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Conservation of Rice Genetic Resources for Food Security

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ABSTRACT

In the Philippines, rice is a primary agricultural crop and major caloric food source of Filipinos. Rice is produced in all of this archipelagic country's provinces, wherein total production (~18.4 million MT) is ranked eighth in the world. PhilRice was established as a dedicated research and development arm to propel sustained rice yield growth and stability toward self-sufficient production. Supporting its rice varietal improvement program is its Gene bank, a national repository of local- and foreign-sourced rice genetic materials. Currently, there are 14,388 rice accessions conserved at PhilRice Gene bank and 44% of which are landraces and traditional rice varieties. To date, 89% of the accessions have been Phenotypically characterized. To make these genetic materials desirable parent lines for rice breeding programs, a more comprehensive phenotypic characterization and evaluation of responses to various stresses remains to be done. A gene-bank's capacity to explore genetic potential of its holdings using molecular technology advances could pinpoint important traits in potential parent lines that are valuable in developing better rice varieties. The bottom line among the challenges of rice gene banking is striking a balance between fund resource availability and undertaking the numerous core research activities, including collection, conservation, documentation, characterization, evaluation, distribution and dissemination of rice genetic materials.

KEYWORDS: Rice genetic resources; Genebank; *Ex situ* conservation; Landraces; Phenotypic diversity; Germplasm characterization; Rice farming practices.

ABBREVIATIONS: GDP: Gross Domestic Product; NPT: New Plant Type; IRRI: International Rice Research Institute.

INTRODUCTION

Rice is the primary agricultural crop in the Philippines. Its production of 18.4 million MT places the Philippines eighth among the world's rice producing countries.[1] Rice production is a major income source for 12 million Filipino farmers and their families[2] and contributes 2.2% to the Philippines Gross Domestic Product (GDP).[3] Aside from being a major caloric food source for most Filipinos, rice is a culturally important crop in the Philippines, as showcased in many traditional festivals and rituals in various parts of this archipelagic country.[4,5] In 1985, the importance of rice to the Philippine economy led to the creation of the Philippine Rice Research Institute (PhilRice) enacted through Executive Order 1061. PhilRice is mandated to lead the country's rice research and development programs that fuel the rice sector's growth through breeding new or improved rice varieties, and developing and promoting yield-enhancing and component technologies.[2]

Breeding new or improved rice varieties would benefit from readily available germplasm with excellent traits. Similar to most agricultural crops, the continuing infusion of ge-

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netic resources in rice breeding results in yield stability and growth. For instance, a yield plateau was observed 28 years later from the successful release of the IR8, the first semi-dwarf rice plant type that was introduced in 1966.[6] As such, in 1993, rice breeders proposed the development of a New Plant Type (NPT) focused on morphological traits rather than physiological characteristics, because the former were easily observable in breeding activities.[6-8]

Furthermore, with current pressure to feed a burgeoning population as well as the potential effect of climate change on food production, breeding programs have recently included physiological traits that address such issues.[9] Thus, ensuring the availability of rice germplasm with excellent morphological and physiological traits remains very crucial toward successfully breeding new rice varieties expressing desired traits.

This is one major contributory role of PhilRice's Genetic Resources Division to any rice varietal improvement program in the Philippines. The division, among its other research activities, maintains the PhilRice Gene bank, a national repository of rice genetic materials consisting of traditional landraces, improved rice varieties, research/breeding lines, materials generated from molecular methods, interspecific hybrids, and foreign accessions among others.

In this review, discussion focuses on the rice germplasm conservation program of PhilRice Gene bank and how these genetic resources are characterized and explored. This review also provides information about the contribution of genetic materials in rice varietal improvement, as well as limitations, prospects and the future direction of rice germplasm conservation.

CONTRIBUTION OF RICE GENETIC RESOURCES IN CROP IMPROVEMENT

Rice farmers have continually contributed to rice diversity as they cultivated selected and nurtured thousands of rice cultivars throughout time. These cultivars represent a vast wealth of genetic material, composed of landraces and traditional varieties, which are good sources of important morphological and physiological traits crucial to breeding improved rice varieties. These rice genetic resources are key components to breeding programs and serve as sources of important traits in developing better rice cultivars.

In rice breeding history, several studies have identified rice landraces as parent lines of promising new varieties. Notable of these reports are the development of IR8, and discovery of genes for submergence tolerance, and increasing rice yield. Tropical Japonica rice landrace Daringan expresses the NAL1 allele responsible for significantly increasing the yield of modern rice varieties.[10] Rice landrace FR13A is the source of submergence tolerance SUB1 QTL.[11] Dubbed as miracle rice, IR8 was released in 1966 and is a cross product of two landraces: *Dee-geo-woo-gen*, a Chinese semi-dwarf rice variety and *Peta*, a vigorous and tall rice from Indonesia.[12] The rice variety IR8 is an important part of rice breeding programs in the Philippines as it serves as a parent line for breeding new varieties. One study reported that 92% of the 67 Philippine rice varieties released from 1960 to 1994 were directly related to IR8, or to IR8 through the variety *Peta* as a common ancestor.[13,14] The study also showed that 57 common donor parents made these Philippine rice varieties related to each other. At the centre of this ancestry were 19 landraces that provided the basic template for rice varietal improvement[14] which highlight the importance of these germplasm in the breeding program.

STATUS OF RICE GERMPLASM CONSERVATION AND UTILIZATION AT PHILRICE GENE BANK

Following PhilRice establishment in 1985, conservation of rice genetic resources through its PhilRice Genebank was initiated with an initial collection of around 300 varieties reacquired from the International Rice Research Institute (IRRI).[15] The germplasm holdings increased through donations and various explorations conducted around the country. A collaborative project between PhilRice, IRRI and the Swiss Agency for Development and Cooperation conducted in the mid-1990's to safeguard rice genetic resources in the country resulted in the acquisition of 458 traditional rice varieties. To improve the management and operation of the Genebank, an operation manual was published serving as a protocol to the daily activities of the Genebank.[16]

To date, the PhilRice Genebank is conserving 14,388 rice germplasm both from local and foreign sources (Figure 1). Nearly half of the collections (44%) are traditional rice varieties, while the second largest portion of the collection (32%) represents breeding lines and improved varieties donated by various researchers and breeders.

To fill in the gaps in the collection with emphasis on provinces in the country with limited representation in the germplasm collections, a PhilRice-funded project to conduct and ecogeographic survey and collection was implemented in 2008. A total of 387 samples were collected during the conduct of the project. Assessment of the collections phenotypic diversity showed high diversity in the agronomic traits measured.[17] Table 1 provides a glimpse of the phenotypic diversity in selected grain traits of the 387 rice germplasm collection. Awn length is the only grain trait that showed low diversity because most of the collected germplasm had no awns. Presence of awns is one of the peculiar traits in the Indonesian bulu or javanica group within the tropical japonica varieties.[18] Analysis of correlation among the agronomic traits showed several traits to be highly correlated. The size of the flag leaf width was shown to be highly correlated with some grain traits, such as grain and caryopsis width. Flag leaves are important in grain filling stage in rice as it contributes to 80% of the total carbohydrates as well as being a source of photo assimilates during water stress.[19]

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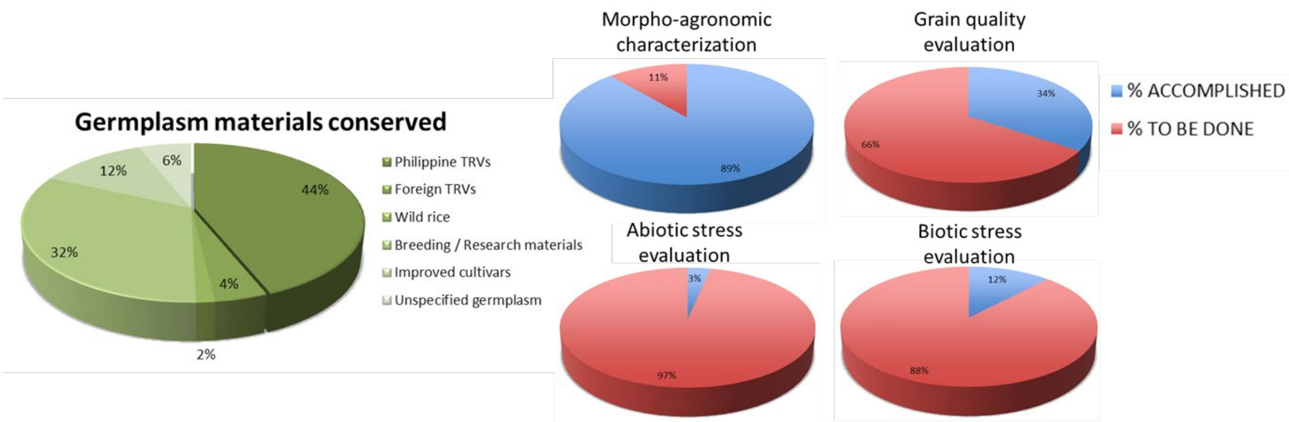

Figure 1: Composition of rice germplasm holdings, and status of characterization and evaluation of materials conserved at PhilRice Genebank.

Descriptors	High		Low		H'
	Variety	Value	Variety	Value	
Low diversity					
Awn Length (mm)	Burdagol (11083)	69.64	Puchagwan (11241)	1.98	0.016
Moderate diversity					
Caryopsis Length (mm)	Binaka (Malagkit) (10838)	13.72	Milagrosa (11102)	4.37	0.640
Caryopsis Width (mm)	Doriat Pula (10934)	1.28	Kaimpas (11315)	4.15	0.701
Caryopsis Length/ Width Ratio Score	Binaka (Malagkit) (10838)	5.12	Kaimpas (11315)	1.42	0.737
High diversity					
Grain Width	Kipil (10837)	6.56	Duriat (10943)	1.51	0.775
100 Grain Weight (g)	Binaka (Malagkit) (10810)	5.5	Kinakaw (10857)	1.1	0.812
Grain Length (mm)	Binaka (Malagkit) (10810)	10.76	Dinorado (10860)	5.29	0.843

Table 1: Diversity analysis of selected grain traits in Philippine rice germplasm. Extents of diversity in the collection were calculated based on phenotypic frequency using standardized Shannon-Weaver Diversity index (H').

Figure 2 illustrates the germplasm diversity (A) and (B) some of the indigenous rice farming practices (B) that were observed during the collection mission.[17] These practices could form part of the documentation process of germplasm acquisition. The most interesting farming practice noted was the use of coconut palm stalks in paddy fields, resembling snakes ready to strike, and therefore acting as decoys to scare away rats. This practice is common to provinces of the southern Luzon region of the country.[20]

Germplasm characterization and evaluation are two important components of an efficient utilization of germplasm materials. Germplasm evaluation is more useful if the traits measured are of interest to breeders.[21] Phenotypic characterization based on selected traits from the internationally agreed upon standards has been carried out on much of the germplasm conserved at PhilRice Genebank. To date, 89% of the accessions conserved are fully characterized (Figure 1). What is lagging is the comprehensive phenotypic evaluation of the whole collection based on important traits that breeders need to breed for improved varieties. Also, evaluation of germplasm based on their response to various stresses has commenced, but so far only 12% and 3% of the total accessions conserved underwent evaluation for biotic and abiotic stress, respectively. For grain quality evaluation, 34% of the collection has been screened. Phenotypic characterization at PhilRice Genebank is usually carried out alongside regeneration of germplasm, which explains why most of the collections had been characterized. Germplasm evaluation on the other hand requires technical inputs from end users who have variable traits of interest, so this activity was carried out in collaboration with breeders and researchers at the Institute.

CHALLENGES AND FUTURE DIRECTIONS IN RICE GENETIC RESOURCES CONSERVATION

One of the challenges in a genetic resource conservation program is access to actual field materials. Some areas remain remote because of poor road networks. Researchers need to walk or hike many kilometres during exploration trips to collect germplasm. An example is the collection trip to Aurora, one of the Philippine provinces that is highly engaged in rice production. Researchers had difficulty in reaching farming areas because of poor farm-to-market roads. Figure 3 shows the location of the rice varieties collected in Aurora province. Notice that the

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Figure 2A: Diversity of rice germplasm collections. 2**B:** Some Filipino farmers'practices in rice production: panicle drying (top), and use of coconut palm as rat deterrent (bottom).

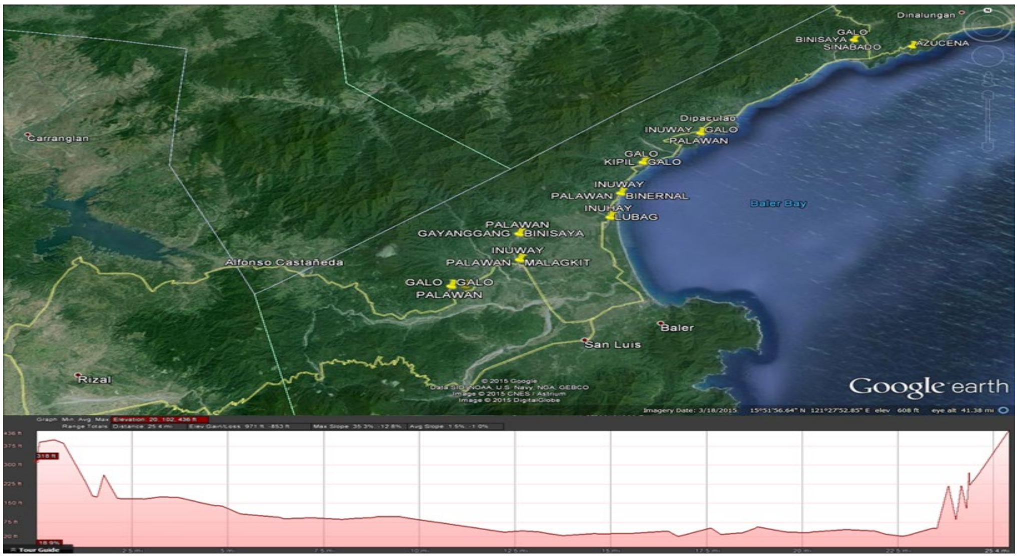

Figure 3: Location map of Philippine traditional rice varieties collected in Aurora province.

samples collected were close to road networks, while not much collection was done in areas that lacked road infrastructure.

Collection bias due to infrastructure is common in collection missions because collectors tend to follow roads that connect to main towns for the reason of efficiency, logistics and convenience.[22] This bias has been observed in numerous germplasm collections.[22-24] Hermann[23] reported that most of the Andean tuber crop collection sites sampled in Ecuador were located near the Pan-American Highway and other major roads. The same observation was noted by Von Bothmer and wherein the distribution map they constructed showed that most of the collection sites for *Elymus cordilleranus* were located around major cities like La Paz (Bolivia), Lima (Peru) as well as the Pan-American Highway in Ecuador. The same observation can be noted for the Bolivian collection of wild potatoes, wherein 68% of the total germplasm holdings were collected within 2 km of the nearest roads.[22] Geographic distribution of *Huperzia* also revealed that most of the collection sites were located near roadways.[25] To gain access to areas that are far from the main road networks, collaboration with local government and non-government organization (GO and NGO) personnel could facilitate effective and efficient collection missions.

Another challenge in germplasm conservation is managing the increasing amount of material. *Ex situ* conservation is expensive, and maintenance of these materials for a long period of time will require sustained funding. A cost analysis done on major gene banks around the world showed that the annual cost could range from US $0.6 million to US $1.2 million, depending on the location and total germplasm holdings.[26]

In rice genetic conservation, IRRI holds the largest collection of rice germplasm, with 126,601 accessions conserved. IRRI requires an annual budget of US $797,553 to conserve and disseminate its germplasm,[26] of which 61% of the total cost is allocated for labour. Since gene banks do not have unlimited resources at their disposal, gene banks should consider the size and scope of their collections, while conserving as much of the total crop gene pool as possible.[27] To rationalize the number of accessions for conservation, prioritization in material acquisition must be practiced. Another option is to reduce redundancy in the collection by developing a core collection that would represent the genetic spectrum of the entire conserved genebankcollection.[28] This approach was taken by Ebana, et al.[28] for Japanese rice landrace, where a core collection composed of 50 accessions was developed, based on an original collection of 236 accessions. They were still able to retain 87.5% of the alleles that had been detected in the original collection.

Another challenge to rice gene banking is the availability of phenotypic evaluation data of germplasm collections for potential traits that can be utilized in breeding programs. One of the major reasons why germplasm may be under-utilized is a lack of evaluation data that breeders can use for their parental choices.[29,30] This is a common challenge in most gene banks around the world, and it has become a major priority activity for the Global Plan of Action on the Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture.[29] Unlike characterization that can be carried out during the regeneration of germplasm, phenotypic evaluation requires more technical expertise, financial inputs and specialized facilities, and some gene banks do not have the ability to implement this activity.[29,31] One approach to address the issue of insufficient evaluation data in the germplasm collection is to share the responsibilities with researchers and other germplasm users. At PhilRice, we have collaborated with researchers from various fields (plant breeding, entomology, plant pathology and chemistry) to generate phenotypic evaluation data that can be useful for breeders and other stakeholders.

In the future, the availability of genotypic and phenotypic data from the rice germplasm conserved in gene banks could facilitate rice breeders to efficiently and rapidly incorporate important traits in the development of new high-yielding varieties with enhanced tolerance to biotic and abiotic stresses. This assumption is based on the premise that the continuing infusion of genetic resources in rice breeding programs will result in yield stability and growth, as previous breeding breakthroughs have demonstrated.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

CONSENT

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