CHAPTER 15

Diversity of wild and weedy rice in Laos

Y. Kuroda, S. Appa Rao, C. Bounphanousay, K. Kongphanh, A. Iwata, K. Tanaka, and Y.I. Sato

The first scientific study of wild rice (*Oryza* spp.) in Laos was undertaken by the Japanese scientist Hamada, in 1957 and 1958 (Hamada 1965). In subsequent decades, collections of traditional cultivated rice and wild *Oryza* genetic resources have been conducted by Vaughan (1989), Appa Rao et al (1996, 1997, 1998, 1999a,b), and Sato et al (1994, 2001). These surveys have reported five *Oryza* species in Laos: *O. granulata, O. nivara, O. officinalis, O. ridleyi*, and *O. rufipogon*. Of these, *O. rufipogon* and *O. nivara* have the AA genome and are part of the primary gene pool of rice. *O. officinalis* has the CC genome*, O. granulata* has the GG genome, and *O. ridleyi* is a tetraploid species with the HHJJ genome. *O. officinalis, O. granulata*, and *O. ridleyi* are in the secondary or tertiary gene pools of rice and cannot be easily used in rice breeding. Of the five *Oryza* species found in Laos, *O. rufipogon* and *O. nivara* are particularly significant from the viewpoint of rice breeding and conservation of genetic resources.

Description of wild and weedy rice distributed in Laos

O. rufipogon

O. rufipogon (AA genome) (Table 1, Fig. 1A) is believed to be one of the ancestors of cultivated rice. Currently, it is generally accepted that *O. rufipogon* was the progenitor of the japonica ecotype of rice (Yamanaka et al 2003, Cheng et al 2003). This perennial species grows in full sunlight and is often seen in the lowland plains of Laos. It has also been found at the fringe of paddy fields in Bokeo Province in the remote north of the country (Sato 1994). In the Vientiane Plain in the central agricultural region, large populations of *O. rufipogon* are often seen at the edge of paddy fields, in roadside ditches, and in naturally occurring depressions. This species is usually found in areas where there are large fluctuations in the water level (from 50 to 200 cm). It flowers in the last quarter of the year, from October to December, suggesting that it is photoperiod-sensitive (Fig. 2). The regenerative ability from each node is high. Culms of *O. rufipogon* can extend up to 4 m, depending on water depth of the habitat. *O. rufipogon* is highly heterozygous and has high genetic diversity, a high outcrossing rate (30% to 60%), and low fixation index (Barbier 1989, Kuroda et al

Table 1. List of species in the genus *Oryza* in Laos.

Species	Eco-type[a]	Chromosome no. (2n)	Genome group	Geographical distribution in	
				Laos	World
O. sativa L.	A/P	24	AA	Throughout Laos	Worldwide
O. rufipogon Griff.	P	24	AA	Throughout Laos (mainly in central and southern regions)	Asia, Oceania
O. nivara Sharma et Shastry	A	24	AA	Throughout Laos (mainly in central and southern regions)	Asia
O. officinalis Wall ex Watt	P	24	CC	Khammouane and Savannakhet provinces	Asia
O. ridleyi Hook. f.	P	48	HHJJ	Champassak Province	Asia
O. granulata Nees et Arn. ex Watt	P	24	GG	Luang Prabang, Oudomxay, and Saravane provinces	Asia
Weedy rice	A	24	AA	Central and southern regions	Worldwide

[a]A = annual type, P = perennial type, A/P = perennial-like type.
Sources: Vaughan (1994), Appa Rao et al (1998).

2003a,b). Some strains of this species from Thailand have been found to have a high level of resistance to tungro viruses and have been used in the breeding programs of the International Rice Research Institute (IRRI).

O. nivara

O. nivara (AA genome) (Table 1, Fig. 1B) is primarily confined to mainland South and Southeast Asia. Recent research suggests that it may be an ancestor of indica cultivars of rice (Yamanaka et al 2003, Cheng et al 2003). It is an annual species that grows in full sunlight and it is found across the lowland plains of Laos. It has also been reported in Houaphanh and Bokeo provinces in the north of the country (Appa Rao et al 1999a). It is found at the edges of fishing ponds and roadside ditches that are seasonally dry (Sato 1994). *O. nivara* propagates by seeds. It flowers over an extended period, from July to November (Fig. 2). The plant is short (< 1.5 m), and does not exhibit the floating ability of *O. rufipogon*. Although recent studies, particularly those based on DNA analyses, have shown that *O. nivara* and *O. rufipogon* are differentiated in both the nuclear and organelle genomes (Chen et al 1993, Cheng et al 2003), there are no reproductive barriers among *O. nivara, O. rufipogon*, and cultivated rice (*O. sativa*) (Oka 1988, Vaughan and Morishima 2003). Compared with *O. rufipogon, O. nivara* has lower genetic diversity, a lower number of heterozygous loci, lower outcrossing rate (5% to 20%), and higher fixation index in a population because of its being predominantly inbred (Barbier 1989, Kuroda et al 2003a). A gene for grassy stunt virus resistance has been found in this species, which has been transferred to cultivated rice (Chang et al 1975, Brar and Khush 1997).

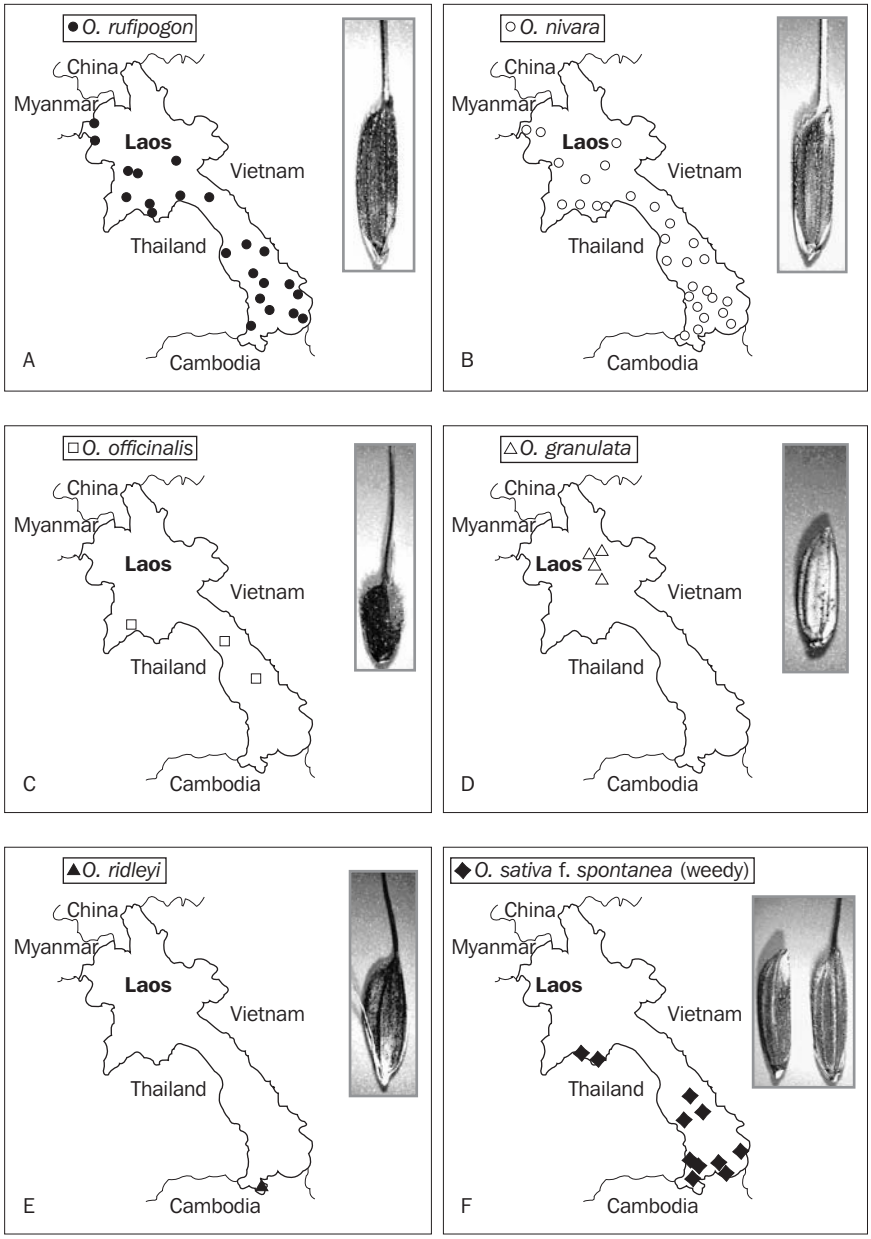

Fig. 1. Geographical distribution and view of spikelet of wild rice (A) *Oryza rufipogon*, (B) *O. nivara*, (C) *O. officinalis*, (D) *O. granulata*, and (E) *O. ridleyi*, and (F) weedy rice.

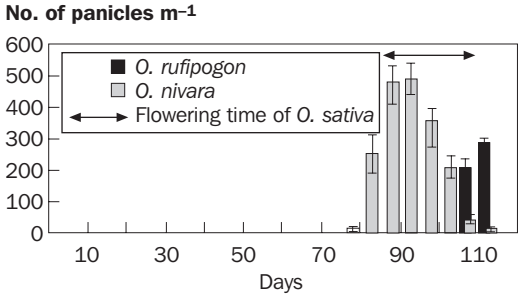

Fig. 2. Flowering time of wild rice (*Oryza rufipogon, O. nivara*) and cultivated rice (*O. sativa*) on the Vientiane Plain of Laos. Flowering times of *O. rufipogon* and *O. nivara* were recorded at a swamp in Thong-Mang and roadside ditch in Nalom village, respectively.

O. officinalis

O. officinalis (CC genome) (Table 1, Fig. 1C) has a wide distribution in tropical Asia. In Laos, this species has been recorded in Mahaxai District of Khammouane Province, in Phonehong District of Vientiane Province in a roadside ditch, and in Atsaphangthong District of Savannakhet Province in a rainfed lowland rice field (Appa Rao et al 1998). It is reported to flower in early August (Appa Rao et al 1998). *O. officinalis* is usually found in full sunlight and occasionally in half-shaded conditions. Its habitat varies from forest margins to open grassland, and from seasonally dry to permanently wet environments. Its habit of herbaceous clumps can produce culms up to 3 m (Vaughan and Morishima 2003). The Chinese name of this species is "medicinal rice," although the reason for this connotation is unclear. Strains of *O. officinalis* have been found to have a high level of resistance to several pests and diseases (Brar and Khush 1997). Brown planthopper resistance from a Thai strain of *O. officinalis* has been transferred to rice, and lines from this cross have been released as varieties in Vietnam (Brar and Khush 1997).

O. granulata

O. granulata (GG genome) (Table 1, Fig. 1D) is distributed widely across Asia. In Laos, it is found mainly in the northern agricultural region, particularly in the provinces of Luang Prabang, Oudomxay, and Xieng Khouang; it has also been recorded in the southern province of Sekong (Appa Rao et al 1998). This species is generally found in shaded, upland forested habitats in hilly and mountainous regions of the country. It is photoperiod-insensitive and flowers year-round. Its panicles are nonbranching and the awns are less than 6.4 mm long (Vaughan and Morishima 2003). A low level of genetic diversity within populations and high differentiation among populations have been reported (Gao et al 2000). It is very difficult to cross with rice, but hybrids with rice have been reported through the embryo rescue technique (Brar and Khush 1997).

O. ridleyi

O. ridleyi (HHJJ genome) (Table 1, Fig. 1E) has been recorded in only a single location in Champassak Province in southern Laos (Appa Rao et al 1998). It was found to be growing in shaded conditions under bamboo and trees on the bank of a canal where the water was generally stagnant. It is reported to flower in September. Panicles have very few erect primary branches and the species also has erect or semierect dark green leaves (Vaughan and Morishima 2003). Seed production is very low and propagation is mainly through rhizomes, which remain dormant during the dry season. It is reported to be resistant to stem borers.

Weedy rice

In Laos, weedy rice (AA genome) (Table 1, Fig. 1F) (often called *O. sativa* f. *spontanea*) is generally the result of interspecific hybridization between wild and cultivated rice. Weedy rice is common in the central and southern plain regions of the country, where *O. rufipogon* and *O. nivara* are frequently observed (Appa Rao et al 1998). Several populations, which appeared to be intermediate forms between wild and cultivated rice, have been observed. They have characteristics similar to those found in both wild and cultivated rice. Until flowering, the weedy intermediate forms resembled the cultivated forms in most characters (culm size, leaf blade length and width) and in gross morphology. After flowering, their panicle and grain characteristics differ, making distinction easy. In the Vientiane Plain, weedy rice can be found in and around rice paddies. The characteristics of weedy rice are numerous. Weedy plants found in paddy conditions have wild rice-specific traits such as small grain, nonglutinous endosperm, spikelets with long awns, red pericarp, and open panicle shape. Interspecific hybridization between cultivated rice and both *O. nivara* and *O. rufipogon* is common. Weedy rice has successfully been used as a source of cytoplasmic male sterile lines for hybrid rice.

O. rufipogon, O. nivara, and weedy rice in the Vientiane Plain in central Laos

Distribution and ecology

Most previous field observations of wild rice have covered wide areas over relatively short periods (Morishima et al 1980, 1984, 1987, 1991, Sato et al 1994, 2001). Long-term field surveys focusing on areas of rich biodiversity are needed to understand the sustainable conservation of wild rice biodiversity in its natural habitats. The Vientiane Plain is an area of particularly rich diversity in the Asian common wild rice *O. rufipogon* and *O. nivara*. The Plain was the focus of a year-long survey and intensive study of this wild rice in 2002.

Geography and climatic conditions of the Vientiane Plain

The Vientiane Plain (3,000 km^2) is located in central Laos and is bordered by the Mekong River to the south and by mountains to the west, north, and east (Fig. 3). The Plain accounts for about 6% of the total area and 11% of the population of Laos. The topography of the area undulates from 160 to 200 m above sea level. The Namngum

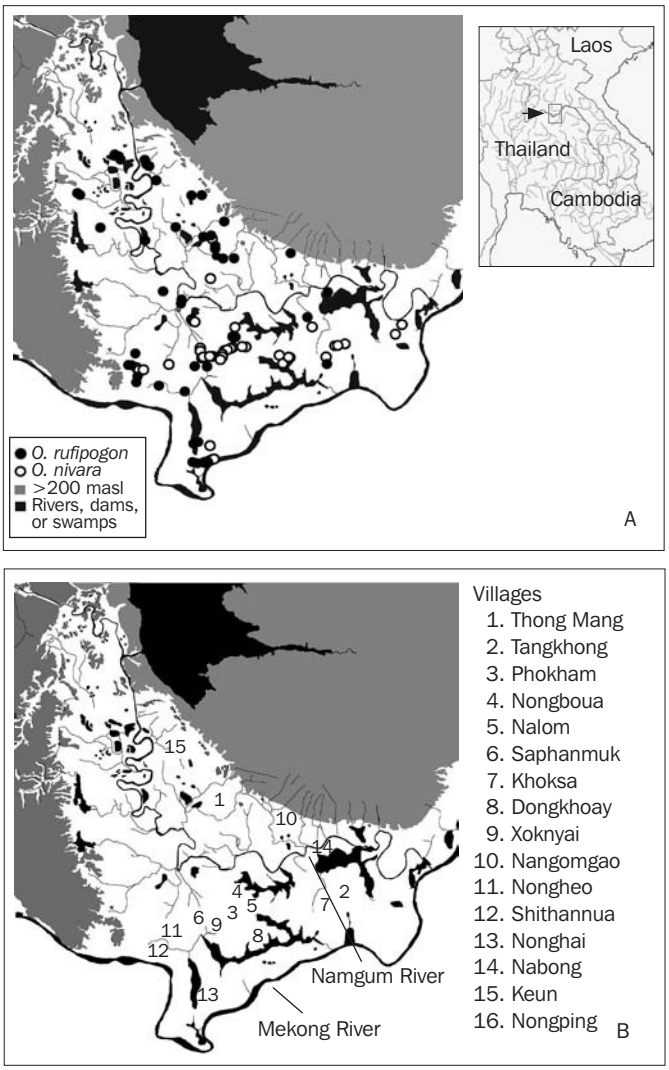

Fig. 3. Geography and distribution of (A) wild rice populations and (B) villages (used only in the text) on the Vientiane Plain of Laos.

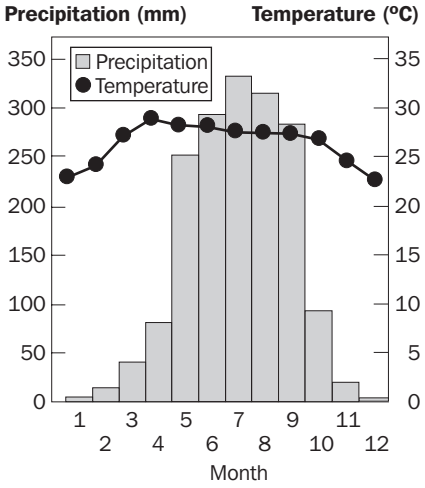

Fig. 4. Precipitation and temperature averaged by month over the past 10 years on the Vientiane Plain of Laos.

River is the main river that runs from the north to southeast across the Plain, and it has a complex pattern of tributaries along its course. The climate of the Plain can be broadly described as humid tropics containing two seasons: a dry season from November to March and a wet (monsoon) season from April to October (Fig. 4).

Distribution of *O. rufipogon* and *O. nivara*

Oryza rufipogon and *O. nivara* are common throughout the Vientiane Plain. A total of 110 sites of wild rice populations constituting 46 of *O. rufipogon* and 64 of *O. nivara* have been recorded (Fig. 3). Populations of *O. rufipogon* were scattered throughout the Plain. In contrast, populations of *O. nivara* were mainly found adjacent to major roads. The populations of *O. rufipogon* and *O. nivara* were generally found to be isolated from each other by distances of at least 100 m, with the exception of one site where both *O. rufipogon* and *O. nivara* populations were found in different parts of the same swamp in the village of Nongboua in Xaythany District of Vientiane Municipality.

Habitat differences

The habitat differences of *O. rufipogon* and *O. nivara* reflect the different levels of water conditions to which they are adapted (Oka 1988). *O. rufipogon* is found at sites where flooding is to a depth of up to about 200 cm (Fig. 5A), whereas *O. nivara* occurs in habitats where the water depth is to about 50 cm (Fig. 5B). In general, *O. nivara* populations are associated with annual plant species, while those of *O. rufipogon* are associated with perennial species.

Oryza rufipogon is found in the places with the greatest water depth, whereas *O. nivara* is found in areas where the water is shallow. Natural rainfall accounts for

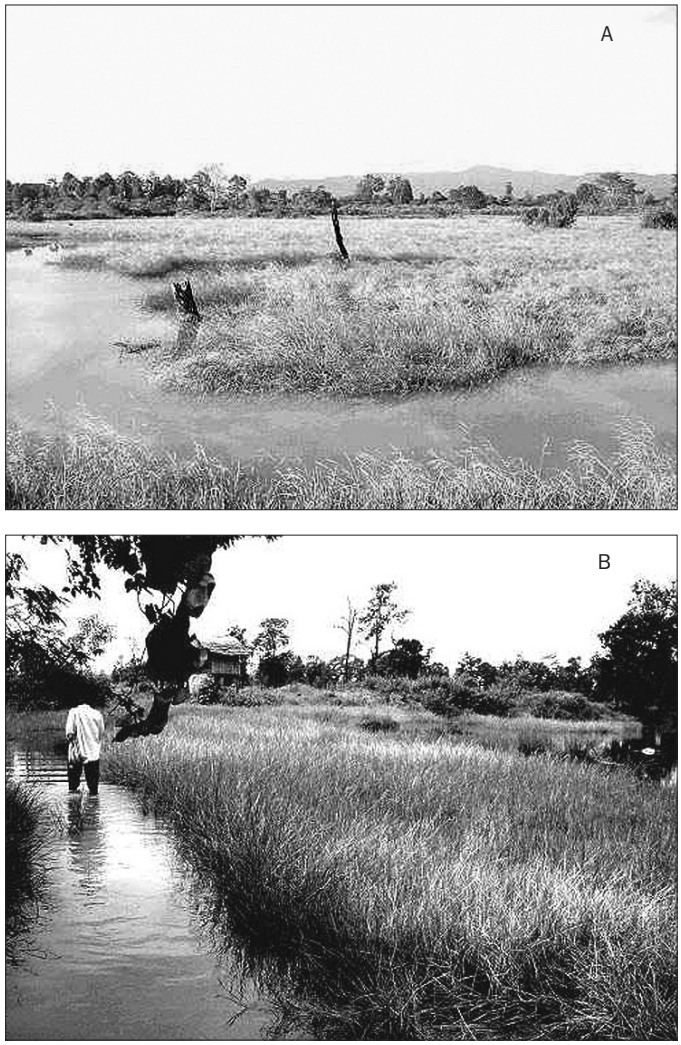

Fig. 5. Views of the habitat of wild rice populations late in the rainy season: (A) *Oryza rufipogon* was observed in a deepwater area in Thong-Mang village and (B) *O. nivara* was found in a shallow-water area in Tangkhong village.

most of the water source in habitats of wild rice populations (77% for *O. rufipogon* and 87% for *O. nivara*). Seasonal fluctuations in water level can therefore be expected to affect the distribution of wild rice. No populations were found in artificial reservoirs or along main rivers; relatively higher water-level fluctuations in these areas might be responsible for this.

In relation to the site characteristics of wild rice habitats, 70% of *O. rufipogon* populations were found in deep swamps where soil moisture remains year-round. In contrast, 72% of *O. nivara* was observed in roadside ditches that have only standing water in the wet season. Other studies also suggest that populations of annual types of wild rice (*O. nivara*) are adapted to unstable transient habitats compared with perennial types of wild rice (*O. rufipogon*) (Barbier 1989).

The mean population size for *O. rufipogon* was found to be generally greater than for *O. nivara*. Although all the *O. nivara* populations were less than 1.0 ha in area, 33% of the *O. rufipogon* populations were found in patches of more than 1.0 ha. Several very large populations were also found, including a 600-ha population at Nongkhoay in Thoulakhom District of Vientiane Province and a 500-ha population at Salakham village in Hadxaifong District of Vientiane Municipality. This suggests that the Vientiane Plain contains large areas of habitats more favorable to *O. rufipogon* than to *O. nivara* populations.

Life-history traits

The life histories of *O. nivara* and *O. rufipogon* in the Vientiane Plain were found to differ in a number of ways. In reference to reproductive strategies at the start of the rainy season, plants from clones and seeds were observed in *O. rufipogon* populations (Fig. 6A), whereas only seed-derived juveniles were observed in *O. nivara* populations (Fig. 6B). Maximum plant height at the flowering stage was 150 cm for 63.6% of the *O. rufipogon* populations, whereas only 4.1% of the *O. nivara* populations reached a height of 150 cm. Plant height reflects the adaptation of these two species to habitats with different water levels.

The flowering period of the two species in the Vientiane Plain was also clearly different. Generally, *O. nivara* plants flower from July to November, with most (87%) plants reaching maturity during September. In contrast, *O. rufipogon* plants flower from the end of October to the end of January, with 95% of the plants reaching maturity during December (Fig. 2). After flowering, *O. rufipogon* plants produce culms from each node for the next generation, whereas plants of *O. nivara* wither and die after flowering, even in areas with a favorable moisture regime. It was apparent that *O. nivara* plants allocate their energy producing seeds, whereas *O. rufipogon* plants can allocate energy reserves for both seed production and culms for the next generation.

Human influence

The *O. rufipogon* and *O. nivara* populations on the Vientiane Plain were usually located near roads and paddies. Approximately 92% of the *O. nivara* populations and 59% of the *O. rufipogon* populations were found close to roads. Most populations of both species were also found at the edges of rice fields—84% of the *O. rufipogon* popula-

Fig. 6. Views of the reproductive system of wild rice in the beginning of the rainy season: (A) both clone and seed propagation observed in an *O. rufipogon* population, Thong-Mang village, and (B) only seed propagation observed in an *O. nivara* population, Phokham village.

Table. 2. Local names and meaning of wild rice (*Oryza rufipogon* or *O. nivara*) and weedy rice on the Vientiane Plain of Laos.

Name	Species	Meaning
Nyaa khaw kyee nok	*Oryza nivara* or *O. rufipogon*	Rice that comes from bird droppings
Nyaa khaw nok	*Oryza nivara* or *O. rufipogon*	Rice eaten by birds
Khaw maa nyeen	Weedy rice	
Nyaa khaw kyee nok ped	*Oryza nivara* or *O. rufipogon*	Rice that comes from wild duck (*Anas* spp.) droppings
Nyaa khaw kyee nok khaw	*Oryza nivara* or *O. rufipogon*	Rice that comes from wild pigeon (*Streptopella* spp.) droppings
Nyaa khaw nok ped	*Oryza nivara* or *O. rufipogon*	Rice eaten by *Anas* spp.
Nyaa khaw nok khaw	*Oryza nivara* or *O. rufipogon*	Rice eaten by *Streptopella* spp.

tions and 77% of the *O. nivara* populations, respectively. In areas where cultivated rice and wild rice are sympatric, spontaneous hybridization may occur between wild and cultivated rice. Although some populations are found isolated from residential areas, the effect of human habitation is to convert many of the habitats that wild rice occupies to other uses.

The relationship between wild rice and human activities

Awareness and naming of wild rice

Most of the Lao farmers are aware of their environment and can accurately describe the natural vegetation and the wild rice (Table 2). All the village representatives interviewed in 46 villages in the Vientiane Plain were found to be aware of wild rice and its location in relation to the village. The only exception to this was with three villagers living within 5 km of the capital city, Vientiane. However, only one elderly resident was aware that wild rice is the ancestor of cultivated rice, having learned this in the form of a story related to him when he was young. Most of the village respondents recognized wild rice to be "a favorite grass for water buffalo," the buffalo being common on the Vientiane Plain.

Wild rice as a famine food in the past

The people of Asia have a history of collecting seeds of wild rice for human consumption (Oka 1988, Harlan 1992). Discussions with members of five villages on the Vientiane Plain revealed clear memories of wild rice being used as a food.

Xoknyai village. This is a well-known village established more than 200 years ago. A respondent in the village related the story of his grandparents collecting wild rice in times of famine. The harvested seeds were dehulled in a mortar and the brown rice was boiled or steamed for consumption. Near this village exists a large population of *O. rufipogon* covering about 500 ha.

Khoksa (Navay) village. The informant was the head of the village, who had moved from the neighboring village of Navay. His grandparents had narrated stories

to him of the collection and consumption of wild rice in times of famine in his former village of Navay.

Nangomgao village. The informant was the head of a young men's association, and the village has a history of more than 200 years. According to the respondent, wild rice seeds were collected and eaten until 20 years ago, when rice production was reported to have stabilized. Wild rice was harvested before maturity using a sickle. After harvest, the panicles were stripped of their seeds and the kernels were steamed and eaten. Near the village was a large population of *O. rufipogon* covering more than 200 ha.

Nongheo village. The informant was the head of the village, who had moved from another district several decades ago. His grandparents told him of periods when, in times of famine, they had harvested wild rice using a sickle, threshed the seeds in a mortar, and eaten the kernels.

Shithannua village. This village is in a residential area. However, an old villager who originally lived in the southern province of Champassak related a story of wild rice use in southern Laos. He reported that villagers, in times of famine, collected wild rice by swinging a basket over the panicles. They ate the rice after steaming, and sometimes used it to make noodles. According to the informant, the taste and flavor of wild rice were acceptable. It was reported that wild rice had continued to be collected until about 20 years ago, when production of traditional rice had improved.

Based on these reports, it appears that people in Laos had a custom of consuming wild rice until about 20 years ago. However, the villagers were generally unable to indicate which of the wild rice species was the source of the grain consumed in the past. It is occasionally still eaten out of curiosity. There is a tendency for existing wild rice populations on the Vientiane Plain to be associated with the larger older villages.

The co-evolution of buffalo and wild rice

The water buffalo (*Bubalus bubalis*) is native to tropical Asia. The average number of buffaloes per 1,000 people in Laos (195) is the highest of any country in the region. Water buffaloes need access to water in which to immerse their bodies to adjust their temperature. Swamps and roadside ditches, where wild rice is often abundant, are the preferred places for water buffaloes to immerse themselves.

On the northern part of the Vientiane Plain is a particularly large swamp (about 600 ha) containing *O. rufipogon,* which is called Nong Khouay, or "water buffalo swamp." Villagers living nearby have noted the association of the use of the swamp by water buffaloes and the development of wild rice, suggesting a potentially important role of the water buffalo in the distribution of wild rice from place to place. Water buffaloes can often be seen grazing on wild rice (Fig. 7) and wild rice is clearly an important food for these animals, a fact that is well recognized by Lao farmers. By grazing mature wild rice seeds and moving from swamp to swamp, the buffaloes disperse the seed through dung and hooves to new habitats. Wild rice seeds are also occasionally found germinating in water buffalo dung. There appears to be a symbiotic and co-evolutionary relationship between water buffaloes and wild rice. Water buf-

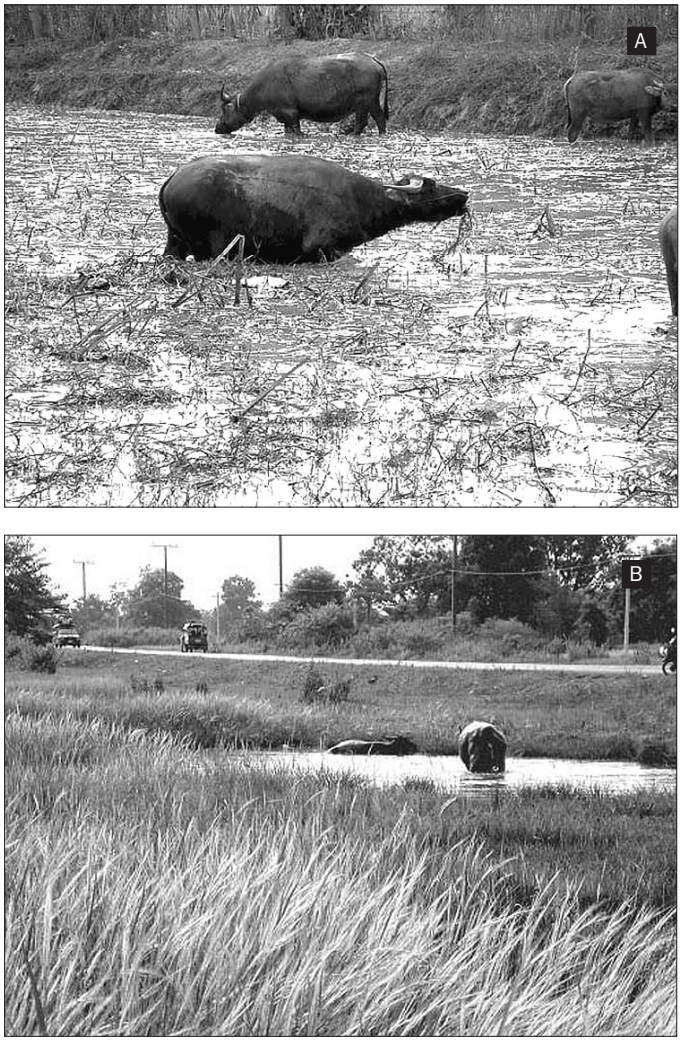

Fig. 7. Cross-section of typical land use of (A) swamp and (B) roadside ditch wild rice habitats on the Vientiane Plain.

faloes may be particularly important in the distribution of *O. rufipogon* that grows in deepwater swamps. However, cattle, ducks, and goats may be more important in the dispersal of *O. nivara* that occurs in shallower ditches and ponds, as these animals do not spend time in deep water.

Fisheries and wild rice, and wild rice habitats

Fish production is an important activity, particularly in rural Laos, as freshwater fish provide one of the main sources of protein for a large proportion of the rural population. In Lao villages, common usage rules, such as the prohibition of fishing and the regulation of fishing methods, are established for each village. These rules are useful for the conservation of native fish and the rules apply from the period of spawning to adulthood. There is an important relationship between wild rice and fish production. Wild rice populations function as a nursery for young fish and provide protection or a hiding place from predators. Fish provide nutrients to the wild rice in the form of their excreta. Roadside ditches and swamps serve as a passageway for native fish to move from their dry-season habitat to wild rice habitats and rice fields during the wet season. The conservation of such wetlands serves both in helping to conserve the wild rice populations and in helping support the fishery industry on the Vientiane Plain of Laos.

Sustainable conservation of wild rice biodiversity

Wild rice as a host of pests and diseases

Wild rice is a host of several rice pests and diseases. Gall midge (*Orseolia oryzae*) is one of the important pests of rice in Laos that appears to have increased in significance in recent times. Not only cultivated rice but also perennial species of wild rice, such as *O. rufipogon*, and weeds such as *Leersia hexandra* are potential hosts of gall midge during the dry season.

Weedy rice

Spontaneous interspecific hybrids between cultivated rice (*O. sativa*) and AA genome *Oryza* species (*O. nivara* and *O. rufipogon*), often called weedy rice (Fig. 8A, B), are of common occurrence in the southern and central regions of Laos. Wild rice and cultivated rice can exchange genes freely. The gene flow from wild rice to cultivated rice reduces the quality and quantity of cultivated rice. Farmers on the Vientiane Plain view wild rice as an aggressive weed when it invades their rice fields. However, in recent times, the significance of weedy rice on the Vientiane Plain has declined. A reason for this decline has been the relatively recent (since the mid-1990s) development and distribution of seed of improved rice varieties throughout the main rice-growing areas of Laos. Although the gene flow from wild rice to cultivated rice does not occur at high frequency, it is difficult to remove weedy rice once it contaminates improved rice varieties. For farmers who own paddies near wild rice populations, it is recommended that rice seed be changed for better-quality seed every few years.

Fig. 8. Views of weedy rice in wild rice habitats: (A) a plant showing characteristics of awnless, nonshattering, and large number of seeds per panicle; (B) two clumps of weedy plants showing characteristics of high stature and their necks of spike were bending owing to high fertility and weak-shattering traits.

Genetic erosion of wild rice

Although wild rice is common across tropical Asia, particularly mainland South and Southeast Asia, in many areas the rapid economic development, particularly urban development, that is taking place is altering the natural ecosystems that include the natural habitat of wild rice. The impact of such development has been clearly shown in Thailand, where, over a ten-year period, the rate of reduction of the biomass (size of population × cover rate) has been estimated at 21% for *O. rufipogon* and 79% for *O. nivara* (Sato 1994). Among the five *Oryza* species found in Laos, it is also *O. rufipogon* and *O. nivara* that are at greatest risk, on account of their habitats being mostly found in agroecosystems where human activity is frequently observed (Oka 1988).

On the Vientiane Plain of Laos, large-scale paddy cultivation in association with irrigation development and residential land development projects has been increasing. These developments are destroying the natural wild rice habitats. For example, a half of the area of swamp containing a wild rice population in the village of Keun, about 60 km from the capital, Vientiane, has been converted into rice paddies in the past decade. Some wild rice populations in the suburbs of Vientiane have been destroyed in recent land development initiatives (Fig. 9A, B). Irrigation developments near annual wild populations of *O. nivara* are endangering these populations and are a potential threat to the ecological replacement of these species with perennial plant species.

Conservation of the wild rice resources of Laos

For cultivated rice, genebanks are available for *ex situ* conservation at national and international centers. These genebanks are already playing an important role in the conservation of the Laotian genetic resource base for traditional cultivated rice (Jackson 1997). *Ex situ* conservation can be effective for the conservation of some wild *Oryza* species and as an insurance against population destruction in the wild. However, some *Oryza* species cannot be adequately maintained *ex situ*. This is particularly true for low-seed-producing outcrossing forms, such as some ecotypes of *O. rufipogon*. These *Oryza* species require large populations to maintain their genetic integrity, and *in situ* conservation is a more appropriate approach than *ex situ* conservation for such material. The genetic dynamism of natural populations of wild rice requires conservation in nature or *in situ*. Consequently, attempts have been made to establish an *in situ* conservation site in Laos. This began at Thong-Mang village on the Vientiane Plain in 1996. This site was established after discussions with local village officials, representatives of the Lao Ministry of Agriculture and Fisheries, and advisers from Japan. The site is a pond of about 1.5 ha and is surrounded by forest. Ecological population genetic observations of this wild rice population have been conducted based on repeated surveys since 1991 to elucidate the dynamics of wild rice populations on the Vientiane Plain. Some of the wild rice observations reported in this chapter are based on these studies. Laos is rich in diversity of the wild relatives of rice. Of the five species of the genus *Oryza* recorded in Laos—*O. nivara, O. rufipogon, O. officinalis, O. ridleyi*, and *O. granulata*—it is *O. ridleyi* that is found least frequently and that needs the most immediate attention to prevent its complete disappearance from the country. The *ex situ* conservation facilities that have been established in the past

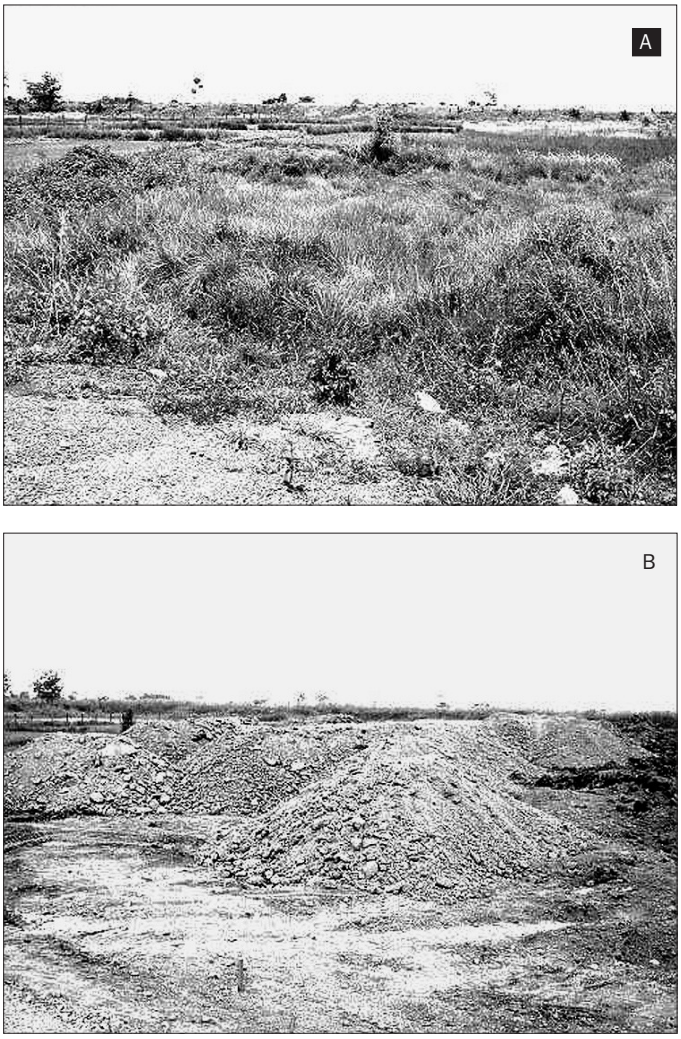

Fig. 9. An example of habitat destruction of a wild rice population near Vientiane City, Saphanmuk village: (A) June 2002 and (B) November 2002.

decade near the capital Vientiane need to be strengthened to allow increased *ex situ* conservation of wild rice, while at the same time improving the *in situ* conservation initiatives. Spontaneous interspecific hybrids between cultivated rice (*O. sativa*) and AA genome *Oryza* species (*O. nivara* and *O. rufipogon*), often called weedy rice, are of common occurrence in the southern and central regions. These offer considerable scope for the conservation and use of rice genetic resources in Laos.

References

Appa Rao S, Bounphanousay C, Vandy P, Kongpanh K, Bounmy S, Schiller JM, Viravanh P, Jackson MT. 1996. Collection and classification of rice germplasm from the Lao PDR. Part 1: Southern and central regions, 1995. Vientiane, Lao-IRRI Project. 116 p.

Appa Rao S, Bounphanousay C, Kongpanh K, Phetpaseuth V, Sengthong B, Schiller JM, Thirasack S, Jackson MT. 1997. Collection and classification of rice germplasm from the Lao PDR. Part 2: Southern, central and northern regions, 1996. Vientiane, Lao-IRRI Project. 208 p.

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. Presented at the International Symposium on Wild and Weedy Rices in the Agroecosystems, 10-11 Aug. 1998, Ho Chi Minh City, Vietnam. 14 p.

Appa Rao S, Phetpaseuth V, Kanyavong K, Bounphanousay C, Sengthong B, Schiller JM, Jackson MT. 1999a. Conservation of Lao rice germplasm at the International Rice Genebank, IRRI, Phillipines. Collection period: October 1997 to February 1998. Vientiane, Lao-IRRI Project. 149 p.

Appa Rao S, Bounphanousay C, Kanyavong K, Sengthong B, Schiller JM, Jackson MT. 1999b. Collection and classification of Lao rice germplasm. Part 4. Collection period: September to December 1998. Vientiane, Lao-IRRI Project. 101 p.

Barbier P. 1989. Genetic variation and ecotypic differentiation in the wild rice species *Oryza rufipogon*. I. Population differentiation in life-history traits and isozymic loci. Jpn. J. Genet. 64:259-271.

Brar DS, Khush GS. 1997. Alien introgression in rice. Plant Mol. Biol. 35:35-47.

Chang TT, Ou SH, Pathak MD, Ling KC, Kauffman HE. 1975. The search for disease and insect resistance in rice germplasm. In: Frankel OH, Hawkes JG, editors. Crop genetic resources for today and tomorrow. Cambridge (UK): Cambridge University Press. p 183-200.

Chen WB, Nakamura I, Sato YI, Nakai H. 1993. Distribution of deletion type in cpDNA of cultivated and wild rice. Jpn. J. Genet. 68:597-603.

Cheng C, Motohashi R, Tsuchimoto S, Fukuta Y, Ohtsubo H, Ohtsubo E. 2003. Polyphyletic origin of cultivated rice: based on the interspersion pattern of SINEs. Mol. Biol. Evol. 20:67-75.

Gao LZ, Ge S, Hong D. 2000. Low level of genetic diversity within populations and high differentiation among populations of a wild rice, *Oryza granulata* Nees et Arn. ex Watt, from China. Int. J. Plant Sci. 161(4):691-697.

Hamada H. 1965. Rice in the Mekong valleys. In: Matsumoto N, editor. Indo-Chinese studies: scientific research of the culture of rice-cultivating races in Southeast Asian countries (I). The Japanese Society of Ethnology. Yokohama (Japan): Yurindo Publishing. p 505-586.

Harlan JR. 1992. Crops and man. 2nd ed. Madison, Wis. (USA): American Society of Agronomy, Inc. 295 p.
Jackson MT. 1997. Conservation of rice genetic resources: the role of the International Rice Genebank at IRRI. Plant Mol. Biol. 35:61-67.
Kuroda Y, Urairong H, Sato YI. 2003a. Population genetic structure of wild rice (*Oryza rufipogon*) in mainland Southeast Asia as revealed by microsatellite polymorphisms. Tropics 12:159-170.
Kuroda Y, Urairong H, Sato YI. 2003b. Differential heterosis in a natural population of Asian wild rice (*Oryza rufipogon*) due to reproductive strategy and edge effect. Genet. Res. Crop Evol. 52:151-160.
Morishima H, Sano Y, Oka HI. 1980. Observations on wild and cultivated rices and companion weeds in the hilly areas of Nepal, India and Thailand. Report of study tour in tropical Asia, 1979. National Institute of Genetics, Japan. 97 p.
Morishima H, Shimamoto Y, Sano Y, Sato YI. 1984. Observations on wild and cultivated rices in Thailand for ecological genetic study. Report of study tour in 1983. National Institute of Genetics, Japan. 82 p.
Morishima H, Shimamoto Y, Sano Y, Sato YI. 1987. Trip to Indonesia and Thailand for the ecological genetic study in rice. Report of study tour in 1985/86. National Institute of Genetics, Japan. 75 p.
Morishima H, Shimamoto Y, Sato T, Yamagishi H, Sato YI. 1991. Observations of wild and cultivated rices in Bhutan, Bangladesh and Thailand. Report of study tour in 1989/90. National Institute of Genetics, Japan. 73 p.
Oka HI. 1988. Origin of cultivated rice. Tokyo/Amsterdam: Jpn. Scientific Societies Press/ Elsevier. 254 p.
Sato YI. 1994. Genetic erosion in the tropics. Tropics 3:33-50.
Sato YI, Ando K, Chitrakon S, Morishima H, Sato T, Shimamoto Y, Yamagishi H. 1994. Ecological-genetic studies on wild and cultivated rice in tropical Asia. Tropics 3:189-245.
Sato YI, Ueno K, Shimamoto Y, Sato T, Nakamura I, Shishido R, Ishii T, Chitrakon S, Schiller JM, Kanyavong K, Palaklang W, Urairong H. 2001. Ecological-genetical survey for wild and cultivated rice in the tropical Asia. 62 p.
Vaughan DA. 1989. Trip report of the collaborative Department of Agriculture-Lao-IRRI collection of wild rice, 26 Nov.-7 Dec. 1989. Los Baños (Philippines): International Rice Research Institute.
Vaughan DA. 1994. The wild relatives of rice: a genetic resources handbook. Los Baños (Philippines): International Rice Research Institute. 137 p.
Vaughan DA, Morishima H. 2003. Biosystematics of the genus *Oryza*. In: Smith CW, Dilday R, editors. Rice: origin, history, technology, and production. John Wiley & Sons, Inc. p 27-65.
Yamanaka S, Nakamura I, Nakai H, Sato YI. 2003. Dual origin of the cultivated rice based on molecular markers of newly collected annual and perennial strains of wild rice species, *Oryza nivara* and *O. rufipogon*. Genet. Res. Crop Evol. 50:529-538.