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The problems of *ex situ* genetic conservation at the universities in developing countries: lesson learn from Universitas Gadjah Mada

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Abstract. Agriculture faces enormous challenges for providing sufficient food, feed and fuel raw materials for a growing global population. In the case of food, for instance, global food production must always increase to meet the projection of continuously increase of global food demand. The future challenges of food supply and demand can be addressed by diversification of food sources, introducing high yielding cultivars and improving culture techniques. Food sources can be diversified by collection and evaluation of genetic resources for nutritive values. In contrast, new varieties can be developed through breeding activities that also require genetic resource as genetic material. Genetic resources spread around the world, and to optimally utilize, genetic resource must be explored and conserved both by *in situ* and *ex situ* approaches. The genetic resource exploration through missions requires proper preparation including human resources, logistics and time allocations. Universitas Gadjah Mada (UGM) as a higher education institution has three big university missions, i.e. education, research and community service through student involvement. These three missions through student involvement have been applied to conduct the genetics resource exploration and *ex situ* conservation. The course of genetic resource collection and management has been introduced at different faculties, and because community service at the rural area for two-month times is compulsory for the student, UGM makes use of student to carry out genetic resource exploration and collection. The student must collect the passport data for the genetic resources and send the data to the Agriculture Innovation Center (AIC). In case that seed of genetic material can be found, student must collect also seeds and send to AIC for *ex situ* conservation. Based on UGM experience, *ex situ* conservation, especially seed genebank, faced sustainability problem due to insufficient human and funding resources. UGM integrates some approaches such as crop focusing, networking, student involvement in the characterization and evaluation, and breeding activities to solve such problems.

Keywords: genetic resources, *in situ* and *ex situ* conservation, student involvement.

1. Introduction

Agriculture, as a poineering technology that has a remarkable impact on the planet, has been the foundation of socioeconomic progress. Agriculture will continue to play a significant role in development. Agriculture faces enormous challenges for providing sufficient food, feed and fuel raw materials for a growing global population [1]. Global food production must always increase to meet the projection of continuously increase in food demand. To increase crop production, many agricultural activities are unsustainably carried out due to the overuse or misuse of agrochemicals, irrigation water, fertilizer and other inputs, and the loss of crop rotation. Climate change is a very considerable environmental threat likely to affect the ecosystem and its production potential, and the dynamics of pest and diseases, therefore, it reduces agricultural productivity. The future challenges of food supply and demand can be addressed by diversification of food sources, introducing high yielding cultivars and improving culture techniques. Food sources can be diversified by collection and evaluation of genetic resources for nutritive values. In contrast, new varieties can be developed through breeding activities which also require genetic resource, viz. any genetic material of organism with actual and potential value for human use. Plant breeding should remain a vital component of effective agricultural systems. Plant breeding has contributed to increasing productivity by systematically creating new genotypes with superior adaptation to needs of society, the resource of the production system and the demand of nature in the target environment [2]. Breeding activities successfully improve genetic resource performance with continuously increasing yield potential and adaptation to management practice, because genetic resource provides the building blocks to improve productivity, biotic resistance and abiotic tolerance. Genetic resources spread around the world, and in order to optimally utilize, the genetic resource must be explored and conserved in appropriate ways.

2. Genetic resource conservation at Universitas Gadjah Mada

Genes are the blueprint of organisms and breeding is the art and science of organism improvement which its product can feed the world [3], and the effective use of genetic resource in breeding relies on a thorough understanding of the existing diversity. Genetic diversity plays an essential role in food security, nutrition and sustainable intensive agriculture [4]. Genetic resource as sources of genes can be found everywhere around the world, however, due to deforestation, population growth and climate change, the genetic resource can be eroded. Genetic resource, therefore, must be appropriately conserved. Several types of arguments are used to promote genetic resource conservation, such as species as a valuable resource for humanity, both nowadays and in the future; species play significant role in maintaining a stable environment, the scientific value of species and the opportunity to study and determine ecological processes.

There was a broad consensus on some of the principles of genetic conservation which include (a) high levels of genetic diversity within populations are almost always desirable to ensure that they are genetically sustainable, (b) adaptability is correlated with diversity and should be an essential driver for conservation in response to environmental change, (c) genetic diversity is broadly associated with population size; hence conservation should seek to maintain or create large populations, (d) low levels of genetic diversity are detrimental to populations when they lead to inbreeding depression but can be of particular scientific interest and may indicate ongoing evolution and speciation, (e) gene flow between populations is desirable, but care may be required where small populations have been isolated for an extended period and local adaptation may be swamped, and (f) action to increase landscape permeability for one species may be adverse for another, but what is suitable for most species should take precedence. The concept of genetic resource conservation must capture maximum variation [5].

There are several methods available for preserving crop genetic resources, and they are all necessary for overall, sustainable conservation, however, the standard genetic conservation methods include *in situ* and *ex situ* approaches at local, national and international levels [6].

In situ conservation is a method for preserving crop species, especially crop wild relatives, in nature. *In situ* locations are usually in protected areas, like nature reserves and other places with restricted access. *In situ* methods are necessary for sustainable and useful conservation of essential and potentially critical genetic resources and cultures in which they are embedded. The advantages of *in situ* conservation include preservation of indigenous knowledge; conservation is linked with use and change in the field; allelic richness and genotypic diversity; unique adaption; localized divergence and diversity to meet temporal environmental variation; continuing crop evolutionary process; human involvement; dispersed sharing of benefits derived from genetic resources. Whereas, the disadvantages are as long as genetic resource remains in the hands of the farmer; it is not directly useful for breeders; farmers can not be trusted to maintain valuable genetic resources; *in situ* conservation is not popular with breeders because of a long and tortuous road that genetic resource must travel between the field and the breeding program; as long as conservation and improvement are directly linked, conservation will be judged by its short-term benefits. Therefore, an ideal area of *in situ* conservation would be peasant farmers (direct land to mouth agriculture), active community, an area of high environmental heterogeneity and ecological complexity, in an area of landrace crop origins or secondary center of crop diversity, and the area should also have the support of agricultural extension services and some market availability for farmers to sell local crops. Although *in situ* conservation represent the most effective way to protect endangered species, it is also evident that not all species can be efficiently preserved at their natural habits [7].

Table 1. Universitas Gadjah Mada field genetic resource conservation.

Field name	Size (ha)	Crop species	Field function
Pagilaran Tea Plantation	1,100	Tea Coffee Quinone	Collection and production
Segayung Cocoa Plantation	160	Cocoa Coconut	Collection and production
Samigaluh Tea and Cocoa Plantation	5	Cocoa	Collection and production
Gunungkidul Wanagama	600	Pinus Eucalyptus	Collection and production
Berbah Agrotechnology Innovation Center	35	Arrow root Breadfruit Cassava Cattle Catfish Corkfish Deer Durian Litchi Orchid Papauw Sauerfruit Sheep Starfruit	Collection
Mangunan Agrotechnology Innovation Center	151	Arrowroot Banana Eucalyptus Ginger Gmelina Glerecidae Jackfruit Pinus Sauerfruit Squamoya Zingiber	Collection

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The *ex situ* conservation is the conservation and maintenance of species outside their natural habitat and is used to safeguard population in danger of destruction, replacement and deterioration [5]. *Ex situ* methods are designed to maintain the genetic material in the state in which it is collected, to avoid loss or degeneration of a variety. *Ex situ* methods give rise to one type of diversity because the selection is directed by crop science and commercial/public breeding interests [8]. Approaches to *ex situ* conservation include methods like field genebanks and botanical garden, seed bank and gene libraries.

Field genebank means that accessions in the form of seedlings or clonally propagated species are conserved by cultivating in the open field or pot. Field genebank is the most suitable genetic resource conservation approach for animals and perennial plant which clonally propagated, such as banana, tea and cassava. Field genebank must also be fitted to sexually propagated crops which seeds show recalcitrant characteristic (Table 1). Such conservation can be categorised as static and evolutionary techniques [9]. Static conservation is applied in connection with the relatively intensive breeding program, where identified and characterized genotype are clonally propagated and kept in the clonal archive. In contrast, evolutionary conservation is the opposite to static conservation in the sense that it aims to support genetic changes to the extent that they contribute to continued adaptation. Evolutionary conservation is characterised by plant reproduced by seed in successive generations, and genetic variation between populations from different environments is in general maintained and expected to increase over time [10].

The seed of some species can maintain their initial high germination capacity for many years, and this seed is categorized as orthodox one. Such orthodox seed can be dried and stored at low temperature for a long time. A seedbank is the most conventional for long-term conservation of the genetic resource. Once a seed is kept in refrigeration, it is isolated from the evolutionary process. Seedbank represents the most effective *ex situ* conservation strategy [11]. However, seedbank requires not only essential infrastructure for short and long-term seed storage, but also efficient management of back up regeneration, characterization and evaluation, and data management [12].

At Universitas Gadjah Mada (UGM), the importance of seedbank has been recognised since the university was established. When the Faculty of Agriculture was initiated in 1946, “selection” became one of the sections with the purposes was to conserve and utilize genetic resources around Yogyakarta. To support such purposes, rice seedbank with convenient facilities has been built, and some foreign breeders were invited as a professional expert. The facilities such as coolroom, drying field, screenhouse and seed processing unit could be seen till 1998 at Bulaksumur campus complex of UGM. In 1978, Agriculture Training, Research, and Development Center (ATRDC) was established at Kalitirto, Berbah, Sleman, Yogyakarta, and rice accessions collection was transferred from Bulaksumur to Kalitirto due to better facilities. Old seedbank facilities at Bulaksumur was then used for the winged bean breeding project. The coolroom in Bulaksumur was broken in 1981 and, as a result, winged bean accessions were lost.

In 1998, Bulaksumur campus complex for agriculture was reconstructed; therefore, all seedbank facilities were destroyed. Screenhouse has been moved to Banguntapan, while new coolroom was placed at the new building. New building for the agricultural complex was inaugurated in 2004; however, the coolroom for seedbank was not well performed. The seedbank at ATRDC was also broken almost at the same time. Seed accessions were stored at the refrigerator at different laboratories, and fortunately some accessions still exist until now (Table 2).

In 2015, ATRDC and UGM Mangunan Girirejo Field were merged as Agrotechnology Innovation Center of UGM (AIC-UGM). AIC-UGM was appointed as tropical vegetable genebank through the collaboration between UGM and East West Seed Indonesia (Ewindo). Seedbank of ATRDC will be repaired and enlarged to store some important tropical vegetable seeds such as aubergine, chili pepper, cucumber and yardlong bean, therefore, AIC-UGM will become one of national seedbank focused on the tropical vegetable.

Table 2. Universitas Gadjah Mada seedbank conservation.

Institution name	Crop species	Utilization
Kalitirto Agrotechnology Innovation Center	Aubergine Cucumber Greenbean Hot chili pepper Rice Maize Peas Soybean Tomato Yardlong bean	Collection and some breeding works
Faculty of Agriculture	Rice Maize Peas Tomato Soybean Garlic	Collection and breeding
Faculty of Biology	Rice Maize Strawberry Melon	Collection and breeding

Table 3. Number of province and student for community service in 2014–2018.

Year period	Number of		
	Province	Village	Student
2014	23	280	7,331
2015	27	264	7,077
2016	31	251	6,695
2017	231	231	6,733
2018	221	221	6,279

Source: Community Service Directorate of UGM, 2018 (personal communication).

3. Student involvement in genetic resource

Genetic resource collection can be expensive, and the fund is usually very limited [3]. UGM as a higher education institution has three big university missions, i.e. education, research, and community service, through student involvement. More than 6,000 students with enough knowledge will be sending and stayed at the community both at the urban and rural areas at least two months for community services (Table 3). Several students come from the faculty of agricultural complex, biology, and pharmacy. Such student can conduct the genetic resource exploration and *ex situ* conservation because the course of genetic resource collection and management has been introduced at such different faculties. To make sure that everything will go properly, AIC-UGM in 2018 prepares accession passport and carries out workshop before departure. The student must then collect the

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passport data for the genetic resources and send the passport data to AIC-UGM. In the case that seed of genetic material can be found, AIC-UGM also provides seed bags for the student. The student must collect the seeds and send them to AIC for *ex situ* conservation.

4. Problems in *ex situ* genetic resource conservation and their solutions

Based on Fu [13], ten most challenging issues of *ex situ* conservation including insufficient funds, facilities and staff; costly activities requiring laboratories, land, labor, material resources and complex financing for maintaining seed viability; diluted political support; inadequate characterization and evaluation of genetic resource; lack of updated genebank information systems; incomplete diversity coverage; deteriorating genebank support; unbalanced support; lack of professional staff and genebank collapse. Based on UGM experience, *ex situ* conservation, especially genebank, faced sustainability problem due to insufficient human and funding resources. Therefore, UGM integrates some approaches such as crop focusing, networking, student involvement in the characterization and evaluation, and breeding activities to solve such problems.

Crop focusing depends on institution levels at the university. AIC-UGM will focus only to species, which do not become the focus of the faculty or other related institutions in the university. Faculty of agriculture, for instance, has long experience working in tomato and garlic. Therefore, AIC-UGM will work on other vegetable crops such as aubergine, cucumber, hot chili pepper, cosmos, wing bean and yardlong bean. Pagilaran estate plantation grows intensively tea and cocoa tree crops, but fails to work on breeding, nursery and organic fertilizer-based development, AIC-UGM will then intensify on such issues. To speed up the research progress, financial support is given and to improve the research organization. The government also appoints AIC-UGM as a center of excellence for agrotechnology innovation.

The success of breeding programs depends on germplasm [14–16] which can be enriched through an exchange by networking. Networking can be carried out at the national and international levels through correspondences, seminar and symposium, workshop, consortium meeting, publication and collaboration. Correspondence to individual expert and related institutions is an important step to start networking. Although it sometime fails of success and it needs some time, but it must be executed diligently. Seminar and symposium even workshop can be the best way to connect people with similar interest. The attractive theme will encourage many people to participate in the event. After succeeded in correspondence and organizing seminar, symposium and workshop, involvement at the consortium will become a further step to writing useful publication and at the end will produce sustainable collaboration. With focusing on only several crop commodities, networking can be quickly done because AIC-UGM will be easily recognized worldwide based on these commodities. Global collaboration to conserve as much plant diversity as [17] will become an effective and efficient practice for plant genetic resource conservation and management for future generation [18].

A lot of genebanks find difficulties to respond effectively an accession requirement due to inadequate characterization and evaluation [19] which require many human resource or technology investments. The advantage of universities related to human resources is their availability to research because research is compulsory even for bachelor student. In term of the student body, UGM has the most significant number of student in Indonesia and the involvement of the student in the characterization and evaluation of collected accessions will improve the database of every accessions. As a result, accession duplication can be avoided, and the usefulness of the accessions will increase.

Cultivar development through breeding work may be considered as a type of university start-up, which means that university can earn revenue from such activity [20]. With a more complete database of the accessions, breeding works can be conveniently conducted. Breeding duration time probably can be shortened. The economic value of genetic material will be realized. If the wide yielding varieties are frequently developed and released from the collected accessions, and the majority of the growers cultivate these varieties, the funding problems might be solved.

5. Conclusions
UGM has recognized the importance of *ex situ* conservation of genetic resources since it was established. The genetic resource was conserved in *ex situ* collections in the form of fieldbank and seedbank. Seed genebank faced sustainability problem due to insufficient human and funding resources and UGM integrates some approaches such as crop focusing, networking, student involvement in the characterization and evaluation, and breeding activities to solve such problems.

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