CHAPTER 9

# Diversity within the traditional rice varieties of Laos

S. Appa Rao, J.M. Schiller, C. Bounphanousay, and M.T. Jackson

The development of improved rice varieties in most countries of Asia has generally resulted in their widespread adoption by farmers, with the replacement of traditional varieties, leading to an erosion of the rice germplasm base in these countries. In most Asian countries, this change took place during the 1970s and 1980s. In Laos, however, the period of the Green Revolution had little impact on the way rice was cultivated and, as late as 1990, more than 90% of lowland rice cultivation in the country was still based on the use of traditional varieties. In the rainfed upland environment, almost 100% of production was based on the use of traditional varieties (Schiller et al 2001). Change in rice production in Laos started about 1995, following the 1993 release of the first of a series of improved varieties developed within the country as part of the development of a national rice research program. Anticipating that Lao farmers would quickly adopt these improved varieties, in combination with the adoption of other technical recommendations capable of bringing about a substantial increase in yield, a program to assemble a representative collection of the traditional rice germplasm for long-term conservation began in mid-1995. In a collaborative program with the Lao Ministry of Agriculture and Forestry, the International Rice Research Institute (IRRI) jointly explored most rice-growing areas of the country from 1995 to early 2000. During this period, a total of 13,192 samples of cultivated rice were collected, together with 237 samples of six wild rice species of the genus *Oryza*. This chapter primarily describes the classification of the traditional rice germplasm that was collected and that is now being preserved at the Genetic Resources Center (GRC) of IRRI, as well as being used for the further improvement of varieties being developed by the national rice research program of Laos. More detailed information on the collections is available in records maintained by the GRC, as well as in detailed reports of the collecting missions (Appa Rao et al 1997b, 2002a,b,c).

## Laos and the origin of Asian cultivated rice

The genus *Oryza*, to which cultivated rice belongs, has 20 wild and two cultivated species. Of the 20 wild species of *Oryza*, six are found in Laos (Appa Rao et al 1998, Kuroda et al, Chapter 15). Among these, the wild progenitor, *O. rufipogon,* of Asian

rice, *O. sativa,* is found throughout the country and is particularly abundant in the central and southern agricultural regions. Spontaneous interspecific hybrids between the wild and cultivated forms of rice, showing continuous variation from wild to cultivated forms, have also been observed in Laos (Appa Rao et al 1997a, 1998, 2000d). Pottery shards bearing the imprints of the grains and husks of *O. sativa* and that date to at least 2000 B.C. have been recorded at archaeological sites in northeast Thailand, an area with geographic and historic continuity with modern-day Laos (Solheim 1972, White 1997). It is generally accepted that Laos lies within the general area that is accepted as the area of origin of Asian rice, *O. sativa* (Chang 1976, Oka 1988, Khush 1997).

## Rice germplasm collected before 1995

Recognizing the diversity and importance of the traditional rice varieties in Laos, a number of rice germplasm collecting missions were undertaken in Laos from 1970 to 1990, being variously supported by USAID, Russia, Japan, and other agencies/countries (Schiller et al 2001, Inthapanya et al 1997). From 1991 to 1994, a further collection of more than 1,000 samples was made in the upland environment in six provinces of the northern agricultural region of the country in a joint initiative between the Lao Ministry of Agriculture and Forestry (MAF) and a Swiss-supported national rice research program activity implemented through IRRI (Roder et al 1996). However, the passport information on the samples from for these collecting missions was generally incomplete. Further, because of the lack of appropriate storage facilities in the country during that time, the collections were unable to be maintained without annual rejuvenation and, unfortunately, these collections are no longer available.

## Rice germplasm collected from 1995 to 2000

The systematic collecting undertaken from 1995 to 2000 was part of a project to collect and conserve the biodiversity of the rice gene pool in 22 countries in South and Southeast Asia, sub-Saharan Africa, and Central America (IRRI 1994). This was carried out with financial support from the Swiss Agency for Development and Cooperation (SDC).

### Collection strategy

MAF and IRRI jointly undertook rice germplasm collecting throughout the country. In consultation with the Provincial Agriculture and Forestry Offices (PAFOs) for all provinces of the country, a 5-year collecting program was prepared and agreed upon. The level of genetic erosion occurring in a particular area (as reflected by the rate of adoption of improved varieties), the availability of local support, safety considerations, and accessibility of target areas formed the basis for selecting priority areas for collecting. From October 1995 to April 2000, all 136 districts in 17 provinces and the Saysomboun Special Economic Region (Fig. 1) were explored.

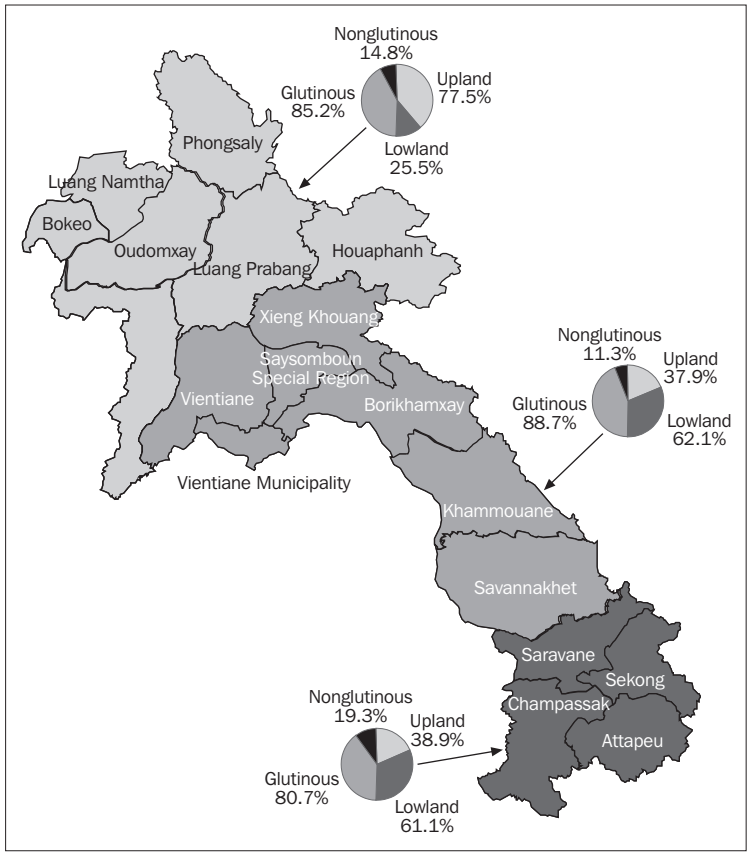


**Fig. 1. Rice samples collected from the upland and lowland environments, with glutinous and nonglutinous endosperm, for the agricultural regions of Laos.**

## Collection procedure

The objective was to collect enough material to represent the maximum diversity with a minimum number of samples. To achieve this, the goal was to collect at least one sample of each variety from each district. While recognizing that farmers sometimes call different varieties by the same name, it was also acknowledged from the outset that different names are used in different areas for the same variety. Collecting started at crop maturity (about 1 week before harvest) and continued until threshing. Though the goal was to obtain most of the samples directly from farmers' fields before harvest (September-December), in areas inaccessible during the wet season, samples were obtained after harvest from the threshing floor or farmers' grain stores, from January to April. Generally, a greater proportion of upland varieties was collected after harvest because of difficulties of access during the growing season.

The collections were made by officials attached to the District Agriculture and Forestry Offices (DAFOs), supported by staff of the Lao national rice research

program and an IRRI germplasm specialist. The district-level staff usually had a good knowledge of local farming practices and could communicate effectively with the farmers. The germplasm samples collected included landrace varieties, slightly improved varieties, intermediate weedy forms that occurred as spontaneous hybrids between wild and cultivated forms, and wild species of the genus *Oryza*. Collecting was done only from wet-season cropping areas, as, at the time of collecting, only improved varieties were being grown in the dry-season irrigated environment.

### Sampling technique

The 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, together with any other distinct type(s) 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 use. When sampling from relatively uniform fields, only one random bulk sample was collected. However, when rare phenotypes were encountered, they were kept as separate samples. In general, an attempt was made to retain the landrace structure in the samples.

Although the goal was to collect one sample of each variety, for a number of reasons, several samples were sometimes collected for certain varieties. As collecting was being undertaken simultaneously in several districts, extension officers collected whatever varieties they found in their respective districts. Hence, duplicate samples (based on variety names) were sometimes collected, with their frequency of collection reflecting their relative abundance in an area. Though some duplicates appeared uniform in relation to grain characteristics, considerable variation was sometimes observed in some duplicate samples, particularly when these samples came from areas with differences in elevation. It is therefore acknowledged that, within the 3,169 different variety names assigned by farmers and recorded during collecting (see Chapter 10), some varietal names represent duplicate samples, whereas, at the same time, many samples that appear as duplicates may in fact be genuinely different varieties.

Apart from some localized areas for which accessibility was restricted, the collection of 13,192 samples of cultivated rice made from 1995 to 2000 is regarded as being representative of the rice genetic resource base of the whole of Laos. It is also regarded as one of the most comprehensive collections of the traditional rice germplasm made for conservation and use, for any single country, and by far the most comprehensive collection made for any country the approximate size of Laos.

## Classification of the rice germplasm samples collected from 1995 to 2000

At the time of collecting samples from the farmers, information for up to 36 descriptors was obtained to provide the passport information for each sample, based on guidelines of the IRRI Genetic Resources Center. These descriptors were modified to suit the conditions of Laos by including endosperm type, aroma, and other traits

**Table 1. Classification of germplasm samples based on region, ecosystem, and endosperm type.**

| Region | Total samples | | Ecosystem | | | | Endosperm type | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lowland | | Upland | | Glutinous | | Nonglutinous | |
| | No. | % | No. | % | No. | % | No. | % | No. | % |
| Central | 4,625 | 35.1 | 2,868 | 49.3 | 1,757 | 23.8 | 4,102 | 36.4 | 523 | 27.3 |
| Northern | 5,915 | 44.8 | 1,332 | 22.9 | 4,583 | 62.2 | 5,037 | 44.7 | 878 | 45.9 |
| Southern | 2,652 | 20.1 | 1,621 | 27.8 | 1,031 | 14.0 | 2,140 | 19.0 | 512 | 26.8 |
| Total | 13,192 | 100.0 | 5,821 | 100.0 | 7,371 | 100.0 | 11,279 | 100.0 | 1,913 | 100.0 |

unique to Laos. The passport information collected was largely based on the information provided by the farmers themselves. With the passport information collected, the germplasm samples were classified according to origin (province and district), ecosystem (lowland or upland), endosperm type (glutinous or nonglutinous), and maturity time (early, medium, or late).

The numbers of samples collected from the northern, central, and southern regions were 5,915 (44.8%), 4,625 (35.1%), and 2,652 (20.1%), respectively (Table 1). More samples (55.9%) were collected from the upland environment than from lowland sites (44.1%). Most of the samples (85.5%) had glutinous endosperm. The highest proportion of upland samples was collected from the northern agricultural region (77.5%), whereas about 38% of the samples came from the upland environment in the central and southern regions (Fig. 1). In all three regions, samples with glutinous (waxy) endosperm accounted for the majority of those collected (Fig. 1), with 85.5% of the total samples collected being in this category (Table 1).

The province from which the largest number of samples was collected was Luang Prabang in the northern agricultural region, with 1,243 samples (9.4% of the total), of which 875 (70.4%) were collected from the upland environment (Table 2). Other provinces from which large numbers of samples were collected in the upland environment were Oudomxay (675) and Sayabouly (632). Provinces for which the largest numbers of samples were collected in the lowland environment were Savannakhet (759) and Khammouane (671) in the central agricultural region and Champassak (677) in the southern region.

## Diversity in the traditional rice varieties

### Diversity of variety names

For the total of 13,192 samples of traditional varieties collected from 1995 to 2000, variety names were recorded for all but 6% (789). The inability to record variety names for these samples reflected the great ethnic diversity that exists in the areas where collections were made (Laos has 48 recognized ethnic groups, ADB 2001), and associated difficulties in translating some of the variety names of some ethnic groups

**Table 2. Classification of germplasm samples based on region, province, ecosystem, endosperm type, and maturity.[a]**

| Region | Province name | Total | Lowland environment | | | | | | | | Upland environment | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Nonglutinous | | | | Glutinous | | | | Nonglutinous | | | | Glutinous | | | |
| | | | E | M | L | Total | E | M | L | Total | E | M | L | Total | E | M | L | Total |
| Central | Borikhamxay (BK) | 594 | 5 | 16 | 4 | 25 | 59 | 151 | 35 | 245 | 7 | 10 | 4 | 21 | 186 | 89 | 28 | 303 |
| Central | Khammouane (KM) | 867 | 9 | 30 | 15 | 54 | 147 | 329 | 141 | 617 | 1 | 2 | 3 | 6 | 101 | 62 | 27 | 190 |
| Central | Savannakhet (SK) | 989 | 5 | 36 | 8 | 49 | 130 | 401 | 178 | 709 | 10 | 6 | 2 | 18 | 97 | 65 | 51 | 213 |
| Central | Vientiane Municipality (VM) | 486 | 6 | 35 | 17 | 58 | 115 | 158 | 23 | 296 | 4 | 5 | 0 | 9 | 51 | 66 | 6 | 123 |
| Central | Vientiane Province (VP) | 787 | 1 | 15 | 15 | 31 | 71 | 183 | 104 | 358 | 14 | 18 | 2 | 34 | 181 | 165 | 18 | 364 |
| Central | Saysomboun (XS) | 342 | 5 | 18 | 5 | 28 | 25 | 62 | 22 | 109 | 11 | 36 | 12 | 59 | 36 | 94 | 16 | 146 |
| Central | Xieng Khouang (XK) | 560 | 6 | 25 | 18 | 49 | 47 | 83 | 110 | 240 | 22 | 27 | 33 | 82 | 47 | 107 | 35 | 189 |
| Northern | Bokeo (BO) | 686 | 16 | 10 | 13 | 39 | 34 | 68 | 62 | 164 | 17 | 20 | 39 | 76 | 98 | 161 | 148 | 407 |
| Northern | Houaphanh (HP) | 631 | 1 | 4 | 12 | 17 | 9 | 57 | 81 | 147 | | 32 | 25 | 57 | 58 | 215 | 137 | 410 |
| Northern | Luang Namtha (LN) | 858 | 16 | 20 | 14 | 50 | 25 | 76 | 71 | 172 | 12 | 55 | 58 | 125 | 70 | 228 | 213 | 511 |
| Northern | Luang Prabang (LP) | 1,244 | 2 | 17 | 8 | 27 | 39 | 89 | 50 | 178 | 46 | 66 | 50 | 162 | 309 | 380 | 188 | 877 |
| Northern | Oudomxay (OD) | 848 | 7 | 5 | 5 | 17 | 11 | 27 | 39 | 77 | 20 | 18 | 42 | 80 | 177 | 201 | 296 | 674 |
| Northern | Phongsaly (PL) | 664 | 10 | 16 | 20 | 46 | 20 | 75 | 24 | 119 | 11 | 30 | 42 | 83 | 68 | 197 | 151 | 416 |
| Northern | Sayabouly (SB) | 984 | 6 | 13 | 8 | 27 | 66 | 108 | 78 | 252 | 14 | 23 | 35 | 72 | 127 | 311 | 195 | 633 |
| Southern | Attapeu (AT) | 640 | 20 | 62 | 38 | 120 | 56 | 149 | 72 | 277 | 8 | 26 | 44 | 78 | 67 | 55 | 43 | 165 |
| Southern | Champassak (CS) | 842 | 25 | 42 | 12 | 79 | 161 | 364 | 73 | 598 | 2 | 13 | 25 | 40 | 42 | 62 | 21 | 125 |
| Southern | Saravane (SV) | 774 | 2 | 24 | 8 | 34 | 90 | 215 | 84 | 389 | 9 | 22 | 12 | 43 | 100 | 146 | 62 | 308 |
| Southern | Sekong (SG) | 396 | 4 | 13 | 12 | 29 | 10 | 70 | 15 | 95 | 5 | 42 | 42 | 89 | 59 | 92 | 32 | 183 |
| | Total | 13,192 | | | | 779 | | | | 5,042 | | | | 1,134 | | | | 6,237 |

[a]E = early maturity, M = medium maturity, L = late maturity.
Source: Appa Rao et al (2002b).

**Table 3. Distribution of distinct variety names in regions of Laos.**

| Region | Total samples collected | Number of samples with names | Number of names |
|---|---|---|---|
| Northern | 5,915 | 5,613 | 1,120 |
| Central | 4,625 | 4,321 | 613 |
| Southern | 2,652 | 2,469 | 583 |
| Total | 13,192 | 12,403 | 2,316 |

into the Lao language (and subsequently into English). In addition, some farmers, particularly younger ones, did not know the variety names. Of the 12,403 samples for which variety names were recorded, ethnic names were recorded for 1,414 samples, which were later translated into Lao and English, whereas ethnic names for another 151 samples that were recorded were unable to be translated.

The largest number of names (1,120) was recorded in the northern agricultural region, and least (583) in the southern agricultural region (Table 3). A detailed analysis of the naming of the varieties is reported by Appa Rao et al (2002c) and in Chapter 10.

There was usually greater diversity of names in provinces with the larger areas of upland rice cultivation, reflecting the greater ethnic diversity in such areas, together with the associated diversity of rice preferences with different food quality attributes (see Chapter 10). The northern province of Luang Prabang, which has the largest area of upland rice of any single province in the country, had the highest number (462) of variety names. Although fewer individual varieties were collected from some provinces in the southern agricultural region, several of these provinces had high numbers of unique varieties (a variety was classified as unique to a province when it was recorded as having been collected only in that province). In the southern province of Attapeu, 62.2% of the samples collected and names were classified as being unique. This province, together with others with high levels of unique varieties, is remote and has a high level of ethnic diversity in the population. As might be expected, the number of unique variety names recorded in the lowland rice-growing provinces in the Mekong River Valley was generally lower than in other areas of the country. This reflected the fact that there is generally less ethnic diversity within the population in these areas, together with greater opportunities for variety exchange across provincial boundaries, and greater adoption of introduced varieties in the period before the collecting missions.

## Diversity within a population

Traditional lowland varieties are relatively more uniform in terms of maturity, plant height, and grain and panicle characteristics than upland varieties. Upland farmers usually grow upland rice crops, which contain a mixture of several morphological

**Table 4. Classification of germplasm samples based on growing environments and maturity.**

| Ecosystem | Total samples | Maturity[a]: no. (%) | | |
|---|---|---|---|---|
| | | Early | Medium | Late |
| Upland | 7,371 | 2,087 (28.3) | 3,147 (42.7) | 2,137 (29.0) |
| Lowland[b] | 5,821 | 1,261 (21.7) | 3,066 (52.7) | 1,494 (25.7) |
| Total | 13,192 | 3,348 (25.4) | 6,213 (47.1) | 3,631 (27.5) |

[a]Percentages represent comparisons between maturity groupings within each growing environment. [b]Represents the wet-season lowland environment (mainly rainfed) as the dry-season irrigated environment is planted only to improved varieties.

phenotypes, with variation in flowering, plant height, and panicle and grain characteristics (Photo 9.1). This difference between upland and lowland variety characteristics may be related to the differences in agroclimatic conditions, together with cultural differences and different seed selection practices in the different growing environments. Greater diversity in upland varieties is also probably partly due to the deliberate mixing of several phenotypes, with the hope that some types will perform better in the year-to-year uncertainty of growing conditions that are a feature of the upland environment. In one instance, where collecting was being undertaken in an upland field in the southern province of Champassak, 11 different phenotypes were found to be growing together, with differences in the shape and size of panicles, and in the pigmentation of the grain. In the northern province of Luang Namtha, eight different phenotypes were identified in a single upland field, with differences in the shape and size of panicles, and in the pigmentation of the grain.

## Diversity for morphological characters

Landrace cultivars grown in both rainfed upland and lowland ecosystems differ for a range of characters, including crop duration; plant height; tillering; pigmentation on various plant parts; panicle shape and size; grain shape, size, and color; and cooking and eating qualities. The latter represent varietal preferences for different food preparations. A high level of variation was observed for brown rice color, from black to red, and to brown or white. Appa Rao et al in Chapter 12 give a separate description of the "black rice" collected from 1995 to 2000.

## Diversity for races

Based on gross morphology of the plant, most upland varieties belong to the javanica group, as they produce thick culms, dark green, long, and wide leaf blades, few but large panicles, and large grain. Most lowland varieties produce narrow and long leaf blades, many thin culms, panicles that are small and numerous, with varying grain size that is typical to the indica race. Only two accessions in the collection belonged to the

japonica group, both of which appear to be recent introductions. Intermediate forms between javanica and indica predominate. Most of the morphological characteristics that are generally considered typical for the tropical japonica are classified as the javanica varietal group. Isozyme analysis was done on 318 entries at IRRI-Los Baños using the methods described by Glaszmann (1987). Enzymatic analysis confirmed that more than 90% of the upland accessions belonged to the tropical japonica group (Roder et al 1995). Varieties belonging to this group often have a superior root system when compared with those of the other groups, and should be better adapted to areas, such as the upland growing environments, that experience periodic moisture stress.

Some characters appear to be associated with the particular ethnic groups found in different parts of the country. For example, farmers in Bolikhan District of Borikhamxay Province grow varieties that produce long peduncles, as the practice is to harvest the panicles with a small iron blade and tie them into bundles. Several ethnic groups in predominantly upland areas hand-strip the grain from a standing crop. These varieties have fewer but larger panicles with larger grains that thresh easily to facilitate easy stripping. The lowland Lao, who live near urban areas and along the border with Thailand, grow aromatic varieties because of the market demand and premium paid for high-quality aromatic grain. Some varieties are suited to specific food preparations; for example, the grain of some varieties of *Khao kam* (black rice) is often cooked with coconut milk to provide a sweetened dessert. The variety *Lep nok* (bird's claw), so named on account of the tip of the spikelet being hooked like a claw, is popular in the districts of Khong and Bachiang in Champassak Province, Phouvong District of Attapeu Province, and Khongsedon District of Saravane Province, all of which are in southern Laos, together with Viengxai District of Houaphanh Province in northern Laos. This variety is used to make the popular Lao confectionary crisp called *khao kiap*. The strong preference for such specialized uses of rice contributes to the overall diversity in grain quality attributes. In many situations, farmers grow specific varieties with specific quality attributes for particular food preparations, rather than select types that are specifically adapted to either the short growing season or the dry mountainous environments.

## Diversity for ecosystems

Farmers' varieties grown under rainfed lowland and upland environments differ considerably for morphological, physiological, and grain quality attributes. The morphological differences are so great and distinct that it is often possible to differentiate and identify upland rice plants and/or rice grains from lowland plants or grains (Photo 9.2). The main characteristics used to differentiate between the two types are grain size, aroma, tiller number, and stem diameter. According to the farmers' main selection criteria, typical upland varieties are expected to have large but few panicles, strong thick stems, broad thick leaves, early flowering and maturity, and few but larger panicles with large grains. In contrast, lowland varieties often have many thin culms, narrow thin leaf blades, and many but smaller panicles with small to medium-sized grain.

Farmers normally do not grow upland varieties under lowland conditions and vice versa, unless compelled to do so on account of a lack of sufficient seed of appropriate varieties at sowing time. However, some varieties can be grown in both upland and lowland environments. Variety *Hai na (*upland-lowland) collected in Phoukhout District of Xieng Khouang Province, Xai and Beng districts of Oudomxay, and Fuang District of Vientiane Province is considered suitable for cropping in both environments. Another variety, *Hai na suan* (upland, lowland, garden), is popular in parts of Xieng Khouang Province and, although mainly grown under upland conditions, is also regarded as being suitable for the lowland environment. Usually, this variety is grown on elevated but level land, and is dibble-planted in the usual manner for upland rice. After 3 to 5 weeks, depending on the rainfall, excess seedlings are uprooted and planted in lowlands. Variety *Dok tiaw* (tiaw flower) grown in Saythany District of Vientiane Municipality is mainly grown in the lowland environment but can also be grown in upland conditions. Another variety, *Phae deng* (multi-tillering, red), also found in Saythany District, is normally an upland variety but is also considered suitable for lowland conditions. These varieties are of considerable evolutionary significance as they may represent the transition of the adaptation of varieties from lowland to upland conditions, or vice versa. They may have also developed as a result of spontaneous hybridization between upland and lowland varieties, both of which are sometimes grown in close proximity.

## Diversity for crop maturity time

Lao farmers allocate varieties to particular fields based mainly on crop duration and likely duration of available soil moisture. Care needs to be taken in the interpretation of maturity times between environments, for the definition of early, medium, and late varieties by upland farmers can differ from that of farmers in the lowland environment. The information recorded and the classification summarized in Tables 1 and 3 are based on the classification of individual samples provided by farmers who donated seed samples. It is generally accepted that varieties in the rainfed upland environment mature earlier than varieties in the wet-season lowland environment. Although a variety classified as early maturing might ripen in 90 to 120 days in the uplands, such a variety might in fact be harvested 3 or 4 weeks earlier than a variety classified as early maturing in the lowland environment. Despite the difference in harvest time, the actual time to maturity between the two environments might be similar on account of the earlier planting in the upland situation. Similarly, for late-maturing varieties, in the upland environment they would be harvested sometime in October, whereas, in the lowland environment, late-maturing varieties might not be harvested until late November or early December; however, sowing of late-maturing varieties in uplands would usually be considerably earlier than in lowlands. Generally, all the traditional varieties in each maturity category are photoperiod-sensitive, with the later-maturing varieties being more strongly photoperiod-sensitive than the earlier-maturing varieties.

For samples collected in the rainfed upland environment, 42.7% were classified as being of medium maturity, with approximately equal proportions classified

as being early- and late-maturing (28.3% and 29.0%, respectively). For the lowland environment, 52.7% of the samples were classified as being of medium maturity, with a slightly higher proportion of late-maturing relative to early-maturing samples (25.7% and 21.7%, respectively).

Early-maturing varieties in the uplands are generally planted close to 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, in particular, have exhausted their food-grain reserves. In situations where households have significant and chronic rice deficits, early-maturing varieties are sometimes grown in fields that would normally be planted to a medium-maturing variety, the choice of the early-maturing variety being based on the need to obtain grain for consumption as early as possible in the growing season. Harvesting of early varieties often takes place in September, coinciding with the period of heaviest rainfall. After harvesting and threshing, the grain is dried on raised platforms in a shaded location.

Some farmers interviewed planted five different rice varieties. In lowland areas, farmers often grow varieties of different maturity to spread labor requirements, provide stability to offset environmental variation, and produce more. Some farmers interviewed planted five different rice varieties. Early- and medium-maturing varieties are usually grown in the upper parts of terraces where there is a greater likelihood of drought stress immediately after the end of the wet season. 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. These varieties are planted last; they flower at the end of the 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, are synchronous in flowering and maturity, and produce large panicles. 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.

Harvesting methods along with seed selection practices have probably contributed to variety 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.

## Diversity for endosperm type

The type of endosperm in the rice grain is related to cooking quality characteristics of rice. Glutinous grains have a higher viscosity than nonglutinous grains when heated, and so this type is popularly called sticky rice. Only after harvest, while drying, does

glutinous rice grain become distinguishable from nonglutinous rice. In the overall collection, glutinous samples accounted for 85.5% of the total, reflecting farmer and consumer preference for this type of rice. Overall, 86.6% of lowland and 84.6% of upland samples collected were glutinous (Fig. 1). The relatively higher proportion of nonglutinous types sampled in the northern region is probably a reflection of the presence of significant numbers of farmers belonging to the Hmong and Yao ethnic groups in this region (UNDP 1998); both these ethnic groups consume nonglutinous rather than glutinous rice. Similarly, the greater number of nonglutinous varieties found in the upland environment (1,134 samples) relative to the lowland environment (779) also reflects the fact that the Hmong and Yao ethnic groups are to be found almost exclusively at higher altitudes in the upland environment.

For a few varieties, the endosperm is intermediate between glutinous and nonglutinous forms. Two such varieties are referred to as *Chao kheng* (nonglutinous, hard) and *Khao ma-yeng* (rice watched by a dog). Samples of *Chao kheng* were collected from Long and Nale districts of Luang Namtha Province, Xai District of Oudomxay Province, and Houayxay District of Bokeo Province, all in northern Laos, and also from Atsaphangthong District of Attapeu Province in southern Laos. *Khao ma-yeng,* on the other hand, was collected mainly from provinces in the central and upper southern regions—Vientiane Municipality and the provinces of Borikhamxay and Savannakhet; it was also collected from three districts of Luang Prabang Province. The eating quality of these intermediate types is considered to be so inferior that even a dog does not like to eat them but prefers to sit and look at them (hence the name *Khao ma-yeng* or rice watched by a dog). This type of rice is not usually grown by farmers but is found occasionally among glutinous varieties. Such types are eliminated during the time of seed selection. The occurrence of these intermediate types might be the result of spontaneous crossing between the glutinous and nonglutinous forms. The type *Chao niaw* (nonglutinous sticky rice), though considered as a nonglutinous variety, becomes sticky after cooking. Some varieties have the word *paeng* as part of their name to reflect their floury or powdery endosperm. A study of the amylose and amylopectin content of these varieties could help provide a better understanding of the evolution of sticky rice.

## Varietal diversity at the household level

### Lowlands

In the wet season, most lowland farmers grow a group of homogeneous stands of several varieties in small plots as a mosaic in the same field. The varieties grown differ for several characters that include grain quality attributes to suit various types of food preparations and maturity duration—early, medium, and late—besides others. Mixtures of two different varieties are sometimes grown to complement one another, but farmers usually try to keep their varieties separate. Lowland farmers, when growing traditional varieties, usually do not grow more than three (although small areas of speciality rice might also be grown in addition to the main varieties). With the adoption

of the more recently available improved varieties, fewer varieties are generally being grown by individual households.

### Uplands

Upland farmers clearly differentiate among early, medium, and later-maturing varieties and most households plant varieties from each group. This allows them to harvest rice for consumption as early as possible, distribute labor requirements for the harvest, and spread risk (Roder et al 1996). In addition, special varieties are sometimes grown for religious ceremonies, nonglutinous varieties for noodle making, and some varieties suited to making alcoholic beverages. Most upland farmers grow three to five varieties, with each variety showing differences in maturity.

### Mixing of varieties

In both the upland and lowland environments, farmers sometimes grow a mixture of varieties in one field. This is more often the case in the upland environment, where a heterogeneous mixture of several varieties is sometimes grown. The purpose of such mixtures is to reduce the potential risks associated with single-variety cropping such as drought, pests, and diseases. The variety mixture usually results in greater yield stability. Although less frequent in the lowland environment, planting of varietal mixtures occasionally does take place. For example, in parts of Kham District in Xieng Khouang, a variety called *Mak pho* (banyan fruit), which has good resistance to lodging but has poor grain quality and is susceptible to gall midge, is mixed with another variety, *Khao bong,* which is susceptible to lodging but has good grain quality, is aromatic, has a high recovery after milling, and is resistant to gall midge. Farmers mix *Mak pho* with *Khao bong* at a ratio of about 35:65; the mix results in a crop that does not lodge and that gives a product with good eating quality. The two varieties are of the same height, mature at the same time, and have glutinous endosperm. However, the seed of the two varieties can be differentiated by the color of the glumes. In each of the three northern provinces of Luang Namtha, Oudomxay, and Houaphanh, some districts have varietal mixtures that are also sometimes grown in the lowlands, with the mixtures being believed to give higher yields and greater yield stability than single-variety crops.

In Pakse District of Champassak in southern Laos, farmers sometimes grow a single variety consisting of two morphologically distinct types. This variety, known as *Pua-mia* (husband-wife), appears to be composed of two isogenic lines that differ only in respect to glume color: one line has purple to brown glumes, while the other has green glumes that turn yellow upon maturity. The lines not only are similar morphologically but also flower and mature at the same time; farmers grow them together as if they constituted a single variety. The two types appear to be identical until the time of maturity, when a change in glume color identifies each line.

## Varietal diversity at the community level

Lao farmers live in small community villages, with each village usually being inhabited by a particular ethnic group. However, in some areas, particularly resettlement areas in central and southern Laos, a village sometimes contains more than one ethnic group. Although individual farming households may grow only two or three varieties, at a community level there is often much greater diversity, depending on the region, ecosystem, and ethnic group. In the southern region, most communities grow a minimum of three varieties representing three maturity groups—early, medium, and late. However, some communities in Vientiane Province in the central region were found to be growing up to 10 varieties (Appa Rao et al 1997b). In Khamkeut District of Khammouane in the central region, 19 varieties with varying grain characters were collected from a single village. These varieties included rainfed lowland, rainfed upland, glutinous, and nonglutinous types of varying maturity time. In general, diversity at the community level is greater in the northern region than in the southern and central regions. In a single village in the district of Vieng Kham in Luang Prabang, 18 distinct varieties were recorded as being grown. Generally, variety diversity at the community level is greater in upland environments than in lowland areas. This, in turn, reflects the generally greater diversity of both ethnic groups and growing environments in the more mountainous northern areas of the country than in the main lowland rice-growing areas in the central and southern agricultural regions.

## Seed selection procedures

The maintenance of the great diversity of traditional rice varieties found in Laos reflects the seed selection practices that have been developed. These practices are often quite different between the upland and lowland environments, with these differences in turn being reflected in the "within-crop" diversity that exists between these environments.

### Upland environment

As upland farmers often grow mixtures of different varieties in the same field, as part of their seed selection process, they deliberately collect panicles representative of all types and keep the mixed population for seed purposes. While some households thresh the panicles and store the seed, others tie the panicles into bundles and store them in this form until planting time in the subsequent year. Another technique sometimes used is to hand-strip the grain from the more attractive panicles separately at the time of stripping panicles for grain purposes. Occasionally, farmers collect a small quantity of seed from the bulk-harvested grain for use as seed. However, specific attention is generally given by upland farmers to the selection of seed to be used for the following season's crop. Differences also exist in the seed selection procedures within the diverse ethnic groups found in the upland environment.

### Lowland environment

Most lowland farmers select their most uniform and best fields for the purpose of obtaining seed for the succeeding crop; the area selected for this purpose is usually harvested and threshed separately from that which provides grain for consumption. Often, the part of the crop to be used for seed grain is also harvested after the harvest of the remainder of the crop. Before threshing the seed-grain component of the crop, off-type panicles are usually identified and removed, resulting in a crop with more uniform panicles. The seed grain is usually carefully packed and stored separately from the component of the crop used for consumption. Occasionally, to obtain seed grain, farmers may take bulk seed from the threshing floor and then sieve this to eliminate unfilled or partially filled seed and other impurities.

## Germplasm erosion

Rice cultivation in both the rainfed lowland and rainfed upland environments of Laos has, until relatively recently, been based on the use of traditional varieties and minimum inputs, using family labor as the most important input. Even in the main lowland rice-growing areas of the Mekong River Valley in the central and southern agricultural regions, until as recently as the early 1990s, it was estimated that more than 90% of rice cultivation was based on the use of traditional varieties. In the upland environment, only traditional varieties were grown. The first improved Lao glutinous varieties were released in 1993 and they proved well suited to the main lowland areas, such that, by 2000, more than 80% of the wet-season rice area in most provinces in central and southern Laos was being cultivated with these varieties. The expanding dry-season irrigated rice environment at that time was being cropped only with improved varieties. The adoption of the improved varieties in the main lowland rice-growing areas of Laos has generally been associated with the discarding of most of the traditional varieties that had been selected by farmers and grown for generations. Many of the varieties collected from the wet-season rainfed lowland environment in the central and southern agricultural regions in the early years (1995 and 1996) of the germplasm collecting and conservation project were no longer being grown or available by the early 2000s. The samples in the germplasm collections being maintained *ex situ* now represent the only source of much of this material. In the northern agricultural region, the traditional varieties have continued to be grown in the rainfed lowland environment in many provinces only because the varieties released for the central and southern agricultural regions were not well suited to cultivation in the northern region. However, in the late 1990s, efforts began to develop improved higher-yielding varieties better suited to the specific growing conditions in the lowlands of the north. It can be expected that, as better-adapted improved varieties become available and are introduced to farmers in this region (and in some elevated lowland areas in more southern provinces), many of the traditional lowland varieties will disappear as fast as has happened in the lowland environment in the southern and central regions. The erosion of the traditional germplasm in most lowland areas of Laos, as a result of the adoption of improved higher-yielding varieties, might therefore be expected to

be almost complete by about 2010. It is probable that only some specialist traditional rice such as black rice (Appa Rao et al, Chapter 12) and some well-known aromatic rice (Appa Rao et al, Chapter 11) will continue to be grown on a regular basis in some lowland farming areas.

In relation to the upland environment, there has not been the same level of focus on the development of improved higher-yielding varieties as for the lowland environment. Upland farmers have, until the early 2000s, continued to grow their traditional upland varieties. However, even in this environment, superior upland varieties have been identified from the evaluation of the collection of upland varieties assembled between 1995 and early 2000. In some areas where variety selections have been introduced to upland farmers in northern Laos, they are already being adopted and are expected to replace many of the varieties that have been grown for many years. It might be expected that, as a result of more active agricultural extension services introducing a few superior upland varieties throughout upland areas, there will be a gradual but significant reduction in the number of traditional rice varieties being grown throughout much of the rainfed upland environment in the north and elsewhere in the country. The erosion of the upland germplasm base might also be accelerated as a result of a gradual decline in the area of upland rice cultivated throughout Laos, in line with government policy to move from annual cropping (rice and other annual crops) to more sustainable agricultural practices in the uplands throughout the country.

## Conservation of germplasm diversity

### Conservation within Laos

*Ex situ* conservation of genetic resources in genebanks is the most secure and cost-effective strategy for the long-term preservation of rice germplasm. The country's first national cold storage facility to conserve germplasm was built in 1997 at the National Agricultural Research Center (NARC) at Thadokkham in Saythany District of Vientiane Municipality. The facility was designed for seed storage at 4 °C, at about 50% relative humidity. For long-term conservation, 20-g samples are kept in deep freezers maintained at –18 °C. This germplasm base is available for long-term breeding and evaluation purposes.

### Duplicate conservation at the International Rice Genebank

Under an agreement signed between the Lao Ministry of Agriculture and Forestry and the International Rice Research Institute (IRRI), for long-term conservation, a duplicate set of all rice samples collected between 1995 and 2000 is being conserved at the International Rice Genebank (IRG) at IRRI headquarters in the Philippines.

## Conclusions

The remarkable genetic diversity of the traditional rice cultivars in Laos jointly reflects the country's rich cultural and geographic diversity together with the country's relative isolation until recent times. The collecting that was undertaken from 1995 to 2000 was

timely in that many of the traditional varieties collected then are no longer available in the farming areas where they were developed and grown, often for many generations. As with most other countries in the Asian region, farmers have been receptive to the adoption of improved higher-yielding varieties that have quickly replaced traditional lowland varieties. In the upland environment, a combination of the evaluation and subsequent distribution of superior upland varieties from among those collected in the latter part of the 1990s, together with a reduction in upland rice cultivation, can also be expected to result in a significant reduction in the diversity of varieties being grown in the uplands. Care needs to be given to ensure the proper maintenance and use of the traditional rice germplasm collections stored *ex situ* in both Laos and at the GRC at IRRI in the Philippines.

## References


ADB (Asian Development Bank). 2001. Participatory poverty assessment: Lao People's Democratic Republic. Manila (Philippines): ADB. 108 p.

Appa Rao S, Bounphanousay C, Phetpaseuth V, Jackson MT. 1997a. Spontaneous interspecific hybrids in *Oryza* in the Lao PDR. Int. Rice Res. Notes 22:4-5.

Appa Rao S, Bounphanouxay C, Phetpaseuth V, Schiller JM, Phannourath V, Jackson MT. 1997b. Collection and preservation of rice germplasm from southern and central regions of the Lao PDR. Lao J. Agric. Forest. I:43-56.

Appa Rao S, Bounphanousay C, Schiller JM, Jackson MT. 2002a. Collection and classification of rice germplasm from the Lao PDR between 1995 and 2000. Ministry of Agriculture and Forestry, Lao-IRRI Project, Vientiane, Laos. 576 p.

Appa Rao S, Bounphanousay C, Schiller JM, Jackson MT. 2002b. Collection, classification, and conservation of cultivated and wild rices of the Lao PDR. Genet. Res. Crop Evol. 49:75-81.

Appa Rao S, Bounphanousay B, Schiller JM, Alcantara AP, Jackson MT. 2002c. Naming of traditional rice varieties by farmers in the Lao PDR. Genet. Res. Crop Evol. 49:83-88.

Appa Rao S, Phetpaseuth V, Bounphanousay C, Schiller JM, Jackson MT. 1998. Geography, ecology, and morphology of the wild and weedy rices found in the Lao PDR. Paper presented at the International Symposium on Wild and Weedy Rices in Agro-Ecosystems, 10-11 August 1998, Ho Chi Minh City, Vietnam, organized by the Asia-Pacific Weed Science Society and Cuu Long Delta Rice Research Institute.

Appa Rao S, Phetpaseuth V, Bounphanousay C, Schiller JM, Jackson MT. 2000d. Geographic distribution, ecology, and morphology of wild and weedy rice in Lao PDR. In: Baki BB, Chin DV, Mortimer M, editors. Wild and weedy rice in rice ecosystem in Asia – a review. Limited Proceedings No. 2. Los Baños (Philippines) International Rice Research Institute. p 59-67.

Chang TT. 1976. The origin, evolution, cultivation, dissemination, and diversification of Asian and African rices. Euphytica 25:425-441.

Glaszmann JC. 1987. Isozymes and classification of Asian rice varieties. Theor. Appl. Genet. 74:21-30.

Inthapanya, Sipaseuth P, Sihathep V, Chanphengsay M, Fukai S. 1997. Drought problems and genotype requirements for rainfed lowland rice in the Lao PDR. In: Fukai S, Cooper M, Salisbury J, editors. Breeding strategies for rainfed lowland rice in drought-prone environments. Proceedings of an International Workshop held at Ubon Ratchathani, Thailand, 5-8 November 1996. ACIAR Proceedings. 77:74-81.

IRRI (International Rice Research Institute). 1994. Safeguarding and preservation of the biodiversity of the rice genepool: report of a Discussion Workshop on On-Farm Conservation and Crop Genetic Resources held at IRRI, Los Baños, Philippines. 43 p.

Khush GS. 1997. Origin, dispersal, cultivation and variation of rice. Plant Mol. Biol. 35:25-34.

Oka HI. 1988. Origin of cultivated rice. Tokyo (Japan): Japanese Scientific Societies Press. 254 p.

Roder W, Keoboulapha B, Vannalath K, Phouaravanh B. 1996. Glutinous rice and its importance for hill farmers in Laos. Econ. Bot. 50:401-408.

Schiller JM, Appa Rao S, Hatsadong, Inthapanya P. 2001. Glutinous rice varieties of Laos, their improvement, cultivation, processing and consumption. In: Chaudhary RC, Tran DV, editors. Specialty rices of the world: breeding, production and marketing. FAO, Rome, Italy, Enfield, N.H. (USA): Science Publishers. p 19-34.

Solheim WG.1972. An earlier agricultural revolution. Sci. Am. 222(4):34-41.

UNDP (United Nations Development Program). 1998. Development cooperation report 1997, Lao People's Democratic Republic. Vientiane, Laos. 159 p.

White JC. 1997. A brief note on new dates for the Ban Chiang cultural tradition. Bull. Indo-Pacific Prehist. Assoc. 16:103-106.

## Notes

*Authors' addresses:* S. Appa Rao, Genetic Resources Center, IRRI, DAPO Box 7777, Metro Manila, Philippines; J.M. Schiller, School of Land and Food Sciences, University of Queensland, St Lucia, Brisbane, 4072, Australia; C. Bounphanousay, National Agriculture and Forestry Research Institute, P.O. Box 811, Vientiane, Laos; M.T. Jackson, Program Planning and Communications, IRRI, DAPO Box 7777, Metro Manila, Philippines.

*Acknowledgments:* The authors gratefully acknowledge the farmers of Laos, who provided not only samples of their valuable seed for conservation but also their invaluable knowledge about the traditional rice varieties of Laos. Special acknowledgment is due to the many Lao officials within the Ministry of Agriculture and Forestry for their role in collecting the information reported in this chapter. The financial support of the Swiss Agency for Development and Cooperation (SDC) to the project that undertook the collection of traditional varieties for conservation and preservation is also acknowledged.