

Crop management research and recommendations for rainfed lowland rice production in Cambodia

M. Sarom

Director General, Cambodian Agricultural Research and Development Institute, Phnom Penh, Cambodia

INTRODUCTION

Rainfed lowland rice dominates the farm cropping systems in Cambodia. More than 80 percent of the cultivated area sown to rice is rainfed lowland culture: the systems are traditional and ancient in origin and rice is monocropped year after year on the same land; shortages of water and inadequate irrigation infrastructure are typical of rural areas.

In areas where supplementary water is available, other crops are also grown, providing a measure of diversification, crop rotation, change of diet and opportunities for off-farm sales and trading – all positive factors. Supplementary water also enables rice production to be intensified with two – or even three – crops grown annually. Where supplementary water is insufficient for a second rice crop, growers will typically sow a second short-duration cash or food crop. Mung beans, black gram and vegetables are popular, and frequently precede or follow a wet season rice crop. Rainfed lowland rice is grown in a variety of environments, even where production resources are poor: it is not uncommon, for example, for no fertilizer to be used despite the low level of nutrients, particularly N and P (White, Oberthur and Sovuthy, 1997).

The risks inherent in intensification can be minimized with the choice of suitable varieties. For example, early-maturing varieties that flower to coincide with the peak of the rain season risk damage to spikelets and this reduces pollination levels; furthermore, spikelets at this time are more likely to be damaged by rodents. An understanding of crop scheduling is essential for double or multiple cropping, in order that growers can select varieties, stagger planting to suit the season and space crops on their small areas of land (Sarom, 2001).

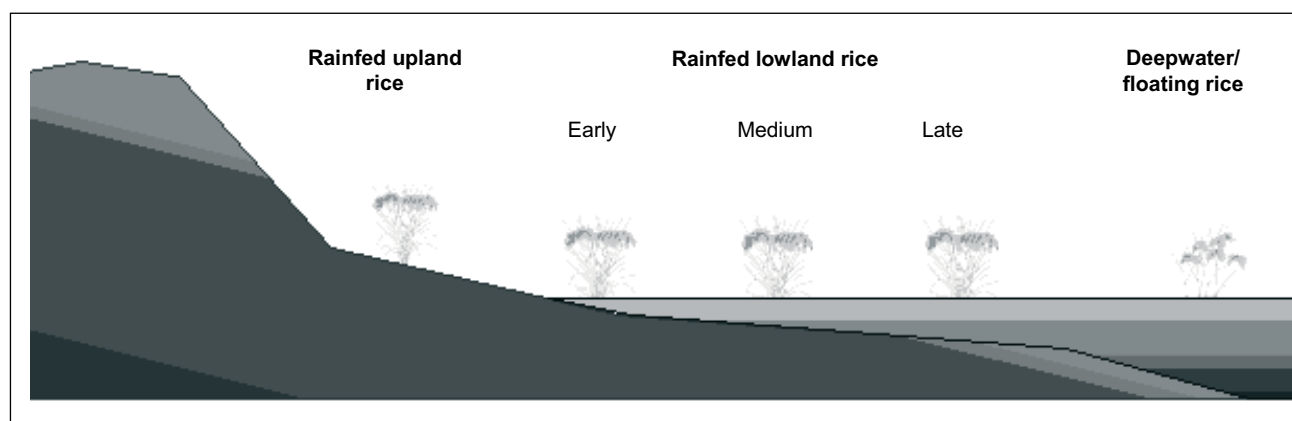
RICE GROWING IN CAMBODIA

Cambodia enjoys a monsoon climate with two distinct main seasons: wet and dry. Rice is grown throughout the year, with wet-season rice accounting for 88 percent of national production and dry-season rice the remainder. Wet-season rice depends mainly on rainfall from May to October. Dry-season rice is cultivated in the main cropping period with full or supplementary irrigation or in receding floodwaters. On the basis of rainfall, flooding patterns and topography, wet-season rice can be categorized further into rainfed upland, rainfed lowland and deepwater production (Figure 1).

- Rainfed upland rice is grown in small areas and mainly in the hill regions of northern and north-eastern Cambodia, where annual rainfall is higher than in the central plain. This is small sector production and accounts for around 2 percent of total production.
- Rainfed lowland rice accounts for about 93 percent of the total production area of wet-season rice. In Cambodia, rainfed lowland rice is found in all provinces, but mainly in the central plain around the great lake (Tonle Sap), and on the lower streams of the Mekong and Bassac rivers. Annual rainfall in the region is between 1 200 and 2 000 mm.
- Deepwater/floating rice is cultivated in the same areas as rainfed lowland rice, but is found mainly on the edges of lakes where the water is deep (Figure 1); it occupies about 5 percent of national ricelands.

In Cambodia each year, rice is cultivated on an estimated 2.2 million ha (Table 1). Therefore, rainfed lowland rice, as the major category of rice produced in

FIGURE 1
 Rice agro-ecosystems in Cambodia



the country, has contributed significantly to the growth of the Cambodian economy. With this rice ecosystem, farmers have cultivated thousands of varieties for many hundreds of years. While subject to environmental pressures – flooding, drought, adverse soils and insect pests – throughout a diverse history of cultivation, these traditional varieties provide not only grain for farmers, but also highly valuable genetic stocks for plant breeders. Variations in time to flowering mean that varieties from different groups are grown at different water levels in the fields. Normally, early varieties are grown near villages where the water level is shallow and where the crop can be given supplementary irrigation. Intermediate-maturing varieties are often grown on middle field terraces, and late-maturing varieties are grown in the lowest part of the fields where water is likely to be deeper

and where submergence may frequently occur. Low rainfall can, however, result in drought for all three groups. Most rainfed lowland rice varieties have traits (such as time to flowering) that are adapted to local environments; they also satisfy the taste preferences of the local people. Although only a few varieties are actually resistant to drought, a large proportion of traditional varieties are able to recover once the drought is over. The highly variable levels of recovery exemplify the different levels of drought tolerance.

CONSTRAINTS OF RAINFED LOWLAND RICE PRODUCTION

Rainfed lowland rice occupies 88 percent of the rice area. Crop losses caused by natural disasters such as floods and drought can be high. During 2000–03, the area

TABLE 1
 Production loss in rice farming in Cambodia

Year	Area planted (‘000 ha)	Area harvested (‘000 ha)	Area damage (‘000 ha)	% loss	Total production (‘000 tonnes)	Yield (tonnes/ha)	Production loss (‘000 tonnes)
2000	2 318	1 903	415	17.9	4 026	2.12	879
2001	2 186	1 980	206	9.4	4 099	2.07	426
2002	2 113	1 995	119	5.6	3 823	1.92	227
2003	2 314	2 242	72	3.1	4 711	2.10	152
Mean	2 233	2 030	203	9.1	4 165	2.05	421

Note: Figures are based on the following assumptions (based on MAFF calculations):

Milling recovery is 64%

Consumption rate is 143 kg/capita/annum

$421 \times 0.64 \times 10^6 / 143 = 188\,341$ persons

Approximately 188 341 people could be fed with the production loss caused by the reduction in total rice harvested areas against total planted.

Source: MAFF reports, 2000–03.

NATIONAL RICE PROGRAMMES

PROGRAMMES NATIONAUX SUR LE RIZ

PROGRAMAS NACIONALES DEL ARROZ

planted to rice each year was in the order of 2.23 million ha. During the same period, however, an estimated 200 000 ha of croplands were lost each year resulting in annual crop losses of more than 420 000 tonnes (Table 2). The major constraints of rainfed lowland rice production are outlined below.

Water availability

Rainfall is highly variable from year to year, season to season and location to location. Frequency and distribution vary, with a significant effect on productivity. Excessive rains can cause floods, while droughts can follow a shortage of rain; sometimes the unfortunate rice grower is subject to both floods and droughts during the growing season. Irregular rainfall at the beginning of the wet season may delay planting, encourage weed growth and encourage build-up of insect pests, resulting in yield loss. Excessive rain at crop maturation not only reduces productivity, but affects grain fertility. Excess water encourages the growth of fungal diseases (which lowers yields), gives poor grain appearance and reduces grain-milling recovery. Drought during flowering reduces yield and – if the drought comes later in the growing cycle – the crop may face an outbreak of grasshopper pests.

Soil fertility

Rainfed lowland rice areas typically have sandy soils with low fertility. These are soils that respond poorly to fertilizer application. Nitrogen and phosphorus deficiencies and iron toxicity are common in most rice soils (White, Oberthur and Sovuthy, 1997); some soils are also deficient in potassium and micro-elements. Low organic matter and poor water-holding capacity are also common. The productivity of rainfed lowland rice can be increased if the appropriate fertilizer is applied to overcome deficiencies in soil fertility (often associated with toxicities). In general, however, fertilizer use in Cambodia is neglected and compares poorly with other countries in the region (Table 2).

Pests and diseases

There are a large number of weeds, insects and diseases that typically attack rainfed lowland rice. Productivity suffers and, depending on the severity of the attack, crop losses can be high.

- Broadleaf weeds, grasses and sedges are a greater problem if weeding is poor at the time of crop establishment.

TABLE 2
Fertilizer use in some countries in Asia

	Agricultural area	Fertilizer use	
	(million ha)	(tonnes)	(kg/ha)
Cambodia	5 307	12 716	23.96
Australia	472 000	2 110 000	44.70
Lao People's Democratic Republic	1 678	10 166	60.58
Myanmar	10 505	171 805	163.55
Philippines	11 280	627 930	556.68
China	535 566	35 077 600	654.96
Indonesia	42 164	2 772 900	657.65
Thailand	21 175	1 660 863	784.35
India	180 600	16 797 500	930.09
Malaysia	7 890	1 406 111	1 782.14
Viet Nam	7 892	1 947 400	2 467.56

Source: Maclean *et al.*, 2002 (adapted).

- Insect pests in rice are numerous: brown plant-hopper, armyworm, caseworm, leaf-folder, stem borer and gall midge are the main predators; Cambodian rice is particularly sensitive to hopper attack, which causes the plant leaf to turn brown – a phenomenon known as “hopper burn” and which results in serious crop losses. Rats and crabs are other major pests. Control depends mainly on community involvement with mass trapping and killing. In recent years, golden apple snails have also become pests of rainfed lowland rice (Jahn *et al.*, 1997).
- Diseases occur frequently, but their effect varies depending on the variety grown, the management practices adopted and the climate. Major disease incidences are rare, but most crops are susceptible to minor attacks of, for example, blast, brown spot, sheath rot and sheath blight (fungal), bacterial leaf streak, bacterial blight and tungro.

Variety and seed

The cultivation of improved varieties is strictly limited in rainfed lowland rice production. Traditional rice varieties are still grown and are only being slowly replaced. The traditional varieties are generally low-yielding, but are well adapted to local growing conditions and have acceptable grain quality. It is common practice for growers to cultivate several different varieties of rice on a small block of land, planting one variety adjacent to

the next with no isolating distance between them. Where flowering times are similar, cross-pollination occurs and varietal purity can be adversely affected. Harvesting, threshing and storing of seeds of the different varieties take place together or in close proximity, leading to varietal mixing, which in turn leads to yield reduction (Sarom, 2002).

CROP MANAGEMENT RESEARCH AND RECOMMENDATIONS FOR RAINFED LOWLAND RICE PRODUCTION

Investments in research and development (R&D) quickly filter through to the national economy. Where funding is limited, it is important to target those sectors where cost-efficiency is more certain. However, given the traditional nature of much of rice production in Cambodia, it tends to be existing and well-proven technologies that are disseminated in preference to new innovation. There is scope for both approaches, and the industry has done much to promote the use of improved technologies, crop care and information exchange.

Variety

To overcome low productivity, one major strategy applied has been the replacement of existing low-yielding varieties with newer higher-yielding varieties, taking into account taste preferences and market requirements. The CARDI (Cambodian Agricultural Research and Development Institute) breeding programme has developed and released more than 30 new varieties of rice to growers (Sarom, 2001 and 2002). Different varieties are recommended for the different sub-ecosystems, ranging from favourable to unfavourable. A 2002 study showed not only that newly recommended varieties gave yield advantages of 17 percent or more over traditional varieties, but that they were preferred by consumers for their taste.

Double cropping system

Rice-based cropping systems have been developed and adapted to farmers' fields. Double cropping (i.e. rice and rice, rice and cash crops) has been widely tested and recommended to farmers. The development of small-scale deep-well systems has contributed significantly to the adoption of double cropping techniques, as small-scale irrigation can be guaranteed. The introduction of legumes (e.g. mung bean, soybean and sesbania) has led to improved soil structure and nutrition, providing the basis

for increased rice yield. Major limitations in double cropping systems include: lack of reliable rainfall for early season rice; risk of soil water saturation for early season mung bean; and lack of water for the establishment and subsequent growth of mung bean following wet season rice.

Current practice is to minimize risk and maximize yield in the wet season rice crop, resulting in limited flexibility when growing other crops. For example, early season mung bean should be planted early on to reduce the risk of soil water saturation, whereas dry season mung bean should be planted as soon as possible after harvesting the wet season rice. Another option is to shift the planting dates: grow wet-season rice earlier to accommodate dry-season mung bean, or later to accommodate early-season rice. A systems approach is required to maximize the use of the limited water available and to minimize the risk of crop failure. Characterization of rainfall patterns will assist with the evaluation of risks inherent in the different cropping systems. The availability of supplementary irrigation – even for limited strategic irrigation – reduces the risk of crop loss and increases the value of double cropping.

Land levelling

Uneven (i.e. non-level) fields require more water to wet the soil for ploughing, and to maintain complete water cover for weed control. The unevenness (i.e. the difference in height between the highest and lowest part of the field) of Cambodian rice fields ranges from 70 to 330 mm, with an average of 160 mm. Research by CARDI has shown that land levelling alone can increase rice yields by 15 percent, and reduce weed burden by 40 percent and weeding time by 5–21 labour-days/ha. Land levelling is therefore a technology with the potential to improve the performance of rice-based farming systems in Cambodia, and it has been widely promoted and practised in recent years.

Fertilizer recommendations

Soil classification systems for rice have been developed linking recommended fertilizer rates to different soil types (White, Oberthur and Sovuthy, 1997) on the basis of "fertility capability". Both advisor and farmer are thus able to predetermine the rates of fertilizer applications that may apply to a given soil type. Rice soils in Cambodia have been divided into 11 groups with names relating to the most popular location in which they predominate.

Rat control

Rats cause serious damage in both rice fields and rice stores. There are two main types of field rat that attack rice, namely *Bandicota indica* (“big rat”) and *Rattus argentiventer* (“small rat”). Control is difficult, requiring the full involvement of the community. Every grower suffers from rat infestation and in recent years, the trap-barrier system (TBS) has been tested and recommended for use by rice farmers for all ecosystems including rainfed lowland rice. Following the introduction and adoption of TBS, a significant number of rats have been caught, the threat of rats has declined and productivity has been enhanced. Vigilance, however, is required to prevent the build-up of rat populations.

Farmer knowledge

Significant increases in national rice yield have been noted over the last 10 years thanks to CARDI’s R&D work and the distribution of technical packages to farmers. Such progress must be supported by human resource development, and programmes to boost the capability of farmers and others have been undertaken. Participants from the provincial agricultural offices, agricultural extension offices, technical departments of the Ministry of Agriculture, Forestry and Fisheries (MAFF), international organizations, non-governmental organizations and others have been trained in various technologies and activities. Farmers have been trained to identify and distinguish rice pests from friendly insects and shown recommended pest control measures; they have also been trained to follow appropriate planting times and to grow pest-tolerant or disease-resistant varieties of rice, resulting in rapid increases in rice yields.

CONCLUSIONS

Traditional varieties of rice grown in a traditional manner remain a valuable resource, but yields can be low, which lowers crop productivity. Growers must keep up with research and development and adopt new technologies as they become commercially available. Two general conclusions can be made:

- Agricultural R&D is the basis for national development in Cambodia; it is the focal point for

innovation and for the introduction of agricultural technologies to help promote economic growth and alleviate poverty. More than 80 percent of the population live in rural areas and Cambodia is dependent on the productivity of the rural economy. However, rural poverty is more common than urban poverty; investments in agricultural productivity will help reduce rural poverty.

- New technologies are required in order to improve crop productivity. Core research policies centre on the development of appropriate technologies that take into account the socio-economic reality of people living in harmony with their environment. Such technologies should aim to enhance the natural resource base within sustainable production systems.

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Recherche en gestion des cultures et recommandations pour la production de riz pluvial de bas-fonds au Cambodge

Les systèmes de production à base de riz au Cambodge consistent essentiellement en systèmes de production pluviaux de bas-fonds. L'accroissement de production qui s'est récemment fait sentir (tant pour le riz que pour d'autres cultures) a permis au pays d'accéder dans une certaine mesure à l'autosuffisance alimentaire. L'amélioration des rendements a eu pour origine

l'élaboration, l'introduction et la mise en œuvre de nouvelles technologies sélectionnées, plus particulièrement adaptées à une utilisation à petite échelle.

Parmi celles-ci, la diffusion de variétés améliorées de riz a revêtu une importance significative. Le principe de la double récolte (riz et riz, riz et culture de rente) a été largement essayé et adopté par les

producteurs. Le nivellement des terres, l'utilisation d'engrais et une lutte plus efficace contre les infestations de rats ont également contribué à l'amélioration des rendements. Ceux-ci restent néanmoins faibles en ce qui concerne le riz; la diffusion de l'information et des technologies est appelée à s'étendre de plus en plus dans un avenir proche.

Investigaciones sobre gestión agraria y recomendaciones para la producción de arroz de regadío en las tierras bajas de Camboya

En Camboya, la agricultura basada en el arroz tiene lugar sobre todo en sistemas productivos de tierras bajas que emplean riego. El considerable incremento de la producción registrado recientemente (con arroz y otros cultivos) ha permitido al país alcanzar un cierto grado de autosuficiencia. Los mayores rendimientos se deben al desarrollo,

la introducción y el empleo de ciertas tecnologías nuevas particularmente idóneas para las explotaciones en pequeña escala, entre las cuales ha tenido particular importancia la entrega de variedades mejoradas de arroz.

El doble cultivo (arroz y arroz, o bien arroz y cultivos comerciales) ha sido ampliamente experimentado y

adoptado por los agricultores. La nivelación del terreno, el empleo de fertilizantes y un control más eficiente de la infestación por ratas también han contribuido al aumento de la producción. Sin embargo, la productividad del arroz sigue siendo baja, por lo que se ha previsto seguir ampliando la difusión de información y tecnologías en el futuro próximo.

Rice production in Japan

K. Maruyama

Director General, National Agricultural Research Center for Hokkaido Region, Japan

INTRODUCTION

Rice has always been important in Japan. It is the basic staple and was at one time also used as currency. Until the Edo era (c. 1870), local feudal lords were rated on the basis of the quantity of rice produced in their territories. The salaries of their liegemen were paid in rice: the unit was the *koku* and one *koku* was the equivalent of 150 kg of rice (sufficient to feed one subordinate soldier for 1 year). The amount of rice produced did not meet demand – it was never sufficient after tax (farmers and others living in the countryside were “owned” by the feudal lords, and they taxed the farmers half of all the rice produced on their land). Land holdings were small – usually less than 0.5 ha. In an effort to minimize taxes and to provide for their families, farmers made every effort to boost yields, an approach which lives on today.

TECHNOLOGIES CONTRIBUTE TO YIELD INCREASES

About 2 tonnes/ha of brown rice was a typical yield during the mid-nineteenth century (i.e. 150 years ago). The twentieth century saw a steady increase in yields, thanks to numerous technological advances, better use of farm resources, application of fertilizers and improved crop care – resulting in the current average yield of 5 tonnes/ha of brown rice. Technological achievements include:

- Greater water-use efficiency (e.g. improved timeliness of application), thanks to the construction of dams, canals, reservoirs and other water management structures.
- Improved soil performance, following the understanding of the role of plant nutrients, organic manures, improved water-holding capacity etc.
- Chemical fertilizer use, which boosts yields (ammonium sulphate-nitrogen fertilizer was first applied in 1913 and soon became commonplace).
- Variety development, taking advantage of technical innovation, with cross-breeding mainstream practice since 1904.

Rapid yield increase was seen in the mid-twentieth century, but has slowed down since the 1970s (Figure 1).

Rising labour costs saw Japanese rice farmers quick to mechanize, supported by an innovative and dynamic manufacturing sector. Power threshers were developed in the 1930s, power cultivators in the 1950s, binders (i.e. simple harvesters) in the 1960s, and transplanting machines and combine harvesters in the 1970s. There has been similar technical innovation in the post-harvest sector for handling and processing rice and Japan is a world leader in this field.

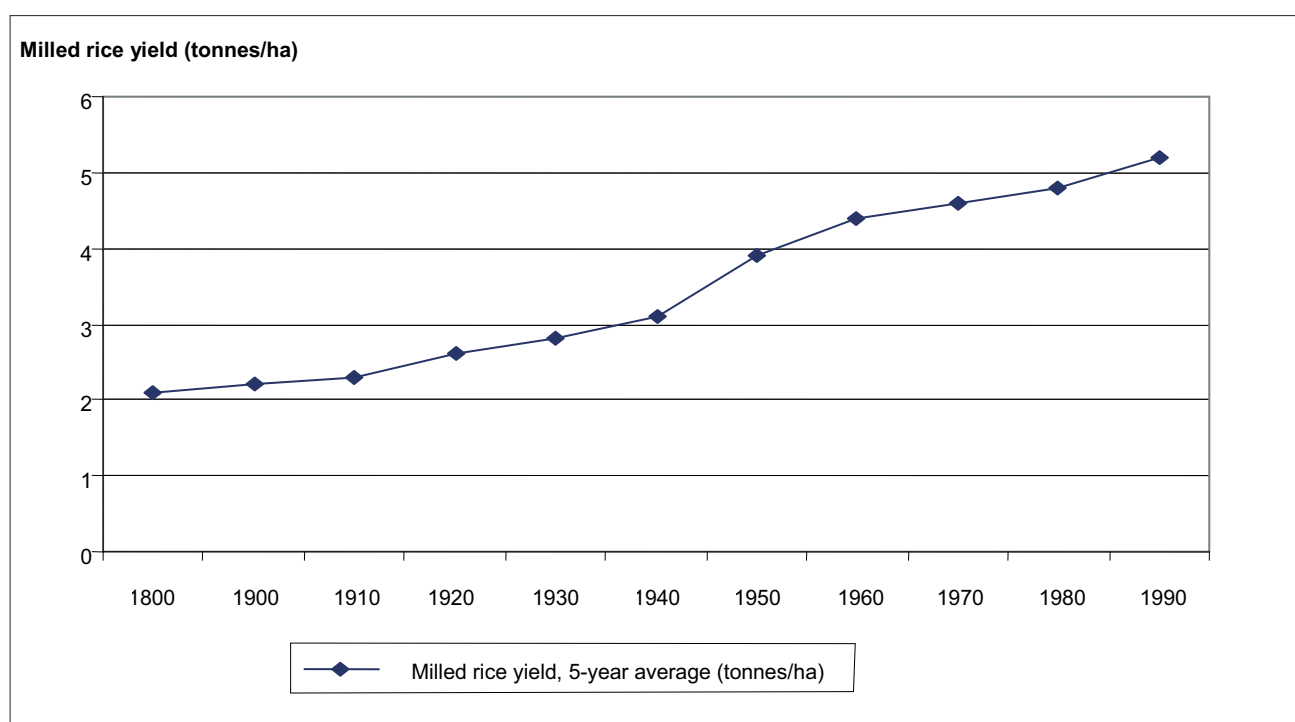
RESPONDING TO CHANGES IN DIETARY LIFESTYLE

Population increase and rice consumption have generally kept pace with yield increase. Consumption reached a peak of 120 kg/year/caput in 1963 and has since been decreasing; by 2003, it was around 60 kg/caput.

Lifestyle changes have driven dietary change: industrialization has led to imports of large quantities of different foods and cereals; people have adopted foods from other countries and large quantities of meat, eggs, fish, bread and oil are now eaten. Rice is thus being replaced in the diet and the shift from country to town, combined with the demand for convenience and novel foods has exacerbated the change. The rural population was down to 5 million in 1970 and has since decreased further.

The change in dietary lifestyle and increases in yield had a profound effect upon the rice industry: over-production became an issue. The trigger was the bountiful harvest of 1968, when an estimated 7.5 million tonnes of surplus was produced at a time when national consumption was 11 million tonnes. The export of surplus rice was impractical given the high costs of production sustained by the public sector. Instead, government policies reduced the area given over to rice while encouraging the production of alternative crops such as wheat and soybean. There were problems: growers lacked experience with alternative crops and paddy fields were used for growing crops that were not adapted to poorly-drained soils, but it

FIGURE 1
 National rice yield (5-year average), 1800 to 1990



had nevertheless been decided to shift the emphasis to alternative crops.

Research and development (R&D) programmes emphasized the importance of alternative cropping and also directed the rice industry towards varieties that were more disease resistant, had lower water, fertilizer and pesticide requirements, and which produced grains that were easier to cook. Taste became important, yield less so. Yield nevertheless retained some importance because lower quality grains could be used for animal feed. Japan currently imports more than 20 million tonnes of feed grains a year for use in industrial chicken, pig and cattle production.

Development of rice with good cooking quality

Koshihikari – introduced in 1956 (i.e. 50 years ago) – is still the preferred variety of rice grown in the country. The variety dominates the industry with 560 000 ha sown annually (i.e. an estimated 37 percent of the national crop in 2004). A shift from yield to lifestyle parameters during the 1960s emphasized the importance of the cooking quality of this variety (Figure 2), unmatched by the other varieties grown. The ten leading varieties are all descendents of this original variety (Table 1) and share over 80 percent of the total cropping area.

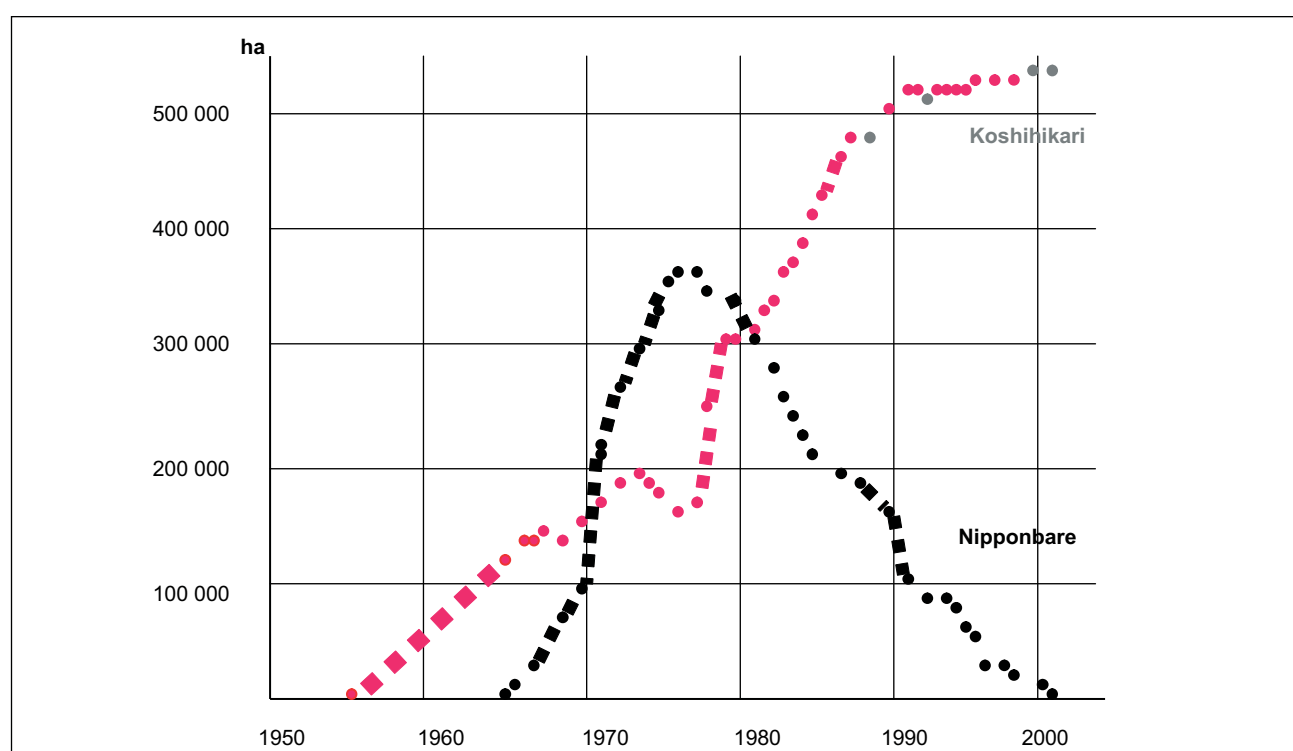
Amylose content and protein content in rice grains

R&D programmes have been introduced to boost the value of rice when cooked. Most Japanese people typically eat rice from a small bowl using a pair of chopsticks. Stickiness and softness (besides taste) are therefore important and the Koshihikari variety dominates, as people want to be able to pick up the rice grains easily. The physical properties of the rice and its chemical content are interlinked. R&D has shown that amylose content in starch and protein content in grain are strongly correlated to cooking quality (Table 2).

The characteristics of rice starch depend on the variety. The typical *indica* variety contains 25–30 percent amylose, *japonica* 18–23 percent and glutinous varieties no amylose. Low amylose mutant varieties containing 5–15 percent have been developed and in 2004, more than 3 000 ha of the milky queen variety were planted.

The higher the protein content, the harder the cooked grain becomes; consumer interest is high and people will check the protein content on the packet before buying, with manufacturers ensuring that protein quantity is prominently displayed. Contracts are placed for low-protein grains with growers who therefore apply less N fertilizer (N increases yield but lowers cooking and eating quality).

FIGURE 2
 Harvested areas of Koshihikari and Nipponbare from 1950 to 2000



Development of varieties with different grain characteristics

Between 1989 and 1994, R&D programmes focused on targeting different traits, cooking qualities and tastes to meet consumer demand. Low-gluten rice was produced for people with kidney illnesses; then other varieties suited to particular dietary requirements – low-allergen rice, polyphenol-rich rice and big-embryo rice. The latter contains more gamma-amino-butyric acid (GABA – producing an angiotensine-like effect) than ordinary rice varieties (Table 3).

NEW TREND IN CROP MANAGEMENT

Excessive application of agricultural chemicals and chemical fertilizers can result in groundwater pollution with adverse effects on the natural ecosystem around rice paddies. There is growing concern about the potential ill-effects of agricultural production systems (Figure 3); while chemicals that are obviously damaging to the natural ecosystem are quickly banned, the effects on consumers can be far-reaching. People are beginning to demand non-chemical (“organic”) foods to control their health – they are no longer prepared to tolerate the perceived risks of agricultural chemicals. Legislation is an effective tool for controlling chemical use.

TABLE 1
 Ten most popular non-glutinous varieties planted in 2004

Variety name	Area planted (ha)	Total harvested rice area (%)
Koshihikari	552 000	37.2
Hitomebore	149 200	10.1
Hinohokari	146 700	9.9
Akitakomach	128 400	8.7
Kinuhikari	53 400	3.6
Kirari397	49 800	3.4
Haenuki	43 900	3.0
Hosinoyome	38 300	2.6
Tugaruromanroman	23 500	1.6
Nanatsubosi	17 500	1.2

TABLE 2
 Relationship between grain characteristics and cooking quality of Japanese rice varieties

Grain characteristics	Cooking quality
High amylose (25–30%)	Hard
Medium amylose (18–23%)	Medium hard
Low amylose (5–15%)	Soft
Amylose free (0%)	Sticky
High protein	Hard
Low protein	Soft

Reducing agricultural chemical use

Growers are obliged to follow market trends: if consumers demand less use of chemicals, growers must comply. There are several ways of doing this:

- Predictions of pest attacks (weeds, insects etc.) prevent over-application of chemicals.
- Adoption of cropping methods to naturally disrupt pest development, e.g. application of pheromone

compounds which naturally disrupt the supply of nutrients to pests or introduction of natural enemies which provide a measure of biological control.

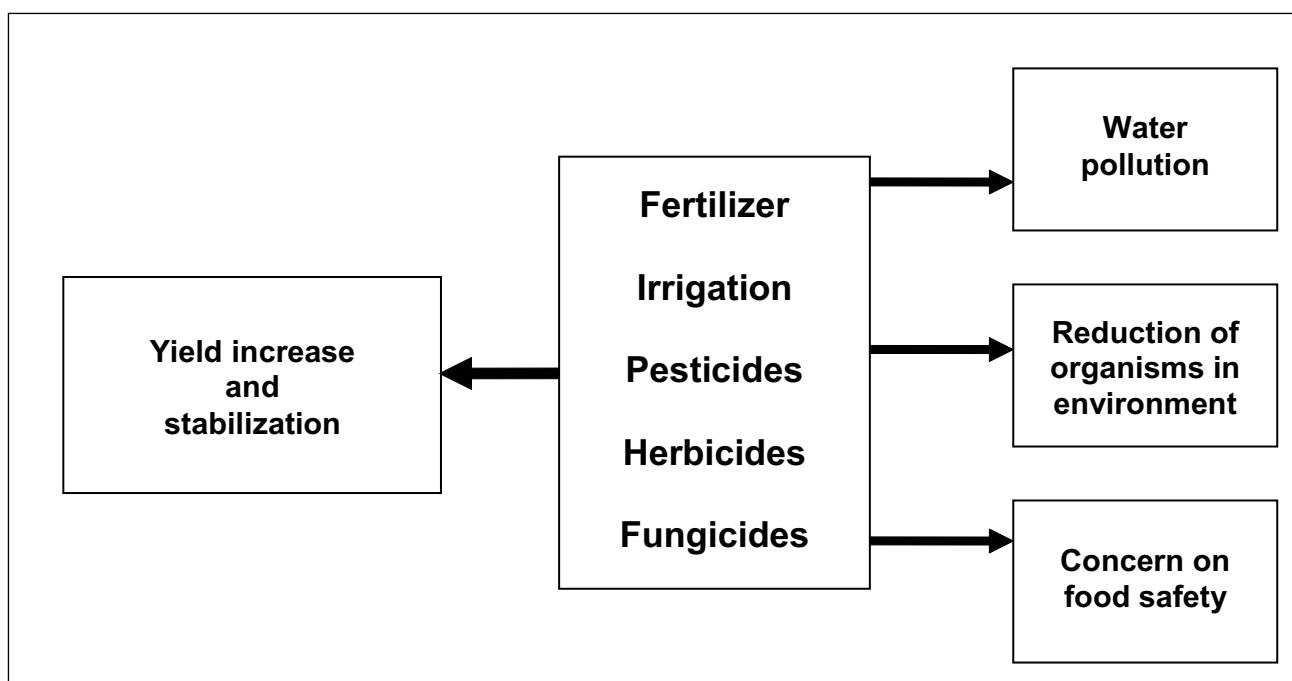
- Adoption of mechanical weed-control methods.

Many of these alternatives to chemical control are less efficient and require experience and knowledge; they can also be more costly (Table 4).

TABLE 3
Rice varieties bred for specialized markets and use

Grain characteristics	Breeding objectives	Name of variety
Low amylose	For ordinary steamed rice	Oborozuki (14% amylose) Yawarakomach (12% amylose) Milky queen (10% amylose)
Low allergen	For patients	LA-1
Low glutelin	For patients with kidney problems	LGC-1 Shunyo LGC Soft LGC Jun LGC Katsu
Low protein	For making sake (alcoholic drink)	Kuranohana
Large embryo	For making brown rice with high GABA	Haiminori
Pigmented rice	Polyphenol-rich rice	Asmurasaki Okunomurasaki Beni Roman
Scented rice	For special occasions	Sari queen Haginokaori Kitakaori
Biomass rice	For animal feed through whole crop silage	Kusahonami Kusayutaka Kusanohoshi

FIGURE 3
Schematic expression of the relationship between input application and the outcomes of such application



If the trend is to move away from chemical use – whether in crop production or crop protection – the R&D industry is obliged to follow the trend and advise the grower accordingly. R&D must meet the challenge of maintaining high yield and high grain quality and plant breeding offers the possibility of producing varietal resistance to all kinds of pests and diseases. When accumulating resistant genes, the selection of DNA marker aids is a valuable approach. Then there are genetically modified (GM) technologies which – linked to environmentally friendly agriculture – are on the brink of a revolution in plant breeding. In this context, the complete analysis of rice genomes was completed in 2004, providing a platform for fundamental work by future scientists and technologists.

Direct seeding

Direct seeding has always been an important technique for sowing rice in Japan. Nevertheless, in 1970 less than 50 000 ha of rice were direct seeded, and when transplanting machines were developed direct seeding became less popular and only 7 000 ha were direct seeded in 1993. With the development of direct-seeding machines, by 2004 this area had crept back up to 10 000 ha – still less than 1 percent of rice production in the country. Direct-seeding technologies are, generally speaking, not compatible with the Japanese climate (temperate and cool), the resulting slow germination and the short elongation that characterizes Japanese rice varieties. Japanese plant breeders are currently developing high-value cooking rice varieties suitable for direct seeding.

CONCLUSION

Despite its long history of rice production, Japan's rice production industry differs from most other Asian countries, mostly because of the climate (the land is subject to a cold temperate winter), but also because of

socio-economic factors, as modern Japan is heavily industrialized, affecting the cost of production. The development of appropriate rice production systems in the near future depends on four main issues concerning: farmers, consumers, the environment and population increase.

Farmers

Rice farmers are faced with trying to make a living in an increasingly competitive world where:

$$\text{Income} = \text{Quantity of production} \times \text{selling unit price} \\ - (\text{production cost} + \alpha)$$

and:

- quantity of production is equal to planted area × yield;
- selling unit price is affected by the quality of rice;
- production cost is based on inputs (manures, agrochemicals, fuels etc.) + water supplies + machinery + labour + etc.
- alpha is the cost attributable by society at large for the use of the paddy field and its effects upon the environment and the landscape.

The equation makes no reference to the quality of the rice produced. It is not sufficient to simply target yields. Traders will pay according to the quality offered and the demands of the market.

Consumers

Consumers dominate the production-processing chain. Ultimately, they dictate what the farmer can grow. When consumers demand safe foods, good flavours, a healthy image and reasonable price, then farmers are obliged to produce to satisfy this demand; the alternative is failure.

Environment

Issues of sustainability have come to the fore in recent years. Farmers and others are no longer simply seeking yield increases, but are doing so with environmental awareness. The relationship between paddy field and the surrounding areas is symbiotic. There has been – and will continue to be – a better understanding of the need for sustainable production maintaining the harmony of the natural environment. Farmers are becoming increasingly involved with agrochemical free production methods that meet the requirements of the consumer.

TABLE 4

Choices: activities and end result

Activity/tactic	Result
Prediction of occurrence of pests, weeds and pathogens	Reduction in rate of pesticide and herbicide use
Transplant at low density	Reduction in rate of pesticide use
Use sex pheromone to jam communication amongst insects	Reduction in insect density
Apply low rate N fertilizers	Reduction in blast infection
Use natural enemies/biological control	Reduction in insect density

Population increase

Food supply normally keeps pace with population increase and technically competent people can generally feed themselves within their socio-economic systems. In the near and distant future it seems likely that paddy rice will be more appropriate than upland rice production as a means of feeding people. With fixed areas of land

available and little likelihood of new lands coming into production, R&D in paddy rice will need to be increased in order to help maintain crop yields. Here it will be nutrition value, cooking qualities and niche varieties that will be important so that the consumer can choose protein, fat, mineral and vitamin content to suit his/her particular needs. The future of the crop looks remarkably buoyant.

La production rizicole au Japon

La production rizicole japonaise domine le secteur agricole du pays. Le riz a toujours été de première importance pour l'alimentation de la population et ce n'est qu'à partir du milieu du XX^e siècle que la demande alimentaire a commencé à se diversifier. Le niveau de production s'est maintenu malgré le rétrécissement des surfaces cultivées; différentes approches technologiques ont été élaborées et mises en œuvre pour multiplier les rendements. Le

rendement, à lui seul, ne suffit pas à maintenir l'intérêt du consommateur, et diverses variétés ont été créées en vue d'améliorer le goût, la tenue à la cuisson et la facilité de manutention. Plus récemment, les consommateurs sont devenus conscients de l'impact écologique de la riziculture, et ont commencé à exiger des riz cultivés avec un minimum d'intrants agrochimiques. Les consommateurs s'attachent davantage à la qualité et au contenu des aliments. Il en est

résulté pour les producteurs agricoles l'obligation de se plier aux tendances du marché pour pouvoir rester concurrentiels; ils ont bénéficié de l'appui des sélectionneurs, des chercheurs et des ingénieurs agricoles. La production est désormais plus ciblée, centrée sur les besoins de quatre secteurs:

- les petits producteurs;
- les consommateurs;
- l'impact sur l'environnement;
- la croissance démographique.

La producción de arroz en el Japón

El sector agrícola del Japón está dominado por la producción de arroz. Este cultivo siempre ha sido fundamental para alimentar a la población, y la población no comenzó a demandar otros alimentos para su dieta hasta mediados del siglo XX. La producción se ha mantenido pese a la reducción de la superficie cultivada con arroz; se ha desarrollado tecnología agrícola que se explotó para fomentar el rendimiento. Por otra parte, puesto que el rendimiento no alcanza por sí solo para mantener el

interés de los consumidores, se han desarrollado variedades con el propósito de potenciar el sabor, la calidad en la cocción y la manipulación del producto. En tiempos más recientes los consumidores han tomado conciencia del impacto ambiental del cultivo de arroz y, lo que es muy importante, ha surgido una demanda de arroz cultivado con un empleo reducido de agroquímicos. La población ha adquirido más conciencia del valor y el contenido de los alimentos que

consume. Los agricultores se ven, por tanto, obligados a seguir las tendencias del mercado si quieren mantener su actividad, y en este esfuerzo han recibido el apoyo de fitomejoradores, investigadores especializados e ingenieros agrónomos. La producción se ha hecho así más selectiva, y ahora se orienta fundamentalmente hacia cuatro ámbitos:

- los agricultores,
- los consumidores,
- el impacto ambiental; y
- el incremento demográfico.

The evolution of rice research towards sustainable rice production in Nigeria

M.N. Ukwungwu, M.E. Abo, A.T. Maji, I.O. Fatoba, G. Agidi, E.O. Bright and A.A. Ochigbo
National Cereals Research Institute, Bida, Nigeria

INTRODUCTION

The rice improvement programme in Nigeria started under the British colonial administration in the 1920s with the establishment of the Federal Department of Agriculture (FDAR) at Moor Plantation, Ibadan. In 1939, a recommendation for the establishment of a rice research station to serve all the West African territories was first put forward in a report by the West African Commission (1938–39). By 1945, Nigeria's rice production had increased by about 25 percent over the 1939 level and as a result it was necessary to establish a rice research station in Nigeria. Due to shortage of trained manpower, the project was shelved until 1947 when a plan for three rice research stations was approved by the colonial office, although not put into effect.

The National Cereals Research Institute (NCRI), with headquarters at Badeggi, was established in 1975. The institute has the national mandate for the genetic improvement of rice, soybean, sugar cane and other crops, as well as for research and extension in the middle belt zone. Extension activities are carried out under the Research Extension Farmer Input Linkage System (REFILS) with the participation of farmers, agrochemical companies, non-governmental organizations (NGOs) and other stakeholders (Abo *et al.*, 2003). Early research work in NCRI was conducted on the basis of disciplines, but by 1980 programmes had been established, each dealing with one of the institute's mandate crops and scientists were grouped accordingly.

Rice research activities at Badeggi are centred on shallow swamp and irrigated rice; at Bende on inland valley swamp; at Birnin-Kebbi on deep swamp; and at Warri on tidal swamp. Other research centres include Ibadan, Amakama, Uyo and Yandev – for upland rice – and there are about ten other testing stations across the rice-growing areas of the country. Nigeria's rice research activities are reviewed herein – the long- and short-term strategies and the impact on rice production.

RICE IMPROVEMENT IN NIGERIA

The early years

The initial challenge facing rice research scientists was the production of new varieties in relation to the specific requirements of the four recognizable rice-growing zones (Hardcastle, 1959; Beck and Hardcastle, 1965):

- High-yielding, shallow swamp varieties were produced to replace BG 79 (established in 1921), resulting in the release of FARO 1 (FARO means Federal Agricultural Research *Oryza*) in 1954/55 (FDAR, 1961).
- Early-maturing shallow swamp varieties were then introduced enabling rice cultivation to be extended into the northern areas where rainfall is limited.
- White grain floating varieties – FARO 2, 4, 5 and 6 – were successfully introduced to replace the indigenous red rice, *Oryza glaberrima* Steud, cultivated in the deep flooding valleys.
- Disease-resistant upland varieties were bred for the upland ecologies of Oyo, Ondo and Ogun (in the then midwestern and northern states with adequate rainfall), resulting in the release of FARO 3 in 1958.

Most of the varieties released had high-quality grains, but they were tall and lodged easily, had low to moderate yield, were photoperiod-sensitive and susceptible to prevailing diseases and pests (Ayotade and Fagade, 1986).

The optimum field populations under the various systems of irrigation husbandry were worked out and special attention was given to the behaviour of the rice plant under limited soil-water regimes. Economic rates of application of inorganic fertilizer were established and the time and methods of application were studied. There was a successful programme for mechanizing the wet cultivation of the irrigated fields; the integration of draught cattle into swamp rice cultivation was proposed; and the use of leguminous grain and fodder crops in short-time rice rotation was researched.

From 1962 to 1980

The shallow swamp rice improvement programme observed that the major zones of the non-inundated lowland, could be further subdivided and varieties selected for specific areas within the zones. The rice improvement programme was hence divided to target the individual zones through introduction, adaptation and hybridization work (Imolehin, 1991). In 1963, work on the selection of varieties for the naturally inundated lowlands and for the non-inundated irrigable lowlands continued. Work also commenced on an experimental site in the mangrove swamps of Edbe Island, Warri in 1964. In the same year, research focused on diseases (*Pyricularia oryzae* or *Magnaporthe grisea*, and *Helminthosporium oryzae*) that were severely attacking trials located in the western states. Screening trials identified rice varieties imported from the Congo as the most promising: short duration, with good resistance to *P. oryzae* and generally high-yielding. Post-harvest research was also important: milling studies were conducted and the optimum soaking time for the parboiling of the released varieties in the multiplication scheme was determined (18–48 hours) (Hardcastle *et al.*, 1965) – all activities which set the pace for high-quality rice grain in Nigerian markets. Breeding for resistance to blast continued, with the release of 19 rice varieties with desired quality traits for pest and disease resistance, and nutritional and yield characteristics: two upland varieties (FARO 11 and 25), two deep swamp (FARO 7 and 14), 13 shallow swamp (FARO 8, 9, 10, 12, 13, 15, 16, 17, 18, 20, 21, 23 and 24) and two irrigated swamp varieties (FARO 22 and 26) (Umanah, 1980).

From 1981 to date: coordinated trials

A global network was established by the International Rice Research Institute (IRRI, Philippines) for the systematic collection, evaluation and distribution of genetic materials through the International Rice Testing Programme (IRTP) (renamed as the International Network for Genetic Evaluation of Rice [INGER] in 1989). IRTP/INGER was regionalized in 1995 and INGER-Africa was established with headquarters at the International Institute of Tropical Agriculture (IITA), Ibadan and as a joint programme of IRRI, IITA, the Africa Rice Center (WARDA) and the National Agricultural Research Systems (NARS) in Africa. The early 1980s therefore marked the watershed for the systematic exchange, utilization and spread of improved varieties in the country.

Co-ordinated Rice Evaluation Trials

The first nationally coordinated programme on rice was the National Co-ordinated Research Project on Rice (NCRPR), established in October 1982 and funded in 1983 by the Federal Ministry of Science and Technology. It had three main objectives:

- Develop through appropriate collaborative research efforts improved technology for profitable rice farming in Nigeria.
- Mobilize all available talents and resources on rice in the country and direct them towards solving national rice problems.
- Develop appropriate nationwide acceptable recommendations for growth of the rice crop in different ecologies.

Given the need to increase rice production and boost rice supply to keep pace with the ever-increasing rate of demand, the project focused on the identification of high-yielding, disease- and pest-resistant varieties with acceptable grain qualities for the various ecologies, and the network of Co-ordinated Rice Evaluation Trials (CRET) was established. This network aimed to identify superior, improved cultivars of rice, based on their performance in 2-year multilocation trials in upland, irrigated lowland, rainfed lowland and mangrove ecologies, and in 1986 trials began on specific stresses (e.g. cold and iron toxicity). The same year saw the creation of the National Network on Soil Fertility and Fertilizer Evaluation for Rice (NNSFFER).

The major stakeholders in the CRET network are NCRI (the coordinating institution), IITA, WARDA, IRRI, IRTP and INGER; it is their job to nominate outstanding entries into the CRET network. On-farm varietal evaluation of promising entries from CRET was undertaken by agricultural development projects (ADPs) through the supervision of the National Accelerated Food Production Programme (NAFPP). On the basis of the data collated, NCRI recommended outstanding varieties to the Varietal Release Committee for consideration and release as commercial varieties. Through the CRET network, 21 rice varieties (FARO 30–50) were officially released for commercial production in the country, 10 for lowland and 11 for upland (Fagade *et al.*, 1988; Imolehin *et al.*, 1997a, b).

FARO 44 and 46 are very popular varieties with farmers (Table 1):

- FARO 44 (Sipi 692033) is a high-yielding lowland variety with good grain quality (long slender grains

and high amylose content) and was introduced from Taiwan. It is short to semi-dwarf, early-maturing and has moderate tolerance to drought. It is widely adopted in the irrigated ecologies of northern Nigeria, such as Sokoto, Kano, Borno, Jigawa, Kaduna and most shallow swamps and fringes of the central states of Niger, Benue, Plateau and Nasarawa.

- FARO 46 (ITA 150) is about the most widely adopted improved upland rice variety in Nigeria today. With moderate yield (approx. 2 tonnes/ha), it is of intermediate to tall plant type and early-maturing. It has golden paddy grain colour, is easy to thresh and has long grains. It can be intercropped with sorghum, maize, millet or cocoyam in northern parts of the country; in southwest Nigeria, it may be cropped twice in a season.

National Co-ordinated Research Programme on Rice

The subsequent phase of NCRPR was the National Agricultural Research Project (NARP), launched in 1992 by the Federal Ministry of Agriculture and Natural Resources with the assistance of the World Bank, in order to revitalize the agricultural research system. The National Agricultural Research Strategic Plan (NARSP) was thus formulated for the 15-year period, 1996–2010 (Shaib, Aliyu and Bakshi, 1997b). The plan has three main components:

- **Background information** on: the country's macro-economic and policy environment; the agricultural

zones and their production potential; the performance of various agricultural subsectors and the constraints faced; and the current status of the national agricultural research system.

- **Strategic research objectives** to guide research for 15 years. Long-term research goals and the Medium Term Research Plan (MTRP) for the first 5 years (1996–2000) with regard to: socio-economics and policy; soils; crops; forestry and tree crops; resource conservation; livestock and fisheries; and the research extension linkage and delivery system (Shaib, Aliyu and Bakshi, 1997a).
- **The strategy for implementation of the MTRP** through NCRPs; hence the birth of the NCRPs for arable crops, including rice (NCRP-Rice).

NCRP-Rice (Misari, Idowu and Ukwungwu, 1996) concentrated on the development of varieties with desirable traits, particularly disease and pest resistance, in accordance with the needs of the farmers in different zones. The plan also focused on integrated pest management techniques, the development of agroforestry/cropping system-based technologies for improving inherent soil fertility and the integration of fish into rice farming. The development of small-scale processing machines was also emphasized.

NCRP-Rice provided a mechanism for the participation of various partners in the National Agricultural Research Systems (NARS): NARIs (national agricultural research institutes), universities, polytechnics,

TABLE 1
Improved upland and lowland rice varieties commonly grown in different zones of Nigeria

Zone	Upland varieties	Lowland varieties
South-West	FARO 3, FARO 11, FARO 45, FARO 46, FARO 49, FARO 53, FARO 54, FARO 55	FARO 26, FARO 27, FARO 37, FARO 15, FARO 44, FARO 52
South-East	FARO 43, FARO 46, FARO 47, FARO 49, FARO 55	FARO 12, FARO 15, IR1416, ^a FARO 35, FARO 37, FARO 44, FARO 51, FARO 52
South-South	FARO 11, FARO 45, FARO 39, FARO 46, FARO 49, FARO 55	FARO 34, FARO 44, FARO 15, FARO 29, FARO 30, FARO 35, FARO 50, FARO 51, FARO 52, BW 348-1 ^a
Central	FARO 41, FARO 43, FARO 46, FARO 48, FARO 49, FARO 55	FARO 33, FARO 44, FARO 35, FARO 15, FARO 12, FARO 37, FARO 29, FARO 51, FARO 5, FARO 8, FARO 19, FARO 21, BG 400-1, ^a IR 30, ^a IR 72 ^a
North-East	FARO 45, FARO 46, ITA 116, ^a ITA 118, ^a ITA 235, ^a FARO 49, FARO 38, Ex-China	FARO 15, FARO 27, FARO 29, FARO 30, FARO 44, FARO 50, FARO 52 Ex-China, ^a FARO 35, FARO 36, FARO 37
North-West	FARO 45, FARO 46, Ex-China, ^a FARO 49, FARO 55	FARO 15, FARO 27, FARO 29, FARO 37, FARO 44, FARO 50, Ex-China, ^a Paroline, ^a WITA 1 ^a

^a Improved varieties not officially released to farmers.

Source: Abo and Abdullahi, 2004.

development projects, private organizations, ADPs (agricultural development projects), NSS (National Seed Service) and other relevant public and private organizations. With more stakeholders in the circle of varietal evaluation nationwide, CRET's scope was widened. Each crop programme was coordinated by the NARI with the national mandate for research into that particular crop or commodity – in the case of rice, NCRI was charged with the mandate.

The activities of NCRP-Rice culminated in the release of two rice varieties:

- Cisadane: released as FARO 51 for gall midge endemic areas; it is widely adopted by farmers in eastern Nigeria, where gall midge is a serious biotic constraint to lowland rice production (Table 1); it was officially released in 1993.
- WITA 4: released as FARO 52 for the lowland ecology; it is widely adopted by farmers for both rainfed and irrigated ecology (Table 1), combining drought resistance with iron toxicity tolerance (two main constraints to rice production in the rainfed lowland ecology); it is also high-yielding; it was released in 2001.

The Task Force Mechanism

Rice varietal improvement in Nigeria has also benefited from other collaborative research activities; the positive effects already felt will increase in the near future. The main such activity was the creation of task forces (TFs) – promoted by WARDA – to conduct research in collaboration with the national programmes. Production constraints were identified and the relevant task force worked on developing appropriate technologies. The task forces were established in 1991 and drew participation from over 17 West and Central African countries. In 1998 the WARDA TFs were merged with the West and Central African Council for Agricultural Research and Development (CORAF) Rice Network to eliminate duplication and improve efficiency. This gave rise to a single rice research and development (R&D) network – the Regional Rice Research and Development Network for West and Central Africa (ROCARIZ) (WARDA, 1999) – with the following task forces: Rice Breeding (RB), Mangrove Swamp Rice (MSR), Natural Resource Management (NRM), Sahel Natural Resource Management (SNRM), Integrated Pest Management (IPM), Technology Transfer (TT) and Rice Economics (RE).

The key rice-based technologies tested in Nigeria include:

- identification of potential interspecific and intra-specific lines for high yield, resistance/tolerance to rice yellow mottle virus (RYMV) disease, blast, iron toxicity and African rice gall midge (AfRGM);
- study of the weed competitiveness of these new improved varieties; and
- testing of cover crops, edible legumes (groundnut, cowpea), water and nutrient management and use of plant and animal manure for the maintenance of soil fertility.

Oryza glaberrima entries with high resistance to AfRGM have been used successfully to create interspecific lines for the lowland ecology.

Participatory varietal selection

Nigeria participates in farmer participatory varietal selection (PVS), a collaborative rice improvement project between WARDA and the NARS (WARDA, 2001) which puts the farmer first in the varietal selection process: farmer-acceptable rice cultivars are identified and the period between varietal development and release for farmer use is shortened. Since its introduction in 1998, PVS has seen the release of five rice varieties for commercial production:

- ITA 321 (released as FARO 53) – medium-maturing, high-tillering, high yield potential, adapted for hydromorphic and very dry upland ecologies;
- WAB 189-B-B-B-8-HB (FARO 54) – early-maturing, big bold grains, selected by farmers from southwestern Nigeria;
- NERICA 1 (FARO 55) – golden grain variety, early-maturing, high-yielding, gaining in popularity in many states;
- NERICA 2 (FARO 56); and
- tox 4004-43-1-2-1 (FARO 57).

The Rice Box Technology

Collaborative work by some national institutions has led to the development of the conservation tillage practice known as “R-Box” (Rice Box). Organizations involved in 2003 include The Candel Company Limited, NCRI, the Federal Department of Agriculture (FDA), Premier Seed Company, NSS and ADPs. R-Box aims to standardize the planting culture in both upland and lowland rice, by adopting appropriate planting materials

and spacing, conservation tillage (using Round-up®), post-emergence control of weeds (Orizoplus®), top-dressing (Boost xtra®), and pest control (Delphos protex®). The stepwise operations are contained in an advisory leaflet – R-Box® Rice Production Technology Package. This technology has increased yields from 1.5 to 3–5 tonnes/ha. The package is adopted in the execution of the Presidential Initiative on Rice Production, Processing and Export, a programme launched in 2002 with the objective of enhancing household food security and income, eliminating imports and generating exportable surpluses.

Minimum tillage has the following advantages:

- Yield increase: the soil quality is improved and the soil retains moisture.
- Money saving: less labour is required for land preparation and weeding.
- Time saving: much less time is required for land preparation and weeding.
- Less drudgery: it is easier to prepare land and control weeds by spraying Round-up® than by digging.
- Soil protection: minimal disturbance of the soil and covering the ground with mulch improves soil fertility and protects land from soil erosion.

DEVELOPMENT OF RICE PRODUCTION PACKAGES

The development of high-yielding varieties is the first stage, typically followed by the development of a production technology package. Over the years, NCRI – in collaboration with other research institutes and organizations – has developed comprehensive packages for the production of rice in the three ecologies (rainfed upland, irrigated lowland and shallow swamp).

A production package for any particular ecology incorporates the following: high-yielding varieties; seed rate; land preparation method; time of planting; seeding method; fertilizer rate/method and time of application; integrated pest management; weed control; water management; bird/vertebrate pest control, time of harvesting and storage method. Each component practice differs from one ecology to another and across the agroclimatic zones. The following packages have been developed to date:

- Production technology for lowland rice in Nigeria.
- Production technology for upland rice in Nigeria.
- Guide to integrated pest management in rice.
- Guide to raising rice seedlings.
- R-Box planting with conservation tillage.

- Guide to production of high-quality rice breeders' seeds.
- Rice processing technologies in Nigeria.

Some of these production technology packages have been translated into the major languages spoken and are already available, with rice farmers receiving assistance to increase yield vertically as access to more riceland is increasingly limited.

DEVELOPMENT OF RICE PROCESSING TECHNOLOGY

Rice processing research focuses on the development of a processing technology to produce wholesome edible rice with high milling quality. In 1996, with the assistance of the World Bank, the Engineering and Fabrication Unit of NCRI developed a rice processing technology for small-scale processors; it entailed a parboiling method to produce high-quality milled rice and a rice mill that is simple to operate but also efficient. Known as the “NCRI Rice Processing Technology”, it comprises the following components: rotary parboiler, dryer, rice mill and the pneumatic cleaner.

Parboiling

There have been intensive studies on the process of soaking, steaming, drying and tempering (Sluyters, 1963; Sluyters, 1964). The parboiling process is as follows:

- The paddy is cleaned in a wet cleaner to remove stones and impurities.
- The cleaned paddy is then transferred to the steamer and water from the boiler is released to the steamer to cover the paddy (left for 6–8 hours).
- The remaining water in the boiler is heated further to generate steam which is released into the steamer for 40–50 minutes.
- The parboiled paddy is spread on a concrete slab, polythene or tarpaulin for a period of 5–6 hours in the sun (depending on the intensity of sunshine); or it is put in a steam rotary dryer until it reaches a moisture content of 16–17 percent.
- The dried paddy is left in the shade for tempering to a moisture content of 13–14 percent.
- The rice is milled and packaged.

The rice mill

The rice mill developed by NCRI is made for over 90 percent using local components; only the electric motor is imported. A hopper is mounted on a half hollow

cylinder containing a solid fluted cylinder that rotates within the assembly. The lower half of the cylinder is made of perforated metal (a screen). A grain outlet is incorporated at one end of the upper half of the hollow cylinder. Power is provided by a 16 horse power engine or 15 horse power electric motor. The rice is released into two rubber rolls which dehusk the rice. An aspirator separates the husks from the grains, while the scouring unit finally polishes the rice.

Small- and medium-scale processors can now process and market high quality milled rice in Nigeria and in the West African subregion. The potential of the rice processing technology is limitless.

DISSEMINATION OF RESEARCH RESULTS

The results of R&D efforts are destined for use by the end-users – i.e. the rice producers and processors. The extension arm of research institutes has the role of extending research results to end-users. However, with the promulgation of the research institute's 1975 decree which gave various research institutes specific mandates, the extension system was reorganized on a zonal basis (Abo *et al.*, 2003). The country was divided into five zones: northeast, northwest, middle belt, southwest and southeast. Under the Research-Extension-Farmer-Input Linkage System (REFILS), a research institute was mandated to coordinate extension activities in each zone; in the middle belt zone, the mandated institute was NCRI.

REFILS is an extension system in which farmer participation is important in research project design, testing and adoption; there is constant feedback from farmers and end-users on the viability adaptability and sustainability of technologies from research institutions. Under REFILS, technology packages emanating from research institutes are taken to the farmer or end-user by means of the following:

- on-farm trials (OFTs);
- multilocation trials (MLTs);
- on-farm adaptive research (OFAR);
- small plot adoption technique (SPAT); and
- mass adoption.

Each technology differs in content, sophistication and application, hence the need to simplify and adapt them to the conditions of farmers and other end-users. Various tools are used to disseminate proven technologies, including:

- training of trainers (TOT) workshops;
- monthly technology review meetings (MTRMs), where messages are passed to subject matter specialists (SMSs) of the agricultural development programmes (ADPs) in the states;
- SPATs and management training plots (MTPs), where the technology package is demonstrated and validated to prove its superiority over the local or traditional method;
- advisory pamphlets and farmers guides;
- farmers field days;
- farm broadcasts;
- agricultural shows, exhibitions and trade fairs;
- role play and film shows;
- incentives to farmers;
- farmers meetings; and
- gender specific programmes.

The MTRMs and diagnostic and thematic surveys provide the foci for feedback from farmers. This feedback is actually the premise from which research begins and hence the bottom-up farmer-driven technology generation activities of research institutes.

STATUS OF RICE PRODUCTION

Rice is the only crop grown throughout all agro-ecological zones of Nigeria (Singh *et al.*, 1997). The potential area available for the cultivation of the crop in the country is close to 5.0 million ha. Several reports have indicated marked increases in rice production in Nigeria from the 1970s to date (Nyanteng, 1986; Adpokdje, Lancon and Erestein, 2001). Production figures have risen from about 500 000 tonnes to over 3 million tonnes. The increase in production is attributed mainly to the expansion in cropped ricelands, which rose from 225 000 ha in 1970 to about 3 116 000 ha in 2002. The annual growth rate of rice area at over 10 percent is the largest in the world and the growth rate in output of between 8 and 10 percent is also amongst the largest in the world. These figures have all surpassed the projections in the national agricultural development plans (FMA, 1993). Unfortunately the paddy yield per unit area, has remained relatively low (\pm 1.9 tonnes/ha), resulting in an inability to attain self-sufficiency in rice production.

The demand for rice in Nigeria is growing faster than for any other major food staple, with consumption increasing across all socio-economic classes, including the poor. This is the result of, for example, increasing

population, higher income levels due to oil, rapid urbanization, changes in family structure and ease of preparation. An average Nigerian consumes 23.3 kg of rice a year (Maclean *et al.*, 2002). The annual demand for rice in the country is estimated at 5 million tonnes, while production is about 3 million tonnes of milled rice, resulting in a deficit of 2 million tonnes. Rice is imported to bridge the gap and, according to the Central Bank of Nigeria (CBN), the rice import bill was US\$ 259 million in 1999, almost tripling to US\$ 655 million in 2001 and reaching US\$ 756 million in 2002.

Self-sufficiency in rice production has not been attained nor the potential for export explored until recently, because appropriate policies and programmes were not put in place to address some of the constraints that limit production. The constraints include the following:

- poor maintenance of irrigation facilities;
- inadequate and irregular input supply such as seeds, fertilizers and credit;
- lack of small farm equipment, especially for post-harvest operations;
- poor maintenance of developed swamps;
- poor drainage and iron toxicity in undeveloped swamps; and
- lack of well-defined rice policy.

Past government policies and programmes include: NAFPP, set up in 1974; the World Bank Assisted Development Programmes (1975); Operation Feed the Nation (OFN) (1976); the River Basin Development (RBD) Authority (1977); the Back to Land Programme (BLP) and the Directorate of Food, Roads and Rural Infrastructure (DFRRI) (1988); and the National Land Development Authority (NALDA) (1995).

Most of these interventions were found to be ineffective. Through the recently introduced Presidential Initiative on Increased Rice Production, Processing and Export, a solid foundation has been laid for sustainable rice production and development for the future. The programme comprises the following components: production, inputs and crop protection; irrigation and land management; and processing and marketing. It promotes the policy of enabling private-sector-led rice production. Rice farmers and processors receive government support through the provision of inputs and services at affordable prices as private sector operators.

The adoption of the “R-Box” technology with adequate publicity given to the project has given rise to:

- increased national output of over 0.8 million tonnes;
- declining trend of import bills;
- conservation of foreign exchange;
- enhanced employment, income and living standards of farmers and stakeholders; and
- increases in other downstream businesses.

CONCLUSION

Despite the fact that rice research in Nigeria began about 85 years ago, the structural conduct and performance have not changed much. The structural operational unit is small, the conduct is traditional, with increasing productivity at a decreasing rate. Yields and resource-use efficiency have been very low and labour-land inputs considerably under-utilized. Capital inputs in chemical, biological, mechanical and financial terms are yet to make any meaningful impact on increasing rice production. In general, output per unit of input is very low and much of the agricultural output is for subsistence.

If the Presidential Initiative on Rice Production, Processing and Export is to play its full and proper role in effectively contributing to economic growth and if the food problems bedeviling the national economy are to be rapidly resolved, rice research and production must be given a more meaningful direction. Where there is national and household food security, there is generally strong support to agriculture, careful consideration of economic incentives for agricultural production, and human and economic investments in research, extension and training.

The Government should therefore work to ensure a clear focus on poverty alleviation in national and international research efforts, giving priority in research and investment to applications such as soil fertility and biological pest and weed control that can give higher and environmentally sustainable yields at lower costs to enhance the competitiveness of local rice with imported rice. Adaptive breeding trials should be encouraged for varieties suited to vulnerable and marginal areas.

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L'évolution de la recherche rizicole vers la durabilité de la production de riz au Nigeria

Le programme nigérian d'amélioration rizicole a commencé sous l'administration coloniale britannique dans les années 20. Le développement de variétés de bas-fonds à haut rendement a été démarré en 1921 et les variétés de riz flottant FARO 2, 4, 5 et 6 ont été introduites avec succès en remplacement du riz rouge indigène, *Oryza glaberrima* Steud, cultivé dans les vallées profondes inondables. Durant la période 1962–1980, la recherche s'est concentrée sur la phytopathologie, notamment sur les champignons *Pyricularia oryzae* (également appelé *Magnaporthe grisea*) et *Helminthosporium oryzae*, à l'origine de sévères infestations sur des essais implantés dans les États de l'Ouest. Des expériences de sélection ont abouti à l'identification de variétés de riz importées du Congo comme étant les plus prometteuses. Ces variétés avaient une végétation rapide, avec un degré élevé de résistance à *P. oryzae* et étaient généralement considérées comme d'un meilleur rendement. Depuis

1981, des essais coordonnés de résistance ont été poursuivis en collaboration avec l'IRRI (Institut international de recherches sur le riz), l'IITA (Institut international d'agriculture tropicale) et WARDA (Centre du riz pour l'Afrique) avec pour résultat l'obtention et la diffusion de plusieurs variétés améliorées et à haut rendement, tant pour les écosystèmes de bas-fonds que de hauts plateaux des différentes parties du pays. Plus récemment, l'accent a été mis sur l'élaboration de kits intégrés de production rizicole et de technologies de transformation du riz. Dans le cadre du REFILS (Research-Extension-Farmer-Input Linkage System, Système d'interactions vulgarisation-exploitants-intrants), des kits technologiques émanant d'instituts de recherche sont amenés au niveau de l'exploitant ou de l'utilisateur final via les processus qui suivent: essais sur champ en exploitation; essais en multilocation; recherche en exploitation sur l'adaptation des kits technologiques; et la technique de

l'adoption de petites parcelles (SPAT), le but d'ensemble étant d'arriver à une adoption généralisée de l'innovation. Cependant, l'autosuffisance du pays en riz n'est toujours pas atteinte, en raison de l'absence de politiques et de programmes appropriés visant les contraintes qui limitent la production. Ces contraintes comprennent: le mauvais entretien des installations d'irrigation; un approvisionnement irrégulier et insuffisant en intrants (par exemple semences, engrais, crédit); le manque de petits matériels agricoles, notamment pour les activités de post-récolte; le mauvais entretien des bas-fonds aménagés; un mauvais drainage et une toxicité due au fer dans les bas-fonds non aménagés; et l'absence d'une politique rizicole bien définie. Récemment introduite, l'Initiative présidentielle sur l'accroissement de la production, de la transformation et de l'exportation de riz pose une fondation solide pour une production rizicole durable et son développement futur dans le pays.

Evolución de la investigación arrocera para una producción sostenible de arroz en Nigeria

El programa de mejoramiento del arroz en Nigeria comenzó durante la administración colonial británica, en la década de 1920. El fomento de variedades de alto rendimiento en ciénagas someras empezó en 1921, y se introdujeron con buenos resultados las variedades flotantes FARO 2, 4, 5 y 6 en sustitución del arroz rojo autóctono *Oryza glaberrima* Steud, que se cultivaba en valles profundos

inundables. En el período comprendido entre 1962 y 1980 la investigación se centró en las enfermedades, principalmente *Pyricularia oryzae* (también denominada *Magnaporthe grisea*) y *Helminthosporium oryzae*, que infligían graves ataques a las parcelas experimentales situadas en los estados del oeste. En ensayos de selección se determinó que las

variedades de arroz importadas del Congo eran las que prometían mejores resultados. Ofrecían un ciclo breve, una resistencia elevada a *P. Oryzae* y, en general, un rendimiento considerablemente mayor. Desde 1981 se realizaron ensayos coordinados de evaluación del arroz en colaboración con el IRRI (Instituto Internacional de Investigación sobre el Arroz) y el

ADRAO (Centro Africano del Arroz), que permitieron desarrollar y entregar diversas variedades mejoradas y de alto rendimiento para su cultivo tanto en ecologías de tierras altas como de tierras bajas en diferentes zonas del país. Recientemente los esfuerzos se han orientado hacia el desarrollo de paquetes productivos y tecnologías de procesamiento del arroz. En el marco del sistema REFILS, que establece un vínculo entre la investigación, la extensión, los agricultores y los insumos, los paquetes tecnológicos elaborados por los institutos de investigación se hacen llegar hasta los agricultores,

sus usuarios finales, mediante los siguientes procedimientos: ensayos en las explotaciones; ensayos en múltiples localidades; investigación adaptativa en las fincas; y técnicas de adopción en pequeñas parcelas. La finalidad de este proceso es la adopción generalizada de dichas tecnologías. Sin embargo, la producción de arroz aún no ha alcanzado la autosuficiencia, y esto se debe a la falta de políticas y programas apropiados para hacer frente a los obstáculos que limitan la producción. Dichos obstáculos incluyen el escaso mantenimiento de los sistemas de riego; un suministro irregular e insuficiente de insumos

(como semillas, fertilizantes y crédito); la falta de pequeños equipos agrícolas, especialmente para las actividades de postcosecha; el mantenimiento deficiente de las ciénagas que han sido objeto de ordenación y, en las que no lo han sido, el escaso drenaje y la toxicidad provocada por el hierro; por último, la falta de una política arrocera bien definida. De cara al futuro, la reciente iniciativa presidencial orientada a incrementar la producción, elaboración y exportación de arroz proporciona una base sólida para la producción y desarrollo sostenibles de este cereal en Nigeria.

Potential of broadcasting seedlings for making savings in seed, water and labour in irrigated rice production systems in Sri Lanka

D.S. de Z. Abey Siriwardena, S.N. Jayanwardena, K.D.S. Kiriwaththuuduwage and S.W. Abeysekera
Rice Research and Development Institute, Department of Agriculture, Ibbagamuwa, Sri Lanka

INTRODUCTION

Rice is the staple food of the majority of people in Sri Lanka and annual consumption is about 100 kg per capita. The total land area of the country is about 6.84 million ha, of which about 25 percent is used for agriculture. Rice is grown on about 720 000 ha, of which 550 000 ha are cultivated during the wet season (Oct.–Feb.) and 310 000 ha during the dry season (Mar.–Sept.). Sri Lanka may be divided into three major agro-ecological zones on the basis of annual rainfall:

- dry zone (<1 400 mm)
- intermediate zone (1 400–2 500 mm)
- wet zone (>2 500 mm).

The dry and intermediate zones are the major rice-growing areas with, respectively, 63 and 19 percent of total production. Approximately 80 percent of rice is irrigated – 55 percent in major irrigation schemes (> 80 ha with tank/reservoir resources) and 25 percent in minor (< 80 ha). The remaining 20 percent is rainfed. (Abey Siriwardena, 2000).

Most farmers in major irrigation schemes prefer to cultivate high-yielding and high-quality rice varieties that mature around 120 days. However, the irrigation authorities in Sri Lanka are currently encouraging rice farmers to cultivate varieties with short-maturity duration (i.e. 90–105 days) for a more equitable division of the resources, guaranteeing water supply to all farmers throughout the cropping season. When there is sufficient water in the reservoirs, however, the authorities will release water for 120–150-day cropping, enabling the cultivation also of long-duration varieties.

In Sri Lankan rice cultivation, more than 90 percent of farmers choose to broadcast seed (MoADR, 1989). Studies have shown that under good management there is no significant difference in yield between broadcasting

and transplanting (Bandara, 1984), so farmers adopt broadcasting and harness the economic advantage of saving labour at the expense of producing and planting paddy. However, more water is used in land preparation and weed control in the early stands of rice, accounting for around 40 percent of total crop water requirements.

MAJOR ISSUES OF RICE PRODUCTION

Rice production in the country has been facing a number of issues with a potential impact on sustainable rice production in the long run. The major issues are:

Water requirements

Water requirements depend on soil type, climate, duration through to maturity of the variety, and cultivation system used. Average water requirements for rice cultivated under irrigated conditions can be as high as 2 100 mm in the dry and intermediate zones (Jayathilaka, 2000). However, water scarcity is an increasingly important issue as a result of the inconsistent rainfall in recent years and the competition for water from other users; it is probable that not even the major irrigation schemes will be able to guarantee sufficient supply to growers. The efficiency of water use for rice production must be enhanced, particularly in the formal irrigation sector.

Seed paddy production and requirements

Seed paddy requirement per unit of land is high due to the Sri Lankan practice of sowing at high density. The recommended seed rates for direct seeding are 100 kg/ha for normal-size and 75 kg/ha for small grains. However, in some areas, seed rates may be as high as 250–400 kg/ha to aid weed control (Mettananda *et al.*, 1990). At a rate of US\$ 320/tonne of seed paddy, the seed cost for one hectare at the recommended rate is US\$ 32, i.e. about 15 percent of the total cost of cultivation. The

Department of Agriculture and private sector seed producers produce only about 15 percent of the current annual certified seed paddy requirements (AgStat, 2004).

Cultivation costs

The cost of rice cultivation is about Rs 50 000/ha (US\$ 500/ha), with labour accounting for about 50 percent of the total costs. Compared to other rice-growing countries in the region, wage rates in Sri Lanka are high (US\$ 3.5–4/day). For transplanted rice, about 15 percent more labour is needed than with direct seeding. During the past 20 years, labour costs have increased threefold, and they continue to rise. With a rapidly developing industrial and service sector, it is increasingly difficult for rice producers (and farmers in other agricultural sectors) to pay enough to attract and keep skilled labour. Mechanization is one solution to labour shortages and it has already been accepted in the region's industrialized rice-producing countries. Sri Lanka is likely to follow a similar pattern of rural development.

Methods of establishing a stand

Stand establishment depends on climate, soil, the availability of water, the availability and cost of labour and the choice of variety. In Sri Lanka, three methods are generally used to establish a stand of rice:

- broadcasting
- transplanting
- row seeding

Seed broadcasting is the traditional system, practised since rice was first introduced into the country, and may be “dry” sowing or “wet” sowing.

Dry sowing is typical of areas in which rice is largely rain dependent. The land (characterized by sandy soil) is ploughed after the first rains; a few days after ploughing, the seeds are broadcast and harrowed into the soil. Sri Lanka is becoming rapidly industrialized and mechanization is creeping into agriculture as labour costs rise. The land is cultivated by tractors and animals – buffalo and mammoties. Following the rains, the seeds germinate and the fields are flooded. Seed rate varies depending on the environmental conditions: it is generally 150–300 kg/ha, but in eastern parts of the country, for example, it is 300–400 kg/ha. The seed rate for dry seeding is 3–4 times higher than the recommended rate for wet seeding. High seed rates mean high seed costs and also high incidence of pests (e.g. brown planthopper) and disease (e.g. sheath

blight) (Mithrasena, Adhikari and Wickramasinghe, 1987).

Wet sowing is typical in low-lying areas where water is plentiful. In Sri Lanka, the majority of paddy fields are sown to wet-seeded rice: pregerminated seeds are uniformly sown into well-puddled, well-levelled and well-drained fields. Seed rate varies according to the size of the seeds sown and the region. When the seedlings are about 1 week old, the fields are flooded.

SEEDLING BROADCASTING – A POTENTIAL TECHNOLOGY

Seedling broadcasting was first introduced into Sri Lanka from China, and is now widely recommended by the Rice Research and Development Institute for the establishment of a stand of rice. Seedling broadcasting helps to reduce the seed rate and related costs, while not exceeding the labour costs of seed broadcasting techniques. Seedlings with 12–15 day growth in root balls are broadcast-sown in well-prepared fields, thus reducing the need for transplanting. Seedlings are raised in specially adapted plastic trays (59 × 34 cm²) containing 434 embedded holes. The method is particularly suited for hybrid rice. The principal advantage is the reduction in labour costs as transplanting is expensive. The seed is used more efficiently and the method is therefore particularly adapted to hybrid rice as hybrid rice seeds are very expensive (Jayawardena *et al.*, 2004).

Procedures for seedling broadcasting

About 750 trays are required to raise the seedlings required for 1 ha of crop. To propagate the seedlings for 1 ha, a seedbed of an average 250 m² is required. Nurseries can be established just about anywhere – uplands, lowlands or in specially adapted planthouses. In lowland nurseries, seeds are sown in raised beds 75 cm wide and 12–15 cm high; the length varies depending on the land available and the choice made by the grower. Seedling trays are located in the beds, and the holes in the trays are filled with a mix of mud and the surface levelled. Pregerminated seed is sown evenly over the tray, targeting one seed per hole, which means that only 10 kg of seed is required to plant 1 ha of land (at about 15 × 20 cm² spacing). The trays are then covered with any local materials freely on hand – banana leaves, cajans and other materials that provide the seed or seedling with adequate shelter from prevailing winds and rain and prevent them moving. In upland systems, raised beds are not required

NATIONAL RICE PROGRAMMES
PROGRAMMES NATIONAUX SUR LE RIZ
PROGRAMAS NACIONALES DEL ARROZ

and the trays can simply be placed on the soil surface. Daily watering is essential for an upland nursery, but once every 2–3 days is usually adequate in lowland nurseries; much, however, depends upon the prevailing weather conditions. It is essential that the seedlings do not become water-stressed. Growers normally apply small quantities of insecticide to control pests such as thrips, stem borers and gall midges. After 12–15 days in the nursery, the seedlings are ready for broadcasting. The grower transports the seedlings to the field in their trays or separately packed in baskets or bags. Seedlings are pulled from the trays and thrown into the field. In a single handful, the grower can broadcast 15–20 seedlings. If the fields are small, broadcasting can be done from the security of the bund, and the grower does not have to wade into the field.

Performance of seedling broadcasting

Trials comparing traditional seedling with seedling broadcasting methods have been undertaken under R&D and field conditions to help establish the production parameters required.

There were no significant yield differences between transplanting and seedling broadcasting (Table 1). Pilot testing was undertaken in 2003 on two sites in farmers' fields in the dry zone with the collaboration of extension staff and farmers. There were differences between the

two seeding methods with respect to the number of hills/m² and the number of panicles/m²; in a real production situation, seedling broadcasting gave higher yields (Table 2).

Estimated labour requirements for nursery establishment, uprooting and placement, and field establishment are shown in Table 3. Labour requirements for each activity required of seedling broadcasting are lower than for transplanting. The labour requirements of seedling broadcasting are approximately 50 percent lower than those of transplanting for stand establishment. Seedling broadcasting uses seed more efficiently than standard broadcasting, with 5–10 times less seed required for the same crop or yield. If 1–2 seeds are placed in each tray hole, only 10–20 kg/ha of seed is required; conventional seeding rates for broadcasting are 100 kg/ha.

Seedling broadcasting results in savings not only in labour and seed, but also in water. Typical practice is to apply water every 7–10 days; for a crop with a duration of 3.5 months, about 12 applications are required. Savings of around 15–20 percent are made with seedling broadcasting for the following reasons:

- In a nursery, just two irrigations are sufficient, with additional water applied by hand.
- The nursery area is small and so requires little water compared to the flooding of an entire field using conventional methods.

TABLE 1
Grain yield of BgHR12 under manual transplanting and seedling broadcasting at RRD1, Sri Lanka during 2002/03 wet and 2003 dry seasons

Stand establishment method	Season		Mean
	2002/03 wet	2003 dry	
	Grain yield (<i>tonnes/ha</i>)		
Manual transplanting	6.09	5.66	5.87
Seedling broadcasting	6.06	5.28	5.67
Mean	6.07	5.47	-

TABLE 2
Comparison of manual transplanting and seedling broadcasting with BgHR12 at two sites in farmers' fields in 2003

Characteristics	Site				Average	
	Weera Pedesa		Jayanthipura		SBC ^a	TRP ^b
	SBC ^a	TRP ^b	SBC ^a	TRP ^b		
No. hills/m ²	38	42	49	39	44	41
No. panicles/m ²	321	293	291	302	306	298
Grain yield (<i>tonnes/ha</i>)	8.79	8.45	8.97	8.51	8.88	8.48

^a SBC: seedling broadcasting. ^b TRP: manual transplanting.

TABLE 3
Estimated labour requirements for manual transplanting and seedling broadcasting with BgHR12

Activities	Labour requirements (workdays/ha) ^a	
	TRP ^b	SBC ^c
Nursery establishment and management	5	5
Uprooting and placement	5	3
Field establishment	20	8
Total labour requirements	30	16

^a Average for minor and major seasons in 2003.

^b TRP: manual transplanting.

^c SBC: seedling broadcasting.

- A broadcasted seedling crop matures more quickly than a seeded crop, and less water is needed for the growing crop.

Such savings are important, given the increasing competition for water among farmers and in the light of the failures that farmers sometimes experience with maturing crops of traditionally sown rice. The water control authorities on the major irrigation schemes prefer a 120-day crop as it provides more efficient use of water, and will discriminate against those growing crops for longer. The other advantages of seedling broadcasting are as follows:

- Improved bird control: little or no damage to seedlings in the nursery and the field.
- Promotion of the use of hybrid rice where broadcasting is used.
- Reduction of the quantity of macronutrients and insecticides used for seedlings in the nursery, minimizing environmental effects and reducing input costs.
- Increased timeliness of land preparation and seeding. Farmers make the most of changes imposed by the coming of rains, water availability and the willingness of the irrigation authorities to release water quickly: farmers who already have nurseries of seedlings available are quickly able to cultivate and plant their land. With traditional methods, on the other hand, seed has to be broadcast and germinated before the growing crop can use the water provided.

CONCLUSION

The advantages of seedling broadcasting are well recognized by both farmers and extension advisors.

Several hundred demonstrations were held across the country during the 2004/05 wet season: many farmers have adopted the methods and R&D experts have been quick to train the extension advisors. The supply of trays has not been able to keep up with demand – one leading company, Messrs Hayles Agro, has imported large numbers of trays from China, and more local companies are being encouraged to produce trays to meet demand and lower the costs of purchase.

A major constraint is cost as farmers must purchase the seedling trays required; however, the trays are durable and may be used for at least three seasons, thus lowering annual costs. Another constraint is the crop damage that can occur when heavy rains follow seedling broadcasting; the uniformity of the crop stand is reduced and greater efforts are required for crop care and harvesting.

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La distribution de plants et le potentiel qu'elle représente pour des économies en semences, eau et main-d'œuvre dans les systèmes de production rizicole irriguée du Sri Lanka

Les méthodes de production rizicole faisant appel à la production de plants de repiquage pour démarrer les campagnes rizicoles ont été introduites au Sri Lanka à partir de la Chine et rapidement adoptées par les producteurs. Les expériences réalisées – tant dans le cadre de la R-D que sur des sites pilotes – ont mis en évidence les avantages indéniables de la production de plants de repiquage. Les économies portent sur la main-d'œuvre (environ 50 pour cent), l'eau (environ 15 pour cent) et les semences. De fait, la quantité de semences nécessaires quand les plants sont produits en pépinières n'est que d'environ 10 à 20

pour cent de la quantité requise par les méthodes traditionnelles de repiquage, ce qui se traduit par des économies substantielles quand les variétés utilisées sont des hybrides aux semences coûteuses. Les plants issus de pépinières produisent une récolte plus homogène et le grain récolté à partir de ces plants est donc en général d'une qualité meilleure et plus uniforme. Compte tenu de la hausse rapide des coûts de main-d'œuvre et des autres intrants de la production rizicole au Sri Lanka, ainsi que de la concurrence croissante qui se fait sentir pour l'utilisation des ressources en eau, le passage à la distribution de

plants de pépinières est activement encouragé par les autorités responsables de l'irrigation, entre autres. En comparaison des avantages de cette méthode, les inconvénients sont mineurs; il s'agit essentiellement de l'obligation pour les agriculteurs d'acheter et d'utiliser des pots pour les plants, dans le cadre de l'utilisation de pépinières. Les agriculteurs doivent également acquérir et mettre en œuvre les connaissances techniques nécessaires, notamment pour la conduite des pépinières de plants de riz. Il ne s'agit pas là de contraintes lourdes et les agriculteurs s'y sont pliés sans réticence.

Las técnicas de esparcido de plántulas y sus posibilidades de economizar semillas, agua y mano de obra en los sistemas de producción de arroz de regadío en Sri Lanka

Los métodos de esparcido de plántulas para el establecimiento de arrozales se introdujeron en Sri Lanka desde China, y fueron adoptados con rapidez por los agricultores. La experimentación – tanto en actividades de investigación y desarrollo como en parcelas piloto en las fincas– ha revelado las evidentes ventajas que ofrecen estas técnicas, ya que permiten economizar mano de obra (alrededor del 50 %), agua (15 % aproximadamente) y semillas. De hecho, la producción de plántulas en vivero sólo requiere de un 10 a un 20 % de las semillas que

se necesitarían para la siembra al voleo tradicional, lo que entraña un ahorro considerable cuando se utilizan variedades híbridas de costo elevado. Las plántulas que crecen en viveros forman un cultivo más uniforme, y una vez esparcidas producen, por lo general, un grano más homogéneo y de mejor calidad. En vista del aumento exponencial de los costos de la mano de obra y otros insumos agrícolas en Sri Lanka, así como de la competencia cada vez mayor por el acceso al agua, la adopción de las técnicas de esparcido de plántulas es fomentada

activamente por las autoridades responsables del riego, entre otros. Las desventajas de estos métodos, menores que sus ventajas, residen principalmente en que los agricultores deben adquirir y utilizar cajas de plántulas como parte de los procedimientos que requieren los viveros. Además, es indispensable que comprendan y apliquen los cuidados técnicos necesarios, en particular, en los viveros que producen las plántulas. No obstante, no se trata de obstáculos insalvables, y los agricultores han adoptado rápidamente estas prácticas.

Rice production situation in Uruguay

E. Deambrosi
INIA Treinta y Tres, Uruguay

INTRODUCTION

Uruguay is located between the 30th and 35th parallels of the Southern Hemisphere. Rice production only began at the end of the 1920s and just one crop per year is sown; low temperatures may occur during the crop reproductive phase. More than 90 percent of the rice produced is exported, while the domestic consumption of elaborated rice is between 10 and 11 kg/person/year.

Research, production and industry are closely interconnected – research facilitates the adoption of new technologies and the production demand is thus met. The production and industry sectors join forces to obtain the grain quality demanded by international markets, while respecting the environment.

THE ENVIRONMENT OF RICE PRODUCTION

According to the agrometeorological station at the Paso de la Laguna Experimental Unit (eastern Uruguay), the average annual rainfall in the past 33 years is 1 375 mm, approximately 50 percent of which falls during the rice-growing period (Oct.–Mar.). Table 1 shows the average records of the main climatic variables, considered important for rice growth; the figures are means and do not show the great variability of the climatic variables.

Rice is the principal user of irrigation. Uruguay has important sources of natural waters: rivers, brooks and lagoons, with over 400 intakes installed; in addition, there are 800 artificial reservoirs (> 90 percent assigned to rice). There are three production zones (eastern, central and northwestern) with specific characteristics related to the soil, topography and climatic conditions). Low temperatures in the central and eastern zones during the crop reproductive period reduce productivity and high doses of nitrogen can have negative effects – when there are several consecutive days with daily minimum temperatures below 15 °C in the immediate period before/after flowering, plants that have absorbed high quantities of nitrogen increase the spikelet sterility percentage. In the last few years, 180 000 ha have been planted and average yields have improved significantly: > 6 tonnes/ha in 7 and > 6.5 tonnes/ha in 5 of the last 10 years (Table 2).

There are just under 600 rice-producing farmers: 46 percent are exclusively agricultural; 54 percent have a mixed rice-livestock enterprise. In 75 percent of farms, the land is rented for sowing. Irrigation systems are private and on average, 45 percent of farmers purchase water to irrigate their crops. With regard to business, 27 percent

TABLE 1
Meteorological data registered at INIA Treinta y Tres, 1973–2005

	Month												Annual
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	
Temperature (°C):													
Mean	10.7	11.9	13.4	16.4	18.7	21.4	22.7	22.1	20.8	17.3	13.8	11.1	16.7
Max. mean	16.2	18.0	19.3	22.4	25.0	27.7	29.4	28.3	27.0	23.4	19.8	16.7	22.7
Min. mean	5.6	6.7	7.9	10.5	12.3	14.4	16.7	16.6	15.0	11.6	8.3	5.8	11.0
Frost (days)	4	2	1	0	0	0	0	0	0	0	1	5	12
Luminosity ^a	4.7	5.4	6.0	6.8	8.0	8.5	8.6	7.6	7.1	6.2	5.4	4.7	6.6
Rain (mm)	133	99	113	98	103	98	119	149	106	114	123	120	1 375

^a Daily mean of sun hours.

NATIONAL RICE PROGRAMMES
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TABLE 2
Rice production, yield and harvested area, 1995–2005

Year	Harvested area (ha)	Yield (tonnes/ha)	Production (tonnes)
1995	146 300	5.509	806 100
1996	150 500	6.468	973 500
1997	155 500	6.583	1 023 800
1998	169 901	5.086	864 158
1999	208 089	6.382	1 328 222
2000	189 402	6.383	1 209 139
2001	153 676	6.703	1 030 198
2002	160 234	5.863	939 489
2003	153 400	5.904	905 700
2004	186 465	6.771	1 262 600
2005	184 000	6.600	1 214 500

Source: FAOSTAT.

of farmers have a manager, 77 percent receive technical assistance and 81 percent keep management records.

RICE PRODUCTION AND RESEARCH

Large grain varieties are being cultivated, both *indica* and tropical *japonica* (American quality). Over 95 percent of the national area is covered by the varieties, El Paso 144, INIA Tacuarí and INIA Olimar. Certified seed is being used on 85 percent of the cultivated area: the quality and purity of certified seed contribute to generating a uniform product and controlling rice. The crop is sown mechanically in rows or broadcast in dry soil, drained on the surface during October and November.

The main weed is barnyard grass – a complex of the *Echinochloa* genus, where the *crus-galli* species predominates – and it is controlled by aerial applications of herbicides in early post-emergency. Fertilization depends on each crop's needs: 40–70 kg/ha of P₂O₅ and 45–70 kg/ha of N are applied. Thanks to the presence of natural predators, it is not necessary to apply insecticides.

Disease management varies according to the land's previous use, the fertilizer use and the environmental conditions during the crop reproductive phase. There is positive correlation between nitrogen content in the rice

plants and their susceptibility to stem diseases. During the 140–150-day period between sowing and maturity, the soil remains flooded for 55–70 percent of the time.

The rice crop shares the use of the soil with livestock, which uses the majority of the natural resources in the rotation period. After rice has been sown for 2 or 3 consecutive years, improved pastures (grasses and legumes) are sown by plane without any soil tillage, for 3 to 5 years. Alternating forage and livestock production generates unquestionable benefits to the environment: the alteration of the soil's physical conditions is diminished and fewer agrochemical applications are made. The crop absorbs greater quantities of nitrogen than those applied by the farmer; there are studies on the action of microbial populations that may be affecting biological fixation.

Research is carried out principally by the National Institute of Agricultural Research (INIA): technical staff and farmers attend field days and the transfer of results is carried out mainly by private professionals, who then transfer them to the farmers. INIA also holds annual meetings with rice mills so as to understand the needs of the industry and in particular achieve the quality demanded by the international markets.

CONCLUSION

In recent years, rice production has adopted the agroecosystem approach – i.e. the soil remains in rainfed conditions and fast irrigations are provided prior to the establishment of the definitive flooding. The water-use requirement period is thus reduced, herbicides are applied in the rainfed phase without releasing water to adjacent fields, and the risk of substances damaging the rice is diminished during the oxygen exclusion period (gas and organic acids production, iron precipitation). Uruguay produces a quality rice grain – free of residues and contaminants, meeting the high standards demanded by consumers – while successfully maintaining a correct relationship with the environment. The country must rise to the challenge of sustainable rice production.

La production de riz en Uruguay

La production rizicole est relativement récente en Uruguay. Il y a trois zones de production aux caractéristiques pédologiques, topographiques et météorologiques bien spécifiques, et au cours des récentes années 180 000 ha ont étéensemencés avec des

variétés à gros grain – *indica* et *japonica* tropical (qualité américaine). Les récoltes de riz se font en alternance avec les cultures fourragères et le pacage de bétail, entraînant des avantages incontestables pour l'environnement. La recherche sur le

riz est principalement du ressort de l'Institut national de recherche agricole (INIA). Plus de 90 pour cent de la production est exportée. L'Uruguay se trouve à présent face au défi non négligeable de la mise en place à court terme d'une production rizicole.

La producción de arroz en el Uruguay

La producción de arroz es relativamente nueva en el Uruguay. Tiene lugar en tres zonas cuyo suelo, topografía y clima tienen características particulares; en los últimos años se plantaron 180 000 ha con variedades de grano grande, tanto

indica como *japonica* tropical (calidad americana). El cultivo de arroz se alterna con la producción ganadera y de forraje, con indudables ventajas para el medio ambiente. De la investigación sobre el arroz se encarga principalmente el Instituto

Nacional de Investigación Agropecuaria (INIA). Del arroz producido, más del 90 % se destina a la exportación. Uruguay se enfrenta con el importante desafío de lograr, en tiempo oportuno, una producción arrocera sostenible.