17. THE STATUS OF RICE BREEDING FOR DISEASE RESISTANCE AT THE INTERNATIONAL RICE RESEARCH INSTITUTE

H. M. Beachell*

Introduction

During the next 10 years, in all likelihood, most of the rice varieties now grown on tropical Asian rice fields will have been replaced by disease resistant short, stiff-strawed, nitrogen-responsive varieties. If rice production is to keep pace with the expanding human population, the change to high-yielding, improved plant-type varieties grown under improved agronomic practices is a necessity.

Short, stiff-strawed, non-lodging varieties with relatively short and erect growing leaves have been found to be highly responsive in terms of grain yield to nitrogen fertilizers. In test plots at The International Rice Research Institute located in the Philippines, IR 8, a variety of this type, has produced yields of more than 10 tons per hectare in experimental plots. In farmers' fields, yields of from 5 to 7 tons per hectare are common. By using varieties of this type along with improved agronomic practices, farmers are doubling and sometimes tripling the yields obtained from the tall, profuse-tillering varieties now used throughout tropical Asia.

As insurance against losses from rice diseases, many high-yielding, disease-resistant types of diverse genetic origin must be developed. The level of disease resistance must be as good as and preferably superior to that of the staple varieties now grown.

The major diseases affecting the rice crop in tropical Asia are blast (*Pyricularia oryzae* Cav.), tungro virus and bacterial leaf blight (*Xanthomonas oryzae*). Other important diseases are sheath blight (*Pellicularia sasaki*), bacterial leaf streak (*Xanthomonas translucens*, f. sp. *oryzae*), stem rot (*Leptospheria salvinii*) and several virus diseases (grassy stunt, yellow dwarf, and orange leaf). When high rates of nitrogen fertilizer are used, diseases such as sheath blight and possibly others may become more serious. Therefore, the new improved varieties must possess a high degree of field resistance to all of the diseases mentioned.

Institute pathologists are developing efficient and rapid techniques for screening varieties for disease resistance. As screening techniques are developed, the more than 10, 000 varieties in the Institute's world collection are screened for resistance to the important diseases. As varietal sources of disease resistance are found, rice breeders incorporate this disease resistance into high-yielding varieties and lines through hybridization and selection.

The high-yielding, improved plant type variety most frequenty used in the Institute varietal improvement program to date has been IR 8, which was developed at the Institute. At present, several other similar plant type lines also are being used. The high-yielding strains have many essential morphological traits such as short stature, relatively short and erect-growing leaves, and early and moderately heavy tillering. For this reason, the backcross method of breeding is extensively used in breeding for disease resistance. The high yielding variety is used as the recurrent parent. Large numbers of backcross F_1 seeds are required if the method is to be effective.

* Plant Breeder, The International Rice Research Institute, Los Baños, Laguna, Philippines. Mail address : Manila Hotel, Manila, Philippines.

In some crosses, other desirable traits such as early maturity and various grain characteristics are being obtained from the donor parents. In these crosses only one or two backcrosses are made after which F_2 populations are grown and the selections made and carried in pedigree rows. The selections are classified for disease reaction and grain characteristics (including cooking behavior) as well as for such other economically important morpho-physiologic traits as time of maturity, leaf color, length and angle of growth, tillering ability, and plant height.

Blast

Seedlings from crosses and backcrosses are screened in a blast nursery which is described in Institute annual reports and elsewhere. Field testing, as carried out in a blast nursery, is a more efficient and reliable method of testing for blast resistance than artificial inoculation using specific races. Many more lines can be screened and when grown at several locations, the results are more reliable because of the large number of races involved.

High levels of nitrogen fertilizer are used, and the spreader variety which surrounds the test rows must be susceptible to many races. The hybrid lines are tested through several generations at Los Baños. Resistant lines are then tested at other locations in the Philippines and eventually in other countries.

The varieties used as parents in the blast resistance breeding program are varieties rated as resistant or moderately resistant to Philippine races when tested in a blast nursery. When tested with specific races, they were resistant to most races from the Philippines and from other tropical Asian countries.

Table 1. Some of important crosses made for combining blast resistance with the high yield and improved plant type of IR 8.

Recurrent Parent		Resistant donor parent	Other desirable traits involved
IR 8/3	×	(Peta/3 × Dawn)	Short height, good plant type
IR 8/4	×	(Dawn/3 × Sigadis)	Short height, early maturity, bacterial leaf blight resistance, moderate tillering, clear grain texture, moderate amylose
IR 8/2	×	(Dawn × Pankhari 203)	Short height, early maturity, highly resistant to tungro
IR 8	×	(Sigadis/6 × T(N)1)	Short height, good plant type, bacterial leaf blight resistance
IR 8/2	×	(H-105 × Dgwg)	Short height, good plant type
IR 8	×	(BPI-76 × Ponlai Varieties)	Short height, dark green leaf color, slow leaf senescence
IR 8	×	(CP231 × SLO-17 × Leuang Yai 34)	Short height, long, translucent grain, moderate amylose content
IR 8/3	×	Zenith	Short height, early maturity, bacterial leaf blight, bacterial streak and sheath blight resistance
IR 8	×	Tadukan	Short height, early maturity, long slencer translucent grain.

It is recognized that immunity to all races of blast is probably not possible ; but by selecting parents showing a broad spectrum of resistance to many races and by selecting out hybrid lines showing broad resistance, progress toward blast control is possible. The parental varieties showing a broad type resistance when tested in the field and when exposed to specific races from several tropical Asian countries include Dawn, Kataktara DA 2, Leuang Yai 34, H-105, and Zenith.

As mentioned previously, the backcross method of breeding is frequently used in breeding for blast resistance. F_1 plants usually show a resistant reaction. Therefore, backcrossed F_1

seedlings are subjected to infection of many blast races when grown in the blast nursery. Only resistant F_1 plants are used as parents for the next backcross to the recurrent parent. This makes it possible to obtain two and sometimes three backcrosses in a single year.

Dawn from the United States has been used extensively as a source of resistance. Prior to the development of IR 8 and other high yielding lines, Peta was used as a parent in crosses with Dawn. After two backcrosses to Peta, resistant F_1 plants were crossed with IR 8. Blast-resistant F_1 plants closely resembling IR 8 were obtained after three doses of IR 8. The resistant progenies will be multiplied and grown in pedigree rows as F_3 lines. This approach has been used in other combinations, for other diseases, and for other traits.

IR 8 type plants carrying blast resistance from other resistant donor varieties also are being developed. Other blast resistant varieties used are Sigadis, H-105, Leuang Yai 34, Pah Leuad, Gam Pai, Zenith and several ponlai varieties from Taiwan. These sources of broad resistance will be useful as new blast races develop or become established throughout tropical Asia.

Tungro

A mass screening test, as described in the IRRI 1965 annual report, is used to evaluate the tungro virus reaction of varieties and lines. Test plants 10 to 20 days old are subjected to feeding by caged viruliferous vectors (*Nepotettix impicticeps* I.). At present, 20–day old seedlings are tested. Several thousand lines are evaluated annually with this method.

Several tungro–resistant varieties were used as parents in the early crosses made at the Institute. They included Peta, Sigadis, Mas and Gan Pai. From these single crosses, a number of resistant lines have been selected which vary widely in plant type, time of maturity, tillering ability, plant height, and grain characteristics. They were selected from single crosses using the pedigree method. IR 8 was developed in this way from the Peta × Dee–geo–woo–gen cross. IR 8 is not as resistant to tungro as Peta and Sigadis, based on seedling inoculation tests, but is more resistant than such susceptible varieties as Taichung (Native) 1. However, severe losses from tungro have not been observed on IR 8 when seedlings were protected with insecticides in the seedbed and for the first 30 days following transplanting. When IR 8 seedlings were inoculated at 10 days after seeding, a high percentage of plants showed tungro symptoms. When inoculated at 20 days, a moderately resistant reaction was usually obtained. Consequently, in all crosses in which the source of resistance is from Peta, Mas, Sigadis, or Gam Pai, the seedlings are inoculated at 20 days.

Table 2. Some of the important crosses made for combining tungro resistance with the high yield and improved plant type of IR 8.

Recurrent parent		Resistant donor parent	Other desirable traits involved
IR 8/3	×	(Peta/5 × Belle Patna)	Short height, early maturity, good plant type
IR 8/3	×	(Peta/3 × Dawn)	Short height, good plant type, blast resistance
IR 8/4	×	(Dawn/3 × Sigadis)	Short height, blast and bacterial leaf blight resistance, moderate tillering, translucent grain, moderate amylose
IR 8/2	×	(Dawn × Pankhari 203)	Short height, blast and bacterial leaf blight resistance, translucent grain
IR 8	×	Sigadis/6 × T(N) 1	Short height, good plant type, blast and bacterial leaf blight resistance
IR 8/3	×	Pankhari 203	Short height, early maturity, translucent grain
IR 8	×	IR 5–47–2	Short and intermediate height, bactrial leaf blight resistance
T(N) 1	×	Gam Pai	Short height, blast resistance, waxy endosperm

Virologists have recently found that the variety pankhari 203 from India shows a higher level of resistance to tungro than other resistant varieties, based on the number of infected plants when inoculated at 10 days. Pankhari 203 is being extensively used as a donor parent for this reason. Large numbers of F_2 plants from the Pankhari 203 crosses have not been evaluated, but preliminary results indicate that highly resistant progeny can be obtained.

As in the case of blast, tungro resistant lines of improved plant type are being developed from a number of tungro resistant varieties using the backcross method of breeding as well as by the conventional pedigree method. Resistance behaves as a dominant trait and can be identified in F_1 plants of crosses between resistant and susceptible varieties.

Tungro resistance is being combined with blast resistance in at least one involving IR 8 as the recurrent parent. The F_1 plants of the cross Dawn × Pankhari 203 were crossed to IR 8. The F_1 plants from this three-way cross were first screened for tungro resistance using a test-tube testing technique perfected by IRRI virologists. Following this test, the seedlings were planted in the blast nursery for blast infection. Those F_1 plants showing both tungro and blast resistance were used for backcrossing to IR 8. The F_2 plants of the populations carrying two doses of IR 8 are being tested for reaction to both diseases.

Bacterial Leaf Blight

Bacterial leaf blight is difficult to evaluate on a precise scale under field conditions at Los Barños. As more knowledge is obtained about the prevalence and severity of the disease in other countries, field evaluation of breeding lines may be possible. At present, breeding lines are evaluated using virulent cultures in a flagleaf inoculation technique. Flag leaves are inoculated at the time of panicle emergence from the boot, and readings are taken 20 days later.

The flag leaf inoculation technique developed by IRRI pathologists is described in the 1965 annual report of the Institute. Resistant varieties have been found, and large numbers of hybrid lines have been tested.

Table 3. Some of the important crosses made for combining bactrial leaf blight resistance with the high yield and improved plant type of IR 8.

Recurrent parent	Resistant donor parent	Other desirable traits involved
IR 8	× (Sigadis × T(N) 1)	Short height, good plant type, blast resistance
IR 8/4	× (Dawn/3 × Sigadis)	Short height, blast resistance, moderate tillering, translucent grain, moderate amylose
IR 8/3	× (Bluebonnet 50/2 × Gulf-rose)/2 × T(N) 2	Short height. moderate amylose, translucent grain
IR 8/2	× (BPI-76 × Ponlai Varieties)	Short height, early maturity, blast and bacterial streak resistance, dark green leaf, slow leaf senescence
IR 8/3	× Zenith	Short height, early maturity, sheath blight, stem rot, blast, and bacterial streak resistance
IR 8	× TKM 6	Short height, early maturity, tungro bacterial leaf blight and stem borer resistance, clear grain.

A number of varieties of diverse origin are being used as resistant parents in the breeding program. Many japonica varieties are resistant as are some indica varieties and hybrid lines from japonica × indica crosses.

Usually, bacterial leaf blight resistance has not behaved as a dominant trait, but in some crosses, F_1 plants from single and backcross combinations have shown a moderately resistant reaction. In the backcross of IR 8/2 × Zenith and IR 8/2 × CI 9210, the F_1 backcross plants carrying resistance were moderately resistant. The backcross breeding method is used, but since in most crosses resistnce is not a dominant trait, the F_2 populations of each backcross must be grown and resistant plants identified before further backcrosses can made. Preliminary results indicate that resistant lines are being developed, but full evaluation must await further testing.

Bacterial Leaf Streak

Bacterial leaf streak reaction can occasionally by determined under field conditions when epidemics build up following storms. A reliable artificial inoculation technique is needed for screening breeding lines. Considerable progress has been made using natural infection data, and a number of resistant varieties have been identified. These include many japonicas, Taichung (Native) 1, Sigadis, 81 B–25, Zenith, and others.

Other Diseases

Other diseases which must be considered by the breeder are sheath blight, stem rot, and several viruses. Tests conducted to date indicate that Peta and IR 8 are reasonably tolerant to sheath blight, but occasionally considerable infection appears in IR 8 fields. Most U. S. A and japonica varieties are quite susceptible. Zenith, a U. S. A. variety, appears to be resistant. Improved testing methods are needed before significant progress can be made on this disease.

Stem rot is of minor importance in tropical Asia, but existing varieties probably carry a reasonably high degree of resistance. The cut-stem inoculation test developed by Institute pathologists has not been used extensively. The leading new selections are tested for their reaction to stem rot to make certain that they are moderately tolerant.

Grassy Stunt

Grassy stunt causes serious losses when the vector *Nilaparvata lugens* is not controlled in the seedbed and immediately after transplanting. Varietal differences in severity of infection are indicated but all varieties show symptoms. Highly susceptible varieties, such as most japonicas and some of the U. S. A. varieties show extremely severe losses when leafhoppes are not controlled during the early vegetative stage. Under similar conditions, only minor yield reductions have resulted with Peta, Sigadis, and Mas. Until more reliable testing methods are developed, it would be difficult to breed for resistance.

Little is known about varietal resistance to yellow dwarf and orange leaf. As these two diseases cause only minor losses, they do not receive major attention at this time.

Conclusion

The ocmbining of resistance to blast, tungro virus, and bacterial leaf blight into single strains possessing an improved plant type has begun. At this time, many improved plant type lines combining excellent blast resistance with moderate bacterial leaf blight resistance and the tungro resistance of Peta or Sigadis have been obtained. Many such lines are now being selected for other plant characteristics preparatory to yield testing. As mentioned earlier, the plant type of IR 8 is being combined with the blast resistance of Dawn and the tungro resistance of Pankhari 203 in the backcross IR 8/2 × (Dawn × Pankhari 203). F_3 or F_4 lines from this backcross which resemble IR 8 and appear to be breeding true for blast and tungro resistance will be crossed with bacterial leaf blight resistant F_1 plants from the backcross IR 8/5 or 6 × Zenith.

A large number of crossed seeds will be produced and numerous F_2 plants saved from all populations. When this stage is reached, the morphological appearance of all plants should closely resemble IR 8. The F_8 seedlings of many lines from these populations will be screened for resistance to all of the diseases concerned.

Breeding for disease resistant, high-yielding varieties of varying maturity is also underway. Strains as early as 90 to 100 days (seeding in seedbed to maturity) to as late as 150 days are being developed. As high-yielding strains of early, midseason and late maturity become available, they will be substituted for IR 8 as recurrent parents in the various crossing programs for disease resitance.

Similar procedures are used the development of smooth or glabrous plant parts, grain characteristics, and other traits. Short, medium, and long grain strains with an IR 8 plant type are being developed. A translucent grain appearance is thought to be desirable in reducing breakage in milling. This trait is being successfully combined with other desirable traits, as is varying amylose content and gelatinization temperature of the grain starch. The above traits are present in certain of the disease-resistant parental varieties and are being incorporated into high-yielding varieties along with disease resistance.

While it will take considerable time to accomplish all of the objectives outlined here, rapid progress can be expected when it is realized that in addition to the resources provided by IRRI, two and sometimes three plant generations a year are possible in the tropics.

Furthermore, rice breeders in several tropical Asian countries are crossing high-yielding, improved plant type varieties with their local varieties.

It can be expected that within a reasonable length of time, high yielding disease resistant, improved plant type varieties possessing an extremely wide range of genetic diversity will be available to the Asian rice farmer.

Discussion

T. Hirano, Japan: As I mentioned before, we have experienced that the promissed highly resistant variety got severe damage from blast, three years after distribution in the commercial field. According to your result, there are many races now in the U. S. A. Your variety, "MoR-500" is only susceptible to race "7", and the variety "Nira" is only susceptible to race "1".

Therefore we can easily guess to accumulate the resistant genes to each race by crossing these varieties. The appearance of new race pathogenic to these hybrids would be the further problems and the rates of its distribution. How long would you speculate that this new resistant hybrids keep their characteristics?

Answer: Blast resistance of a broad spectrum should be the goal. This type of resistance should remain effective over a longer period of time. In the U. S. A., the Dawn variety may possess resistance of this type. It has been grown commercially in the U. S. A. for 4 years and experimentally for several years prior to this. So far, Dawn is showing a resistant reaction to blast in the U. S. A. and in most locations where tested in Central and South America and in Southeast Asia.

H. Oka, Japan: I guess that: "early vigor" →high tillering rate: advantageous
→mutual shading→decline in the later stage: disadvantageous

Could you tell us your evaluation?

Answer: High tillering appears to be advantageous since high tillering varieties have been outyielding low tillering varieties. Mutual shading is apparently minimized in varieties of short plant height and erect leaves.

K. Fujii, Japan: I might miss to understand the problem in your explanation. But, could you tell me whether the superiority, for instance high productivity of IR 8 is maintained after the hybridization with disease resistant varieties?

Answer: Disease resistant hybrid lines, selected from IR 8 crosses, which resemble IR 8 are in the early stages of development. They have not been tested for yield but there is no apparent reason why these lines should not be expected to produce yields comparable with IR 8.

H. Oka, Japan: What might be the best gene source of resistance to the bacterial leaf blight? Do you prefer Zenith?

Answer: There are many promising sources of resistance to bacterial leaf blight. Zenith from the U. S. A. and several Taiwan japonica varieties have been used in the IRRI breeding program. In most crosses examined resistance to bacterial leaf blight does not behave as a dominant trait. However, in several Zenith crosses the F_1 plants have shown a resistant reaction.

T. Matsuo, Japan: Did you find any correlation (Genetic or phenotypic) between dwarf gene and resistance to any disease?

Answer: There does not appear to be any clear cut genetic correlation between the dwarf gene of the Taiwan indica varieties (Taichung Native 1), I-geo-tze, and Dee-geo-woo-gen) and resistance to diseases.

R. Ito, Japan: Short stem character of IR 8 is said to have come from single gene. Then, if IR 8 is used as parent variety for breeding, it may be impossible to breed out, intermediate height variety suited to each ecological region. Isn't it?

Answer: The short stature of IR 8 which was derived from Dee-geo-woo-gen is mainly determined by a single recessive gene. Minor genes are also involved and through selection lines shorter and taller than IR 8 which carry the dwarf gene have been produced.

S. C. Hsieh, Taiwan: You tested blast resistance at the seedling stage only in the course of selection as shown in your slide. Do you think it is effective without testing of adult plant?

Answer: Yes, for the sake of testing large numbers of lines early in the breeding program.

K. Toriyama, Japan: For the breeding of resistance to blast, you used many resistant gene source. Does this mean the preparing the new race occurence? Then, which is better changing these resistant varieties when new race appear, or combinig the many resistant gene in one variety?

Answer: In breeding for resistance to blast, we are using parental varieties which show resistance to many races as measured by their reaction in blast nurseries growing at many different locations. This would be classed as resistance of a broad spectrum. Perhaps the breeders may not be able to maintain adequate blast resistance by introducing single-gene resistance to varieties as needed. This method might be effective over a small area such as Japan but probably impractical when considering all of tropical Asia.

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