Chapter 1
Rice and Its Importance to Human Life

RICE is life, for most people living in Asia. Rice has shaped the cultures, diets and economies of thousands of millions of people. For more than half of humanity rice is life (Fig. 1.1). Considering its important position, the United Nations designated year 2004 as the International Year of Rice. Devoting a year to a commodity was unprecedented in United Nations history. However, the 57th session of the United Nations General Assembly noted that rice is the staple food of more than half the world's population, affirmed the need to heighten the awareness of the role of rice in alleviating poverty and malnutrition and reaffirmed the need to focus world attention on the role rice can play in providing food security and eradicating poverty and declared the year 2004 as the International Year of Rice (adopted on December16, 2002; www.fao.org/ag/irc).

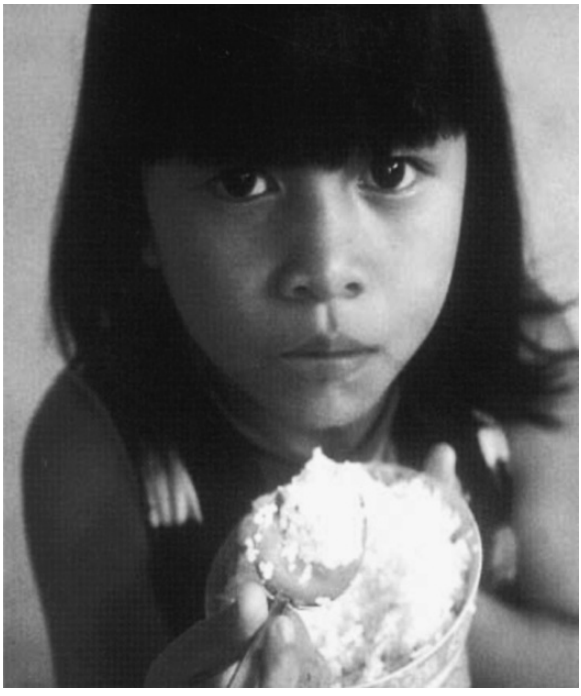

Fig. 1.1 A bowl of rice is life

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Rice, *Oryza sativa*, is a cereal food crop that belongs to the grass family (Family: Poaceae) of the plant kingdom (Fig. 1.2; USDA-NRCS PLANTS Database/ Hitchcock, A.S. [rev. A. Chase]. 1950). Domesticated rice comprises two species of food crops, *Oryza sativa* and *Oryza glaberrima*. These plants are native to tropical and subtropical southern Asia and southeastern Africa (Crawford & Shen, 1998). Rice is a grass "autogame", a crop that is grown more easily in the tropics. Originally rice was probably cultivated without submersion, but it is believed that mutations led it to become a semi aquatic plant. Although it can grow in diverse environments, it grows faster and more vigorously in wet and warm conditions. This plant develops a main stem and many tillers and may range from 0.6 to 6 m (floating rice) in height. The tiller bears a ramified panicle that measures between 20 and 30 cm wide. Each panicle has 50–300 flowers (floret or spikelet), which form the grains. The fruit obtained is a caryopsis (UNCTAD.org).

Fig. 1.2 Rice, *Oryza sativa*, L.

Origin, History and Spread

It is believed that rice cultivation began simultaneously in many countries over 6500 years ago. The first crops were observed in China (Hemu Du region) around

5000 B.C. as well as in Thailand around 4500 B.C. They later appeared in Cambodia, Vietnam and southern India. From there, derived species *Japonica* and *Indica* expanded to other Asian countries, such as Korea, Japan, Myanmar, Pakistan, Sri Lanka, Philippines and Indonesia. *Japonica* is an irrigated rice of the temperate zone, with medium or short grains, also called round grain, and is a rainfed lowland rice of warm tropical zones. *Indica* is an irrigated rice of warm tropical zones, with long, thin and flat grains. The Asian rice (*Oryza sativa*) was adapted to farming in the Middle East and Mediterranean Europe around 800 B.C. After the middle of the 15th century, rice spread throughout Italy and then France, later propagating to all the continents during the great age of European exploration. In 1694 rice arrived in South Carolina, probably originating from Madagascar. The Spanish took it to South America at the beginning of the 18th century (Source: UNCTAD. org).

The origins of rice have been debated for some time, but the plant is of such antiquity that the precise time and place of its first development will perhaps never be known. It is certain, however, that the domestication of rice ranks as one of the most important developments in history, for rice is the longest, continuously grown cereal crop in the world.

Nutritional Value of Rice

Oryza sativa (rice) is recognized as one of the most important crops in the world and it provides the main source of energy (Table 1.1) for more than half of the world

Table 1.1 Nutritional value of white, long grain, un-enriched raw rice per 100 g/3.5 oz) (USDA Nutrient Database)

Nutrient	Amount/Percent (Percentages are relative to U.S. recommendations for adults)
Carbohydrates	79.95 g
Sugars	0.12 g
Dietary fiber	1.3 g
Fat	0.66 g
Protein	7.13 g
Thiamin	0.07 mg (5%)
Riboflavin	0.05 mg (3%)
Niacin	1.6 mg (11%)
Pantothenic acid	1.01 mg (20%)
Vitamin B6	0.16 mg (13%)
Calcium	28 mg (3%)
Iron	0.8 mg (6%)
Magnesium	25 mg (7%)
Phosphorus	115 mg (16%)
Potassium	115 mg (2%)
Zinc	1.09 mg (11%)
Manganese	1.09 mg

population. It is the major food crop in India, China and the rest of Asia where 92% of the world's rice is grown.

Cultivation Methods and Rice Farming Systems

The traditional method of cultivating rice is flooding the direct-seeded fields with or after transplanting the young seedlings. This is also known the irrigated rice commonly in most of Asia. Seeds are machine drilled in puddled soils in the United States and Australia. The other methods of rice farming systems are: the rainfed lowland rice (mainly in Africa and Madagascar), upland or dryland rice (in mountains or plateaus), and the deep water or flood-prone rice (in Bangladesh and in the Mekong, Chao Phraya and Niger deltas). The world average yield is 3.9 tons/ha. Higher yields of 9.5 tons have been harvested in Australia and lower yields of 0.70 tons/ha are harvested from traditional upland areas of Africa.

Rice Production

Rice production represents 30% of the world cereal production today. It has doubled in the last 30 years, in part due to the introduction of new varieties, but its present growth barely follows consumption. In 2025 there will be 4.6 billion people that depend on rice for their daily nourishment, compared with three billion today. A new leap in production is therefore expected. At the same time, small producers will have to use land which is less favorable for cultivation, such as brackish or briny soils, and the availability of water resources will become more and more problematic (en.wikipedia.org/wiki/Rice).

In agriculture, the term "Green Revolution" refers to the transformation of agriculture that occurred from the 1940s through the 1960s, when farmers used the discoveries of science, planting higher-yielding rice varieties to great success. In 1968, rice scientists at the International Rice Research Institute (IRRI) in the Philippines released a variety of rice that yielded 5 tons of rice per hectare with almost no fertilizer and 9.4 tons/ha with fertilizer. This was nearly 10 times the yield of traditional rice and came to be known as Miracle Rice. The introduction of IR8 and new management practices changed a hungry landscape to one of food self-sufficiency in Asia. It is difficult to overstate this achievement; rice sustains about 3.5 billion people either partially or fully for caloric intake around the world, mostly in Asia.

Production and Export

Rice is the second largest produced cereal in the world. At the beginning of the 1990s, annual production was around 350 million tons and by the end of the century

it had reached 410 million tons. World production totaled 395 million tons of milled rice in 2003, compared with 387 million tons in 2002. This reduction since the end of the previous millennium is explained by the strong pressure put on land and water resources, which led to a decrease of seeded areas in some Western and Eastern Asian countries.

Production is geographically concentrated in Western and Eastern Asia with more than 90% of world output. China and India account for more than one-third of global population (52.3% over the 1999–2003 period) and supply over half of the world's rice. Brazil is the most important non-Asian producer, followed by the United States. Italy ranks first in Europe. World production has shown a significant and very steady growth, almost exclusively due to increasing production in Western and Eastern Asia (Fig. 1.3).

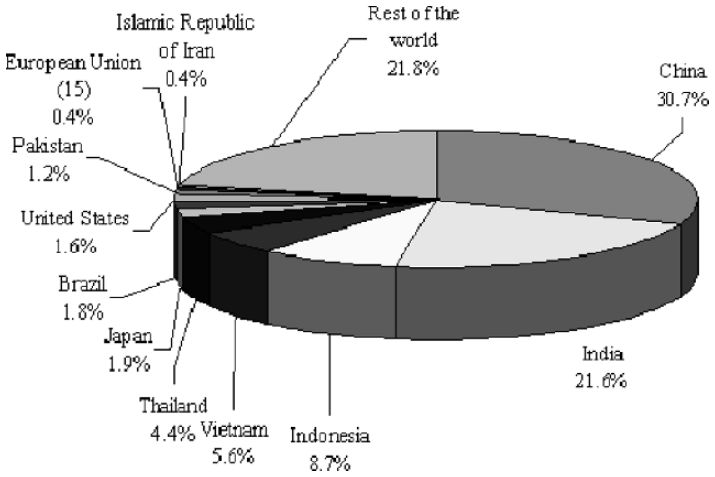

Fig. 1.3 Distribution of the world paddy rice production (average 1999–2003) (UNCTAD.org)
Source: Secretariat from the Food and Agriculture Organization of the United Nations (FAO) data

World trade figures are very different, as only about 5–6% of rice produced is traded internationally. The largest three exporting countries are Thailand (26% of world exports), Vietnam (15%), and the United States (11%), while the largest three importers are Indonesia (14%), Bangladesh (4%), and Brazil (3%). Although China and India are the top two largest producers of rice in the world, both countries consume the majority of the rice produced domestically leaving little to be traded internationally (Rice Wikipedia).

Worldwide Consumption

Between 1961 and 2002, per capita consumption of rice increased by 40%. Rice consumption is highest in Asia, where average per capita consumption is higher than 80 kg/person per year. In the subtropics such as South America, Africa, and

the Middle East, per capita consumption averages between 30 and 60 kg/person per year. People in the developed West, including Europe and the United States, consume less than 10 kg/person per year (United Nations Conference on Trade and Development, UNCTAD).

Rice is the most important crop in Asia. In Cambodia, for example, 90% of the total agricultural area is used for rice production. US rice consumption has risen sharply over the past 25 years, fueled in part by commercial applications such as beer production (UNCTAD briefing, 24 April 2008; Rice Wikipedia). Almost one in five adult Americans now report eating at least half a serving of white or brown rice per day.

Place of Rice in the Global Economy

On December 16, 2002, the UN General Assembly declared the year 2004 the International Year of Rice. The declaration was sponsored by more than 40 countries. It is one of the three major cereal grains (maize, wheat and rice) that feeds the growing population. As the population nearly doubled between the years 1961 and 1999 from 3.07 to 6.05 billion, the production of these three major cereals increased 2.5–3.0 times. IR8 was created through a cross between an Indonesian variety named "Peta" and a Chinese variety named "Dee Geo Woo Gen" (IRRI, 2006). As it was mentioned in the preceding paragraphs, the introduction of IR8 rice and new management practices changed a hungry landscape to one of food self-sufficiency in Asia and it is difficult to overstate this achievement. Rice sustains about 3.5 billion people either partially or fully for caloric intake around the world, mostly in Asia. These achievements in increasing rice production have greatly helped in hunger alleviation in the world.

The importance of rice to human life across the globe can be emphasized strongly by looking at the current global food crisis of 2007–2008. Beginning in 2007 and going forward in 2008, a global food crisis loomed as Asia's rice bowl emptied and world price soared. The crisis over rice showed no signs of easing as the price of the world's benchmark jumped 10% in just one week during April 2008, fanning fears that millions across Asia will struggle to afford their staple food. Increased food demand from rapidly developing countries, such as China and India, the use of biofuels, high oil prices, global stocks at 25-year lows and market speculation are all blamed for pushing prices of staples such as rice to record highs around the globe (Rice Wikipedia).

Rice Germplasm and Cultivars

The largest collection of rice cultivars is at the International Rice Research Institute (IRRI), with over 100,000 rice accessions held in the International Rice Genebank (IRRI, 2006). Rice cultivars are often classified by their grain shapes and texture.

For example, Thai Jasmine rice is long-grain and relatively less sticky, as long-grain rice contains less amylopectin than short-grain cultivars. Chinese restaurants usually serve long-grain as plain unseasoned steamed rice. Japanese mochi rice and Chinese sticky rice are short-grain. Chinese people use sticky rice which is properly known as "glutinous rice" (note: glutinous refer to the glue-like characteristic of rice; does not refer to "gluten") to make zongzi. The Japanese table rice is sticky, short-grain rice. Japanese sake rice is another kind as well.

Indian rice cultivars include long-grained and aromatic Basmati (grown in the North), long and medium-grained Patna rice and short-grained Sona Masoori (also spelled Sona Masuri). In South India the most prized cultivar is "Ponni" which is primarily grown in the delta regions of Kaveri River. Kaveri is also referred to as ponni in the South and the name reflects the geographic region where it is grown. In the Western Indian state of Maharashtra, a short grain variety called Ambemohar is very popular. This rice has a characteristic fragrance of mango blossom.

Aromatic rices have definite aromas and flavors; the most noted cultivars are Thai fragrant rice, Basmati, Patna rice, and a hybrid cultivar from America sold under the trade name, Texmati. Both Basmati and Texmati have a mild popcorn-like aroma and flavor. In Indonesia there are also *red* and *black* cultivars.

High-yielding cultivars of rice suitable for cultivation in Africa and other dry ecosystems called the new rice for Africa (NERICA) have been developed. It is hoped that their cultivation will improve food security in West Africa.

In a major advancement to rice science, the draft genome sequences for the two most common rice cultivars, *indica* and *japonica*, were published in 2002 (Goff et al., 2002; Sasaki, 2002; Yu et al., 2002). Rice was chosen as a model organism for the biology of grasses because of its relatively small genome (∼430 megabase pairs). Rice became the first crop whose genome sequence was fully mapped (Gillis, 2005).

Potentials for the Future

As the UN Millennium Development project seeks to spread global economic development to Africa, the "Green Revolution" is cited as the model for economic development. With the intent of replicating the successful Asian boom in agronomic productivity, groups like the Earth Institute are doing research on African agricultural systems, hoping to increase productivity. An important way this can happen is the production of "New Rices for Africa" (NERICA). These rices, selected to tolerate the low input and harsh growing conditions of African agriculture, are produced by the African Rice Center, and billed as technology from Africa, for Africa. The NERICA have appeared in *The New York Times* (October 10, 2007) and *International Herald Tribune* (October 9, 2007), trumpeted as miracle crops that will dramatically increase rice yield in Africa and enable an economic resurgence (en.wikipedia.org/wiki/Rice).

Rice Improvement Towards Nutrition Security

Improving Vitamin A Deficiency (VAD): Golden Rice

Ingo Potrykus (ZTH-Zentrum) of Switzerland and Peter Beyer of the University of Freiburg, Germany teamed up to engineer rice that will produce beta-carotene, with the intent that it might someday be used to treat vitamin A deficiency (Ye et al., 2000). In the first prototype of Golden Rice developed in 1999, two genes were inserted into the rice genome by genetic engineering, to account for the turned-off genes. This intervention leads in turn to the production and accumulation of β-carotene in the grains. The intensity of the golden color is an indicator of the concentration of β-carotene in the endosperm. According to the World Health Organization, dietary vitamin A deficiency (VAD) causes some 250,000–500,000 children to go blind each year (www.goldenrice.org).

Additional efforts are being made to improve the quantity and quality of other nutrients in golden rice (Beyer et al., 2002; Potrykus, 2001, 2003). The addition of the carotene turns the rice gold. The figures (Fig. 1.4a, b) below show the biosynthetic pathway used by researchers to engineer provitamin-A-rich golden rice (on the left) and kernels of golden rice in Indica rice background.

Improving Iron Deficiency-Ferretin Rice

Iron deficiency is widespread problem in developing countries. In particular, children appear to be much more deficient in iron. Rice varieties are low in iron. Therefore to remedy this, ferretin rices have been created by scientists at the International Rice Research Institute (IRRI) (Datta et al., 2003, 2007).

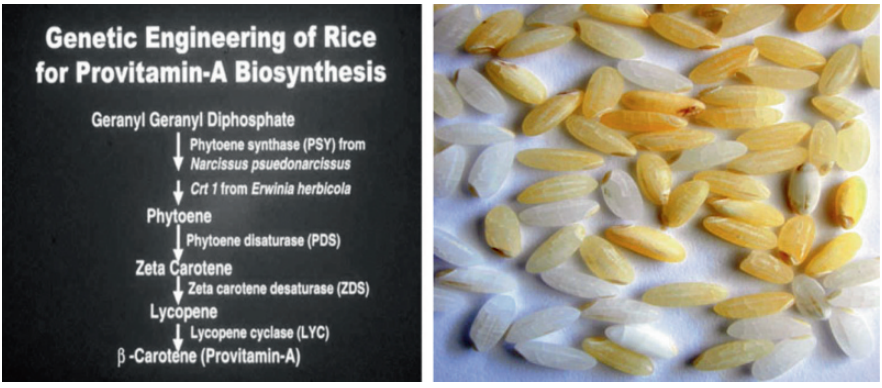

Fig. 1.4 **a**. Biosynthetic pathway for provitamin-A; **b**. Golden rice created in an indica rice background by researchers at the International Rice Research Institute (Datta et al., 2003)

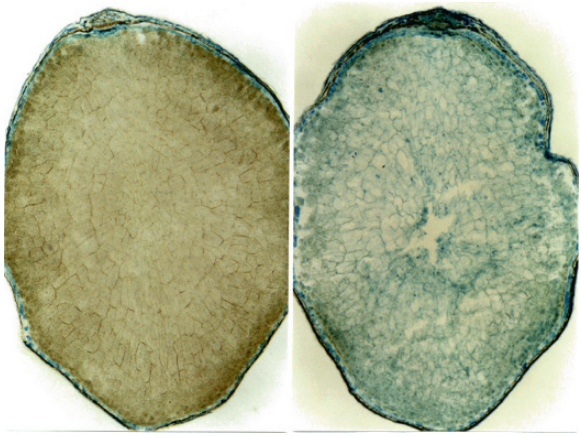

Fig. 1.5 Localization of iron in the endosperm of transgenic rice (ferretin rice) (Datta et al., 2007)

Ferretin rices are transgenic rices that have increased iron in their endosperm (Fig. 1.5).

Improving Protein Content in Rice: Expression of Human Proteins

Bethell and Huang (2004) of Ventria Bioscience genetically modified rice to express lactoferrin and human lysozyme which are proteins usually found in breast milk and have antiviral, antibacterial, and antifungal properties. Using Ventria's ExpressTec™ system, Ventria researchers expressed these two human proteins (lactoferrin and human lysozyme) in rice (Bethell & Huang, 2004). They observed that these proteins have the potential to provide not only the benefits of reduced stool volume and improved weight gain, but also shorten the course of diarrheal episodes via antimicrobial activity against the causative agent.

Rice Pests and Diseases

Entomologists at the International Rice Research Institute (IRRI) have carried out volumes of work on ecology-conscious management of different rice pests. Rice pests are any organisms or microbes with the potential to reduce the yield or value of the rice crop (or of rice seeds) (Jahn, Litsinger, Chen, & Barrion, 2007). Rice pests include weeds, pathogens, insects, rodents, and birds. A variety of factors can contribute to pest outbreaks, including the overuse of pesticides and high rates of nitrogen fertilizer application (e.g. Jahn, Almazan, & Pacia, 2005). Weather conditions also contribute to pest outbreaks. For example, rice gall midge and army worm outbreaks tend to follow high rainfall early in the wet season, while thrips outbreaks are associated with drought (Douangboupha, Khamphouko, Inthavong, Schiller, & John, 2006).

One of the challenges facing crop protection specialists is to develop rice pest management techniques which are sustainable. In other words, to manage crop pests in such a manner that future crop production is not threatened (Jahn et al., 2001, 2007). Rice pests are managed by cultural techniques, pest-resistant rice varieties, and pesticides.

Major rice pests include the brown planthoppers (Preap, Zalucki, & Zahn, 2006), armyworms, the green leafhopper, the rice gall midge (Jahn & Khiev, 2004), the rice bug (Jahn, Domingo, Almazan, & Pacia, 2004), hispa (Murphy et al., 2006), the rice leaffolder, stemborer, rats (Leung Peter, Cox, Jahn, & Nugent, 2002), and the weed *Echinochloa crusgali* (Pheng, Khieve, Pil, & John, 2001). Rice weevils are also known to be a threat to rice crops in the US, China and Taiwan.

Major rice diseases include, sheath blight (ShB), blast (bl), bacterial leaf blight (BB) and tungro (RTD) virus (Ou, 1985). Rice diseases, rice pathogen populations and biological disease control are the central themes of this book. These are dealt with in greater detail in separate, later chapters of this volume.

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