Collecting the rice gene pool

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The rice gene pool

The grass genus *Oryza* consists of about 20 tropical and subtropical wild species and two cultigens, African (*O. glaberrima*) and Asian (*O. sativa*) rice (Chang, 1985b; Vaughan, 1989). The genus is in the subfamily Oryzoideae, which comprises 12 or 13 genera closely related to the bamboos (Duistermaat, 1987). There are no other major cereals that are taxonomically closely allied to the rices but, in the same subfamily, *Zizania aquatica* is harvested for grain in North America and *Z. latifolia* is used as a vegetable in east Asia (de Wet and Oelke, 1978).

The gene pool concept (Harlan and de Wet, 1971) is helpful in suggesting limits to the group of related species that should be of concern to rice breeders and therefore to rice gene banks (Chang and Vaughan, 1991). Because it is never possible to entirely predict what traits will be needed in the future, it is vital to conserve as broad a range of genetic diversity as possible. For example, ten years ago it could not have been foreseen that it would be necessary in the 1990s to find germplasm resistant to the golden snail (*Pomacea canaliculata*), hence the current interest in the conservation of at least some samples even of species in genera relatively distantly related to *Oryza*.

Despite numerous reports of remote hybridization involving rice (e.g. Yieh, 1964; Zhou *et al.*, 1981; Zhou, 1986), the main focus of concern for the rice breeder is the subfamily Oryzoideae. Characters found in other genera in the Oryzoideae but not in any *Oryza* species include seed survival in cold water in *Zizania*, tolerance to salt water in *Porteresia* and unisexual florets in a number of genera. However, most evaluation efforts involving wild species have centred on the genus *Oryza* itself. Hybridization between cultivated *O. sativa* and most other species in the genus has been successful. Table 34.1 lists some of the potentially useful

Table 34.1. Species in the genus *Oryza* and some useful attributes (expanded from Vaughan and Sitch, 1991).

Taxa	Genome group	Distribution	Number of distinct accessions in the base collection at IRRI	Examples of traits being used or of potential use in rice improvement
O. *schlechteri*	Tetraploid	Irian Jaya, Indonesia and Papua New Guinea	1	Stoloniferous
O. *brachyantha*	FF	Africa	11	Stem borer resistance
***O. ridleyi* complex**				
O. *longiglumis*	Tetraploid	Irian Jaya, Indonesia and Papua New Guinea	5	Blast resistance
O. *ridleyi*	Tetraploid	Southeast Asia	11	Stem borer resistance
***O. meyeriana* complex**				
O. *granulata*	Diploid	South and Southeast Asia	7	Shade tolerance
O. *meyeriana*	Diploid	Southeast Asia	7	Shade tolerance
***O. officinalis* complex**				
O. *officinalis*	CC	Tropical Asia	155	Multiple pest resistance
O. *rhizomatis*	CC	Sri Lanka	18	Drought resistance
O. *eichingeri*	CC	Sri Lanka and Africa	18	Multiple pest resistance

O. minuta	BBCC	Philippines	47	Blast resistance
O. malampuzhaensis	BBCC	Southern India	5	Shade tolerance
O. punctata	BB	Africa	29	Multiple pest resistance
O. schweinfurthiana	BBCC	Africa	10	Mutiple pest resistance
O. latifolia	CCDD	Latin America	33	Tungro resistance
O. alta	CCDD	Latin America	10	High biomass production
O. grandiglumis	CCDD	South America	8	High biomass production
O. australiensis	EE	Australia	25	Drought resistance
***O. sativa* complex (equivalent to primary gene pool)**				
O. glaberrima	A^gA^g	West Africa (mainly)	2397	Cultigen
O. barthii	A^gA^g	Africa	147	Drought avoidance
O. longistaminata	A^lA^l	Africa	108	High pollen production
O. sativa	AA	Asia originally, now worldwide	74,357	Cultigen
O. nivara	AA	Tropical Asia	318	Grassy stunt virus resistance
O. rufipogon	AA	Tropical Asia/Australia	494	Bacterial leaf blight resistance
O. meridionalis	AA	Tropical Australia	39	Drought avoidance
O. glumaepatula	AA	Central and South America	32	Deep-water rice

characters of each *Oryza* species, along with the present number of samples at the International Rice Research Institute (IRRI) gene bank, which serves as a repository of a base collection for the cultivated rices and their wild relatives.

Past collecting and the present status of collections

Cultivated rices

The collecting, study and exchange of rice germplasm has a long history. Perhaps the first large-scale introduction was that of Champa varieties from Vietnam to China's Yangtze Delta in AD 1012 by Emperor Chen-Tsung. This stimulated double-cropping of rice (Ho, 1956) and has been called the first rice 'green revolution' (Bray, 1984). One of the earliest systematic collecting efforts was undertaken in India. Watt (1891) reports examining 4000 samples of rice from Bengal on the occasion of an international exhibition in Calcutta. This and other early collecting efforts were geared towards either rice improvement or varietal classification and not conservation. Early rice breeding involved pure-line selection of the 'best' traditional varieties (Parthasarathy, 1972).

Collecting for conservation and use started in the 1950s and is well documented elsewhere (Chang, 1970, 1975; Oka, 1977; Ng *et al.*, 1983; Bezançon and Second, 1984). Collaborative efforts to collect traditional rices on an unprecedented scale in Asia and Africa were stimulated by the 1971 Rice Breeding Symposium held at IRRI (IRRI, 1972; Chang, 1985b) and lasted through the 1970s. The 1980s saw a decline in collecting, however, though extensive plans were made at the 1983 Rice Germplasm Conservation Workshop (IRRI and IBPGR, 1983). This was because of lack of funding, which is surprising given that a high return on investment from this kind of work has been demonstrated (Evenson, 1989; IRRI and IBPGR, 1991).

The present status of the main rice germplasm collections held at national and regional centres is summarized in IRRI and IBPGR (1991). There are about 300,000 rice accessions stored in gene banks worldwide. This may seem more than sufficient, but such a raw number can be a misleading indication of the diversity conserved because of duplication within and among collections as well as repeated collecting from easily accessible locations. Probably about 75% of the approximately 100,000 cultivars of *O. sativa* once grown worldwide (Chang, 1984) are in the base collection at IRRI. Gaps remain with regard to minor cultivars and remote areas. Some re-collecting is also necessary in cases where unduplicated stocks of earlier collections have been lost due to inadequate facilities. New gene banks in rice-growing countries such as Bangladesh, Myanmar, the Philippines and Sri Lanka have stimulated an interest in re-collecting traditional rices, where it is still possible, in these countries.

Wild relatives

Early collecting of wild relatives of rice was carried out by: the National Institute of Genetics, Mishima, Japan; the Central Rice Research Institute, Cuttack, India; and France's Institut de Recherches Agronomiques Tropicales et des Cultures Vivrières (IRAT) and Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM, now the Institut Français de Recherche Scientifique pour le Développement en Coopération) (Chang, 1975). Wild rices were surveyed and then intensively collected in China in the 1970s and early 1980s (Kwangtung Agricultural and Forestry College, 1975; Cooperative Team of Wild Rice Resources Survey and Exploration of China, 1984). In the 1980s, it became apparent that a broad and coordinated plan was necessary, particularly in view of increasing requests for germplasm for wide hybridization, evolutionary and other studies. Not only were there very few accessions of wild rices in gene banks, but many samples were unknowingly duplicated within the same gene bank since they had been received separately from different sources without clear passport information (IBPGR–IRRI Rice Advisory Committee, 1982; Oka, 1983; Sharma, 1983; Sharma *et al.*, 1988). Consequently, from 1987 to 1990, 13 countries participated in a collecting programme for wild relatives of rice in Asia and the Pacific coordinated by IRRI (Vaughan, 1991b).

The status of wild rice collections at the beginning of the 1990s has been reviewed by Ng *et al.* (1991) and Vaughan *et al.* (1991). There is a need for further duplication of wild rice germplasm. Most of the wild rice accessions conserved at the National Institute of Genetics in Japan, at the International Institute of Tropical Agriculture (IITA) in Nigeria, at the Rice Research Institute in Thailand, at the Central Rice Research Institute in India and at IRAT and ORSTOM in France are also in the IRRI gene bank, but some other smaller national collections are not well duplicated.

Further collecting is also needed. Based on a survey of *Oryza* specimens in the world's major herbaria, there are 24 countries in Africa and Latin America where wild relatives of rice have been recorded but from which no material is present in the rice germplasm base collection at IRRI (Table 34.2). Clearly, collecting this germplasm is a priority, especially in view of the speed with which habitats are being destroyed in many tropical areas.

Collecting rice germplasm

Target regions and taxa

A necessary first step in planning any systematic collecting programme is to set explicit priorities for regions and taxa. This will be even more crucial if the programme is to be an extensive international effort. For rice as for other species, broad consultation at international conferences and workshops has proved useful in achieving consensus on priorities

Table 34.2. Countries where wild relatives of rice grow[1] and accessions are not present in the base collection at IRRI.

Angola	*O. longistaminata, O. punctata*
Belize	*O. alta, O. latifolia*
Bolivia	*O. latifolia, O. glumaepatula, O. grandiglumis*
Burundi	*O. longistaminata*
Central African Republic	*O. brachyantha, O. longistaminata, O. barthii*
Dominican Republic	*O. glumaepatula, O. latifolia*
Ecuador	*O. latifolia, O. grandiglumis*
El Salvador	*O. latifolia*
Gabon	*O. longistaminata*
Guinea-Bissau	*O. barthii, O. brachyantha*
Haiti	*O. latifolia*
Honduras	*O. latifolia, O. glumaepatula*
Martinique	*O. longistaminata*[2]
Mauritania	*O. barthii*
Mozambique	*O. longistaminata, O. punctata*
Namibia	*O. longistaminata, O. barthii*
Peru	*O. latifolia, O. grandiglumis*
Puerto Rico	*O. latifolia*
Rwanda	*O. longistaminata*
Somalia	*O. longistaminata*
South Africa	*O. longistaminata*
Swaziland	*O. punctata*
Trinidad	*O. latifolia*
USA	*O. nivara*

[1] Based on herbarium records.
[2] Apparently a recent introduction; identification based on specimen in US National Herbarium.

prior to implementing a collaborative collecting programme. For example, specific recommendations were made during the 1990 Rice Germplasm Workshop for the collecting of both cultivated and wild material (IRRI and IBPGR, 1991). It is then possible to develop appropriate collaborative linkages and to seek the necessary funds. The training of collectors in national programmes has been an integral component of this approach. Further details are given by Chang *et al.* (1977) and Chang (1985a).

Given limited financial resources, the relative merits of single- versus multiple-objective collecting have had to be carefully considered at the planning stage. As an important, widespread and diverse crop, it has not been difficult to justify collecting only cultivated rice during a mission. Looking for a number of wild species at the same time as the cultigen can result in incomplete coverage of both. Considerable time may be spent searching for small, isolated populations of wild rices in difficult terrain. Collecting wild rice germplasm has often involved covering great distances between sampling sites, whereas collecting the cultigen has been carried out by methodical village-to-village surveying, including interviews with farmers in each village. Wild and weedy rices of disturbed habitats can be collected in the same places and at the same time as the cultigen, but even then it is populations growing away from cultivated material that may be genetically most useful, rather than ones highly introgressed with the cultigen. Finally, local contacts tend to be forestry or wildlife department personnel when collecting wild rice but agricultural extension officers when collecting cultivated material. In summary, it is only really possible to comprehensively collect both wild and cultivated rices in any given area by greatly extending the length of the collecting trip.

The problem does not arise if wild species and cultigen are not found together. A number of species of wild rice occur in areas where rice is not cultivated, for example the lowlands of Papua New Guinea, northern Australia and the Amazon basin. In rice-producing areas, some wild relatives occur in habitats where rice is not cultivated, such as the well-developed secondary forests where the shade-loving species of the *O. ridleyi* and the *O. meyeriana* complexes occur (Fig. 34.1). Protected areas such as forest reserves or national parks, where no farming is allowed, are also important sources of wild germplasm, sometimes the only areas where a particular species may be found (Vaughan, 1990; Vaughan and Chang, 1993). Collecting specifically targeted on wild relatives has been necessary in such cases.

The number of samples obtained during a mission has sometimes been used as a measure of the efficiency or success of a trip. However, the quality and the genetic potential of the samples are also factors to consider when proposing to embark on collecting, and when summarizing its results. When writing a project proposal, it has been found worthwhile to indicate the expected number of samples to be collected during the trip and the relative importance of the material being sought. For example, there are many reports of wild rice in southern Vietnam, Laos and south and southeast China, but only very few from northern Vietnam, where only one herbarium specimen of a wild rice of the AA genome has been collected (Dao The Tuan, 1985). Consequently, a mission sent to northwest Vietnam was not expected to obtain much wild material. As it turned out, wild rice of the AA genome (*O. rufipogon*) was abundant in the Dien Bien Phu Valley, geographically isolated from other populations. This collection became an important addition to conserved germplasm of the species and a significant contribution to our knowledge of wild rice distribution. Such isolated populations can be expected to have unique combinations of genes. The two-day walk solely devoted to finding one population of the previously uncollected *O. schlechteri* was worth the effort, since more 'new' genes would be expected from a population of this species than from a large number of populations of a species already in germplasm collections (Fig. 34.2).

A careful search for a specific trait may also occasionally be worthwhile. Thus, the successful search in 1970 for sterile plants of *O. rufipogon* in Hainan Island, China, led to a much-needed breakthrough in

Fig. 34.1. Habitat of *O. granulata* in the Parambikulum forest reserve, India.

Fig. 34.2. Population of *O. schlechteri* at the type locality, beside the Jamu River, Papua New Guinea.

hybrid rice breeding. The consequence of finding this excellent source of male sterility has been the expansion of the area of hybrid rice in China to 8.5 million hectares in 1985 (Lin and Yuan, 1980; Yuan and Virmani, 1988). Of course, new problems are arising in rice production all the time and old problems gaining or losing prominence. Analysis of data accumulated by past collecting missions (among other sources) can indicate 'hot spots', areas where a problem is particularly important or where a pest or pathogen is particularly diverse. These areas have been priorities for intensive sampling of germplasm for rapid evaluation. For example, brown planthopper is a particularly serious problem in southern India and Sri Lanka. The pest is diverse there and the region is also rich in resistant germplasm (Chang *et al.*, 1975; Khush, 1979). Similarly, the nature of the monsoon winds and the hilly topography result in a concentration of pests and diseases in the northeast part of south Asia, and this is an area rich in sources of pest and disease resistance (Sharma *et al.*, 1971; IRTP, 1980; Glaszmann *et al.*, 1989). Evaluation data have also been important in the planning of rice collecting missions. They can reveal areas where resistance to a pest is high in spite of the absence of the pest. In rice, good examples are resistance to hoja blanca virus (Buddenhagen, 1983) and green leafhopper (Chang *et al.*, 1977; Pathak and Saxena, 1980; Vaughan, 1991a).

In the field

During a collecting trip to the Kinabatangan River region of Sabah, Malaysia, the greatest diversity was found along the middle reaches of the river. However, the distinctive agroecosystems around isolated villages at the source and at the mouth of the river were found to be home to a number of varieties available nowhere else. Careful analysis during the first few days in the field of the available diversity and of farmers' knowledge of varieties is the best guide to the intensity with which sampling should be undertaken.

Time is often a precious commodity during a collecting trip, but it is important to be patient. Visiting a teashop at the time of day when a group of villagers are relaxing has often proved worthwhile in rice collecting. The more knowledgeable farmers can then be identified, the names of local varieties from a wide area noted, variation in cultural practices determined and even the location of populations of particular wild species ascertained. In regions where ethnic diversity is great, visiting as many different groups as possible has been important. The range of varieties grown in a village in northwest Vietnam depends on the ethnic group: the Humong hill tribe prefer non-glutinous rices, whereas Thai people in the region eat glutinous rice as their staple food.

Conditions can differ greatly from one region to another. Also, unpredictable factors, such as a plane's late arrival or impassable roads, require flexibility. An ability to adapt to unforeseen events and situations has been essential, as regards both the details of daily life and the scientific content of the mission. For example, guidelines for the number of seeds to collect at a site (Oka, 1975, 1988; Chang, 1985b) may not always be helpful in rice collecting. The collector may be limited by many unexpected or extraneous factors, quite apart from the problem of place-to-place and year-to-year variation in heading time. Poor seed set, small population size or religious taboos on collecting mature seeds from the field can all limit the size of rice germplasm samples. The guiding principle has been to try to collect enough seeds to allow the rapid placement of new samples into long- and medium-term storage, though not at the cost of sampling too few populations (Marshall and Brown, 1975; Oka, 1975; Yonezawa, 1985; Marshall, 1990).

Vegetative samples of wild rice have been collected if seeds were unavailable. Rootstocks and young tillers can be maintained in water (aquatic species) or damp sphagnum moss (mesophytic species), but need to be got back rapidly to base for transplanting. When vegetative material is to be sent to another country, the transfer has been made safer by using a quarantine station in a third country where rice does not grow to check for virus infection or other diseases.

Passport data

The accurate documentation of each sample is a crucial part of all germplasm collecting. The passport data that should be recorded for wild relatives of rice are substantially different from those of the cultigen. Although a common collecting form would perhaps be ideal, separate forms with maximum compatibility have been used by IRRI collectors.

One of the most useful items to record for a rice variety is the type of agricultural system to which it is adapted. This requires discussion with the farmer to determine conditions in the field during the growing season. A comprehensive review of the terminology used to describe rice-growing environments has been developed (IRRI, 1984). This has allowed comparative studies of germplasm adapted to different agroecosystems (IRRI, 1989). Knowledge of the environment from which a rice sample was collected and of the details of cultural practices has been helpful in deciding on the best evaluation strategy and on which breeder or breeding programme the germplasm may be of most direct use to. Data on the rice plants themselves are also collected. The decimal coding system, initially proposed to describe the growth stages of cereals and later adopted by rice workers and others to characterize their germplasm (IRRI, 1988), has been found suitable for a broad range of plant characters. However, some of the information the germplasm collector gathers cannot readily be condensed into such a system, and it has often been found necessary to record free text comments on collecting forms.

A specialist is often necessary if data on such features as disease resistance are necessary. For example, the important rice collection made by Professor H. Conklin, an anthropologist from Yale University, in the Central Cordillera region of northern Luzon, Philippines (Conklin, 1967, 1980) was particularly well documented with respect to Ifugao vernacular names. These can provide information on harvest season and eating quality, but apparently not on pest and disease susceptibility, information that an agronomist or pathologist may have been able to supply.

Rice varieties are sometimes grown in deliberate mixtures. Such information is important to gene-bank staff handling incoming samples. Describing the grain characteristics of a variety or keeping back a few grains for the gene-bank seed file has been found helpful in sorting mixtures. Indicating the extent of variation in a population also helps future users.

New agronomic problems in isolated areas have sometimes been discovered and at the same time germplasm has been collected that might be useful in addressing the problem. In Vietnam's Dien Bien Phu Valley, for example, a new virus/mycoplasma disease of cultivated rice was reported to a collecting team. In the same valley, abundant wild rice was found growing vigorously. Evaluation of this wild material for resistance to the new disease would clearly be a high priority. Surprising uses of the germplasm have also been recorded. For example, *O. granulata* is used as a contraceptive by tribal people in Madhya Pradesh and Orissa, India. In China, *O. officinalis* is used in traditional medicine (CAAS, 1986).

The post-collecting phase

Rice germplasm collected by IRRI collaborative missions has normally been stored at the national centre of the country where it originated, at the international base collection at IRRI and, if possible, at a third centre with storage facilities meeting minimum international standards. The collector has the responsibility of ensuring that material reaches the gene bank and that the accession number eventually assigned there is linked to the correct collecting number and passport data. Copies of passport data closely accompany the germplasm to which they refer in all its movements. Field notes and trip reports are of historic value and are often very helpful in planning future collecting missions. In the case of rice collecting trips, ideally this documentation should also be duplicated at IRRI, whose library and other resources are accessible internationally.

In international collaborative collecting, germplasm will have to cross international boundaries during or at the end of a collecting mission. It then becomes the responsibility, for a variable period of time, of the quarantine officers of the exporting and importing countries. It is submitted to the quarantine officers of the exporting country to check for pests and pathogens and to undergo any treatment necessary to obtain a phytosanitary certificate. The germplasm, together with export and import permits, is then submitted to the quarantine officers of the importing country. This phase of the operation is required by law. When material from a collecting mission is brought to IRRI in the Philippines, it and the relevant permits are handed over to government quarantine inspectors. Guidelines have been developed by the Philippines Bureau of Plant Industry for post-entry growing of cultivated and wild rice. Seeds are tested for the presence of pests and diseases. In the case of vegetative material, the germplasm is placed in a phytotron and portions of the roots and leaves are tested for infection. Seeds of incoming cultivated rices are grown in an isolated and protected area in the dry season. Wild rices are always grown in a protected nursery area screened with fine wire mesh. Wild rices are grown in the wet season because they are generally sensitive to photoperiod. After harvesting, all vegetative parts of wild rices are burned. Further details of these procedures are given by Mew (1991).

The relative importance of different samples and the comprehensiveness of the collection as a whole are very clear to collectors and should be recorded. Collectors' trip reports can be a great help to the evaluator if samples are highlighted which were observed or locally reported to have interesting traits or were found in unusual ecological situations, such as at high altitude or on adverse soils (Chang, 1980). It is important that such material should quickly pass quarantine, undergo multiplication and receive an accession number, thus becoming available for evaluation. Periodic checking by the collector of the stage a set of samples has reached in this process has been important in ensuring that important rice germplasm reaches the user as quickly as possible.

Future directions

Evenson (1989) has pointed out that:

> The costs of adding to the collections of rice have probably not been more than 2 or 3 million dollars per year over recent years. With expenditures of, say, 4 million dollars per year, most rice landraces not now in collections could be collected within the next 10 to 15 years. Would it pay to do so? Almost certainly yes. An expenditure of 50 million dollars for collection would have to generate a benefit stream of only 25 to 50 million dollars 30 years from now. The Indian experience [... of increased rice production resulting from conserved germplasm ...] over the past 20 years strongly indicates that this is very likely.

This critical analysis of the costs and benefits resulting from collecting and conserving germplasm provides a strong argument for greater support for conserving the rice gene pool. One international and ten national gene banks, which preserve large numbers of accessions of rice, have been built since 1984 (IRRI and IBPGR, 1991). These new gene banks have given impetus to national efforts to collect or re-collect germplasm. Several national and regional programmes have also retrieved 9000 accessions from duplicate storage at IRRI to restock their gene banks. The plan for a collaborative scheme of duplicate storage made during the

1977 Workshop on Rice Germplasm Conservation (IRRI and IBPGR, 1978) proved to be important. It will be even more important in the future, especially in areas where re-collecting lost material is no longer possible.

Seed storage is not the only approach to rice genetic resources conservation, of course. Germplasm collectors should take an increasingly active role in the formulation of *in situ* conservation programmes to complement their *ex situ* work. Key farmers or villages with a noteworthy collection of traditional varieties, managed and manipulated in interesting ways, can be identified, encouraged and supported. The input of ethnobotanists will be important in this context. Protected areas such as national parks and wildlife reserves where populations of wild rice grow can be identified and their importance brought to the attention of conservation officers (Vaughan and Chang, 1992). The state of protection of a site, the potential for genetic erosion in the area, the genetic diversity of local populations and unusual features of the habitat are all relevant in identifying sites for *in situ* conservation. *O. schlechteri*, the rarest species in the genus, is only known from three widely scattered localities in Papua New Guinea and Irian Jaya, according to herbarium specimens collected in 1907, 1912 and 1974. The type locality was visited in 1990 and the species found again, apparently in the same place where R. Schlechter found it 83 years ago (Vaughan and Sitch, 1991). However, the small population (about 3 m × 3 m on the banks of a river) is in a young mountain range where numerous natural landslides occur. The herbarium specimen (LAE 212991) of this species from another locality records 'creeping grass on landslip'. These populations may be vulnerable to natural destruction. The only area where *O. officinalis* and *O. minuta* are known to grow sympatrically is in Leyte, the Philippines. This was highlighted in a recent collecting report as a site worthy of protection because of both its uniqueness and the risk of destruction due to nearby urban development. Following discussion of an unusually large population of wild rice in a lake near Ajigara, Nepal, by a germplasm collector in a national newspaper article, the government has endorsed the creation of a reserve at the site (G.L. Shrestha, pers. comm.).

At the moment, the gene pool which the rice genetic resources community is dealing with can be taken to include the whole subfamily Oryzoideae, since crossing barriers between rice and species in related genera are likely to be overcome in the near future. If present developments in biotechnology continue, however, traits found outside the subfamily may become the focus for ever more ambitious hybridization efforts. The Oryzoideae is usually allied with bamboos, which have C_3 photosynthesis. However, some workers ally the subfamily with the arundinoid grasses (Tzvelev, 1989), which include some genera with C_4 photosynthesis, e.g. *Asthenatherum*, *Aristida*, *Stipagrostis*, *Eriachne* and *Pheidochloa* (Watson *et al.*, 1985). Taxonomic considerations suggest that the intricate switch from C_3 to C_4 photosynthesis has occurred during evolution on several occasions in the Poaceae (Watson *et al.*, 1985). It may be possible to introduce this very complex trait or an intermediate system into rice in the future (Chang and Vaughan, 1991).

With both the exploitable gene pool and the international rice genetic resources network widening, critical genetic diversity studies of conserved germplasm, including the identification of duplicates, will be increasingly important in future. Such work will help in identifying diverse and undercollected regions and thus in setting an agenda for future collecting. Molecular techniques will be important tools in this effort. Collectors will clearly need to work very closely with specialists in such diverse fields as ethnobotany and molecular biology in the future to ensure that the full spectrum of rice genetic resources will be readily available to rice scientists worldwide (Chang, 1985b).

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