RICE

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Summary

Rice is the main source of dietary energy for nearly half of the world's population as the second most important crop after wheat. Rice cultivation has been a basis of life of many communities for thousands of years. Improved cultivation practices such as soil puddling and transplanting of seedlings helped to spread growth area by supplying

sufficient water and to compete weeds.

The structure and composition of rice grain is similar that of other cereals, though protein content is somewhat lower, and starch content is higher.

Due to its higher lysine content, rice protein has one of the highest nutritive values among the cereal proteins.

Milling and processing may lead to reduced nutritive value: white or polished rice are poorer in vitamins and minerals than brown rice.

Rice is produced in four types of ecosystems, which are rainfed lowland, upland, flood-prone and irrigated conditions.

Highest yields also with the highest stability are achieved in irrigated ecosystems, while upland rainfed ecosystems have the lowest productivity, with a high risk of soil erosion and degradation.

Rice production requires high amount of water, about 5000 liters for one kg of rice grain. Since water resources are limited, intervention is needed improving the water use efficiency of the crop, reducing evaporation, seepage, percolation losses and surface runoff of water.

For the adequate nutrition of rice crop, with minimized environmental risk, the efficiency in utilizing nutrient sources should be increased by genotype improvement.

Additionally for efficient nutrient use agronomic interventions considering nutrient supply are needed to enhance low recovery of fertilizer nutrients, by tailoring site specific nutrient management tactics to soil nutrient supply and plant nutrient status.

Against weeds and pests the integrated weed management and integrated pest management strategies have been developed, which integrate physical, chemical and biological control techniques.

The new rice varieties planned will be resistant to the major pests, tolerate the abiotic constraints of their ecosystem and have a high and safe grain yield with a favorable nutrient composition. Genetic engineering is a promising tool in development of the new rice varieties.

1. Rice in the world - living with rice

Rice is the main source of food for nearly half of the world's population as the second most important crop after wheat. It is cultivated in more than 100 countries in Africa, America, Australia, Europe and, last but not least in Asia, where 90% of the world's rice is produced and consumed.

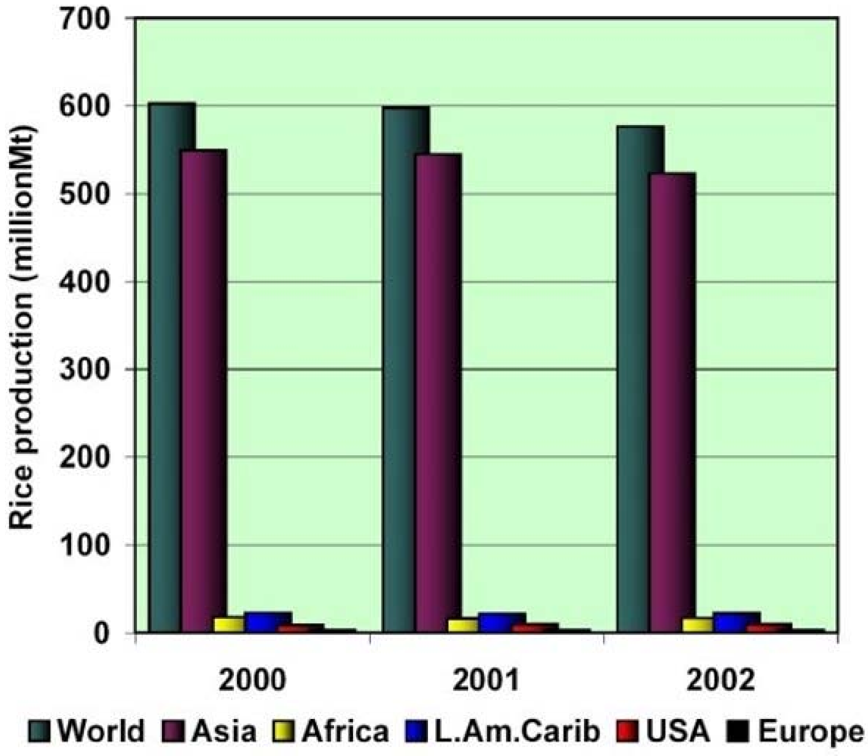

Figure 1. World rice production

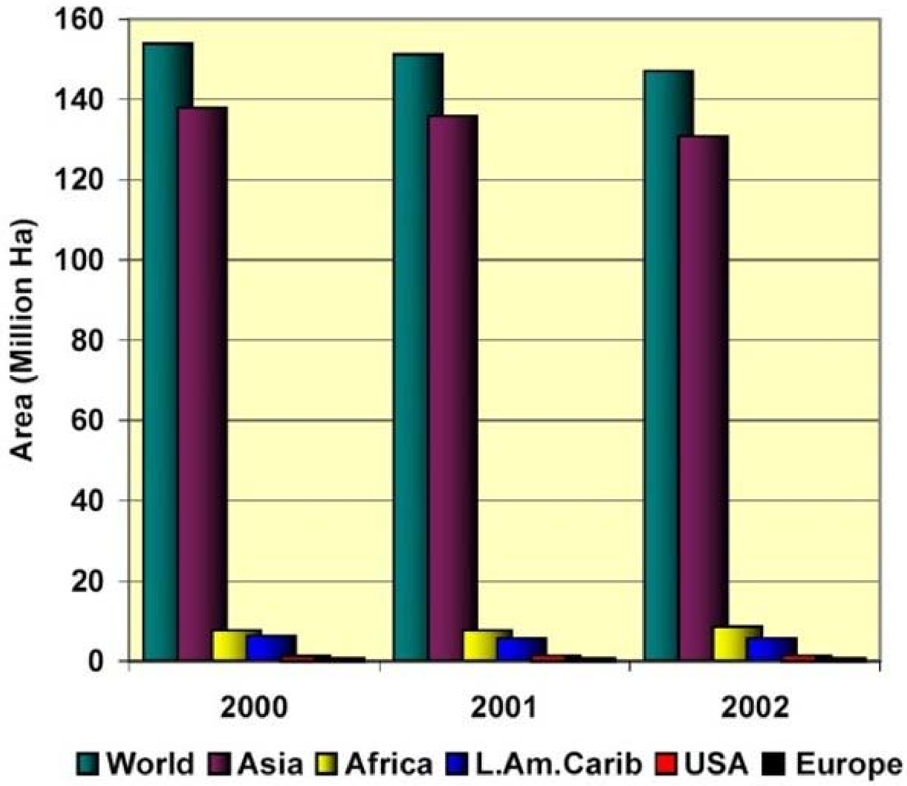

Figure 2. Rice growing areas in the world

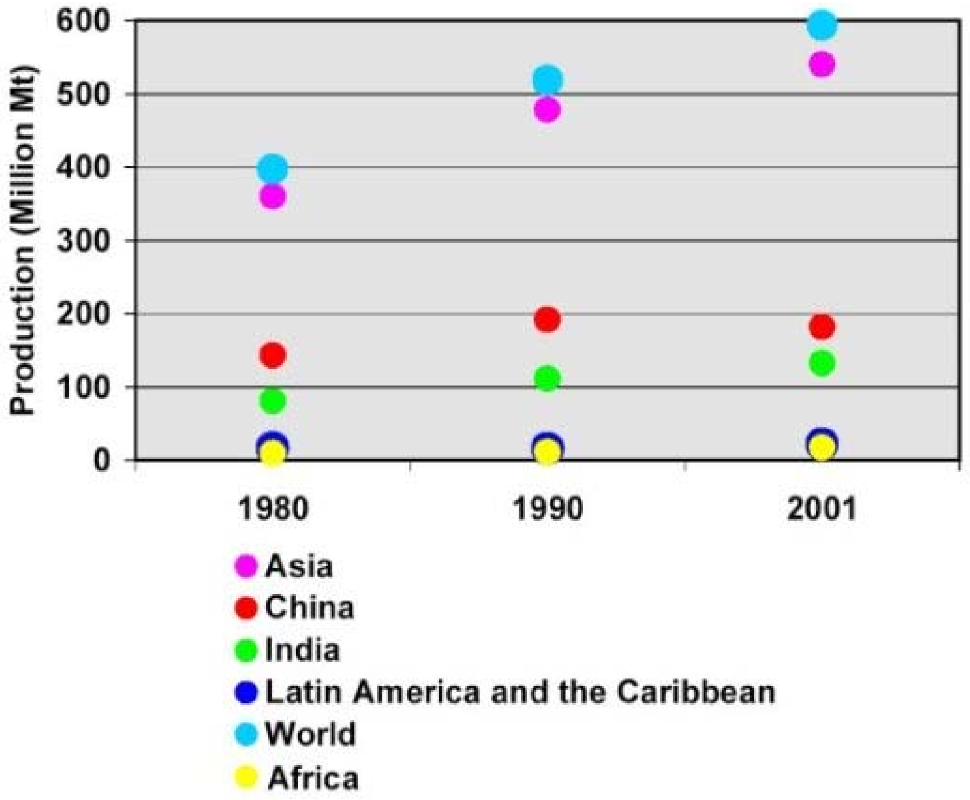

Figure 3. Change in rice production in the last two decades

In Asia 50 to 80 % of daily calorie intake is supplied by rice, while producing rice and its products is often the only possibility of employment and the single source of income for rural people.

From 1961 to 1990, the harvested rice area in Asia had increased by about 30%, due to a combination of the expansion of cultivated area and crop intensification, involved the possibility of two-three harvest in a year in tropical climate with irrigation water. Since 1990 rice growing areas remained more or less unchanged (about 132 million hectares according to FAO, 1999), with a peak in 2000 (more, than 137 million hectares).

The majority of rice farms are small; there mean size is less than one hectare in Bangladesh, Japan and Shri Lanka. Leading rice producer countries are China, India, Indonesia, Bangladesh, Thailand and Viet Nam, producing more, than 69 % of total world′s production. Additionally, both the largest importer and exporter countries of the rice world are in Asia. According to FAO sources the shipments of the world′s leading rice exporters, Thailand and Viet Nam, were 5.900 million tonnes and 4.500 million tonnes respectively in 1999. Indonesia, the world′s largest rice importer was expected to import 3.500 million tonnes in 1999, but the country aims to reduce rice import needs within some years through increasing rice production and encouraging consumption of alternative foodstuff rich in carbohydrates (see Chapter 3.3.”Starch bearing crops as food sources” in this volume) Total rice import in Bangladesh was expected less than 2.5 million tonnes in 1999.

In Africa, rice is grown in 56 countries/territories with a total population of about 758 million people, according to FAO data. There are countries where rice is the main staple food for the population - as Madagascar, where around 75 % of the population are involved in rice production, and annual rice consumption is about 118 kilograms of rice per capita. It is important food in many other countries and its availability has become an important factor of food security, while yields are very different in the various agro-ecological conditions, in North Africa and in Sub-Saharan Africa. In 1997 rice yields in Egypt were the world′s highest, and rice is one of the country′s leading export crops. Though Nigeria had more than one million hectares of harvested rice, forecast of its imports increased to 850 000 tonnes particularly focused on parboiled rice from Thailand, in 1999.

Rice is the staple food of five countries of the 27 countries producing rice **in the American continent**. Additionally it is an important food for the population in seven Latin American and Caribbean countries involving Brazil and Cuba. The harvested area in Latin America and the Caribbean has decreased in the last two decades due to the substantial reduction in upland rice area in Brazil and Mexico, while the continent has considerable land and water resources for the expansion of rice growing. Rice exporters in Argentina are searching markets while Brazil, their traditional customer needs less import due to the increased domestic production in 1999.

Rice is grown in seven of the 50 states in the U.S., these being: Arkansas, California, Florida, Louisiana, Missouri, Mississippi and Texas. Arkansas produces about 40% of the US rice and produces the highest yields in the US. In 1999, the US average of rough rice grain yield was 6600 kg/ha, in 2000 rice yield was 7031 kg/ha, and in 2002 7370 kg/ha. Most of rice is produced for export - US is the third leading rice exporter in the world.

Traditionally rice is grown in 12 of 49 countries **in Europe**. While rice is not a staple food of the European population, consumption increased due to immigration and diversification in diet. While in South Western Europe rice production increased due to expansion of harvested area, in Eastern Europe - as a consequence of the political and economical transition - both harvested area and yield have decreased since 1989. Total rice imports into the EC - mostly from Asia - was about 600 000 tonnes in 1998 and 1999. Since 2000 a slight increase can be seen in yields.

2. Short history

From an early beginning of its domestication rice became an integral part of the life and culture of many communities. Ancient people created their myths around rice believing that it definitely originated from heaven and was obtained as a most precious gift from gods. Although modern Asian people do not believe this, rice is treated with reverence in much of the rice world.

Rice was first domesticated in China - not in Southeast Asia, as previously thought. The remains of rice that was grown more than 9000 years ago along China′s middle Yangtze River was discovered by Richard MacNeish in the1990s. The middle Yangtze River near Dongting Lake not only has the oldest sites but also has the right environment for rice domestication. In the Korat area of Thailand pottery shards bearing the imprint of both grains and husks were found by Wilhelm G. Solheim II in 1966. Results of ^{14}C and termoluminescence testing confirmed the remains to be at least 6000 years old.

Cultivated rices belong to two species, Oryza sativa, which is the more widely utilized, and Oriza glauberrima. As a results of tectonic events and climatic changes seven forms of O. sativa came about, namely Chinese (japonica/sinica), South Asian (indica), New Guinean, Australian, American and two endemic African forms.

The greatest variety of wild species that are believed to have contributed to the cultivated forms is found in the zone of monsoon rainfall extending from eastern India through Myanmar, Thailand, Laos and northern Vietnam and into southern China.
In early cultivation rice was likely grown by direct seeding and without standing water. In Southeast Asia rice was produced under dryland conditions in the uplands. Soil puddling and seedling transplanting - widely practised to this day - are assumed to be processed first in China. By puddling the water use of crop could be tailored to limited water supply, due to reduced percolation through the destroyed soil structure. Transplanting 1-6 week old seedlings in standing water favoured to successful competition to weeds, satisfying early water demand, and accommodation to later water constraints, adjusting the plant calendar, etc.

In western India rice was important food as early as 2500 B. C, and no later than 1000 B. C. in Sri Lanka. The traditions of wetland rice cultivation were carried to the Philippines about 2000 B.C., to Indonesia about 1500 B.C. and to Japan about 100 B. C. In Japan about one million hectares of rice were cultivated between 800 and 900 A.D. The crop was introduced in the Mediterranean by Macedonian troops of Alexander the Great returned from India about 344-324 B.C. Some 1800 years later, the Portuguese carried it to Brazil, and the Spanish spread rice cultivation to several points of Latin America. Crop was carried by West African and Malagasy slaves to North America, and started to produce in the 17th century in South Carolina. Australia, New South Wales, joined to the rice producing countries in the 20th century.

3. Growth, morphology and chemistry of the rice plant

Growth duration of the rice plant is generally 90-180 days, depending on the variety and environmental conditions. Its life cycle consists of three growth phases: vegetative, reproductive and ripening. After germination vegetative phase is characterised by rapid root and shoot growth (tillering, increase in height, leaf emergence). In reproductive phase culm elongation rate is high, flag leaf appears, then heading and anthesis starts and completes in 10-14 days. Fertilization is followed by a 15-40 day period of ripening, divided into milky, dough, yellow-ripe and maturity stages.

3.1. Morphology of rice plant

3.1.1. Root system

The rice plant develops a radicle (seminal root), mesocotyl roots, and nodal roots. Seminal root - with a maximum length of 15 cm - is functioning until the seventh leaf stage. The root system is basically composed of nodal roots, from which crown roots develop from nodes below the soil surface. Tiller and root growth are synchronized: when the n^{th} leaf emerges, simultaneously a tiller and 5-25 roots emerge from the $(n-3)^{th}$ node. Root growth reaches its maximum around flowering although new branches are still forming until maturity, and maintain root activity in favourable soil environment. There is a high genetic variance in root morphology and in vertical and horizontal root distribution; however, it is highly affected by the root environment, especially by water regime.

Typical wetland rice varieties are shallow-rooted partly genetically, partly as anaerobic conditions impair root depth. Modifications in root cortex and in stele are adaptive characteristics of the rice plant in flooded paddy fields.

Traditional dryland varieties generally are described to be tall, low tillering, deep rooted and early maturing, bearing large panicles. Since deeper root system has a greater ability to recover soil and fertilizer N accumulated in the deeper soil layers, and helps the plant to avoid water stress by absorbing water from the deeper layers, it should be beneficial for low input dryland cultivations.

Figure 4. Sampling of rice root system (Photo: Kalman Rajkai)

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Biographical Sketch

Krisztina R. Végh is a research worker in the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences (RISSAC) Budapest, Hungary. She completed her MSc in Biology in Budapest Science University (ELTE) Hungary. Her PhD thesis analysed the nutrient dynamics in the rhizosphere, by using measurements and modelling. Her interests also include system modelling in sensitive environments, in drought-prone areas, and, in nutrient deficient conditions. She has conducted several research projects on plant nutrition, water use and drought tolerance, and cooperated in both Hungarian and international research. She has worked in Uppsala, Sweden, in Tokyo, Japan, and now she works in joint projects on sustainable plant nutrition, together with Indian universities and research institutes.