

# Breeding Rice for the High-Potential Irrigated Systems

**A**BOUT 50% of the world's rice area is irrigated, but that area produces more than 75% of the world's rice. The equivalent figures for West and Central Africa may not be so impressive, but there is no doubt that irrigated systems have the potential to produce the highest yields, and breeding rice plants for these systems has useful spin-offs for the remaining lowlands with less than complete water control.

## Evolving priorities

“The history of WARDA's breeding for irrigated systems is complicated by the fact that until 1997 the program division structure was not simply divided between rainfed and irrigated,” explains WARDA Irrigated Rice Breeder and Irrigated Rice Program Leader Kouamé Miézan. Formerly, the Sahel Station was a program in its own right, and only in 1997 did it become the main base for an expanded program on irrigated rice for the whole of West Africa. Thus, as we look at the breeding activities, we start by looking only at the Sahelian irrigated system.

“When I came to Senegal in 1990,” continues Miézan, “our main concern was to increase the available options for double-cropping.” That is, planting two rice crops in the same field in one year, one in the wet season and one in the dry season. “We were looking either for varieties tolerant to the extreme temperatures in the Sahel, or else varieties with a cycle length which would allow them to avoid the extreme temperatures.” The need for detailed understanding of varietal responses to climatic differences led the Sahel team to develop the crop model RIDEV (Rice Development) to predict a variety's

development and the level of temperature-induced sterility given its location and sowing date.

The other main concern for the Sahel was salinity, which is a major problem in the Senegal River delta—a major rice-producing area in the region. Here, tolerant varieties could directly contribute to reduced yield losses.

One major difference between irrigated systems and rainfed ones is the fact that the former are invariably market oriented. Thus, irrigated-rice farmers are looking to make profit. They are prepared to invest in their crop in ways that are rarely feasible options for farmers in subsistence systems, in particular in mineral fertilizers and herbicides. Consequently, any variety that is responsive to such inputs will be favored over one that is not, so that farmers may maximize the returns to their investments. Another important aspect of marketing is the preferences of the consumers, or rather how the farmers can increase the market value of their produce. Even at local markets, consumers will pay a premium for quality rice, such as long and slender or aromatic grains.

Since 1997, the irrigated-rice team has also been looking south to the savanna and forest zones. Where

water is well controlled, the considerations are similar to those in the Sahelian systems, since fully irrigated systems only pay off with high-input, high-output, market-oriented production. However, additional problems rear their heads in the humid zones (both southern savanna and forest), such as African rice gall midge and iron toxicity.

One major complication south of the Sahel is the definition of ‘irrigated systems.’ The degree of water control may vary from one farmer’s field to the next, or from one year to the next in the same field. As water management becomes less ‘tight’ and the risks increase, it is necessary to adjust management strategies, including the use of adapted varieties with characteristics such as weed competitiveness, height (in case of flooding) and tillering capacity.

### Raw material

“In the early days,” says Miézan, “it was generally assumed that irrigated rice in West Africa—especially in the Sahel—was much like irrigated rice elsewhere in the world.” Consequently, the strategy was to introduce varieties that had been successful elsewhere, and test them under Sahelian conditions. A key player in this was the International Network for Genetic Evaluation of Rice (INGER) under the auspices of the International Rice Research Institute (IRRI). INGER provided a lot of material from all over Asia, but also from elsewhere (for example, Brazil). IRRI also provided a second channel of material, as Miézan had contact with their principal breeder, Dr Gurdev Khush, who sent some material for testing in the Sahel.

Of course, WARDA was not the only institution introducing and testing exotic rice varieties for the irrigated systems; other players in the 1970s and 1980s included the International Institute for Tropical Agriculture (IITA), the *Institut de recherches agronomiques tropicales* (IRAT) and the national agricultural research institutions (NARIs). Thus, a plethora of exotic rice was ‘given a chance’ in the Sahel.

### Evolution of the breeding strategy

**First, or short-term, strategy:** *Introduction of exotic material from Asia and elsewhere; primarily for direct release, later to provide raw material for the breeding (crossing) program. Traits: earliness (for double-cropping), extreme-temperature tolerance, salinity tolerance.*

**Second, or medium-term, strategy:** *Crossing of introduced materials (*Oryza sativa* subsp. *indica*); to combine useful traits. Traits: as for short term, plus grain quality.*

**Third, or long-term, strategy:** *Intra- and inter-specific crossing of introduced *indicas* with traditional *O. sativa* subsp. *japonica* (intraspecific) and with indigenous *O. glaberrima* (interspecific); for traits not available in *indica* material, also to generate diversity for the breeding program. Traits: resistance to rice yellow mottle virus.*

Subsequently, the WARDA, IITA, IRAT and IRRI rice testing programs in Africa were merged into a unified International Rice Testing Program (IRTP, now the International Network for Genetic Evaluation of Rice in Africa, INGER-Africa).

Notable successes of WARDA’s introduction and screening activities have been the Sahel varieties: Sahel 108 (IR 13240-108-2-2-3) from IRRI, Sahel 201 (BW 293-2) from Sri Lanka, and Sahel 202 (ITA 306) from IITA. Between them, these varieties now dominate the irrigated rice area of the Senegal River valley both to the north (Mauritania) and to the south (Senegal). Sahel 108 has also been released in Burkina Faso, and Sahel 202 in Cameroon, Ghana and Nigeria. We reported on the adoption of these varieties last year (*see* Box ‘Sahel 108 and other Sahel rice varieties,’ *WARDA Annual Report 2000*, page 11).

“Even today,” Miézan notes, “introductions are still of value and will continue to be so. We are no longer looking for material for direct release only, since exotic material can bring useful traits and diversity into the breeding program.” In fact, the team continues to screen about 300 such introductions every year.

## Breeding in earnest

In the early 1990s, when the Sahel Station was established, there was neither infrastructure nor staff to carry out crosses or even to handle segregating populations. Consequently, when Miézan launched his breeding activities he was obliged to use a rather circuitous route. “I identified suitable parents here in Senegal,” he explains, “but then sent them for crossing to WARDA’s lowland-rice breeder based at Ibadan, Nigeria [WARDA’s Nigeria Station, hosted at IITA’s headquarters]. I then received second-generation material, which I grew and selected here at N’Diaye [WARDA’s Sahel Station].” These selections were designated as the ‘WAT’ series to show that they were WARDA–ADRAO crosses made at IITA.

These early crosses made at IITA were between exotic parents of *Oryza sativa* subspecies *indica*, using essentially material from Asia. A similar crossing program continued at N’Diaye once the Sahel Station had the resources to do the work. These ‘indigenous’ crosses, however, are designated ‘WAS’ for WARDA–ADRAO Sahel.

The main goals of these *indica*–*indica* crosses were to improve the plant type (height and panicle exertion),



Intraspecific (*indica*–*indica*) line at N’Diaye, Senegal

tolerance to salinity, and grain quality, and to reduce duration without significantly affecting yield potential.

## Looking further afield

Rice yellow mottle virus (RYMV) is a major viral disease of irrigated and rainfed lowland rice in Africa. None of the widely grown, popular irrigated-rice cultivars in West Africa is resistant to this disease.

“When we started to think seriously about breeding for resistance to RYMV, we hit a problem,” explains Miézan. “In the mid-1990s, we had only one *indica* variety [Gigante (Tete) from Mozambique] that was highly resistant to RYMV, but it has a poor plant type (too tall and poor grain quality), is susceptible to blast disease, and doesn’t yield well.”

“To make matters worse,” explains WARDA Pathologist Yacouba Séré, “the RYMV itself is highly variable, so we could not, and cannot, rely solely on one source of resistance.” Fortunately, screening activities at IITA (Ibadan) and at WARDA (M’bé) had identified resistant and tolerant material among both *Oryza sativa* subspecies *japonica* and *Oryza glaberrima*.

Thus, the pieces were in place for a breeding program for RYMV resistance in irrigated rice. “The only remaining hurdle was the crossing itself,” laughs Miézan. At that time, WARDA’s upland interspecific breeding program (involving *Oryza sativa* subsp. *japonica* and *O. glaberrima*) was still in its infancy—the first NERICAs were still to be developed. However, IRRI, the *Institut français de recherche scientifique pour le développement en coopération* (ORSTOM, now *Institut de recherche pour le développement*, IRD), and Japanese institutions had made experimental crosses, mostly for genetic studies. In particular, ORSTOM had found *glaberrima*–*sativa* hybrids highly sterile. However, the WARDA–Sahel team did not give up, and the fruits of their efforts were reported last year (‘Rice Yellow Mottle Virus,’ *WARDA Annual Report 2000*, pages 27–37). Despite the fact that some of the original ‘upland’ NERICAs have shown promise in the lowlands, evaluations—by Miézan

and his team—of several interspecific (*sativa–glaberrima*) progenies have shown that *indica*-based progenies are most appropriate for irrigated and rainfed lowlands.

“A major spin-off of the interspecific hybridization work,” enthuses Miézan, “is the diversity that it has generated.” Any single cross can generate amazing variation among the progenies, but the interspecific crosses bring in genes previously unknown in irrigated rice. “Somewhat surprisingly, but most useful, is the variety in plant type that the interspecific work has produced,” says Miézan. “Plants with different stature and structure opened up the possibility of using this material in ‘rainfed’ lowlands, where water control is not ideal. Thus, *Oryza glaberrima* can contribute significantly to improving irrigated and lowland rice cultivation in the region. However, hybrid sterility with *Oryza sativa* is still a problem.” This issue is currently being addressed by Sigrid Heuer (*see* Box ‘Investigating hybrid sterility at the molecular level,’ page 20).

### Sorting through the mass of material

Given the wealth of material that is now available to the program on a yearly basis, Miézan and his team have a

lot of screening and selecting to do. The network of activities is depicted in Figure 1. “The system looks very complicated,” explains Miézan, “simply because we want to make the best use of the available material—we don’t want to lose anything potentially valuable. However, at the end of the day we are looking at introducing between 300 and 600 new lines into the system each year, and hopefully seeing five to ten of those go right through to release in one or more of our target countries.”

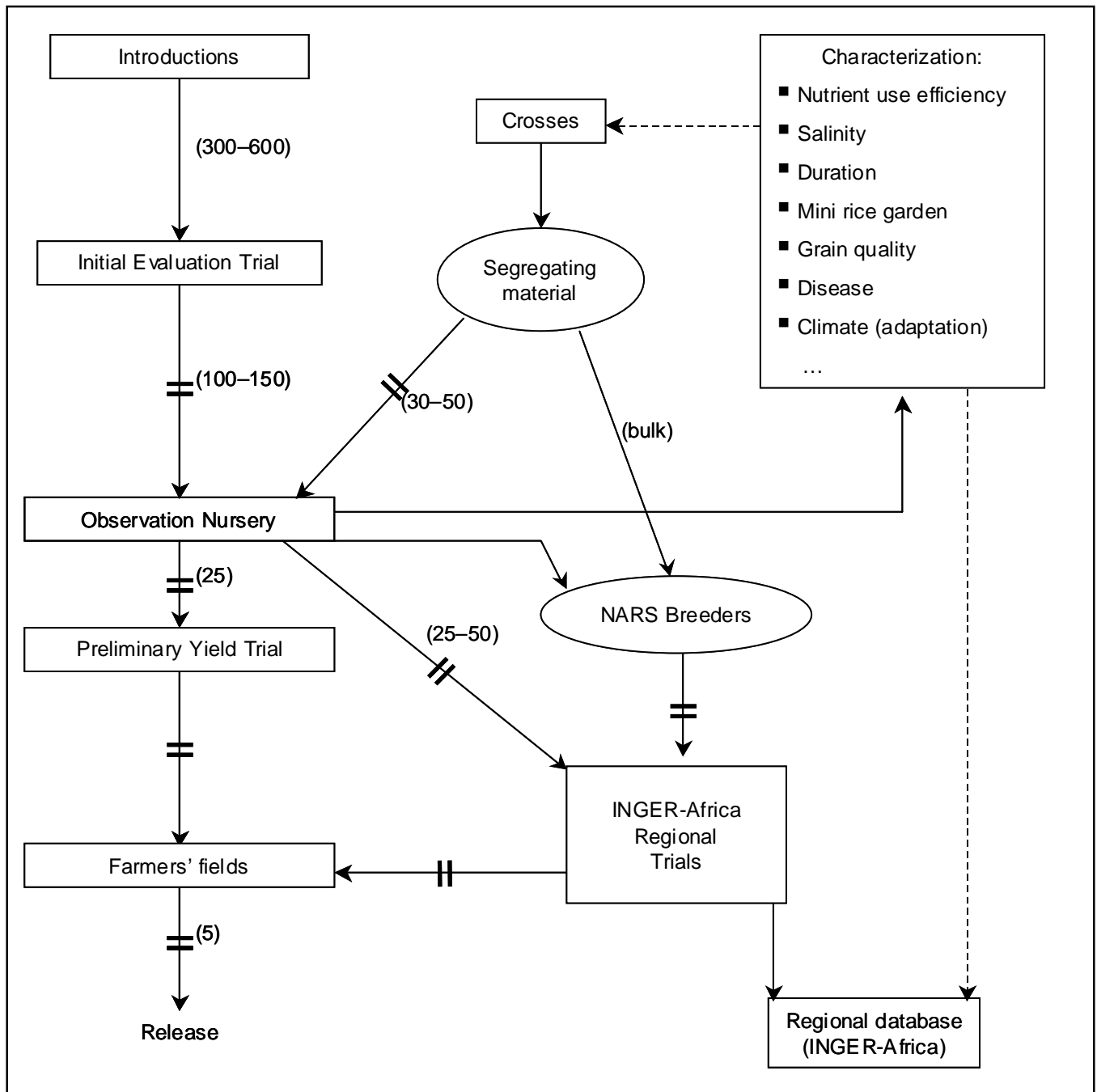
The process starts at N’Diaye. The Senegal River valley is considered a good place to start, because the selection pressure is not strong. The philosophy in the initial screening (Initial Evaluation Trial) is not so much to select the best, but rather to eliminate the worst material that is not at all suited to the environment. In this way, the 300–600 entries are reduced to between 100 and 150. These selections are divided into two groups on the basis of cycle length: short and medium duration.

The short-duration material is given the toughest time, since it is from these lines that the team wants to select varieties for the dry season. Consequently, these lines are almost immediately re-sown in the following dry season. The selection pressure is high, and many will not flower. Those that do survive and produce seed go



Two interspecific lines derived from a single cross: one with awns (left), the other with long glumes (right)

Figure 1. Breeding and selection of new varieties of irrigated rice by WARDA and its partners



### Investigating hybrid sterility at the molecular level

A major problem in interspecific hybridization work is the very poor fertility of the first hybrid generation and its progenies. This was not only true in the production of WARDA's upland NERICAs, but also in the crosses conducted by the irrigated-rice team involving *indica* varieties and *Oryza glaberrima*.

Sigrid Heuer was awarded a post-doctoral scholarship by *Deutscher Akademischer Austauschdienst* (DAAD) in early 2000 to look at the processes underlying the crossing barriers between the two cultivated rice species. "My first problem," she explains, "was to get some sterile plants to work on." For obvious reasons, breeders only select fertile plants. "Having screened hybrids for sterility in the dry season," Heuer continues, "we needed to re-check our results in the wet season—heat also induces sterility, and the dry season is very hot in the Senegal River delta!" A major advantage of working in the Sahelian zone is the ability to advance breeding material by two generations per year, by growing in both wet and dry seasons; however, the dry-season plants always risk heat- (and cold-) induced sterility. "In the dry season of 2001," Heuer continues, "I had the privilege of being able to use the climate-controlled greenhouse and laboratory facilities of the *Centre d'étude régional pour l'amélioration de l'adaptation à la sécheresse* (CERAAS) at Thiès (western central Senegal)." With the climate control, the temperature can be kept below sterility-inducing levels.

Detailed studies finally centered on one line that was segregating for sterility—that is, it was still producing a mixture of fertile and sterile offspring in the third generation after the second backcross to the parents. "I have classified the 33 plants I was working with," explains Heuer, "into fertile (>60% seed set), semi-fertile (30–60% seed set), and highly sterile plants (<30% seed set). Looking at the pollen, it became clear that the spikelet sterility correlated well with pollen sterility" (see Fig. 2). A large proportion of the pollen of sterile plants stops developing at an early stage and is therefore sterile. The higher the number of sterile pollen grains (microspores), the lower was the seed-set.

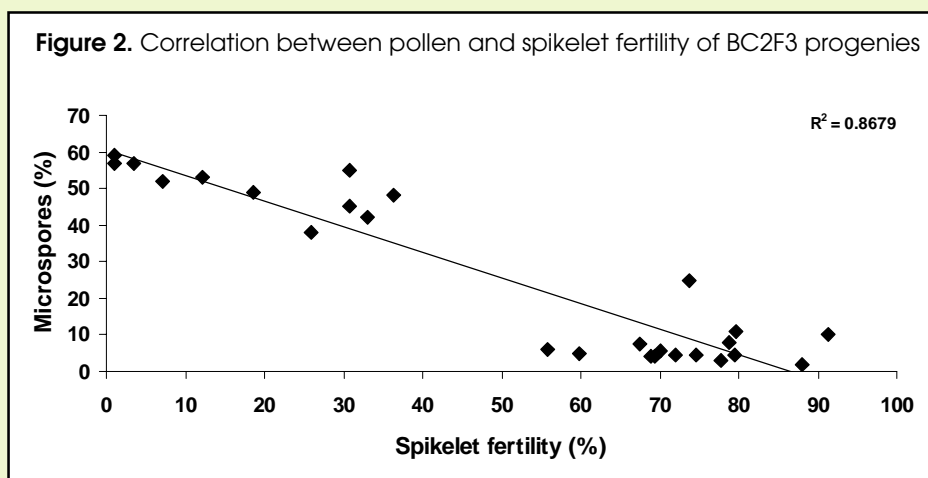
"Apart from our interest in better understanding the processes underlying crossing barriers," Heuer continues, "we wanted to identify

markers that would allow us to predict whether hybrids will be fertile or not. Those markers would also enable us to identify parents from which fertile hybrids could be produced." In Asia, a particular gene locus for sterility, known as *S5*, has been shown to be important in *indica-japonica* sterility. Recent analyses conducted by the *Institut de recherche pour le développement* (IRD) in Montpellier, France, suggested that another locus, called *S10*, is linked to sterility in *sativa-glaberrima* hybrids.

"On the basis of this information," says Heuer, "several markers close to the *S10* locus were tested in order to determine whether there was a correlation of the markers with sterility in our material. The two markers provided by IRD associated well with sterility: with one marker we can clearly distinguish highly sterile plants from semi-fertile and fertile ones; with the second marker, we can additionally differentiate two groups of semi-sterile plants, namely those with and without microspores (immature pollen grains)." This confirmed a role for *S10* in the sterility of *glaberrima-indica* hybrids.

To test whether other sterility genes were involved, Heuer obtained 'wide compatibility varieties' (WCVs) from IRRRI. These are lines that have neutral alleles at the loci of various sterility genes (e.g. *S5*). "The theory is simple," explains Heuer, "if any of these other genes were involved in the sterility process of our crosses, then the offspring from crosses involving the WCVs

Figure 2. Correlation between pollen and spikelet fertility of BC2F3 progenies



would be fertile. We obtained 112 grains from 165 crosses with various *O. glaberrima* accessions and cultivated a subset of the hybrids at CERAAS. All of the resulting hybrids were 100% sterile and we did not find a single grain. These experiments assured us that *S10* is important for sterility in *glaberrima* hybrids rather than the WCV loci which were so important in Asia."

### Why do we bother? The *glaberrima* 'goldmine'

Given the sterility problem, just why does the breeding team bother with such difficult material?

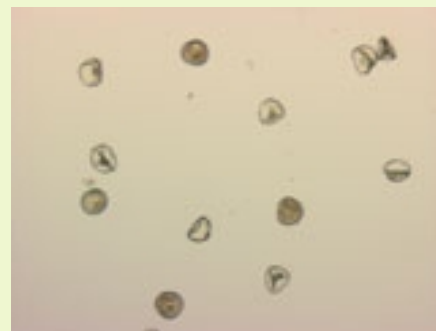
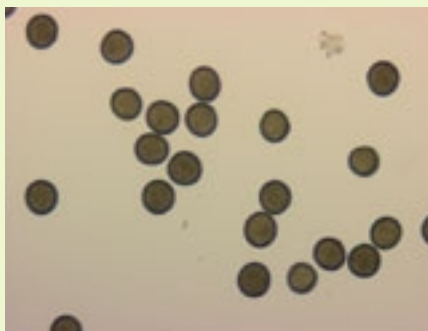
Just as the upland-rice breeding team found at WARDA headquarters, the irrigated-rice team is finding all sorts of interesting things in their interspecific hybridization work. "Some characters are subject to segregation distortion (that is, a bias in the hybrids to express the character like only one of the parents)—for example, all hybrid grains are white, whatever the color of the *glaberrima* grains," explains Heuer, "while some other characters show transgressive segregation." That is, the character differs qualitatively or quantitatively from both parents. "For example," continues Heuer, "many progenies have awns (long, hair-like projections on the grains), whereas none of the parents we used have them." In themselves, awns are neutral—some farmers like them because they make it difficult for birds to eat the grain, while others complain that awns make threshing difficult. Other examples of transgressive segregation, already seen in NERICAs, are number of secondary branches and number of grains.

"Sterility reduces yield," says Heuer, "but otherwise the interspecifics show great potential for improving the yield of irrigated rice. What is more, a single back-cross to the *sativa* parent can restore the fertility of *individual* plants. However, a second backcross to *O. sativa* generally increases fertility even more, and breeders prefer this plant material since desirable *sativa* traits are better represented." The value of this interspecific plant material cannot be overlooked given the success of the first set of NERICAs.

"Herein lies the value of Dr Heuer's work," says Irrigated Rice Program Leader Kouamé Miézan, "she has shown that the *S10* locus is (at least partially) responsible for the hybrid sterility. So, now, if we want to improve the fertility of future interspecific crosses, we need to find *Oryza glaberrimas* which do not have the sterility allele at *S10*, so that when these are crossed with *indicas*, or even *japonicas*, the resultant hybrids will not be sterile." The search goes on.

Meanwhile, the team continues with developing material the hard way. "Important goals for the breeding program," explains Heuer, "are weed-competitiveness and disease resistance." As in the upland NERICAs, the irrigated-rice team wants to transfer the profuse early growth of droopy leaves from *glaberrima* to their new material, in the hope that the plants will suppress weeds, and therefore out-compete them.

For rice yellow mottle virus (RYMV) resistance, the team uses its shuttle-breeding approach. "RYMV is not a serious problem in the Senegal River delta and valley," explains Miézan, "so we do initial screening here for plant type and other characteristics. Eventually, we plan to conduct rigorous screening for RYMV at WARDA headquarters, but that work has been put back by delays in the establishment of the containment facilities there. Meanwhile, our NARS partners in Mali and Burkina Faso are ideally placed to screen the material under natural RYMV infection, and we hope that they will play an active role in the selection work when the new irrigated interspecifics are sent out in nurseries in 2002 and beyond."



Comparison of fertile (left) and sterile (right) pollen

back to join the medium-duration selections for a more serious Observation Nursery in the following wet season. The cycle of observation nurseries continues for three years—that is, three seasons for the medium-duration lines, and six for the short-cycle ones. The output is the best-yielding lines—usually about 10 selections from each maturity-group—which are then ‘promoted’ to Preliminary Yield Trials.

### Partnerships and characterization

We mentioned earlier, however, that the goal is to maximize the use of the material. To achieve this, the same material that goes into the Observation Nursery is also sent to those national programs that have breeders with the resources to handle a large amount of material. These ‘strong’ national programs also receive bulked (unselected) segregating material—that is, material that is not yet fixed—from the breeding program. Meanwhile, the observation nursery entries are also subjected to detailed characterization, both at N’Diaye and at WARDA headquarters (mainly for RYMV).

“The detailed characterization work at such an early stage provides two benefits,” explains Miézan. “First, it provides a wealth of data for those entries that are eventually sent for regional screening through INGER-Africa and, second, it provides information for the breeding program, enabling us to select suitable parents for new crosses.”

Meanwhile, the network approach comes into its own in the selection of breeding material. “Effectively, we do something that we call ‘shuttle breeding,’” explains Miézan. “If you look at some of our more advanced lines, you will see a mixture of acronyms within the names, which designate where they were selected.” So, a line designated WAS122-IDSA-10-WAS-3-B-1, would indicate a cross made by WARDA Sahel Station, subsequently selected by the national program in Côte d’Ivoire (formerly known as IDESSA), and selected again at the Sahel Station. Details of how the process has been

working with one national program—that of Burkina Faso—are given in the Box ‘Working together: WARDA and Burkina Faso.’

Those national programs that do not have much capacity for screening and selection reap the benefit of the detailed program conducted by WARDA and its ‘strong’ partners. And all the national programs benefit from the crossing program conducted by the WARDA irrigated-rice team, since none of them would have the capacity—neither infrastructural nor financial—to handle as many crosses as Miézan and his team do.

### Down on the farm

Does this mean that the team excludes farmers from the variety development process? “By no means!” responds Miézan, “but in the initial selection process for hundreds of varieties, we have to rely on our good grasp of the farmers’ needs.” In addition to the fact that the irrigated ecology itself is more homogeneous than other ecologies in the region, market orientation streamlines the characteristics needed and most farmers are looking for yield, short to medium duration, and grain quality. Then for the Senegal River delta (Senegal and Mauritania) and similar coastal sites, salinity tolerance is essential.

Later, participatory selection of a reduced number of varieties is coordinated by the national institutions. Take, for example, the mechanism as it operates in Senegal. It is the national research institute (ISRA) that takes and multiplies the seed of promising varieties, and then coordinates the on-farm trials prior to release of any variety. “In fact,” says Miézan, “a participatory release mechanism was in place in Senegal before WARDA ever arrived on the scene. However, today, the pre-release trials coordinated by ISRA involve not only farmers, but also the local extension agency (SAED) and ourselves. After two or three years of such trials, we all meet to make recommendations to the national release committee.”

### Working together: WARDA and Burkina Faso

In terms of rice breeding, Burkina Faso has one of the 'strong' NARS in the region. The close collaboration between the two breeding teams illustrates the value placed by both WARDA and the national programs on partnership.

As part of a PhD research program, Sié Moussa of the *Institut de l'environnement et des recherches agricoles* (INERA) Farako-Bâ Station initiated a number of *indica-indica* crosses at WARDA's Sahel Station in 1994–1996. These were essentially to study the genetics of photo-thermal constants (as used in RIDEV—see main text, page 15); however, since several crosses appeared agronomically promising, they were advanced by standard selection methods.

After obtaining his doctorate, Sié returned to the Sahel Station in 1998 for a further year as Visiting Scientist. However, one of the features of Sié's work has been the almost seamless integration of activities that he has conducted under the auspices of WARDA with those for his national program. Sié identifies three kinds of breeders on the basis of the resources they have available and their experience: these correspond to 'weak' NARS, 'strong' NARS and WARDA. "WARDA breeders are equipped," says Sié, "with biotechnology, staff, infrastructure and scientific environment. This allows them to undertake in-depth research activities. My stays at WARDA allowed me to initiate work that I could not have accomplished in my home country." This work included the intraspecific *indica-japonica* and interspecific *glaberrima-indica* crosses that are beginning to produce progeny that are looking promising in the field.

The aim of Sié's on-going research program may be summarized as "increasing the genetic diversity of irrigated rice in the sub-region through a combination of direct introduction, and intra- and inter-specific crossing." More specific targets comprise varieties specifically adapted to double-cropping; improving grain quality; improving salinity tolerance; and, introducing tolerance to rice yellow mottle virus (RYMV).

In 2000, Sié evaluated 571 fixed lines from the intra- and interspecific material under various degrees of lowland water management and along the toposequence in south-west Burkina Faso—irrigated in Banzan and Karfiguela, and rainfed in Banfora. At flowering, Sahel Station Research Assistant Souleymane Gaye visited Burkina Faso and assisted Sié in the selection process. These selections were duplicated at the Sahel Station for advancement and further selection. The resulting fixed lines form the WAS-FKR-WAS series. For example, WAS161-B-6-FKR-1-WAS-1, and WAS122-IDSA-6-WAS-B-FKR-1-WAS-1; the 'IDSA' designation in the WAS122 line shows that the first NARS selection of this line was made in Côte d'Ivoire (at IDESSA), and demonstrates the value placed on 'recycling' the material among the NARS in the search for the best material.

"The participation of NARS breeders in the breeding activities of the program has contributed tremendously to accelerate the selection process as well as increasing efficiency," says Irrigated Rice Program Leader Kouamé Miézan. "This has enabled us to advance generations more rapidly and obtain many excellent fixed new *indica* lines." Some of the lines coming out of this shuttle-breeding process have been nominated for evaluation in regional observational yield nurseries through the INGER-Africa network.



Interspecific lines  
being screened  
at Banzan,  
Burkina Faso

## Looking south

In 1997, WARDA's Sahel Irrigated Rice Program became simply the Irrigated Rice Program. This has meant a broadening of horizons for the team based in Senegal.

In some respects, irrigated systems in the savanna and forest zones of the region were largely ignored prior by 1997, at least in terms of targeted breeding. The then lowland-rice breeder based at Ibadan was producing material for the rainfed lowlands, but many of the varieties developed by that program were found suitable for fully irrigated systems (*see* Box 'The WITA rice varieties'). Unfortunately, the irrigated-rice varieties developed in the Sahel were not evaluated in the humid zones at that time.

With the expansion of the mandate of the irrigated program to the humid zones, material developed for irrigated systems in the Sahel has been increasingly tested at WARDA's main research station in the forest-savanna transition zone of Côte d'Ivoire. "Several of the varieties are very promising," says Inland Valley Consortium Scientific Coordinator Marco Wopereis, who supervised the initial screening at M'bé, "and we expect to see them in multilocational testing, at least in Côte d'Ivoire, Burkina Faso, Mali and Nigeria, in 2002."

A major aspect of moving into the humid zones is the issue of water control. Pierrick Fraval, Water Management Economist with the International Water Management Institute (IWMI)/Cemagref/WARDA at WARDA's Sahel Station, explains: "While in the Sahel, irrigation is essential for rice cultivation and irrigated systems are clearly defined—you either have complete water control or you do not have rice—irrigated systems in the humid zones (savanna and forest) cannot always be clearly delimited. In these agro-ecological zones, the term 'irrigated' is sometimes used strictly for irrigated lowland with full water control, sometimes it includes the important surface areas of lowlands with some degree of water control. In addition, it is quite possible to have a field where a farmer is managing tight control of the water supply adjacent to another field where a farmer is

exercising almost no control of the water. The same thing can happen from one year to the next in the same field, depending on a particular farmer's resources, and the overall water supply." This range of environmental conditions makes breeding for irrigated rice in humid zones a bit more complicated and may require a slightly different strategy.

"For this reason," Miézan continues, "we are increasingly looking at irrigated systems in the humid zones as an intensified lowland continuum based on the level of water-management in the lowlands" (*see* Figure 3). Although an irrigated-rice variety may grow well in any zone provided that water control is maintained, the minute—or rather season—that water supply gets out of control due to limited irrigation infrastructure, the crop may become exposed to traditional rainfed lowland constraints. Therefore, varieties as well as crop management options need to be adjusted accordingly.

"For irrigated systems in humid zones," says Miézan, "what we are looking for is an irrigated rice plant type with wider adaptability to lowland systems." This will require close collaboration between irrigated rice breeding and rainfed lowland breeding for sharing of genetic material and developing new screening methodologies. "For example," says WARDA Lowland Rice Breeder Howard Gridley, "some of the *indica*-based interspecifics may be too tall for fully irrigated ecologies, but may be useful for rainfed lowlands that face a flooding hazard."

## Dynamic present and promising future

A major impact of the 'breeding' work for irrigated systems in recent years has been the success of the three 'Sahel' varieties released in 1994, but even more exciting things are in the pipeline. In 2002, Senegal will release five new varieties from the breeding program. These are two short-cycle varieties introduced from IRRI, and three medium-duration varieties—two from IITA and one from Cuba. The same varieties are also doing well in Mauritania, and should be released there, too, either later in 2002 or in 2003. The interspecific and intra-specific

### The WITA rice varieties

“Until 1997, the WARDA Sahel Station was breeding irrigated-rice varieties for the Sahel ecology *only*,” explains WARDA Deputy Director for Research, Monty Jones. “However, the breeding effort for the rainfed lowlands—based at IITA in Nigeria—was generating material that was suitable for irrigated lowlands in the forest and savanna zones of the region.”

“The lowland varieties from the pre-1997 era are known as WITAs, for WARDA at IITA,” explains WARDA’s Lowland Rice Breeder, Howard Gridley, who joined WARDA in 2001. Several WITAs were released in Côte d’Ivoire in 1998, most of them for both irrigated and rainfed cultivation. Details are given in the following table.

Name (local)	Yield potential (irrigated, t/ha)	Height (cm)	Cycle length (days)	Characteristics
WITA 1 (Yabra)	9	110	130	Iron-toxicity tolerant; Blast resistant
WITA 3 (Kossou)	9	90	125	Iron-toxicity tolerant
WITA 7 (Gagnoa)	8	115	125	Good grain quality
WITA 8 (Sandela)	8.5	120	120	RYMV tolerant
WITA 9 (Nimba)	10	92	120	Early; RYMV resistant

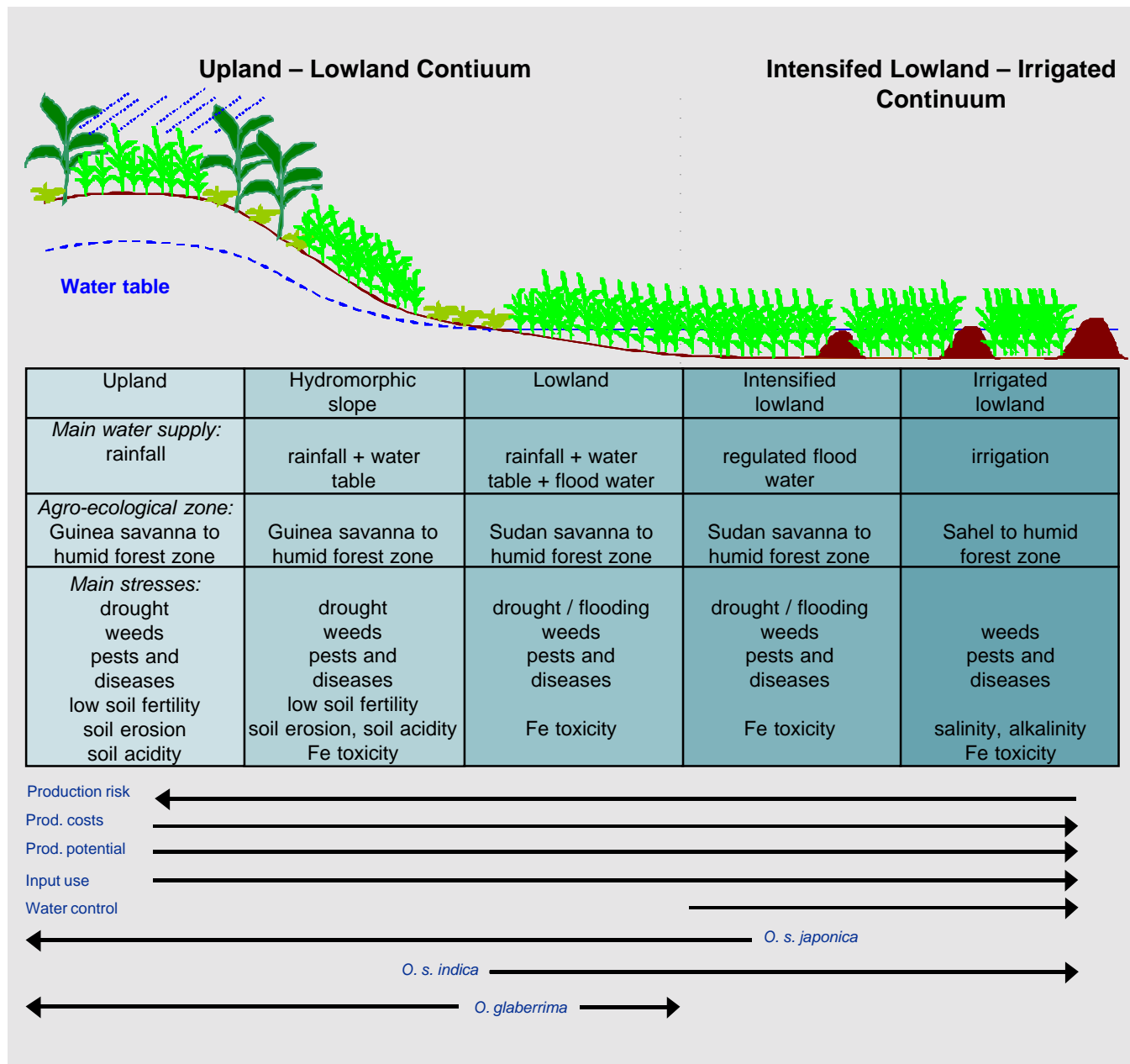
crosses made by the team are also bearing fruit: “In the 2002/03 season,” explains INGER-Africa Coordinator Robert Guei, “we will have *indica*-based interspecific lines from the Sahel Station in regional yield trials through INGER-Africa for the first time, together with intra-specific lines (*indica-indica*).”

Among the new targets of the irrigated-rice breeding work are increased nutrient use efficiency at different input levels (i.e. nitrogen and phosphorus) and good weed competitiveness. Here, a strong link between breeders and agronomists is needed. Stephan Häfele, WARDA Agronomist for Irrigated Systems, explains: “Concurrently with the selection process, we characterize about 30 varieties each season for nutrient use efficiency, weed competitiveness, salt tolerance and photo-thermal constants. The results will help us later to choose appropriate varieties for different environments. For example, we found that the yield of Sahel 108 is very

low under weed pressure, although it is one of our best short-duration and high-yielding varieties. Therefore, we would not recommend that variety in highly weed infested areas or where farmers have problems with weed management. But where weeds can be controlled, Sahel 108 does give highest yields combined with high grain quality.”

The team has found varieties that are highly weed competitive. The use of varieties that compete well with weeds will enable farmers to save money by reducing the quantities of herbicides applied, which in turn will protect the environment. Results of preliminary evaluations are promising—some cultivars, such as Jaya and new *indica*-based interspecific progenies, had only small yield losses when grown without weeding. Such characteristics are extremely valuable, particularly in direct-seeding systems, where weeds are a major yield-limiting constraint.

Figure 3. Conceptual model of topographical and intensification continua of rice-growing ecologies



The need for varieties that can use fertilizer efficiently and enable the farmers to get more crop and more money out of their investment is increasingly voiced by irrigated-rice farmers. Preliminary evaluations have indicated that progenies of inter- and intra-specific crosses have a lot of potential to satisfy this need.

“The hope for an African agricultural revolution lies in the intensification and diversification of the lowlands,”

says WARDA Director General Kanayo F. Nwanze. The fully irrigated systems that are the target of the breeding efforts discussed above should represent the pinnacle of lowland intensification for rice cropping. “The potential for lowland rice cropping is estimated at 20 to 40 million hectares in West and Central Africa alone,” continues Nwanze. “Our long-term strategy addresses the issue of NERICAs in this most robust and promising ecosystem.”

