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Collection, classification, and conservation of cultivated and wild rices of the Lao PDR

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Abstract

The Lao People's Democratic Republic (Lao PDR) lies within the center of domestication of Asian rice (*Oryza sativa* L.). Many traditional varieties are grown in the rainfed lowland and rainfed upland ecosystems, but there is a danger of genetic erosion, particularly in the lowlands, as farmers adopt improved varieties. The Lao Ministry of Agriculture and Forestry (MAF) and the International Rice Research Institute (IRRI) jointly explored most of the rice growing areas between October 1995 and April 2000 and collected 13192 samples of cultivated rice, and 237 samples of six wild rice species. Cultivated samples were classified according to ecosystem, endosperm type and maturity. The numbers of samples collected from the northern, central and southern regions were 5915 (44.8%), 4625 (35.1%) and 2652 (20.1%) respectively. More samples (55.9%) were collected from the uplands than from lowland sites. Most samples (85.5%) had glutinous endosperm. Almost half the samples were medium maturing (47.1%), with approximately an equal number of early and late maturing forms. Apart from some localized areas where accessibility was restricted, the collection is representative of the rice genetic resources of the whole country. A genebank for medium-term storage was established near Vientiane. For long-term conservation, duplicate samples were sent to the International Rice Genebank at IRRI in the Philippines.

Introduction

The Lao People's Democratic Republic (Lao PDR) lies between 14°10′ and 22°10′N, and 100°20′ to 107°50′E (Figure 1). It has an area of 236800 km^2, and is inhabited by about five million people comprising 47 ethnic subgroups (Batson 1991; Goudineau 1997). It has three agricultural regions—northern, central and southern. These regions differ in climate, topography and soils. The annual rainfall for each is about 1450, 1800 and 2100 mm, respectively. Most occurs in the period May to October when farmers grow the main wet season rice crop. Maximum and minimum temperatures are 32 °C and 24 °C in the central and southern regions, and 29 °C and 20 °C in the northern region. Elevation ranges from 150 m above mean sea level in the major rice-growing plains along the Mekong River Valley, to 2818 m in the mountainous central and northern regions.

Rice is the single most important crop in the Lao PDR, accounting for more than 80% of the cropped area. Per capita consumption is among the highest in the world at 240 kg of milled rice per year (UNDP (United Nations Development Program) Lao PDR 1998). Rice also accounts for about 80% of the calorie intake of the Lao people. Hence, a commonly used phrase by the Lao people to describe eating food is *kin khao*, which translates literally as 'to eat rice'. In 1999, the total rice production was 2.1 million tons from an estimated harvested area of 717000 ha. Of this, 83% came from wet-season cropping activities. The rainfed lowlands accounted for 67% of the area and 71% of production, and the rainfed uplands 21% of area and 12% of production. Dry season irrigated

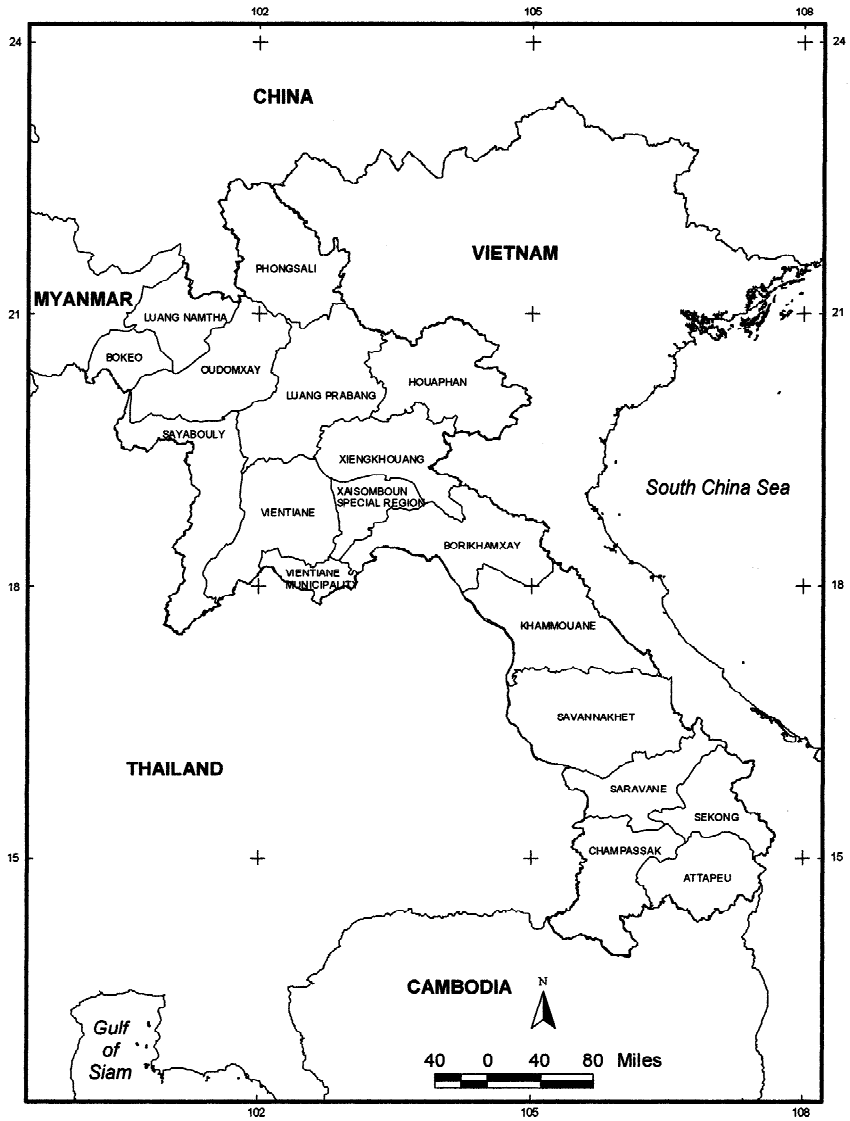

Figure 1. The political geography of the Lao PDR

rice accounted for only 12% of the area and 17% of the production in 1998–1999. The Lao PDR is the largest producer and consumer of glutinous rice in Asia.

Rice cultivation in both rainfed lowland and upland environments is based on systems of minimum inputs or 'natural farming' (Tanaka 1993), and using family labour as the single most important input. Subsistence and modern farming methods coexist side by side, and transition between these two systems is seen in some locations (Worner 1997). Upland rice cultivation is primarily by slash-and-burn shifting systems on steep slopes.

Between 1970 and 1990, collecting missions supported by USAID, Russia, Japan and others collected more than 3000 samples of cultivated traditional rices. Between 1991 and 1994, a further 1000 samples were collected, mainly from the northern region by the Lao Ministry of Agriculture and Forestry (MAF) supported by the Lao-IRRI project to some extent (Roder et al. 1996). Due to lack of cold storage facilities in the country, much of this germplasm was lost in the country although some samples were sent to IRRI for long-term conservation.

As part of a project to conserve the biodiversity of the rice genepool in 22 countries in South and Southeast Asia, sub-Saharan Africa, and Central America, and with financial support from the Swiss Agency for

Development and Cooperation (SDC), systematic collection of rice germplasm in the Lao PDR commenced in October 1995 and continued up to April 2000. In consultation with all the provincial agricultural officers, a 5-year collecting program was prepared and agreed. The level of genetic erosion occurring in a particular area (as indicated by the adoption of improved varieties) and the availability of local support, besides safety considerations and accessibility of target areas, were the basis for selecting priority areas for collecting.

Improved varieties are replacing the traditional varieties developed by farmers over centuries, particularly in the favorable rainfed lowland environment. In 1993, less than 10% of the whole rainfed lowland area was grown to improved cultivars. However, improved cultivars developed within the Lao PDR today cover more than 50% of the rainfed lowland area in the provinces of Khammouane, Saravane, Borikhamxay, Champassak, and Savannakhet and in Vientiane Municipality (Figure 1), and some farmers no longer grow traditional varieties. In Savannakhet, the area planted to improved varieties is as high as 80%. Only improved varieties are grown in the dry-season irrigated environment throughout the country. With a more open market economy and availability of fertilizers, the adoption of improved varieties is increasing rapidly in much of the rainfed lowland environment.

The Lao government has a policy to reduce the area under upland rice by adopting sustainable agricultural practices, reducing slash-and-burn, and encouraging the planting of native trees such as teak. Although the policy will undoubtedly bring overall environmental benefits in many areas, it could threaten the upland varieties if farmers adopt different agricultural systems not based on rice cultivation. In some neighboring countries, glutinous varieties have already been replaced by nonglutinous varieties because of their higher yielding ability and early maturity. A similar change may occur in the Lao PDR, unless there is an increase in the yield potential of traditional glutinous varieties grown by Lao farmers.

Germplasm collection

Collecting strategy

MAF and IRRI jointly undertook the collecting activities. MAF extension officials generally carried out collecting activities at crop maturity (September–December), but samples from the threshing floor and households were also collected from January to April in those areas inaccessible during the rainy season. Officials attached to each district agriculture and forestry office collected in two to five districts during each year of the project. These staff generally had good local knowledge and could communicate effectively with the farmers. Each province nominated one official to take responsibility for coordinating activities that were supported by district-level collectors. Staff of the Germplasm Unit of National Agricultural Research Center (NARC) and the IRRI germplasm collector visited most of these collectors during the time of collection and worked with the teams. This helped to improve their efficiency, and enabled the NARC team to undertake independent collecting, often in more remote areas. The types of materials collected included landrace varieties, slightly improved varieties, intermediate weedy forms that occurred as spontaneous hybrids between wild and cultivated forms, and wild species.

Collecting procedures

Our objective was to collect enough material to represent the maximum diversity with a minimum number of samples. To achieve this, we aimed to collect at least one sample of each variety from each district, while recognizing that farmers sometimes call different varieties by the same name; or different names are used for the same variety. In cases of doubt, we collected duplicate samples. Collecting started at crop maturity (about one week before harvest) and continued until threshing. We tried to obtain most samples directly from farmers' fields but after harvest, samples were obtained from the threshing floor or grain stores.

Our sampling technique depended heavily on the participation of farmers and was a compromise between collecting individual plants from each field as separate samples and collecting a bulk sample of different types found in a single field. The method involved collecting each distinctive phenotype identified by the farmer, and any other distinct types identified by the collectors. For example, if five distinct types were identified in a field, all five types were collected as separate samples to facilitate conservation, and subsequent characterization and utilization. While sampling from relatively uniform fields, only one random bulk sample was collected. When rare phenotypes were encountered, however, they were kept as separate samples. In general, we did not

Table 1. Schedule of germplasm collecting for rice in the Lao PDR between August 1995 and April 2000.

Year	No. explored		Samples collected	%
	Provinces	Districts		
August–December 1995	9	51	2145	16.3
October 1996–February 1997	18	80	4223	32.0
September 1997–February 1998	17	94	3846	29.2
September 1998–December 1998	17	69	2392	18.1
October 1999–April 2000	12	21	586	4.4
Total	18	136	13192	

attempt to retain the landrace structure in the samples. In the Lao PDR, as in many other Asian countries, farmers grow mixtures of rice varieties in traditional systems, either as a 'mosaic' of varieties in a field (essentially a group of homogeneous stands of several varieties in the same field), or as a heterogeneous mixture, a system commonly found in the uplands where farmers make no attempt to separate different varieties from each other. Given their varietal complexity the upland rice fields are much more diverse than those in the rainfed lowlands. At harvest, however, they select varieties for seed, panicle by panicle, and these are stored as panicle bunches. Varieties are thus recognized and maintained as distinct entities by the farmers. Furthermore, in many communities there are seed selectors, most often women, with specialized knowledge about the different rice varieties.

As extension officials had no previous experience of collecting, all potential collectors attended training courses that emphasized the practical aspects of collecting. Between 1995 and 1999, we conducted ten courses for 208 officials.

Germplasm samples

Between October 1995 and April 2000 we explored all 136 districts in 17 provinces and the Xaisomboun Special Region (Table 1), and collected 13192 samples of cultivated rice (Table 2), as well as 237 samples of six wild rice species.

Table 2. Classification of rice germplasm by origin, ecosystem, endosperm type, and maturity.

Province	Total samples	Lowland						Upland					
		Glutinous			Nonglutinous			Glutinous			Nonglutinous		
		E	M	L	E	M	L	E	M	L	E	M	L
Northern region	*5915*	*204*	*500*	*405*	*58*	*85*	*80*	*907*	*1693*	*1328*	*120*	*244*	*291*
Luang Prabang	1244	39	89	50	2	17	8	309	380	188	46	66	50
Sayabouly	984	66	108	78	6	13	8	127	311	195	14	23	35
Luang Namtha	858	25	76	71	16	20	14	70	228	213	12	55	58
Oudomxay	848	11	27	39	7	5	5	177	201	296	20	18	42
Bokeo	686	34	68	62	16	10	13	98	161	148	17	20	39
Phongsali	664	20	75	24	10	16	20	68	197	151	11	30	42
Houaphan	631	9	57	81	1	4	12	58	215	137	0	32	25
Central region	*4625*	*594*	*1367*	*613*	*37*	*175*	*82*	*699*	*648*	*181*	*69*	*104*	*56*
Savannakhet	989	130	401	178	5	36	8	97	65	51	10	6	2
Khammouane	867	147	329	141	9	30	15	101	62	27	1	2	3
Vientiane Province	787	71	183	104	1	15	15	181	165	18	14	18	2
Borikhamxay	594	59	151	35	5	16	4	186	89	28	7	10	4
Xiengkhouang	560	47	83	110	6	25	18	47	107	35	22	27	33
Vientiane Municipality	486	115	158	23	6	35	17	51	66	6	4	5	0
Xaisomboun Special Region	342	25	62	22	5	18	5	36	94	16	11	36	12
Southern region	*2652*	*317*	*798*	*244*	*51*	*141*	*70*	*268*	*355*	*158*	*24*	*103*	*123*
Champassak	842	161	364	73	25	42	12	42	62	21	2	13	25
Saravane	774	90	215	84	2	24	8	100	146	62	9	22	12
Attapeu	640	56	149	72	20	62	38	67	55	43	8	26	44
Sekong	396	10	70	15	4	13	12	59	92	32	5	42	42
Total	13192	1115	2665	1262	146	401	232	1874	2696	1667	213	451	470

Production system = lowland and upland; endosperm = glutinous and nonglutinous; maturity = early (E), medium (M) and late (L).

Some 51 easily accessible districts in 4 southern and 5 central provinces were explored from October 1995 to January 1996 (Appa Rao et al. 1997a). Most of the samples were collected from the rainfed lowlands. The wild rices collected included *O. rufipogon*, *O. nivara* and interspecific hybrids between wild and cultivated rice (Appa Rao et al. 1997b). Considerable diversity was found in the spontaneous interspecific hybrids between wild and cultivated rice.

We made four germplasm collecting missions during the 1996 cropping season (from October 1996 to February 1997) and collected 4223 samples of cultivated rice. Double transplanted rice varieties were collected from the provinces of Oudomxay, Luang Namtha and Phongsali. Cold-tolerant varieties were collected from Phongsali and Xiengkhouang provinces. Wild species collected included *O. ridleyi* from Champassak, *O. officinalis* from Khammouane, and *O. granulata* from Luang Prabang and Oudomxay provinces. In addition, *O. nivara* and *O. rufipogon* were collected from throughout the country.

During the 1997 cropping season (between September 1997 and February 1998) we collected 3846 samples. We also collected 39 samples of wild and weedy forms of *O. officinalis*, *O. granulata*, *O. nivara* and *O. rufipogon*, as well as some spontaneous interspecific hybrids. The fourth year of collecting was carried out from September to December 1998, involving three collecting trips. We explored the central and southern regions during September gathering 142 samples of early maturing varieties. From the northern region, we collected 583 samples of early and medium maturing varieties primarily along the main roads. From November to December we collected 1667 samples in remote areas, mainly from threshing floors and households.

After reviewing the status of samples collected from each district with the provincial agricultural officers, 34 districts were identified for further exploration based on the number of germplasm samples already in the collection and diversity believed to exist in an area. Trained extension officers undertook the final collecting missions between October 1999 and April 2000 in 21 districts of 11 provinces. Germplasm was collected for the first time from Thathom district of Xaisomboun Special Region.

Redundancy in the germplasm collected

Though our aim was to collect one sample of each variety, more samples were collected for several reasons. As collecting was going on simultaneously in several districts, extension officers collected whatever varieties they found in their respective districts. Hence, the number of duplicates (based on variety names) is related to their abundance. Though some duplicates appeared uniform from grain characters, considerable variation was observed in apparent duplicate samples collected from different districts, particularly depending on the elevation. The variation was tremendous among the varieties called winged (*Khao peek*) and black (*Khao kam*) rices. Based on names some are certainly duplicates, but many samples that appear as duplicates may be genuinely different varieties. The germplasm samples comprised almost 3200 different variety names (Appa Rao et al. 2001).

Classification of collected germplasm

We classified the germplasm samples according to origin (province and district), ecosystem, endosperm type and maturity, most often using information provided by the farmers themselves.

Samples collected from the northern, central and southern regions were 5915 (44.8%), 4625 (35.1%) and 2652 (20.1%), respectively. Samples collected from the uplands represented 55.9% of the collected material (Table 2). Most samples (1244) were collected from Luang Prabang, a large province having a high proportion of upland rice. Fewest samples (342) were collected from Xaisomboun Special Region where much of the area was inaccessible. Glutinous varieties were more common (85.5%) than nonglutinous ones (14.5%), reflecting farmer and consumer preferences. Overall, 86.6% of lowland and 84.6% of upland samples collected were glutinous (Table 2). Relatively more nonglutinous types were sampled in the northern provinces, where there is a preponderance of Hmong and Yao ethnic groups (UNDP (United Nations Development Program) Lao PDR 1998). More nonglutinous samples were obtained in the rainfed upland areas (1134) than in the lowland ecosystem (779).

Medium-maturing samples comprised 47.1% of the collection, whereas late- and early maturing samples represented 27.5% and 25.4%, respectively. Early-maturing varieties were slightly more common in the uplands (15.8%) than in the lowlands (9.6%) reflecting perhaps adaptation to low soil moisture conditions in the uplands. Farmers grow varieties of different maturity to spread labour requirements, provide

stability due to environmental variation, and produce varieties of varying food quality.

Glutinous rice and its importance in Laos

It is widely recognized that the center of origin of the glutinous rices is the Lao PDR and northern Thailand (Watabe 1976). The endosperm is related to cooking quality characteristics of rice. Only while drying after harvest does glutinous rice become distinguishable from nonglutinous rice. Glutinous grains have a higher viscosity than the nonglutinous varieties when heated, and so it is popularly called 'sticky rice'.

Of the 47 recognized ethnic groups in Laos, most are predominantly consumers of glutinous rice. The Lao-Tai ethnic groups, accounting for more than 50% of the population (Batson 1991), are also the largest consumers of glutinous rice, averaging about 90% of their rice intake. Other ethnic groups such as Khamu and Lamet from the north, and Taoey, Katu, Laven, and Pako in the south and the Tibeto-Burmese groups (Akha, Lahu, Lolo and Phunoi) also predominantly consume glutinous rice. The two main groups who are consumers of nonglutinous rice are the Hmong and Yao who settled during the 19th and early 20th centuries (Batson 1991; Goudineau 1997).

Diversity for crop duration

Lao farmers allocate varieties to particular fields based mainly on crop duration and soil moisture. In general, the range of maturity of upland varieties is considerably less than that for lowland varieties.

Most samples collected were so-called 'medium duration' varieties (125–145 days). These varieties are usually higher yielding than early varieties that ripen in 90–130 days, and are planted on well-drained middle terraces. They mature about the end of the rainy season and are kept for yearlong consumption. Farmers appear to have selected early and long duration varieties for specific purposes. Harvesting methods have probably contributed to their evolution. Lao farmers practice panicle selection and grain stripping, and these stabilize the main seed types and also bring about systematic grouping among off-types. Early ripening types are harvested as they ripen to secure some grain for consumption in those periods when households have a rice deficit; longer duration types are left in the field to the gleaners. In this way, over a long period of time, panicle selection might have resulted in the differentiation of varieties into three distinct duration classes.

Early varieties are planted around households, in low-lying areas or near the foothills of mountain slopes above the valleys, where water accumulates with the first rains. They provide a food source in the period immediately before harvest when most upland households would have exhausted their food reserves. Most of them are consumed immediately; very rarely are they kept for a long time. The word *do* (early) in a variety name indicates its early maturity. These varieties are also called *sam deuan* (three months) crop. Sometimes early varieties are grown in fields that would normally be planted to a medium maturing variety, in order to meet immediate food needs. Harvesting of early varieties often takes place in September, coinciding with the heaviest rainfall. After harvesting and threshing, the grain is dried on raised platforms in a shaded location.

Long duration varieties are mainly grown in low-lying areas on the beds of watercourses or inland valley swamps in areas with variable water levels. They are the varieties that are planted last; they flower at the end of rainy season (most are photoperiod sensitive), and mature after more than 145 days. They grow very tall, produce very thick stems, and long and broad leaves, are profusely tillering, and synchronous in flowering and maturity, and produce large panicles. They are harvested after the main crop. The area under late varieties is limited on account of the prevailing low temperatures from December through February in the northern region, which limits crop growth. These varieties usually produce good quality grain as they mature after November, when the rains stop.

Germplasm conservation

All the collected samples were dried, threshed, cleaned and processed at NARC. Seeds were air-dried under shade in muslin cloth bags for about 8–10 weeks reaching about 10% moisture content. Dried samples were threshed manually to avoid damage due to cracking, and debris, unfilled or partly filled seeds, and inert material were removed. Samples were stored in sealed laminated aluminum foil packets. The country's first national cold storage facility to conserve rice germplasm was built at NARC in 1995. It was designed for seed storage at 10 and 5 °C and about 50% relative humidity. The genebank has since ac-

quired a long-term storage capability with the installation of three deep freezers, which can maintain 20 g samples at −18 °C. A set of all the samples is also duplicated at the International Rice Genebank (IRG) at IRRI in the Philippines. IRRI has already returned high quality seed samples to the Lao national genebank for long-term storage after multiplication at Los Baños.

The rice germplasm of the Lao PDR is a genetic treasure that has now been safeguarded for future generations of Lao farmers. Much of the germplasm is unique to the country and represents a range of diversity, particularly for glutinous varieties, found to a limited extent in neighboring countries only. Already, the Lao rice improvement program is characterizing and evaluating the germplasm in regional trials with the aim of making selection of superior types that can contribute towards increasing rice productivity, particularly in the uplands.

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