CHAPTER 9

Upland adaptability

THIS BOOK IS DIRECTED to the improvement of lowland rice. But it would be incomplete without reference to the special problems of upland rice breeding. After decades of almost total neglect, rice scientists are beginning to study upland rice. Within a generation the improvement of upland rice will probably be the subject of a book in itself.

Despite the importance of upland rice, particularly in Asia and Latin America, and also in parts of Africa, the crop has consistently received low governmental research priority and few concerted efforts have been made to improve upland varieties or cultural practices. Some argue that in Asia the increased yields of irrigated rice, coupled with progressive improvement in rainfed rice and extension of irrigation systems, will reduce the importance of upland rice and that much of the actual upland rice area should be devoted to other crops. But this is not the case in Brazil, for example, where increases in the yield and area of irrigated rice are not likely to replace the predominant upland culture for many years.

The upland problem is complicated by the range of soil types and rainfall situations in which the crop is grown. One relatively favored type of area is that found in much of Central America and extensive areas of western South America, and in Asia where soils are relatively fertile, rainfall is abundant, and the water table is often high. When rainfall is well distributed in these areas, some of the new dwarf lowland varieties such as IR5, CR1113, IR8, and CICA 4 can yield from 3 to 5 t/ha on farms. Critical research areas for this favored type of upland rice culture are blast and leaf scald resistance and weed control to protect existing yielding ability. Work in Peru and elsewhere suggests that high yielding varieties for this upland situation will also yield well when irrigated. However, the reverse is not true because some highly productive lowland varieties and lines are not satisfactory under favorable upland moisture and soil conditions, indicating basic varietal differences in growth on upland soils that are essentially free of drought.

The great bulk of upland rice in Latin America, however, is grown on relatively infertile, acid soils where rainfall is unpredictable, as in eastern Colombia, Venezuela, and much of Brazil. The absence of a high water table, the extreme soil permeability, and an irregularity of rainfall indicate that drought is the major factor limiting yield, particularly in Brazil.

Although rice farming in Brazil is highly mechanized, regional yields average only about 1 t/ha and the highest yields on experiment station plots rarely reach 3 t/ha. For such upland culture, where rice is subject to periodic drought stress, increased farm yields is more than a question of providing a good dwarf variety, weed control, better agronomic practices, or disease protection. This exceedingly difficult problem is the subject of the rest of our discussion of upland rice.

Upland rice has competed reasonably well with irrigated rice for decades because its lower yield per hectare was largely offset by lower production costs. But the adoption of the high yielding varieties by lowland growers has grossly disturbed that balance and threatens to force those upland rice farmers who cannot switch to the new technology out of rice growing. This would be tragic in areas where increased irrigated yields would not compensate for the loss in upland production.

Partially in recognition of this, research on upland rice appears to be receiving increased priority in some countries. But there is a lack of accumulated knowledge to draw upon that is comparable to the one that existed when the IRRI began its work on tropical lowland rice.

Present upland varieties are moderately tall and have intermediate tillering ability. The leaves are long and broad. Because of their droopy character, the upper leaves are often sun-scalded during periods of water stress.

In Brazil upland rice is planted in rows spaced about 60 cm. At this wide spacing the plant type is reasonably good, blast is usually not severe, and the vegetative growth appears to be in an excellent physiological condition. But the foliage never covers the ground between the rows, the leaf area index remains low, much of the solar radiation is lost, and yields would remain low even if moisture stress of the plant were eliminated.

Sufficient research has been done to show that close spacing does not increase — and may even decrease — the yield of traditional upland varieties. A major reason appears to be that spacing closer than 30 cm between rows results in a deterioration of plant type because the plants grow taller and leafier. Obviously, this causes mutual shading, which adversely affects yielding ability. Probably more important, the increase in plant size and leaf area index in relation to a constant root development intensifies plant moisture stress. Another major reason that density and yield are negatively correlated in traditional upland varieties is that blast disease increases at closer spacing. But high yielding dwarfs at close spacing can not simply be substituted for the locally adapted tall upland varieties because the dwarfs lack drought resistance.

The logical starting point for a breeding program, therefore, is a search for the best levels of drought resistance among the thousands of indica varieties in the world collection. The best material identified so far is from Brazil. Such varieties should be shortened somewhat with the objective of developing a plant about 1 meter tall that can be planted at a relatively high density and that can withstand drought. Short, erect leaves should be sought to reduce evaporation and sun scalding. Moderately high tillering ability probably would not be a disadvantage under drought stress because the tiller number would automatically decrease during early stress. But with favorable moisture conditions, plants with high tillering ability and seedling vigor would cover the ground quickly, thereby reducing soil moisture evaporation and competing better with weeds.

Some Brazilian upland varieties have two important characters not found in other upland rices. They appear to be resistant to brown leaf spot, an important disease on acid, infertile soils. They also have high grain weight and quality. The milled grain has clear endosperm and intermediate amylose content.

Several modifications should be made in existing breeding procedures. In Brazil, a 60-cm row spacing is used in breeding programs. This should be reduced to 30 cm to increase efficiency of nitrogen use and to apply greater selection pressure for drought resistance in segregating populations. Upland soils are easy to work and a breeder could easily space 1 plant every 10 cm within the rows to facilitate plant selection and to avoid the problems of two or more plants growing together.

Many single crosses between the improved varieties of intermediate height and drought-resistant upland varieties should be made. These should be followed by backcrosses and three-way crosses to short-statured parents to produce 200 to 400 F_1 seeds for each backcross. The tall backcross plants would be eliminated and the F_2 seed of the fertile intermediate-height plants with good grain appearance would be bulked.

Replicates of bulk hybrid populations should be spread over several stations to increase the likelihood of encountering drought at different growth stages. As the bulks would be homogeneous for moderate stature, little adverse interplant competition for light would be expected. Modified bulk selection should start in the F_2 for drought resistance, brown spot and leaf scald resistance, intermediate height, desired maturity period, and grain traits. Bulk selection should be continued for four or five cycles of breeding. Selected intercrossing of the better drought-resistant short lines would favor the recombination of these characters with disease resistance, seedling vigor, high tillering, and thick culms for lodging resistance.

Upland rice improvement will require well-organized teams of scientists of several disciplines. If productive varieties can be produced for planting at closer spacing, agronomists will need to improve existing cultural practices for seed density, fertilizer rates and timing, and weed control. Pathologists will have to work closely with the breeders in varietal development, especially in the breeding for resistance to brown spot, leaf scald, and blast. No upland variety from Latin America is resistant to blast, which indicates that improved plant and grain types having stable blast resistance will have to be incorporated into the most drought-resistant, intermediate-statured lines developed through bulking. Mineral nutrition work should be directed toward the evaluation of plant differences in tolerance for such typical upland problems as aluminum and manganese toxicity, and iron and phosphorus deficiency. Basic studies on varietal differences in root development in relation to moisture stress and on alternative ways to measure drought resistance in large segregating populations would be helpful to breeders.

DROUGHT RESISTANCE

RESEARCH EFFORTS AT IRRI and elsewhere only recently have emphasized drought resistance in rice. This has been due mainly to the complexity of the problem rather than to a lack of recognition of its importance. Productivity in upland, rainfed lowland, deep-water, and even irrigated rice has long been known to be limited by inadequate water at certain phases of growth. IRRI scientists concerned with drought resistance estimate that upland rice comprises 10% (8.1 million ha) of the rice hectarage in South and Southeast Asia, almost 80% (4.5 million ha) of the rice area in Brazil, and 75% of Africa's rice hectarage. Rainfed lowland rice is thought to account for about 50% (40 million ha) of the rice hectarage in tropical Asia. Another 10% is floating or deep-water rice, sown in dry soil and grown under upland conditions where there is a risk of drought for several weeks before flood water rises. Water deficiency also occurs in many, if not most, of the irrigation systems serving rice. Thus as much as 90% of the world's rice-growing area is estimated to suffer from drought at some critical growth stage.

Varieties clearly differ in their ability to survive and yield in moisture-deficit situations. The phenomenon, however, is highly complex and may involve several mechanisms. IRRI scientists have found that drought-resistance mechanisms in relation to climatic, edaphic, and cultural conditions are inherently different and location specific. They seek mechanisms that will function over a broad spectrum of environments.

The IRRI drought program has three major objectives:

- to better understand the physiologic basis of drought escape, avoidance, tolerance, and recovery in relation to varietal differences in these component traits;
- to devise and refine techniques to enable researchers to quickly identify the different components of drought resistance, each of which may operate at a particular stage of plant growth; and
- to use the appropriate techniques to screen breeding lines and

accessions in the germplasm bank for adaptability to different water regimes.

DROUGHT SCREENING TECHNIQUES

A number of techniques of varying sophistication may be used to evaluate drought resistance. Presently, the most practical method is to simply plant in fields for a simulated upland or rainfed lowland crop in the dry season. The plants may be established by watering with sprinklers or gravitational irrigation. Water is withheld to impose stress at the appropriate growth stage, which can be determined by examining the climatic data of the target region for the varieties under development. In many soils, it takes at least 2 weeks of rainless days before any marked differences appear in susceptibility to drought during the vegetative stage, and at least 1 week during the reproductive stage. At the appropriate time the test entries are scored for stress symptoms and ability to recover after water is applied. The scale in the standard evaluation system for rice is used.

The results of such dry-season tests should be verified during the rainy season under natural drought conditions. IRRI scientists have found a good correlation, but that might not be true at all locations.

DROUGHT-RESISTANT GERMPLASM

Accessions from the germplasm bank as well as improved breeding lines with some degree of drought resistance are available directly from IRRI and through the International Rice Testing Program (IRTP), especially the International Upland Rice Observational Nursery (IURON). Workers in areas where drought is a pronounced problem should make a special effort to stay abreast of efforts at IRRI and elsewhere.