouvée plantée dans des systèmes de petits fermiers dans le monde. Les principaux types de bananes qui sont importants pour les petits fermiers différent d'une région à une autre. La diversité est importante pour les petits fermiers pour plusieurs raisons. Les systèmes de production de la riche diversité aide à assurer un approvisionnement de nourriture tout au long de l'année, les pertes dues aux attaques des pestes et maladies ou aux conditions environnementales défavorables sont réduites et une diverse gamme des produits avec différents usages peut être produite dans une petite aire. Plus important, les systèmes de production de la riche diversité sont durables, flexibles et adaptables au changement. Plusieurs défies existent pour garantir la maintenance dans les systèmes de diversité des petits fermiers. Ceux ci incluent le besoin de combiner l'augmentation de production en face de la pression de la croissance de la population, avec le besoin de conserver la diversité pour l'avenir. Pour adresser ces défies, des stratégies doivent être développées lesquelles stratégies permettent d'améliorer les variétés de production élevée pour devenir une part des systèmes de culture sans remplacer les variétés traditionnelles. En même temps des stratégies de conservation, qui combinent les approches In situ et Ex situ dans de manière complémentaire doivent être développées. Cet article révise les diverses méthodes de conservation disponibles et souligne le besoin des fermiers, comme les principaux usagers, conservateurs et bénéficiaires de la diversité, à être pleinement impliqués dans le développement de pareilles stratégies.

Mots Clés: Banane, conservation, *Ex-situ, In-situ*

INTRODUCTION

The vast majority of bananas and plantains (*Musa* spp.) produced worldwide are grown by small scale farmers. This production, which often takes place in the context of mixed farming systems incorporating a wide range of other food and cash crops, is based on a diverse mixture of varieties. Banana-based farming systems are found throughout the developing countries of the tropics and sub-tropics, and diversity is very important in these systems. Diversity-rich production systems are sustainable, flexible and adaptable to change. A continuous supply of food throughout the year can be ensured through the use of diversity and losses due to pest and disease attack or unfavourable environmental conditions can be reduced. Furthermore, a diverse range of products with different uses can be produced in a small area. However, in the face of growing populations, farmers are having to address the challenge of increasing production levels on the same, or even reduced areas of land. The pressure to maintain only highly productive or commercial varieties is high and the threat of genetic erosion from smallholder systems is therefore, increasingly real. It is clear that strategies need to be developed that will allow production levels to increase, while continuing to ensure the maintenance of diversity. Threats to the conservation of varieties need to be identified and strategies developed, in collaboration with farmers, to ensure the long-term conservation of *Musa* diversity.

***Musa* diversity.** The genus *Musa* is divided into four sections (Australimusa, Callimusa, Eumusa, and Rhodochlamys), the members of which include both seeded and non-seeded (parthenocarpic) types. The majority of edible (seedless) banana varieties arose from the Eumusa group of species. This section is the biggest in the genus and the most geographically widespread, with wild species being found throughout South East Asia from India to the Pacific Islands. The section contains some 11 species (Horry *et al.*, 1997). Most cultivars are derived from two species, *Musa acuminata* (A genome) and *Musa balbisiana* (B genome). However, cultivars derived from hybridisations with *M. schizocarpa* (S genome) have been identified (Shepherd and Ferreira, 1982; Carreel *et al.*, 1993). In addition, a Philippine clone (Butuhan) is considered to be the result of an ancient hybrid between *M. balbisiana* and *M. textilis* (T genome) and landraces containing the three genomes, *acuminata, balbisiana* and *textilis* have been found in Papua New Guinea (Carreel, 1995).

Musa acuminata is the most widespread of the *Eumusa* species being found throughout the range of the section as a whole. Nine sub-species have been recognised (Horry *et al.*, 1997). The centre of diversity of the species is thought to be either Malaysia (Simmonds, 1962) or Indonesia (Nasution, 1991; Horry *et al.*, 1997).

Edibility of diploid *Musa acuminata* (AA) came about as a result of female sterility and parthenocarpy, and such edible types would no doubt have been selected and maintained by humans. Triploid AAA cultivars arose from these diploids, resulting in a wide range of AAA genotypes. In most parts of South East Asia these triploids, which are more vigorous and have larger fruit, have replaced the original AA diploids. However, in New Guinea AA diploids remain agriculturally significant and a wide range of diversity is still found in cultivation.

The diploid and triploid *acuminata* cultivars were taken by humans to areas where *M. balbisiana* is native and natural hybridizations resulted in the formation of hybrid progeny with the genomes AB, AAB, and ABB. The Indian sub-continent is thought to have been the major centre for hybridisation of *acuminata* types with the indigenous *M. balbisiana* and the region is noted for the wide variety of AAB and ABB cultivars. The indigenous *M. balbisiana* is considered to be more drought and disease resistant than *M. acuminata*, and such characteristics are often found in cultivars containing a ‘B’ genome. Hybridisation would have given rise to a wide range of edible types of banana, some of which would have survived and been multiplied under domestication. Consequently, a diverse selection of cultivars of *Musa* is thought to have arisen in South East Asia along with the earliest development of agriculture many thousands of years ago (Price, 1995). This diversity continues to be maintained today on-farm by small-scale farmers throughout the region.

It is thought that the subsequent dispersal of edible bananas outside Asia was brought about solely by humans (Simmonds, 1962) and the history of banana cultivation is therefore closely linked to the early movement of human populations. This early dispersal of banana cultivars resulted in the development of distinct sub-groups of varieties in different geographic locations. Secondary diversification within the major groups of cultivated bananas is thought to have been the result of somatic mutations rather than sexual reproduction. Mutations affecting traits of economic or horticultural interest have been selected by farmers over the years and multiplied by vegetative propagation to produce morphotypes.

Movement eastwards resulted in the development of a distinct group of AAB bananas which are cultivated throughout the Pacific Islands. These are known as the Maia Maoli/Popoulu group and the progenitors of these bananas are thought to have been carried eastwards by proto-Polynesians from an area in or near the Philippines more than 4,000 years ago (De Langhe, 1996). It is argued by some that bananas existed in South America in pre-Columbian times, and this is taken as evidence for early Polynesian contact with America (Langdon, 1993).

A very distinct type of cooking banana (plantain) is found growing in the wet tropical zones of West and Central Africa. Plantains are rare in most of Asia as well in other parts of Africa, and their origin in West Africa is shrouded in mystery. It is thought that they have been cultivated in this region for more than 3,000 years, but the identity of the people responsible for such cultivation is unknown (De Langhe *et al.*, 1996). It is possible that the same proto-Polynesians that carried the banana east to the Pacific islands, also carried it west to Africa. As dry suckers can survive storage for several months, long sea voyages would not have been a problem. Such a hypothesis fits with phytolith evidence that plantains may have been growing in Africa for the last 3,000 years (Mbida *et al.*, 2000).

Another distinct group of bananas are found in the East African Highlands. These are thought to have been introduced between the 5th and 10th centuries and a wide range of unique varieties now exists here. This area of secondary diversity is clearly the work of East Bantu-speaking people (De Langhe, 1996), but the origins of these bananas remain unknown.

***Musa* diversity in small holder systems.** It is clear that a wide range of *Musa* diversity is to be found in small-holder systems around the world. As described above, the types of varieties differ from region to region, but in home gardens and small farms throughout much of the tropics and sub-tropics, bananas are ubiquitous. In a recent study on home gardens carried out by the International Plant Genetics Resources Institute (IPGRI), bananas were listed as important components of home gardens in almost all the countries involved. These ranged from Cuba and Venezuela in Latin America, through Ghana and Ethiopia in Africa and extending to India and Vietnam in Asia. The maximum number of varieties per garden was found to be 22 in Cuba, 10 in Ghana and 15 in Vietnam (Watson and Eyzaguirre, 2002). In East Africa, where bananas reach their greatest importance as a staple food crop, as many as 30 distinct varieties have been identified growing on a single farm (Karamura, 2002, unpubli.)

Conservation and production. Varieties are maintained on-farm when they meet the producers' needs. As long as these needs remain constant, it is likely that diversity will be conserved. However, conservation is rarely, if ever, the farmers' objective. If, due to changing priorities or circumstances, a variety is no longer considered useful, it is unlikely to be maintained on the farm. Thus, any focus on on-farm conservation has to place the desired conservation objectives in the context of the farmer's production objectives (Hodgkin, 2002).

Three main factors affect the maintenance of crop diversity on-farm. These include the biological characteristic of the crop, the way in which farmers manage the production and multiplication of the material and environmental factors. In the case of a clonally propagated crop such as banana, the selection and source of planting material plays an important role in determining what varieties are grown by the farmer, while somatic mutations provide the main source of new variants that may be selected and maintained on-farm.

Amount of genetic diversity conserved on-farm. When measuring genetic diversity on-farm three important aspects should be considered. These are richness, which is a measure of the number of different types present; evenness, or the distribution of these types spatially; and distinctness, which provides further information on how different the types are (Hodgkin, 2002). In the case of banana, it is known that farmers in the Great Lakes region of East Africa maintain a large number of different types of East African highland bananas, but it is also known that these varieties have a high level of genetic similarity to each other. Thus, although the variety richness may be high, there is a low degree of distinctness between them. In contrast, in South East Asia, while the number of different varieties found per farm may be fewer, there is generally a greater distinctness between these varieties. This situation fits well with the accepted view that bananas originated in the Asia-Pacific region and this is the centre of diversity for the genus, while Africa is considered to be a secondary centre of diversity, with somatic mutations being responsible for the large number of 'morphotypes' found there (Crouch *et al.*, 2000).

The obvious starting point for determining the amount of diversity present on-farm is to make an inventory of the number of distinct varieties present. However, in banana, as with other crops, difficulties can arise when farmers use different names for the same cultivar, or even the same name for different cultivars. Furthermore, characteristics used by farmers to distinguish between cultivars may not be obvious to the outside observer. For example, two varieties may be apparently morphologically identical, but are distinguished by farmers due to differences in the cooking qualities of the fruit. A further problem can be encountered when trying to assess diversity based on traits that are affected by the environment, with the result that the same variety may look very different from one farm to the next.

Difficulties in assessing levels of diversity may be overcome by collecting samples and planting these together in one site for full characterisation, and by the use of molecular markers to determine the extent of 'distinctness' between varieties.

Documentation and indigenous knowledge. As with any programme of conservation, an essential element of on-farm conservation is the recording and documenting of data about the resources being conserved. In the case of *Ex situ* collections, documentation revolves around the morpho-taxonomic descriptions of the varieties, which in the case of *Musa* are based on the IPGRI/INIBAP/CIRAD "Descriptors for banana, *Musa* spp.". However, considering that on-farm conservation is largely based on the use aspects of the variety, documentation systems for on-farm conservation must also incorporate this type of information. A number of approaches to documenting *In situ* conservation are provided by Jarvis and Hodgkin (1998). Knüpffer (2002) recommends the recording of the following information:

- Taxonomy and nomenclature (accepted names and synonyms, including authors and place of publication)
- Vernacular names, including indication of the language or dialect
- Geographical information (distribution etc.)
- Plant uses and plant parts used and other ethnobotanical information
- Narrative text (information on history, diversity, breeding, wild relatives etc.)
- Literature references

Conservation strategies. Information on what is being maintained on-farm and why, is very important in determining conservation strategies. If all the farmers in an area maintain the same diversity, genetic erosion threats may be considered small. Whereas if only a small number of farmers are maintaining unique varieties, any change in the farmers' interest in these varieties may make them vulnerable. In this case, additional *Ex situ* conservation measures may be considered necessary.

Impact of improved varieties. The biggest challenge facing most banana farmers today is the challenge of increasing productivity in the face of increasing pest and disease pressure, declining soil fertility and land and labour shortages. The most appropriate and efficient means of addressing these problems is through the use of improved varieties which are being developed by breeding programmes. Such varieties produce high yields under poor growing conditions, without the need for applications of expensive chemical pesticides. In comparison to most other major staple food crops, improved banana varieties are relatively few in number and it is only in the last few years that such varieties have started to become available on a large scale to farmers. This is due to the difficulties inherent in breeding a crop in which most of the important and popular varieties are highly sterile. However, with the introduction of new biotechnologies and the background of more than 70 years of conventional breeding, the stage is now set for a rapid rise in the number of new varieties being released by the breeding programmes. A consideration of the effect the introduction of such varieties may have on the on-farm conservation of traditional varieties is therefore timely.

On-farm conservation. As mentioned above, varieties are conserved on-farm as long as they meet a production need of the farmer. Such needs may be related to food security, or income generation, or may equally be related to social and cultural traditions. For example in India, specific cultivars are maintained in home gardens because they are used for ceremonies and religious functions, while others are conserved for medicinal purposes (Pushkaran, 2002). Furthermore, some varieties are grown specifically for their leaves, which are harvested for various household uses.

Varieties that are maintained on-farm are available for use and for exchange with neighbours. Selection pressures are present and the opportunity exists for new "morphotypes" to appear and be selected by the farmer. However, the same selection pressures may result in the loss of varieties (drought, pests, diseases etc.) and the duration of conservation is always subject to the needs of the users. Ensuring a constant demand for a variety might be considered a good way of ensuring its conservation, but cannot guarantee its long term security as new and more productive varieties are introduced.

Community genebanks. Community genebanks are repositories of germplasm managed by and for a local community. In the case of banana, community genebanks do not presently exist, but have been proposed in the context of the East African *Musa* on-farm conservation project. The aim is to have a communally managed banana garden containing all the East African highland banana varieties known by the community. This would provide a resource for the community and spread the burden of conserving the less utilised varieties. A number of issues however, need to be resolved before such community genebanks can be established. Such issues include the problem of who 'owns' the bunches when they are harvested, who provides land and labour, and how are they rewarded for their inputs, who provides overall management and ensures that information about the accessions is recorded and other related aspects.

Despite these problems, there are several advantages to maintaining a community genebank. These include the easy access to the material for the community, the continued selection pressure and possible evolution of new types in the genebank, the lack of risk of replacement of varieties by new, improved varieties and the contribution it would make to raising the level of awareness of the community regarding the importance of diversity conservation.

National genebanks. National field genebanks can play an important complementary role to on-farm conservation, especially if good links exist between farmers and the genebank. In a field genebank, farmers can see a wide range of varieties, and if the necessary linkages are in place, material can be readily exchanged between farmers and the field collection. Ideally, the national collection should put particular focus on conserving those varieties known to be vulnerable, or not being conserved on-farm. Studies on richness and distinctness of on-farm diversity should help to determine the composition of the national genebank.

The systematic recording of information about accessions is more likely to be assured for accessions in a national collection, but indigenous knowledge may not always be included. Accessions in a field genebank are subject to environmental stresses and losses may occur if extreme situations prevail. Such losses can be avoided in the case of a crop such as banana by duplicating the accessions *In vitro*. An *In vitro* collection, although safer in terms of long term conservation, is more expensive to maintain than a field collection and morpho-taxonomic characterisation data cannot be collected. Moreover, although accessions maintained *in vitro* may be more amenable to international exchange, local access may be restricted compared to a field collection.

International genebank. In the case of *Musa*, the International Network for the Improvement of Banana and Plantain (INIBAP) maintains an international *In vitro* germplasm collection. The accessions in the collection are held in trust, under the auspices of FAO, and are freely available for distribution. Efforts are underway to cryopreserve all accessions, thus ensuring the safe, long term conservation of all accessions. The Network aims at conserving diversity representative of the genus *Musa*. It is clearly neither practical or desirable for every last variety found in farmers' fields to be conserved at the international level. In order to ensure the long term conservation of *Musa* diversity, a complementary strategy, which combines conservation on-farm, with national and international genebanks is desirable.

Complementary conservation. Conservation of *Musa* diversity is presently based on national genebanks, with important material being duplicated at the international level with INIBAP. Quarantine issues greatly restrict the international movement of *Musa* germplasm, and in this respect INIBAP plays an essential role in promoting the utilisation of germplasm by assuring the safe movement of clean, virus indexed material through its genebank. At the national level, with the exception of the present study in East Africa, relatively little attention has been paid to on-farm conservation of *Musa*. Further studies are required to quantify the extent of diversity presently conserved on-farm and to compare this with diversity in national genebanks. Unique germplasm which is unlikely to continue to be conserved by farmers should be given priority for conservation at the national level, while the focus at the international level should be on conserving representative diversity and ensuring universal access to important material. Issues related to ownership and intellectual property, as well as access and benefit sharing, do however need to be addressed when considering conservation at the international level. Equally important is that farmers, as the main users, custodians and beneficiaries of diversity fully participate in the development of strategies at the local level.

CONCLUSIONS

It is clear that diversity is very important in small-holder systems, and in the case of bananas, a wide range of diversity is found in many countries. However, farmers worldwide are trying to raise productivity, and in this respect, improved varieties developed by breeding programmes have a good potential. At the present time, a wide range of banana varieties are still being grown by small scale farmers, but their long-term conservation on farm is determined by the production needs of the farm family. As improved varieties become more widely available, the time is right to consider the potential impact of these varieties on on-farm conservation. There is clearly a need to identify threats to conservation on-farm and develop complementary strategies that incorporate *In situ* conservation with *Ex situ* approaches, both at the national and international level. Such strategies cannot be developed in isolation, but must combine a clear scientific understanding of the genetic basis for conservation and utilisation, with the moral and ethical issues related to access to germplasm and the sharing of the benefits of its use.

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