Repères

The genetics and breeding of taro

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Cirad

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This book has been prepared within the Taro Network for Southeast Asia and Oceania: TANSAO

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The overall objective of the network is to enhance the competitive position of taro in cropping systems of Southeast Asia and Oceania and to select varieties with high commercial potential, both as a table food and when processed. This is being achieved by improving quality and resistance to pests and diseases, and by increasing the efficiency of production.

Member countries: Indonesia (Research and Development Center for Biotechnology, LIPI, Bogor); Malaysia (Plant Genetic Resources Center, Universiti Putra Malaysia, Serdang); Papua New Guinea (National Agricultural Research Institute, Lae); the Philippines (Philippine Root Crops Research and Training Center, Baybay); Thailand (Horticultural Research Institute, Bangkok); Vanuatu (Vanuatu Agricultural Research and Training Center); Vietnam (Vietnam Agricultural Sciences Institute).

CIRAD, France, responsible for co-ordination of the project, is working in collaboration with Wageningen Agricultural University.

TANSAO objectives:

– to characterize approximately 2000 taro accessions and analyse the genetic diversity using morpho-agronomic traits and molecular markers, both isozymes and AFLPs (all countries and Wageningen Agricultural University);
– to make available 170 genotypes by *in vitro* exchange, to broaden the genetic base of national breeding programmes (all countries);
– to identify sources of disease resistance for use in targeted crosses (crosses are conducted in all participating countries);
– to assess the genetic diversity of *Phytophthora colocasiae* using isozymes and RAPD markers (CIRAD);
– to study the physico-chemical characteristics of starch from 170 selected genotypes (CIRAD);
– to identify and overcome barriers to progress in taro breeding and develop adequate breeding strategies based on data obtained from molecular and agronomical studies (all countries);
–to co-ordinate TANSAO efforts to enhance co-operation between participating countries and to establish an efficient means of sharing information (CIRAD, lebot@vanuatu.com.vu).

Five project components:

– germplasm characterization using biomolecular markers;
– disease resistance of cultivars and improvement through targeted crosses;
– *in vitro* safe exchange and agronomical evaluation of cultivars and hybrids;
– *Phytophthora colocasiae* genetic diversity;
– physico-chemical characteristics of starches from selected cultivars.

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Foreword

Modern taro production is becoming intensive and responsive to modern market demands for cheap, healthy and high quality products. These demands cannot be met without the simultaneous genetic improvement of the crop. One of the key factors in intensive and healthy production is resistance to diseases and pests.

Genetic improvement is becoming more and more sophisticated. The number of traits which need to be improved is increasing. A new cultivar has to be high yielding, with good quality corms (which should not deteriorate when stored for long periods of time), it also has to be resistant to all major diseases and pests, and have a corm of appropriate shape and size.

The scientific literature dealing with taro is relatively rich, however, there is little information on taro genetics (inheritance of plant characteristics, self-incompatibility, potential hybridization with other aroid species) and breeding (breeding approaches, practical techniques, experience and results). It usually takes new taro breeders about two years to gain the necessary experience in hybridization, seed germination, assessment of resistance to diseases and pests, selection techniques and management of field trials.

The authors of this publication believe that it is possible to make the work of breeding taro simpler, efficient and more pleasant by sharing knowledge and experience. We hope that this publication, which is based on practical work rather than on a review of literature, will serve as a useful source of practical and theoretical information.

When preparing the manuscript, we came to the conclusion that the ordinary taro (*Colocasia esculenta*) was frequently confused with other aroid root crop species, especially tannia (*Xanthosoma sagittifolium*). For this reason we decided to include basic information on all major related aroid root crops (*Alocasia macrorrhiza*, *Amorphophallus campanulatus*, *Cyrtosperma chamissonis* and *Xanthosoma sagittifolium*).

The first author illustrated the publication. The majority of sketches for the illustrations were made directly in the field, screenhouse or in the natural environment of the Solomon Islands, Papua New Guinea, Indonesia and New Caledonia during the period 1989–98.

Anton Ivancic and Vincent Lebot
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Port Vila, Vanuatu

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Résumé

Le taro *Colocasia esculenta* (L.) Schott est une plante amylacée ancienne et importante, consommée par plus de 400 millions de personnes. Il est cultivé dans des environnements très diversifiés pour son corme riche en amidon, pour ses pétioles et ses feuilles consommées en épinards et parfois comme plante ornementale. En raison de leur multiplication végétative exclusive, les cultivars ne peuvent s'adapter aux rapides changements environnementaux. De nos jours, et du fait de l'accroissement des échanges, de nouveaux pathogènes sont introduits dans les systèmes de culture traditionnels. C'est le cas de *Phytophthora colocasiae* responsable du flétrissement, qui tend à se développer inexorablement vers de nouvelles zones. L'intensification des cultures s'accompagne d'une amélioration génétique et donc de la caractérisation des ressources existantes. Bien que le taro soit multiplié par voie asexuée, la variabilité morphoagronomique des cultivars est remarquable. Elle est actuellement exploitée par des programmes nationaux qu'il convient d'encourager. Cet ouvrage tente de synthétiser les informations disponibles sur *Colocasia esculenta* et les espèces apparentées. Il traite de la taxonomie, de la botanique, de l'origine et de la distribution des ressources génétiques ainsi que de l'amélioration proprement dite. Il aborde essentiellement les aspects pratiques de la caractérisation et de l'amélioration génétique et s'appuie sur les données scientifiques les plus récentes ; l'objectif étant de revitaliser la production, non seulement du taro, mais aussi des espèces apparentées.

Introduction

Taro, *Colocasia esculenta* (L.) Schott, is an ancient and important root crop species. It belongs to the monocotyledonous family Araceae. According to Bown (1988), about 400 million people include taro in their diets and in many areas of the humid tropics, it is a staple crop. It is closely associated with peoples' culture and traditions.

There are several different kinds of taro: giant taro (*Alocasia macrorrhiza*), giant swamp taro (*Cyrtosperma chamissonis*), tannia (*Xanthosoma sagittifolium*) and ordinary or true taro (*Colocasia esculenta*). Taro (*C. esculenta*) cannot be studied separately from these species. All four species may be grown as root crops or as ornamentals. Giant taro plants are large succulent perennial herbs with large sagittate leaves and thick elongated corms. They require fertile, well drained soils. Giant swamp taro plants are also large perennial herbs with sagittate leaves which are usually larger than those of giant taro. In most cases the corm shape is round. The crop grows in freshwater swamps. Tannia is probably the most similar to ordinary taro, and is characterized by relatively large sagittate leaves, a large main corm and several cormels which are used as food.

Aroid root crops also include the elephant-foot yam (*Amorphophallus campanulatus*). This species is frequently not included in the taro group because of certain specific botanical characteristics (complex-compound leaves, specific floral structures and flowering).

Ordinary taro is the most important species in the group. It is grown as a root crop or as a leafy vegetable and sometimes as an ornamental. The plants have peltate, cordate leaves and corms which may be of different sizes and shapes. The crop is mainly cultivated in tropical rainy climates and requires highly fertile soil.

In the past, taro used to be a much more important crop. With the development of modern agriculture, production started to decrease, mainly because of pests and diseases. Many good, traditional varieties have been lost and replaced with other, more adaptive crops, such as cassava, sweet potato or maize.

Taro is considered to be a less adaptive crop because of its predominant vegetative propagation. All cultivars are vegetatively propagated but this does not mean that they do not flower. Flowering and seed set can be observed frequently, especially in the Solomon Islands, Papua New Guinea, Vanuatu and Indonesia. However, the chances of seeds germinating and plants developing to maturity are very low because of poor germination vigour and slow early growth. Due to the predominant vegetative propagation, taro cannot respond quickly to new environmental changes (new pests, diseases, drought, salinity, soil and air pollution). Seed-propagated, cross-fertilizing crops are, in comparison with taro, much more dynamic.

Taro growing areas are characterized by a wide range of environments. In the past, there existed a large number of cultivars and each cultivar was adapted to specific environmental conditions. Growing areas were generally isolated and this isolation was a form of quarantine which reduced the spread of pests and diseases. Nowadays, because of free communications and migrations, diseases and pests spread easily to new places, for example, taro leaf blight (*Phytophthora* leaf blight), caused by *Phytophthora colocasiae*, has spread extensively in the Pacific.

Modern agriculture has to be accompanied by intense genetic improvement of the crop. Changes in the environment (for example, new pests and diseases or climatic changes), production technology, processing and marketing continuously require new varieties. There is no ideal variety. A good variety has to be high yielding, have a good taste quality, must be resistant to all major pests and diseases and adapted to specific environments (drought, shade, paddy conditions, high or low altitudes). It is impossible to create a variety which will perform equally well in all environments.

The success of taro improvement depends strongly on genetic resources. The improvement process is much easier when adequate genetic resources are available. Although taro is a vegetatively propagated species, its genetic variability is extremely high. The genetic diversity in existing germplasm collections indicate that it might be impossible to register all possible variations. At present, the main challenges for plant breeders are the genetic sources for resistance/tolerance to leaf blight, viral diseases and the taro beetle, and tolerance to salinity.

Genetic variation should be available to all breeders. Presently it is difficult to exchange taro germplasm, especially breeding materials, mainly because of pests and diseases. Present breeding programmes are in most cases national. International co-operation among breeders and a procedure for germplasm exchange are yet to be fully established. There is no international breeding centre for taro nor is there a large international germplasm collection. The situation for other aroid root crop species, except *Xanthosoma sagittifolium*, is even worse.

This publication is far from being complete. It gives general information about taro (*Colocasia esculenta*) and some basic data on its related root crop species. It deals with taxonomy, botany, origin and distribution, genetic resources, reproductive biology, and problems associated with genetics and breeding. The publication concentrates on practical problems which are directly associated with genetics, genetic resources and breeding. Most of the data are from the authors' own experience. The authors hope that the publication will contribute to the promotion of more intense work on problems associated with genetics and breeding of the crop. The final goal is to help to revitalize the agricultural production, not only of taro, but also of other aroid root crop species.

Taro and related aroid species

Taro, *Colocasia esculenta* (L.) Schott, belongs to the botanical family Araceae (aroid family). The family consists of about 110 genera with over 2500 species (Bown 1988). The aroid family is divided into several subfamilies: Acoroideae, Pothoideae, Monsteroideae, Calloideae, Lasioideae, Philodendroideae, Colocasioideae, Aroideae and Pistioideae. The classification is undergoing extensive revision. New systematic studies of members of the aroid family continuously require changes in classification.

The main centres of origin are considered to be tropical America and tropical Asia. Besides this, some aroid species can be found only in the Mediterranean and in Africa. Another possible centre of origin for some species is Australia and Papua New Guinea.

The majority of aroids are climbers and epiphytes of tropical rainforests. Many species are associated with aquatic or semi-aquatic environments but members of the aroid family can be found in almost every climatic region except deserts and arctic regions. Species adapted for areas with cooler or dry periods are characterized by dormancy in the form of corms, tubers, underground rhizomes or seeds. In this way, they manage to survive unfavourable periods.

The Araceae family is extremely heterogeneous. There is enormous variation in chromosome structure and number. The morphological differences among some species are so great that it is hard to believe that they belong to the same family. Typical examples of the morphological diversity are *Acorus calamus, Alocasia macrorrhiza, Amorphophallus* spp., *Colocasia esculenta, Pothos scandens, Anthurium gracile* and *Monstera* spp.

According to Bown (1988), one obvious common characteristic for nearly all aroid species is the spadix–spathe type of inflorescence (Figure 1). A spadix is a spike of flowers on a swollen, fleshy axis. Individual flowers are very small, and either bisexual or unisexual. Bisexual flowers usually have a specific type of perianth, consisting of tepals. (Tepals are floral structures which can be found in flowers lacking clearly differentiated sepals and petals. A tepal is a perianth segment that is not clearly distinguishable as being either a sepal or a petal.)

A spadix with unisexual flowers is usually divided into two distinct parts or zones. The female part is at the base of the spadix while the male part is higher up. These two zones are usually separated by a band of sterile flowers. The spadix often ends in a sterile tip or appendix. The main purpose of this appendix is the dispersal of odorous substances (Bown 1988).

The spathe is a large bract subtending and often unsheathing an inflorescence. The colour and shape varies from species to species and even within species; from white, yellow, orange, red or purple to maroon or green. The size of the aroid inflorescence varies from a few millimetres (*Pistia*) to more than a metre (*Amorphophallus titanum*).

The aroid family is characterized by protogyny. The female flowers become receptive before the pollen is shed. Protogyny is closely associated with cross-pollination. Most aroid inflorescences are specifically adapted for insect pollination. Some inflorescences, i.e. taro (*Colocasia esculenta*) or tannia (*Xanthosoma sagittifolium*), are characterized by the specific shape and size of the spathe. The space between the spathe and the spadix can serve several purposes: as a shelter for insects during rain or at night, as a mating place or as a place for feeding and growth.

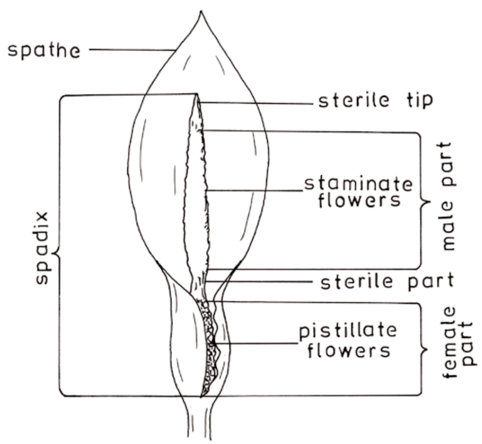

Figure 1.
Typical aroid inflorescence in detail.

Another character of aroid inflorescences closely associated with insect pollination is the presence of an odour. The beginning of flowering is characterized by the release of a specific odour which acts as an attractant. Inflorescences of some species produce odours which can attract only certain species of insects, for example, the saproentomophilous inflorescences of *Amorphophallus campanulatus* produce an odour which imitates the smell of rotten flesh to attract flies.

The leaf structure and shape of aroids are extremely variable. The most common shapes are linear, elliptical, cordate, oblanceolate, obovate, sagittate, hastate, peltate, trifoliate, tripartite, pinnate, radiate, pedate, pedately lobed and compound. Leaves are frequently adapted to specific environments such as shade, continuous flooding, wet conditions or drought. The size of aroid leaves varies from species to species, from variety to variety and even within single plants; it varies from very small to giant. Extremely large leaves are characteristic of some genotypes of giant swamp taro (*Cyrtosperma chamissonis*).

Aroid root crops are economically the most significant group within the family. Taro, one of the most important representatives of this group, can also be used as a vegetable crop (young leaves and inflorescences).

The second most important group is the aroid ornamentals. In future, aroid ornamentals will probably become more important. The Araceae family represents a unique source of variation which has not yet been fully explored. Most of the species can be considered as ornamentals because of their specific (exotic) leaves or inflorescences. With modern techniques of breeding, it may be possible to create additional variability and select specific genotypes according to market requirements. There are many economically important aroid ornamentals. The most important genera are *Aglaonema, Alocasia, Anthurium, Caladium* (Figure 2), *Dieffenbachia, Philodendron, Scindapsus* and *Zantedeschia*. Besides root crop species and ornamentals, the Araceae family also includes vegetables, species with edible fruits (*Monstera deliciosa*) and medicinal plants, such as sweet flag (*Acorus calamus*).

Figure 2.
Caladium bicolor.

Aroid root crops are an important source of food in many tropical countries. They are primarily grown for their corms and cormels although sometimes the leaves are eaten as a vegetable. These crop species can be classified into two main groups according to their origin:
– species of Asian or Asia-Pacific origin (*Alocasia macrorrhiza, Amorphophallus campanulatus, Colocasia esculenta, Cyrtosperma chamissonis*);
– species of American origin (*Xanthosoma atrovirens, X. sagittifolium, X. violaceum*).

Aroid root crop species belong to two subfamilies:
– Colocasioideae (*Alocasia macrorrhiza, Colocasia esculenta, Xanthosoma sagittifolium*);
– Lasioideae (*Amorphophallus campanulatus, Cyrtosperma chamissonis*).

The determination of the genera (*Alocasia, Amorphophallus, Colocasia, Cyrtosperma* and *Xanthosoma*) is not always simple. *Alocasia, Amorphophallus, Colocasia* and *Xanthosoma* species are monoecious while *Cyrtosperma* species have hermaphrodite flowers. Further determination of genera with hermaphrodite species may include the presence/absence of the sterile appendix on the spadix; inflorescences of all, except *Xanthosoma*, are appendaged. The appendix on *Xanthosoma* inflorescences is non-existent or not clearly distinguishable (similarly for *Caladium*). The genus *Amorphophallus* can be easily separated from the others because of its complex-compound laminas. The majority of *Colocasia* species have peltate leaves, while most *Xanthosoma* and *Alocasia* species have sagittate leaves. However, there is tremendous variability, especially among *Alocasia* species. Blades of some *Alocasia* species can be pinnatifid (*A. brancifolia*) or even peltate (*A. sanderiana*, Figure 3).

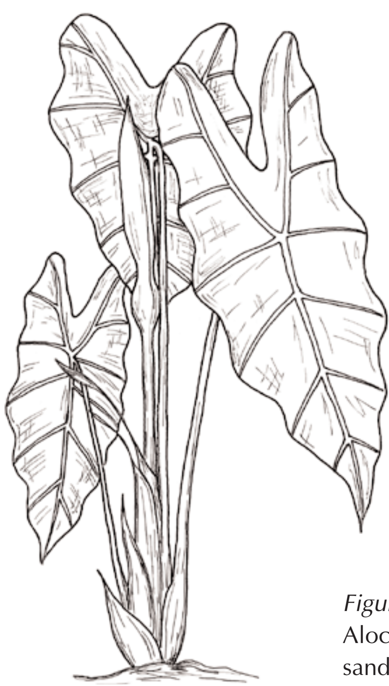

Figure 3. Alocasia sanderiana.