Conserving Traditional Rice Varieties through Management for Crop Diversity

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In situ, *on-farm conservation is an important complement to* ex situ *conservation of traditional crop varieties. In Yunnan Province, China, management for crop diversity by mixed planting (intercropping) of traditional and hybrid rice varieties provides a possible means for sustainable on-farm conservation of traditional rice varieties. Since the adoption of this form of crop diversity management in 1997, the number of traditional rice varieties in cultivation has increased dramatically and now includes some varieties that were formerly locally extinct. The cultivated area of traditional varieties has also been greatly expanded. This form of management is easy to implement and links farmers' economic concerns with conservation. Management for crop diversity can promote on-farm conservation of rice, and potentially other crops too, in a feasible and sustainable way.*

Keywords: oryza sativa, *on-farm conservation, indigenous knowledge, intercropping, biodiversity deployment*

With the advent of modern agriculture, many traditional crop varieties have been replaced worldwide by a few improved, high-yielding varieties, a result of the success of crop breeding and intensive cultivation practices adopted on a massive scale. The extensive cultivation of scientifically developed crop varieties that are high yielding and pest resistant has contributed tremendously to the world's food production. Yet this practice has also led to serious "genetic erosion"—the loss of traditional varieties from agroecosystems (Porceddu et al. 1988, Singh 1999). It hinders efforts to improve crop varieties further (Nevo 1995). Reliance on a narrow spectrum of cultivars grown in monoculture has also been linked to increased pest problems (Shigehisa 1982) and to vulnerable agroecosystems (Qualset et al. 1997). Higher yields and greater food security have come at the expense of higher inputs of pesticides and fertilizers (Lu 1996, Qualset et al. 1997), and many have questioned the sustainability of these modern farming methods. The crop diversity program in Yunnan Province seeks to improve on modern methods for cultivating high-yielding rice varieties by conserving traditional varieties as well.

Conservation of traditional crop varieties *ex situ,* mainly through seed collections, is already widespread in gene banks around the world (Hawkes 1983, Plucknett et al. 1987). At present, it is the most important and effective strategy for conservation of crop varieties. However, *ex situ* conservation has several limitations. It is static in evolutionary terms, because no genetic adaptation to the changing environment can occur. Moreover, it is difficult to work with seeds that may lose their ability to germinate shortly after ripening. Genetic diversity may thus be compromised when collections are multiplied *ex situ.* In addition, the conserved germ plasm is physically far from the users, in particular the farmers who created it.

In situ conservation—preservation of crop varieties in their original habitats on farms, through agricultural practices—is considered an important complement to *ex situ* conservation, and its implementation has lately been much advocated (Altieri and Merick 1987, Brush 1991, Qualset et al. 1997). On-farm conservation of crop genetic resources is defined as the continued cultivation and management of a diverse set of crop populations by farmers in the agroecosystems where a crop has evolved. It is based on the recognition that, historically, farmers have developed and nurtured crop genetic diversity, a process that continues among many farmers despite socioeconomic and technological changes. It emphasizes the role of farmers for two reasons: (1) Crop varieties are the result not only of natural factors, such as mutation and natural selection, but also, and particularly, of human selection and management; and (2) farmers' decisions ultimately determine whether these populations are maintained or abandoned (Bellon 1997).

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In spite of the increasing interest in on-farm conservation, however, few successful cases its use have been reported, owing to limited knowledge and understanding of suitable techniques. The challenge for on-farm conservation is that in modern agricultural systems, farmers' decisions are influenced to a large extent by socioeconomic factors (e.g., market demand), changes of climate, and government policies, as well as by considerations such as culture, religion, labor, technological skills, and dietary preferences. This raises the question of whether on-farm conservation is economically feasible and sustainable in the context of modern agriculture, or whether it must be relegated to areas of the world where subsistence farming, low yields, and low economic returns favor traditional varieties. Innovative approaches to the challenge of on-farm conservation have become increasingly important.

Our system of crop diversity management—using genetic diversity to reduce disease by mixed planting (intercropping) of traditional and hybrid rice varieties—provides an ecologically sensitive approach to disease control, yield increase (Zhu et al. 2000), and fertilizer reduction in rice ecosystems. Further investigation based on a 6-year survey has demonstrated that this approach might make effective and sustainable on-farm conservation of traditional rice varieties possible for both traditional and modern agroecosystems.

Two key points in the practice of crop diversity management are (1) to select the right combinations of traditional and hybrid rice varieties for mixed planting and (2) to determine an appropriate cultivation model. The selection of varieties for mixed planting is based on their genetic background, differences in resistance to rice blast, and agroeconomic characteristics. For planting in the same field, the traditional and hybrid varieties should be genetically divergent, as scored by molecular markers such as the amplified fragment-length polymorphic DNA, and they should have different patterns of resistance to rice blast. Normally, the genetic dissimilarity coefficient between the traditional and hybrid rice varieties selected for mixed planting should be greater than 70 percent, as measured by the resistant gene analogue (RGA) fingerprinting technique. This technique indicates conserved DNA sequences in disease resistance genes among plant species or varieties. The RGA sequences are amplified using the polymerase chain reaction and compared for rapid identification and selection of disease-resistant candidate genes.

The selected traditional varieties should have good market demand, high quality, and palatability. Plants should be tall (preferably 30 centimeters [cm] taller than the hybrid varieties). The hybrid varieties should be high yielding, rice blast resistant, and short. In addition, the difference in time to maturity between the two varieties should be less than 10 days. In Yunnan Province, the main hybrid varieties are Shanyou-63 and Shanyou-22, and the most common traditional varieties for mixed planting include Huangkenuo, Zinuo, Xianggu, Huangbansuo, Milexiangmi, and Jiugu.

In our cultivation model, seedlings of the hybrid and traditional rice varieties are transplanted into the field 40 to 45 days after germination on seedbeds and are sown at different times (though within 10 days of each other) to synchronize the dates of maturation. Usually, hybrid rice varieties are transplanted into fields first, the same way they are planted normally. Wide rows are spaced 30 cm apart and narrow rows 15 cm apart. Hills within rows are separated by 15 cm. Traditional rice varieties are transplanted between wide rows of hybrid rice with 30 cm between hills within rows. Figure 1 illustrates the most common mixed planting models, including 1-row traditional versus four-row hybrid and one-row traditional versus six-row hybrid. Farmers have adopted some other combinations according to their own preferences. One hybrid plant and three to five traditional variety plants are

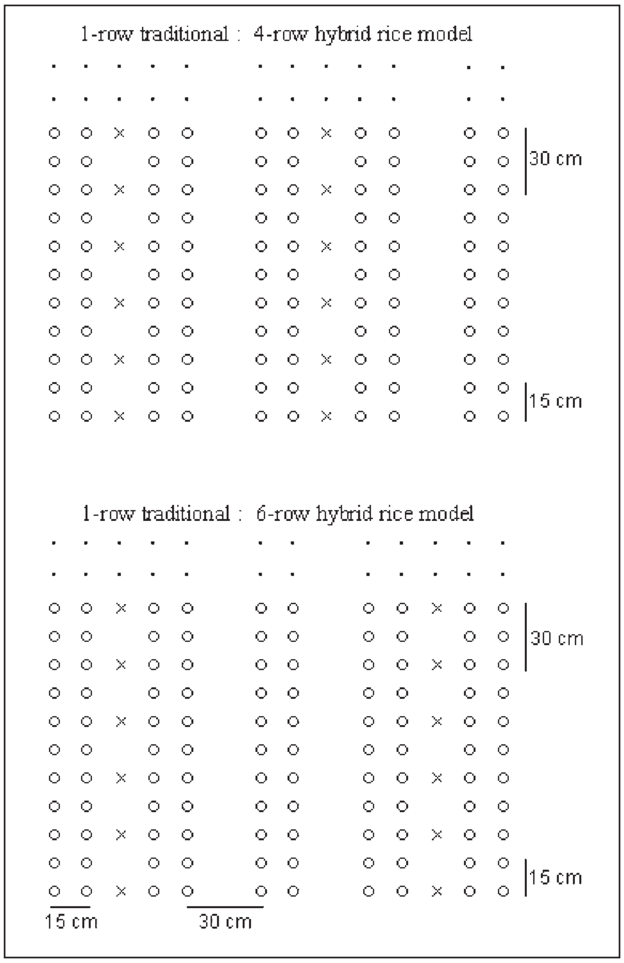

Figure 1. An illustration of the most common mixed-planting (intercropping) practices adopted in Yunnan Province. The top panel shows the 1-row traditional rice versus 4-row hybrid rice model, and the lower panel shows the 1-row traditional rice versus 6-row hybrid rice model. Symbols represent a hill of hybrid rice (o) or traditional rice (x) varieties. Distances between hills within rows and between rows for the hybrid and traditional rice varieties are indicated.

planted in each hill. The hybrid and traditional rice varieties may be transplanted on the same day, or the traditional varieties may be transplanted 2 to 4 days after the hybrids. The mixed planting models were developed by scientists, but the implementation is very simple and can be easily mastered by ordinary farmers, even those with little education. The methods for disease assessment, yield evaluation, and statistical analysis were previously described by Zhu and colleagues (2000).

Since the initiation of the crop diversity program in 1997, traditional and improved hybrid varieties have been planted in various mixtures. More than 44 townships in Yunnan Province have adopted this planting method, a result of its great success in controlling disease and increasing yield (Zhu et al. 2000), as well as reducing the need for pesticides. The method has also spread to neighboring regions such as the Sichuan and Guizhou Provinces. Demand for and cultivation of genetically diverse traditional rice varieties, which have been adapted to various agroecosystems and matched with hybrid rice varieties, have significantly increased. This is because farmers strongly favor planting special traditional rice varieties along with hybrid rice (figure 2). In this region, some traditional glutinous varieties fetch substantially higher prices per unit weight than modern hybrid rice, but traditional varieties produce lower yields and are more susceptible to disease. The traditional varieties are also more susceptible to severe lodging (collapse of stalks) before maturity. Even though farmers like to grow traditional rice varieties for their own consumption or to increase crop value, they cannot grow these varieties in monoculture because of blast and other diseases, as well as lodging. Over the past decades farmers have therefore reluctantly abandoned many of these traditional varieties. Data from the crop diversity program survey in Yunnan Province showed that the number of traditional rice varieties has dramatically increased since the program was initiated (figure 3). Our investigation further showed that the cultivated area of traditional rice varieties (in mixture with the hybrid varieties) has also been radically expanded. Investigational data collected on 20 traditional rice varieties that are commonly used in mixed planting indicated a rapid expansion in their area of cultivation (table 1). The most promising observation is that some traditional rice varieties that were formerly locally extinct, such as Ersigu and Dajiujia, have been restored to agricultural communities in Yunnan Province. Moreover, some rare and endangered varieties have also become more popular.

Figure 2. Rice field in Sanchahe Village, Luliang County, in Yunnan Province, showing extensive mixed planting (intercropping) of traditional and hybrid rice varieties. The main hybrid rice variety is Shanyou-63 (short), and the traditional rice variety is Huangkenuo (tall).

This approach to conservation of crop diversity brings substantial economic benefits to farmers, because it requires low inputs and produces high outputs. It meets the demand of the market for some high quality and culturally important traditional rice varieties and improves agricultural ecosystems by significantly reducing pesticide use. More important, this approach brings back farmers' valuable traditional rice varieties without excessive complexity and promotes *in situ* on-farm conservation of rice diversity. The approach may offer a feasible and sustainable way of conserving varieties of other crops too. We have conducted experiments with mixed planting of various combinations of crop species, such as wheat and fava bean, potato and maize, and oil rape and fava bean. These models have promise for conservation as well, because they similarly use tall traditional varieties (figure 4). Our preliminary results suggest that intercropping of different crop species in appropriate combinations can provide more effective control of diseases and insect pests, although the mechanisms are still under investigation.

Any attempt to conserve crop varieties that omits consideration of the economic benefits will not be sustainable. According to an assessment by the Yunnan government and unpublished government economic reports, farmers gain about $187.50 per hectare from mixed planting (mainly from production of the high-valued traditional rice), excluding the savings that comes from reduced pesticide purchase. The total financial benefits from the diversity program were approximately $7.6 million in 2000 and $16.7 million in 2001, a result of the dramatic increase in mixed planting over that period. Crop diversity management by mixed planting is already showing its potential in southwestern China. Reports from provincial government authorities in-

Table 1. Increase of cultivation area of 20 traditional rice varieties commonly used in the mixed-planting practices in Yunnan Province since the adoption of the biodiversity technique in 1997. The data were collected from our field surveys from a total of 44 townships. (Figures in the parentheses indicate number of townships that used traditional rice varieties).

Variety	Area of plantation (hectares) 1997	1998	1999	2000	2001	2002
Huangkenuo	12 (1)	734 (2)	2,176 (6)	23,164 (22)	45,865 (35)	66,700 (44)
Zinuo	—	78 (2)	1,163 (3)	7,321 (8)	11,752 (12)	15,200 (18)
Huangbansuo	—	—	3 (1)	212 (2)	5,244 (4)	10,000 (6)
Milexiangmi	—	—	0.2 (1)	22 (1)	352 (2)	5,000 (4)
Jiugu	—	—	—	34 (1)	4,353 (3)	66,700 (12)
A-lunuo	—	—	—	2.8 (1)	1,245 (2)	5,000 (7)
Hongkenuo	—	—	—	1.5 (1)	1,312 (2)	3,000 (5)
Xianggu	—	—	—	43 (2)	1,160 (5)	3,334 (9)
Zigu	—	—	—	42 (1)	585 (4)	2,667 (8)
Xiangnuomi	—	—	—	25 (2)	427 (4)	2,334 (9)
Zaiyunuo	—	—	—	35 (1)	215 (2)	852 (3)
Esigu	—	—	—	10 (1)	258 (2)	554 (4)
Babaogu	—	—	—	42 (2)	316 (3)	550 (5)
Lingcanheigu	—	—	—	15 (1)	157 (2)	352 (5)
Wenshandabaigu	—	—	—	12 (1)	76 (2)	350 (5)
Baikenuo	—	—	—	8 (1)	125 (3)	231 (6)
Huanglagu	—	—	—	1.5 (1)	61 (1)	150 (3)
Zhuyanuo	—	—	—	2.2 (1)	45 (1)	120 (2)
Qitougu	—	—	—	1.5 (1)	24 (1)	65 (2)
Duijinnuo	—	—	—	—	15 (1)	165 (1)
Total	**12**	**812**	**3,342.2**	**30,994.5**	**73,587**	**183,324**

dicate that the area of cultivated rice under diversity management has expanded to about 460,000 hectares in the Yunnan, Sichuan, and Guizhou Provinces in the last few years. Therefore, it is feasible to conserve traditional crop varieties in modern agroecosystems using the crop diversity management model. On-farm crop diversity conservation does not have to come at the expense of profits and can enhance farmers' incomes. Conservation of traditional crop varieties can be well integrated into modern agroecosystems through diversity management where appropriate economic incentives are present.

It is important to point out that crop diversity management is not applicable to all agricultural systems. Our experiments demonstrate that this method is powerful for controlling epidemic diseases against which resistance is race specific, such as rice blast, but it is not effective against disease for which resistance is race nonspecific. In addition, this method is easily adopted and popularized only in agricultural systems where manpower operation is still predominant. It would be difficult at present to apply the method in agricultural systems that employ industrial equipment. However, we believe that if crop diversity management proves to be practical for pest control, maintenance of high yields, and environmental protection, industrial equipment suitable for this application will be designed. For example, the celery and leek intercropping system in Switzerland makes use of mechanized management (Baumann et al. 2001).

The concept of on-farm conservation emphasizes farmers' cultivation and management of crop varieties (Bellon 1997), but the role of scientists as active partners is also important. Crop diversity management for disease control in Yunnan Province provides an excellent example: Scientists were in-

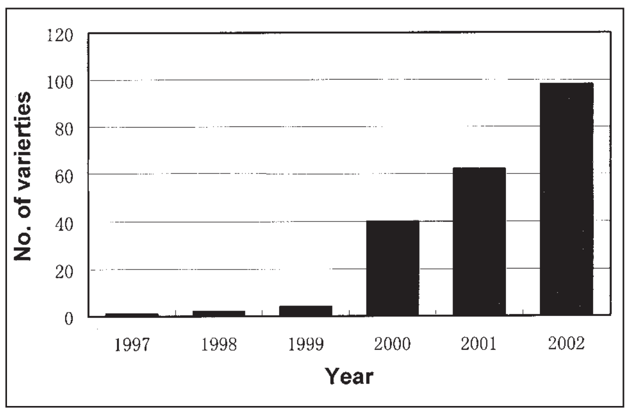

Figure 3. The number of traditional rice varieties grown in Yunnan Province since the adoption of the mixed-planting (intercropping) technique in 1997 has increased substantially. The data were collected in field surveys conducted in the townships that participated in the crop diversity project in Yunnan Province. The rice varieties were identified by farmers and scientists from Yunnan Agricultural University.

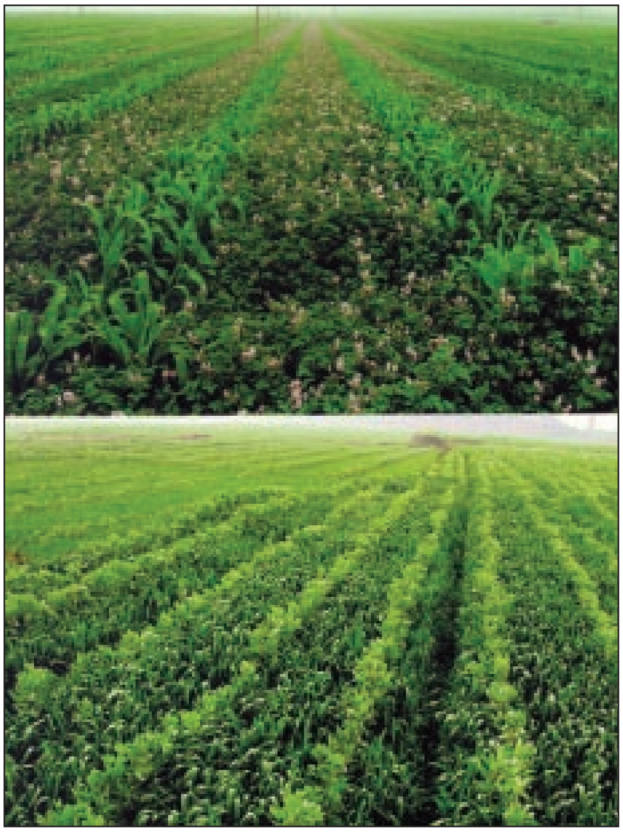

Figure 4. Experiments in Yunnan Province on mixed planting (intercropping) of different crop species, such as potato and maize (above) and wheat and fava bean (below) have shown promise for disease and insect control, in addition to biodiversity conservation.

spired by indigenous knowledge of intercropping, and they modified this knowledge before returning it to farmers. It is essential to understand indigenous knowledge of farming practices that have promoted the maintenance of crop diversity, disease control, and environmental protection, particularly in agricultural systems in which those practices have been shaped over many, many years. The foundation for the maintenance of well-balanced, local agroecosystems rests on the indigenous knowledge developed during thousands of years of farmers' experience. However, this knowledge is often unrecorded and scattered among different communities and cultures. Factors such as cultural and language differences and the isolation of communities impede the application of indigenous knowledge by farmers from different regions.

Scientists must therefore gather and evaluate indigenous knowledge and translate the most useful lessons into recommended practices. Scientifically based but generalized and simplified messages can then be returned to the local community to guide farming practices. For example, intercropping has been practiced in China for hundreds of years, but its current use is sporadic and the scientific basis for this practice has not been fully explored. By focusing on how mixed cultivation can reduce disease problems in rice, Zhu and colleagues (2000) were able to recommend simple techniques that are effective on a large scale. The area of mixed cultivation of hybrid and traditional rice varieties reached 167,000 hectares in 2001, and this has played a tremendous role in rice production and conservation. This model for conserving traditional rice varieties through crop diversity management in the Yunnan, Sichuan, and Guizhou Provinces is a breakthrough that is popular with farmers, good for agroecosystems, and promising for future breeding efforts utilizing traditional varieties. We believe this management method has long-term potential for overcoming the commonly perceived constraints of on-farm conservation.

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References cited

Altieri MA, Merrick LC. 1987. In situ conservation of crop genetic resources through maintenance of traditional farming systems. Economic Botany 41: 86–96.

Baumann DT, Bastiaans L, Kropff MJ. 2001. Competition and crop performance in a leek–celery intercropping system. Crop Science 41: 764–774

Bellon MR. 1997. On-farm conservation as a process: An analysis of its components. In Sperling L, Loevinsohn M, eds. Using Diversity: Enhancing and Maintaining Genetic Resources On-Farm. Ottawa (Canada): International Development Research Centre. (03 January 2002; *www.idrc.ca/library/document/104582)*

Brush SB. 1991. A farmer-based approach to conserving crop germplasm. Economic Botany 45: 153–165.

Hawkes JG. 1983. The Diversity of Crop Plants. Cambridge (MA): Harvard University Press.

Kiyosawa S. 1982. Genetics and epidemiological modeling of breakdown of plant disease resistance. Annual Review of Phytopathology 20: 93–117.

Lu LS. 1996. Agriculture and agricultural science and technology in the 21st century. Science and Technology Review 12: 1–8 (in Chinese).

Nevo E. 1995. Genetic resources of wild emmer, *Triticum dicoccoides*, for wheat improvement: News and views. Pages 79–88 in Li ZS, Xin ZY, eds. Proceedings of the 8th International Wheat Genetics Symposium; 20–25 July 1993, Beijing. Beijing: China Agricultural Scientech Press.

Plucknett DL, Smith NHJ, Williams JT, Anishetty NM. 1987. Gene Banks and the World's Food. Princeton (NJ): Princeton University Press.

Porceddu E, Ceoloni C, Lafiandra D, Tanzarella O, Scarascia A, Mugnoza GT. 1988. Genetic resources and plant breeding: Problems and prospects. Pages 7–21 in Miller TE, Koebner RMD, eds. Proceedings of the 7th International Wheat Genetics Symposium. Cambridge (United Kingdom): Institute of Plant Science Research.

Qualset CO, Damania AB, Zanatta ACA, Brush SB, 1997. Locally based crop plant conservation. Pages 160–175 in Maxted N, Ford-Lloyd BV, Hawkes JG, eds. Plant Genetic Conservation: The In Situ Approach. London: Chapman and Hall.

Singh RK. 1999. Genetic resource and the role of international collaboration in rice breeding. Genome 42: 635–641.

Zhu YY, et al. 2000. Genetic diversity and disease control in rice. Nature 406: 718–722.