IMPACT OF SCIENCE ON RICE

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INTERNATIONAL RICE RESEARCH INSTITUTE
P.O. Box 933, Manila, Philippines

A. BLUMENSCHEIN, A. S. PRABHU,
J. KLUTHCOUSKI, S. STEINMETZ,
B. DA S. PINHEIRO, and A. SILVEIRA FILHO
Centro Nacional de Pesquisa — Arroz e Feijao, Brazil

EXPANDING THE ENVIRONMENTAL COVERAGE OF HIGH YIELD TECHNOLOGY

Cultivated rice evolved from wild rices found growing along river estuaries. According to T. T. Chang, "rice grains were initially gathered and consumed by prehistoric people of the humid tropics who lived near the river estuaries along the wooded foothills where rice grew wild on poorly drained sites."

As a taste for cereal developed, cultivation began and migration of the early cultivators accelerated the evolution of cultivated forms adapted to different environments.

Today most rice is cultivated under controlled irrigation. In several developing countries it is also grown in a variety of difficult environments where drought, soil fertility, insects, diseases, and mineral toxicity are important constraints.

Most international research efforts have been concentrated on irrigated rice. But recently, more attention began to be paid to problems in the more difficult environments.

Here we report some aspects of the Brazilian experience on upland rice, which indicates that technology can increase yields and reduce instability, and that under difficult environments, upland rice can be a stable and profitable source of food.

Brazil produces about 9 million tonnes of rice yearly; 70% from upland and the rest from irrigated land. Total cultivated area varies from 5 to 6 million hectares.

Size of most farmers' fields varies from 40 to 60 ha but some are more than 2,000 ha.

In general, upland rice in Brazil has three main constraints: drought, disease (mainly blast), and weeds. These constraints are closely interrelated and responsible for the high instability observed in upland rice production.

DROUGHT

Drought is considered the main problem in Brazil. It is caused primarily by the occurrence of dry spells (*veranico*) during rainy season. In some areas of the country, veranico can cause great yield decrease, especially if it occurs at the reproductive stage of the crop, due to the following factors:

1. high evapotranspiration demand,
2. low to medium water-holding capacity of the soils, and
3. shallow root system.

Low natural soil fertility and soil compaction in areas of continuous cultivation seem to cause shallow root development.

A study made by Steinmetz et al (4) indicates that the number and distribution of favorable rainfall periods vary greatly depending on the region. Using the ratio ETr/ETm (real evapotranspiration:maximum evapotranspiration) as criteria to evaluate the climatic risk on distinct regions, they showed that the amount of water extracted by the root system is the main factor influencing the agroclimatic classification of the crop for a given location. Using 30 mm as a hypothetical value of the amount of water extracted by the root system, a large part of the country would be considered as *unfavorable* (high risk). On the other hand, if 90 mm is used, the larger area of the country is considered as *favorable* (low risk) or *highly favorable* (very low risk). Results clearly indicate that, at least in some regions where upland rice is grown, plant and soil management to promote a deeper root system are essential to decrease the risk of drought stress.

Influence of soil management on increase drought effect

Soils from most Brazilian upland rice regions are Oxisols, that are very intemperized showing good physical but poor chemical and biological characteristics. Natural fertility is found only in the 0-10 cm layer and results from the accumulation and decomposition of organic matter. This natural fertility is rapidly destroyed, making the soil unsuitable for cropping after 2 or 3 yr of cultivation as a result of the farmers' land preparation methods erosion, and the burning of crop residues. The land is easily mechanized, and farmers have adopted heavy implements responsible for very hard compaction below 10-12 cm depth.

The soil's low fertility and the compaction of the subsurface layer prevent roots from growing deeper, making the crop unproductive and very susceptible to dry spells.

Based on the previous discussions, one realizes that soil management to reduce water stress can be done in two ways: 1) by increasing soil fertility, especially that of the subsoil; and 2) by removing soil compaction.

According to Steinmetz et al (4), deeper root growth can be obtained either by eliminating the aluminum toxicity and other toxic elements or by increasing subsoil fertility. These can be achieved either by applying lime and fertilizers by deep plowing, or by increasing the movement of calcium, magnesium, and other nutrients to the deeper layers of the soil. Calcium moves faster when applied as $CaCl_2$ or $CaCO_4$ than when used as $CaCo_3$.

Experiments at CNPAF by Seguy et al (3) show that upland rice yields in Brazil can be increased more than three times if the land is well prepared before planting. With the traditional method of soil preparation (heavy harrowing), yields were about 1.1 t/ha, whereas with an improved method — preincorporating straw and weeds by a light harrowing and then deep plowing (25-35 cm) — yield increased to 3.1 t/ha. In the second year, the new method improved the yields more (5.7 t/ha).

The increase in yields was explained by the researchers based on the following observations:

1. The initial harrowing provides a fine cutting of the residual materials and weeds allowing a homogeneous incorporation along the soil profile. Consequently, there is an improvement of physical, chemical, and biological characteristics of a deeper profile.
2. Superficial hydric erosion was reduced because the rainfall could infiltrate the soil more easily and become available to the roots.
3. The roots could elongate much more, exploiting nutrients and water deeper than 1 m. Usually, with the traditional method of soil preparation, roots can explore only the superficial layer (0-1 5 cm) of the soil.

Another interesting observation made was the possibility of changing the time of planting. In most regions of Brazil, upland rice is sown in October at the beginning of rainy season. With the new method of soil preparation it is possible to plant rice at the middle of rainy season, during the second or third week of January, and still obtain yields of 3 t/ha.

Breeding for drought resistance

Breeding for drought resistance is difficult. Adding to the complexity of the trait, there is lack of adequate methodology to screen in segregating generations.

Visual screening during reproductive stage, based on spikelet sterility and leaf rolling, has been useful in detecting potential progenitors from introduced and native genotypes at CNPAF. Crosses between national and African genotypes provided several promising lines in advanced generations or in regional trials.

The methodology prevents degeneration of the moderate level of resistance observed in adapted genotypes. However, researchers believe that the strategy for increasing drought resistance is to selectively incorporate certain characteristics of the adapted genotypes. Only in this way can loss of time in crossing and selecting without a good basis of variability be avoided.

However, such a program has to rely on the solid knowledge of the parameters of drought resistance to be transferred. There is general consensus on the importance of root thickness and depth on stress avoidance. But upland rice, and especially Brazilian genotypes, have an adequate root system. The problem is probably lack of expression of the characteristics under upland condition and soil management.

Leaf area has been a concern in the CNPAF program. National genotypes have a great plasticity in leaf growth. With adequate fertility and water availability, leaf area indexes as high as 7 can be attained, which promotes lodging. CNPAF data indicate a relationship between yield losses due to drought in the reproductive stage and leaf area indexes higher than 3. Fortunately, such leaf area does not prevent attaining the target yield for upland rice. On the other hand, effect of reduced leaf area on root development and carbohydrate accumulation during vegetative stage is not known. There is indication that translocation of reserves plays an important role in grain filling under water stress.

Other investigations concern the role of stomatal closure, leaf rolling, and leaf death, in the balance between stress avoidance, growth, and ultimately, yield.

Studies on rice water relations, especially on panicles and spikelets, are few. Studies available on leaves do not fully exploit possible genetic variation. Nevertheless, rice was found to have the ability to adjust osmotically.

The mechanisms or processes by which low water/turgor potentials are transduced into spikelet sterility are still not known. CNPAF researchers are currently developing studies on the subject. The possible relationship between loss of turgor in leaves, abscissic acid export to the spikelets, and damage to the reproductive structure in certain species, complicates this studies.

The role of stress-induced accumulation of metabolic substances is still controversial. Do they represent a stress adaptation linked to specific genetic information or are they passive results of changes in growth? There is a recent evidence of active accumulation of betaines, in certain species, related to synthesis of specific enzymes, under stress conditions. Such stress-mediated metabolism eventually contributes to osmotic adjustment.

RICE BLAST

Rice blast is the principal disease problem of upland rice. It continues to cause significant yield losses in central Brazil where most upland rice is grown. The losses are of varying dimension depending on the cultural practices adopted and the soil and environmental conditions. Widespread planting of blast-susceptible cultivars increases disease incidence in Brazil. Average yield losses have been estimated to be 36% in IAC 47 and 17% in IAC 25, when blast was partially controlled under experimental conditions. In farmers' fields, losses from blast up to 100% have been registered. Despite efforts to breed for resistant varieties, the problem will continue because of need to grow upland rice in extensive areas where conditions favor disease incidence and development. Besides, the pathogen is highly variable and readily adapts to different agroclimatic conditions. The danger is enhanced if cultivars are released without regard for their susceptibility to the pathogen. The solution, according to Prabhu (2), lies inlearning to live with the disease and reduce its impact by proper disease management practices. All practices such as planting date, seed quality, seeding rate, cultivar, fertilization rates, and tillage, influence blast. It is, however, incorrect to adopt the same practices in different upland production systems. For example, in subsistence and shifting agriculture systems where rice is intercropped with maize, cassava, and beans, blast is of little economic importance. The system is confined to north and northeastern parts of Brazil. Farm size is small and production is totally dependent on family labor. In general, unimproved local varieties are planted. Such a system requires only the introduction of a cultivar with moderate blast resistance.

Efforts of CNPAF to reduce rice blast to tolerable levels are concentrated on a highly mechanized extensive monocropping system where the disease constitutes a limiting factor.

High blast incidence in upland rice

Blast incidence is higher in upland rice than in irrigated rice because of 1) prolonged dew duration periods due to wide differences in day and night temperatures, 2) predisposition of rice plant to blast under soil moisture stress, and 3) altered changes in nutritional status in plant tissue under drought conditions. The soil factors and their influence on uptake of nutrients under water-deficit conditions have been overlooked in the past. Available information has shown that accumulation of soluble sugars and nitrogen in different parts of the panicle under moisture stress conditions is associated with high panicle blast severity. Thus, all practices that reduce soil moisture stress suppress panicle blast to tolerable levels.

Disease management

Efforts that involve several measures are likely to yield more profitable results than adopting only one measure (1). In many cases, varietal resistance is insufficient for adequate disease suppression and should be accompanied by other disease management techniques. Considering the environmental and edaphic conditions in Brazil, several disease management practices have been evolved that reduce blast to tolerable levels. Early planting in October is one of the disease escape measures. Planting short-duration (100-110 days) cultivars in the early season reduces the risk from drought in February, and the uniform distribution of rain during grain formation reduces panicle blast incidence.

Planting rice against the wind prevents dissemination of inoculum from early planting to the later ones on the same farm. Avoiding excessive use of nitrogen fertilizer at planting reduces leaf blast. Balanced fertilizer rates promote plant growth and vigor resulting in reduced percentage of leaf area affected. Practices to reduce soil moisture stress during plant growth such as deep plowing, deep fertilizer placement, and low plant population reduce leaf blast to low levels. Using healthy or disinfected seed delays establishment of primary inoculum. One application of systemic fungicide at heading reduces panicle blast and increases grain yield under conditions favorable for disease development.

These measures involve little or no additional expenditure. Disease-resistant varieties are an important component of blast disease management. Brazilian upland rice varieties are drought tolerant; well adapted to acid, low-fertility soil; and possess consumer-preferred grain quality. The challenge lies in improving local upland rice cultivars for stable blast resistance. The recent breeding efforts at CNPAF yielded several blast-resistant promising lines. Crosses made with local cultivar IAC 47 utilizing resistant sources from Korea (SR 2041-50-1) and Nigeria (TOS 2578/7-4-2-3-B2) resulted in two resistant cultivars, CNA 108 and CNA 104. The improved blast-resistant lines outyielded the local check IAC 47 (Table 1).

Grain yield of the blast-resistant cultivars was stable in both low- and high-input tests. Our experience has shown that there is potential in developing blast-resistant upland rice germplasm and in sequential release of resistant intermediate-height, early-maturing cultivars. With improved blast-resistant cultivars and recommended disease management practices, an average yield of 3 t/ha under unfavorable upland conditions is attainable.

WEEDS

Weeds are considered one of the primary constraints in upland rice production in Brazil.

In newly open areas, weed populations are low and weed control is not a problem. However, during the second year onward, weed population increases causing yield losses of 50% or more, depending on rainfall distribution. This is one of the reasons farmers shift to crops such as soybean or pasture, that offer less risks and good profits. Weeds not only affect rice yields by competing for water, nutrients, and light, but also hamper harvesting.

To avoid or minimize decreases in rice productivity, efficient weed control during the first 40-45 days is necessary. Experiments at CNPAF have shown that depending on the size of the crop field and labor availability, handweeding, use of mechanical cultivators, or use of herbicides can satisfactorily control weeds.

To assure effective and economical weed control in upland rice, a combination of methods is most convenient. Good soil preparation must be combined with adequate plant spacing and densities and use of fast-growing cultivars with high competitive ability.

Table 1. Yields (t/ha) of three promising blast-resistant lines in unfavorable upland, Goiås, Brazil, 1983-84.[a]

Line/variety	Grain yield (t/ha)	Blast reaction
CNA 108-B-28-13-1B	3.0	Resistant
CNA 104-B-2-43-2 [b]	2.6	Moderately resistant
CNA 104-6-34-2-1	2.5	Moderately resistant
IAC 47 (local check)	2.4	Susceptible

[a] Averages based on 16 multinational yield trials. [b] Released as Cuiabana in the Mato Grosso state.

Chemical weed control in upland rice cannot be overlooked, because herbicides are efficient weed control tools in extensive farming systems where there is a labor shortage.

CONCLUSION

The Brazilian examples are found in other Asian, African, and Latin American countries. They are upland and other *difficult environments* for rice. The examples show that high yield technology can be developed and extended to rice grown in these environments.

The international centers, mainly IRRI, can be very important in coordinating the definition and organization of research priorities for the different environments and regions and in promoting cooperation among national and international rice research agencies.

IRRI has a comparative advantage in carrying out some basic research directly or in cooperation with laboratories from developed countries and in rendering scientific services through its germplasm bank, genetic evaluation and utilization, and training programs.

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