

Rice Yellow Mottle Virus

RICE YELLOW mottle virus is the most problematic disease affecting irrigated rice in West and Central Africa; it also affects rice cultivated in rainfed lowlands. When it first appeared in the huge *Office du Niger* irrigation area of central Mali, the farmers felt that they only had their god to turn to, and prayed for deliverance. WARDA and its partners have invested a lot of time and funds in the search for resistant rice varieties and in other aspects of the disease's biology with a view to providing a solution for the region's farmers.

What... where... how bad... and how?

What? Rice yellow mottle virus—usually known by its abbreviation, RYMV—as its name suggests, is a plant virus disease. It is endemic to Africa, having first been discovered in Kenya in 1966. It gains entry into rice plants through injuries, which may be inflicted by insects (which also act as vectors) or mechanically during the course of crop cultivation, for example damage to plants during hoe-weeding.

Where? RYMV was first recorded in West Africa in Sierra Leone in 1975. By 1990, it had been recorded in all West and Central African states, except Mauritania. It had also shown up in Madagascar and Tanzania. Over the last 20 years or so, it has become a major problem in irrigated rice systems, especially in Burkina Faso, Côte d'Ivoire, Mali and Niger, and in lowlands in Burkina Faso, Côte d'Ivoire, Senegal and Sierra Leone. It will, however, attack rice in any lowland situation.

How bad? RYMV can be devastating. Major field losses have been measured at 64–100% in Mali, and at 58–68% in Niger. That's a large proportion of a rice crop, and more than most farmers can afford. It's no wonder that farmers who suffered in the catastrophic epidemic

that affected 50,000 ha of the *Office du Niger* (Mali) in the early 1990s prayed for deliverance from the curse of the disease! However, RYMV is unpredictable in its appearance—for example, the irrigated rice scheme at Karfiguela, near Banfora, Burkina Faso, suffered heavy symptoms in 1990, and yield losses of between 0.4 and 1.6 tonnes per hectare were recorded, but by 1993 the disease



A rice field devastated by RYMV, Karfiguela, Burkina Faso, August 1990

was restricted to a few small patches in a few farmers' fields. WARDA's Plant Pathologist Yacouba Séré is under no delusion about the threat that RYMV poses: "RYMV has the potential to devastate lowland rice anywhere in Africa," he says. "And crop losses seem to be higher in the large monocrop irrigation schemes in the Sahel than in the smaller schemes in the humid zone." If we take that as our baseline, then there is in excess of 3 million ha of lowland and irrigated rice potentially at risk from RYMV in Sub-Saharan Africa.

How? There are two aspects to the "how" question. First, how does the disease 'get a hold,' or what puts a rice field at risk from RYMV attack? Second, how does the disease affect the plant and cause yield loss? We get the clue as to how the disease was encouraged by looking at the catastrophic epidemic of the *Office du Niger*. Séré again: "RYMV came almost as an immediate 'result' of changes in management of the irrigated rice crop. In particular, the change from direct seeding to transplanting." The act of uprooting the rice seedlings and transplanting them inevitably inflicts some damage on the roots.

If there is any RYMV in the field into which the rice is transplanted, the virus can enter the plants via the injured roots. Séré continues: "But then the disease was able to spread rapidly because 70 to 90% of the area in each country was planted with the same high-yielding varieties—varieties that are unfortunately susceptible to RYMV." So, when RYMV was not a problem, the fact that the popular varieties were susceptible to it was of no consequence. However, as soon as transplanting was introduced, giving RYMV a foot-hold, the susceptibility of the varieties was the farmers' undoing!

"There are four principal characteristics of RYMV symptoms on a rice plant," explains Séré, "and these give an indication of how yield-loss is effected: chlorosis of the leaves, stunting, reduced panicle exertion, and panicle sterility." Chlorosis in plants is a reduction in green pigment. Since the green pigment in plant leaves is the all-important energy-capturing chlorophyll, chlorosis results in reduced photosynthesis, and therefore reduced plant growth. Stunting refers to severely reduced plant height—infected rice plants are simply much shorter than healthy

Healthy (background) and RYMV-infected (foreground) rice. Note the paleness of the leaves (chlorosis) and short stature of the plants (stunting)



The panicles of infected plants (left) do not exert properly



There's no food inside sterile grains!



ones. Panicles are the grain-bearing parts of the plant and therefore essential to good yield. In RYMV-infested plants, the panicles often do not grow normally. What is more, many of the grains on an infested panicle are sterile—that is, either the grains are not formed or else they are empty.

With such potential to wreak havoc in lowland rice fields, and such unpredictability, RYMV was an obvious target for WARDA research. With WARDA taking the lead, the research takes on a regional perspective, and the individually affected countries are not working in isolation.

Groundwork and developing a research strategy for RYMV

WARDA's first experiences with RYMV were not alone. "Before WARDA joined the Consultative Group on International Agricultural Research (CGIAR) in 1987," explains WARDA Deputy Director for Research Monty Jones, "the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, also had a mandate for rice in West Africa." Thus, region-wide surveys for RYMV in 1984 were conducted jointly by WARDA and IITA. It was these surveys that detected the disease in the majority of West African countries. However, it was a few more years before RYMV came to the fore of the WARDA research agenda.

In the early 1990s, Yacouba Séré was working for his national program in Burkina Faso, but was also a member of the newly formed Integrated Pest Management (IPM) Task Force of WARDA. "In February 1992, we had our first meeting," he explains, "at which we identified regional priorities for disease, pest and weed research. RYMV and blast were identified as top priorities."

In September 1995, several donors sponsored a regional symposium on the disease to review the state of the art, and determine research priorities. Among others, representatives from the Malian and Nigerien national programs, together with representatives from the *Office du Niger* irrigation scheme, made it clear that RYMV

was their Number One rice research priority. The findings of the symposium were taken by WARDA and its IPM Task Force to develop the first RYMV research strategy for the region. "A project proposal based on this strategy was developed and then accepted by the UK Department for International Development (DFID)," explains Séré, "and much of the on-going work has been funded by DFID ever since." The research strategy that was developed in the mid-1990s remains relevant even today:

- Rice varieties resistant or tolerant to RYMV need to be identified to replace susceptible varieties grown by the majority of farmers
- Resistant rices need to be identified, even if not suitable for release to farmers, for use in the breeding program for RYMV resistance, and their resistance needs to be characterized; then, new resistant varieties can be bred from this material
- Strategic research concentrates on filling in the gaps in existing knowledge of the disease, especially in disease epidemiology, with a view to developing integrated management of RYMV in the lowlands of West Africa.

The importance of screening

The three countries that are the focus of the DFID-funded screening project share a common problem: most of their irrigated-rice farmers grow varieties that have proven highly susceptible to the onslaught of the spreading RYMV epidemic—Bouaké 189 in Côte d'Ivoire, BG90-2 in Mali, and IR 1529-680-3 in Niger.

Screening for resistance to RYMV was actually started in the mid-1980s by IITA. Owing to the ferocity of the virus epidemics, and the urgent need to find resistant material, large nurseries were established and distributed through the International Network for Genetic Evaluation of Rice in Africa (INGER-Africa)—formerly operated through IITA by the International Rice Research Institute (IRRI), but relocated to and operated by WARDA in 1997.

Diagnosing the disease

Symptoms are not always indicative of RYMV, so researchers require a simple test to determine whether the virus is present in plant tissues.

The fact that virus particles elicit an immune response from animals and plants is used by plant pathologists to aid the identification of virus diseases. Antibodies can be produced by inoculation of the virus into a suitable host (often rabbit). These antibodies can be isolated, purified, concentrated and then used as a sensitive test for the virus in plant tissue. 'Polyclonal' antibodies to RYMV have been developed at the WARDA pathology laboratory. These antibodies attach themselves to the virus's protein coat, they are easy to produce, and are not strongly pathotype-specific. These antibodies have been made available to WARDA's partners in those countries that need a rapid tool for diagnosing RYMV.

In order to ensure high disease pressure without the risk of starting an epidemic, screening for disease resistance is done in isolation, in what is known as a screen house. By this method, the test plants are not left to the vagaries of natural disease spread, which vary in space and time, but are artificially subjected to high disease pressure. At the same time, the virus is confined within the screen house and prevented from starting a disease outbreak in rice fields in the vicinity. The screen houses are also used for the uninoculated, or control, plants, to keep them free from possible outside infection.

At first, screen houses were only available at WARDA, and 'hot-spot' screening by the national programs depended on natural disease spread. However, the DFID project established screening facilities in Mali and Niger. These will improve the screening efficiency, especially as more and more breeding material needs to be tested.

Pathotypes: variations on a theme

"We did the initial screening against RYMV in the screen house at WARDA's Main Research Center at M'bé,"



Inauguration of the screen house constructed in Mali under the DFID-funded screening project

continues Séré. "We used an isolate of the virus from Gagnoa [south-central Côte d'Ivoire] and identified a good number of resistant and tolerant lines." The trouble was that when these lines were taken to other sites in Côte d'Ivoire for field testing, many of them were no longer tolerant! "This is why RYMV is the most problematic disease of irrigated rice in West Africa," says Séré. "The virus is highly variable—the viruses in one location are not necessarily the same as those in another location." The different types of RYMV are known as pathotypes. This makes the whole issue of rice resistance to RYMV rather complicated, since a variety that is resistant in one location to one pathotype may be susceptible in another location where there is a different pathotype.

A highly virulent pathotype is defined as one that attacks many of the differential varieties. Conversely, a pathotype with low virulence attacks only a few varieties (see Table 1). The virus isolate from Gagnoa, used in the early screening trials, had low virulence, and so the selected lines were attacked by the more virulent pathotypes of RYMV in the field at sites like Danané and Odienné.

Table 1. Virulence of two RYMV pathotypes on the differential set of varieties.

Differential	Reaction with pathotype†	
	Hypervirulent (from Odienné)	Hypovirulent (from Korhogo)
Gigante (Tete)	-	-
Bouaké 189	+	+
Faro 11	+	-
Morobérékan	+	-
Lac 23	+	-
ITA 305	+	-
PNA 647 F4-56	+	-
H 232-44-1-1	+	-

† + = symptoms, - = no symptoms.

Another source of pathotype variation

A rice variety that is grown at a site where it is resistant to the local pathotype may 'lose' its resistance if a new pathotype spreads into the area. But this may not be the only source of variation. Pathologist Yacouba Séré explains: "RYMV has its genetic code on a single strand of RNA, therefore any mutation is likely to be expressed in the virus makeup." Most organisms have two strands of DNA, so that mutation in one is likely to be masked (that is, prevented from being expressed) by the dominant gene for the same character on the other member of the pair. "Therefore," continues Séré, "there is potential for pathotypes to change by mutation." This has not yet been proved in the field, but WARDA has started to study the stability of the virus population structure at certain sites.

"With individual variation among pathotypes and varieties," explains Séré, "we end up with a matrix, or grid, of pathotype versus variety in terms of which pathotypes attack which varieties or, conversely, which varieties are susceptible to which pathotypes." Thus, a set of varieties may be used to differentiate a range of pathotypes—this is then known as a set of 'differential varieties.'

"At present we have a differential set of eight varieties for RYMV pathotype characterization in West and Central Africa," says Séré, "but this is being refined in collaboration with our NARS partners." 'New' virus isolates are collected in each country and then tested (in the same country) on a set of 15 to 20 varieties—the eight differentials are used in all the sets as a cross-reference point. "In Côte d'Ivoire," Séré continues, "we currently identify six pathotypes on the eight differential rice varieties."

Differences among virus pathotypes must be detectable at the molecular level. Our partners at the *Institut de recherche pour le développement* (IRD, France) and the International Laboratory for Tropical Agricultural Biotechnology (ILTAB, USA) have been working on sequencing of the genetic code of several RYMV isolates. This is with a view to developing pathotype-specific tests for use in outbreak areas.

First fruits of the search for resistance

Fifteen, or so, years of screening have not been without some success: resistant or tolerant material (*see* Box 'Resistance vs tolerance,' page 33) has been identified in the three main rice types.

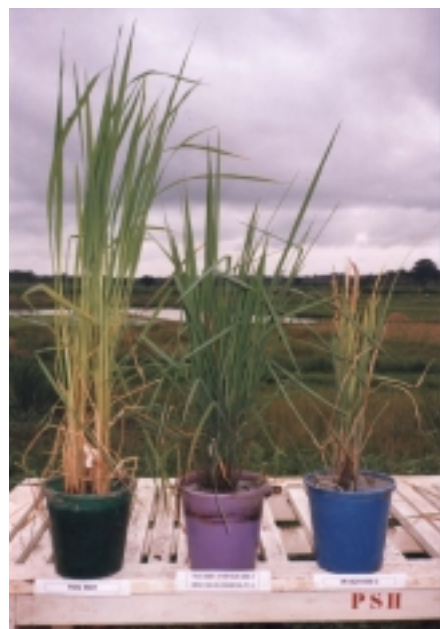
- Many *Oryza glaberrima* (native African rices)—but these are susceptible to lodging (falling over) and grain-shattering, and therefore low yielding.
- Many *O. sativa* subspecies *japonica* (traditional rainfed or ‘upland’ rices)—potentially suitable for direct-seeded rainfed lowlands, but not adapted to irrigated conditions.
- One *O. sativa* subspecies *indica* (traditional irrigated or ‘lowland’ rice) is highly resistant to RYMV—Gigante, a traditional cultivar from Mozambique; it is susceptible to blast and low yielding.
- A further 11 varieties that are resistant or tolerant to the Gagnoa virus isolate have been identified since 1998.

“In plant breeding and selection, ‘short term’ does not necessarily fit everybody’s definition of the phrase,” says Séré. “In 1999, we had these 11 resistant/tolerant varieties in hot-spot trials in three countries. Two or three of these gave yields close to those of the released varieties in the field with no disease pressure.” The implication is that, since these plants are tolerant to RYMV, they should yield better than the released susceptible varieties once the disease strikes—they are to be tested on farmers’ fields in Côte d’Ivoire, Mali and Niger in 2001. “In addition,” continues Séré, “we have recently identified at least four *japonicas* that have *indica* grain type”—when direct-seeded with close plant-spacing, these rices behave somewhat like lowland-adapted *indicas*—“and that give yields under virus pressure that are comparable with the yields of the popular varieties in the absence of RYMV.”

Breeding for resistance

“We had interesting resistant and tolerant material of *glaberrima*, *japonica* and the *indica* Gigante by 1996,” explains WARDA Irrigated Rice Program Leader and Breeder Kouamé Miézan, “so we started targeting intra- and inter-specific crosses at developing RYMV-resistant material. In particular, popular but susceptible cultivars,

such as IR 1529-680-3, BG90-2, Bouaké 189 and IR64, were crossed with Gigante, and also with resistant *glaberrimas*.” Screening against RYMV inoculum in the screen house has shown that both types of crosses have successfully transferred resistance to RYMV into the popular varieties.



Like other NERICAs, the cross (center) between *glaberrima* TOG 5681 and popular variety IR 1529-680-3 of Niger combines the best of its parents—in this case including the RYMV-resistance of TOG 5681

“Several years on, we have even more components for the breeding program,” says Miézan. “We have plants that are resistant to one pathotype of RYMV, and others that are resistant to several pathotypes. We also have the means of differentiating the resistant lines from those that are merely tolerant” (see Box ‘Resistance vs tolerance’). But, breeding is a slow process—until recently it has taken breeders anything up to 10 years to develop new varieties.” Enter molecular biology.

Resistance v tolerance

A crop variety is resistant to a disease if that disease has a less damaging effect on the resistant variety than it does on other (susceptible) varieties. The resistance may be the result of the disease being less able to infect the plant (i.e. enter its tissues), multiply or move within a plant of the variety, or it may be due to the variety's ability to grow and yield better than susceptible varieties despite being infected. The latter form of resistance is known as 'tolerance' (see Table 2).

Table 2. Effects of disease pressure on yields (g/m²) of rice varieties susceptible, tolerant and highly tolerant to RYMV. Note how the tolerant varieties out-yield the susceptible one at high disease pressure; the highly tolerant variety also out-yields the susceptible one at low disease pressure.

Variety	Reaction to RYMV	Disease (RYMV) pressure		
		None	Low	High
Bouaké 189	Susceptible	590	164	38
WITA 11	Tolerant	294	168	107
IR 47686	Highly tolerant	274	268	136

The trouble with tolerance

The problem with 'field' screening is that symptoms do not tell the whole story. As an additional level of assessment, plants classified as resistant or tolerant on symptoms were subjected to laboratory-based pathological tests, to look for the presence of virus particles within the plants. "Once we were in the laboratory," explains Pathologist Yacouba Séré, "we found that not all the resistant material was the same. Some of the lines that had no or few symptoms in the screen house had very little virus inside them and could rightly be classified as resistant. However, other lines that looked just the same as the resistant ones in the screen house were in fact full of virus particles. What is more, if we let the plants grow to maturity in the screen house, we discovered that those in the latter group in fact gave reduced yield." These plants can fairly be termed tolerant, but Séré sees little future for this group: "the plants in these groups may be tolerant, but they provide a source of virus inoculum ready to infect adjacent plants or neighboring fields. Since one of our goals is to reduce disease pressure in the field, I do not want such plants around, and neither should a conscientious farmer!"

In last year's Report, we mentioned that our partners at the IRD had identified a gene that confers RYMV resistance in both *Oryza glaberrima* and *O. sativa*, and molecular markers associated with it (see 'Molecular Biology Facilities at WARDA,' *WARDA Annual Report 1999*, especially page 20). WARDA Molecular Biologist Marie-Noëlle Ndjiondjop takes up the story: "with a desirable gene and appropriate markers to follow its inheritance by the offspring of a cross, we have the means to conduct marker-assisted selection for RYMV resis-

tance." The great advantages of marker-assisted breeding are, first, that the material does not have to be screened in the field or in the screen house in the early generations and, second, that the markers can be detected in young plants, so time and space is not taken up with growing large numbers of plants every season—only those with the required gene need be grown to maturity for their seed. "When we combine this with other tools, such as double-haploid breeding," continues Ndjiondjop, "we can speed up the production of useful lines considerably."

But the breeding does not stop there. “A variety with a single gene for resistance is still very vulnerable,” explains Miézan. “If the local virus pathotype should mutate, or another pathotype arrive in the area, the variety’s resistance could very well break down. In the worst scenarios, the disease resistance of upcoming varieties has been known to break down even before the variety is released. Then we are back to square one and years of work are effectively wasted!” This is why WARDA talks about ‘durable’ resistance—the aim of the breeding program is to combine several genes for resistance into varieties, so that they are fore-armed against mutations and invasions of new pathotypes. Ndjioudjop again: “once we know the type of resistance operating in a particular variety or line, and the genetics of its inheritance, then the same tools that make it possible to transfer one gene can be used to speed the process for combining resistance genes.”

Meanwhile, the John Innes Centre in the UK has developed transgenic resistance from the coat protein of the RYMV particle itself. This transgene has been successfully incorporated into popular varieties Bouaké 189 and BG90-2, which will be available for testing in the region once biosafety regulations are in place (*see* Box ‘Transgenics and biosafety’).

Epidemiology—the how and why of disease epidemics

“We do not want to be limited to using just resistant plants,” says Séré. “After all, we’ve been screening for over 15 years, and there are still no highly resistant varieties in farmers’ fields!”

“One thing that became perfectly clear at the 1995 symposium,” he continues, “was that we knew so very little about the epidemiology of the disease, and there were so many questions to be answered.” Thus, elucidating the components of RYMV epidemiology was, and continues to be, one of the principal foci of the WARDA research on RYMV.

Transgenics and biosafety

The transgenic rices developed by the John Innes Centre in the UK are ‘genetically modified organisms’ (GMOs). As such they need special treatment. “There are genuine concerns around the world about the potential effects of GMOs on the ‘natural’ environment,” explains Pathologist Yacouba Séré. The UK-based Gatsby Foundation not only funded the original research on RYMV at John Innes Centre, but have also been supporting WARDA’s efforts to ensure proper handling and regulation of the plants should they come to West Africa.

“Gatsby are funding the construction of a containment facility at our M’bé site,” continues Séré. The idea of this construction is to enable the testing of the new material in an appropriate climate and with the local pathogens with minimal risk of their escape. The containment facility will effectively isolate the transgenic material from the surrounding vegetation. Not only is it located at some distance from the nearest experimental fields, but it is in itself a barrier to pollen flow—it is the fear of pollen flow from transgenics to cultivated and wild species, and the consequent ‘escape’ of the transgenes that environmental groups are so worried about. “Thus, we will be able to test the material to ensure that it is stable against the virus pathotypes here, and also has no undesirable effects once exposed to the prevailing climate, while safeguarding the surrounding environment from possible contamination,” says Séré.

“In addition,” he continues, “we have been working with our member states on the whole issue of biosafety.” First, the state governments need to know what the GMO issue is all about, and then they need appropriate regulations. “And it is no good having a biosafety regulation in only one or a few countries,” says Séré. “Farmers can cross international borders as easily as anyone else, and cross-border trade in seeds is a well-known phenomenon in the region.” WARDA has been actively involved in the development of biosafety legislation in Côte d’Ivoire and this has regional implications: it could serve as a template for regional guidelines, as well as being promoted among other member states’ policy-makers as the basis for national legislation region-wide. “Without blanket application of biosafety regulations for the exploitation, diffusion and marketing of transgenic crop plants, we will not consider introducing such plants into individual countries of the region,” explains Director General Kanayo F. Nwanze.

An important early finding was that RYMV is ‘inoculum dependent.’ That is, the more virus there is in the environment, the worse the disease affects the crop. Thus, if we have a field of a susceptible variety, the worse the disease pressure, the more virus (inoculum) is produced—a vicious spiral.

“What we want, therefore,” says Séré, “are options for reducing disease pressure in the field. Planting resistant varieties is just one of these options.”

A first question that anyone interested in crop pest control is likely to ask is: “where does the organism spend the off-season?” In the case of RYMV, rice is not cultivated in the fields continuously for 12 months each year, so the virus has to live somewhere else when there’s no rice in the fields. Three groups of alternative hosts have been identified for RYMV: crop residues, volunteer rice plants, and weeds. Crop residues are the bits left after harvest of the grain, they include roots, stems and straw. RYMV can survive on any or all of these—simple destruction of crop residues after harvest should, however, remove this option. Volunteers are rice plants that grow up during the off-season from grain scattered or spilled at harvest time. These are a little more problematic than residues, in that they have to be dealt with some time after the harvest of the crop, which puts an extra demand on the farmers’ time. However, removal of volunteers could be combined with a post-harvest weeding, that would also deal with the third reservoir of off-season virus inoculum.

Once we know where the virus spends the off-season, the next question is: how is it transmitted? “The essential aspect of the epidemiology of RYMV,” explains Séré, “is the role of mechanical injury of plants—any mechanical injury in the presence of virus particles.” In addition to root damage during transplanting, rice plants are especially prone to damage during weeding operations when farmers use hoes—if an infected rice plant is damaged during weeding, virus is deposited on the hoe. If a healthy plant is then damaged with the same hoe, the virus is immediately available to enter via the fresh wound. The virus can



‘Inoculum dependence’: gradation of RYMV symptoms from uninoculated (left) through spot-inoculated and single-leaf inoculated, to fully inoculated plants of Bouaké 189

also survive in irrigation water, so any damage inflicted on a plant in a flooded field is prone to virus infection from contact with contaminated water. Then, of course, there is the whole issue of insect vectors.

WARDA Entomologist Francis Nwilene takes up the story: “It has been known since 1974 that insect vectors transmit RYMV mechanically. That is, they feed on an infected plant, collect virus particles, and then pass them on to the next plant that they feed on—the virus does not undergo any changes within the insect itself, but simply uses it as a vehicle.” Some 12 insect species are known to transmit RYMV between rice plants, and from rice plants to alternative (weed) hosts, including beetles and grasshoppers that bite the plants, and leaf-sucking bugs. Another avenue for controlling the disease is therefore to control the vectors—this has been a focus of WARDA’s entomology work in 2000 (see Box ‘Controlling the vectors of disease’).

Integrated management of RYMV and the future

Like so many problems that affect growing crops, there is no single method of approaching RYMV that is going to rid the region’s rice of this insidious disease. Instead, we

Controlling the vectors of disease

With the exception of insect vectors, all the mechanisms for virus infection require the presence of the virus either in the field to which rice is transplanted, or else in the nursery. Entomologist Francis Nwilene: "if a field is completely cleared of virus during the off-season—for example, by destruction of all crop debris, ratoons, volunteers and alternative hosts—then the *only* source of RYMV lie outside the field, and it is only the insects that can bring it to the crop. Thus, there is justification for looking at methods for controlling these insects."

Like the disease itself, there is no single control measure that does a satisfactory job. "We have left the route of host-plant resistance to the breeders and pathologist," explains Nwilene, "and have concentrated on cultural methods and bio-pesticides." The logic behind the plant-resistance decision lie in the extensive screening that has been done, which will select for insect-resistant types as much as for purely virus-resistant types.

Among the cultural practices, water management can play a key role in the dry (off-) season. "During the dry season," explains Nwilene, "the vectors tend to leave the uplands, as the air is too dry for them, and their food supplies are dying out." If the lowlands are also drained at that time, the humidity there will also be reduced, and the food supply there will also be diminished, with consequent impact on the vector population in the lead-up to the cropping season.

"One positive trend," Nwilene continues, "is the move towards direct seeding." This trend is driven by labor costs, but it has two advantages in the fight against RYMV. First, there is no transplantation-induced root damage. Second, the populations of vectors spends the whole season in an interactive phase with its natural enemies (predators, parasites)—there is no relocation of vectors with seedlings, and a certain level of natural control is achieved.

However, it is the potential role of bio-pesticides that attracted Nwilene's attention in the last season. "We compared the effects of extracts from neem and pawpaw with commercial insecticide Decis," he explains. "I'm delighted to report that neem oil was not only more effective in controlling all three groups of vectors (beetles, grasshoppers and leaf-sucking bugs) than pawpaw extract was, but also even better than Decis! What is more, the preliminary results suggest that the neem oil had less of an impact on the vectors' natural enemies than either of the other two insecticides." Research into this potential role for neem oils is continuing in the 2001 wet season.

need to combine elements to provide adequate relief. As is often the case when dealing with resource-poor farmers, the researchers' first line of approach is through the development of resistant varieties—WARDA and its partners have come a long way with this work, but there is still much to do, as explained above. This, however, is backed up with other interventions—using appropriate cultural practices to minimize the spread of the disease, removing alternative hosts where virus populations can survive or build up over the off-season, and managing insect vectors. "In 2001," explains Séré, "we will begin to look at the role of overall crop management, including fertilizer, in the epidemiology of the disease, and that may provide yet another entry into RYMV population control."

Also in 2001, WARDA is expecting to begin collaboration with the University of Leuven, Belgium on a project to enhance the sustainability of rice production in RYMV hot-spot locations. This will involve training of national-program advisers and farmers on virus management. In addition, the project aims to develop new tools for identifying the virus—within rice plants and insect vectors, and in the field—and others for monitoring the disease in the field (in relation to climate).

Another approach in the RYMV work is through WARDA's Interspecific Hybridization Project. Specific areas of interest are identification of the types of resistance present in the three basic rice groups—*Oryza glaberrima*, *O. sativa* subspecies *indica*, and *O. sativa* subspecies *japonica*; continued study of RYMV variability in West, Central and East Africa; and, further strengthening of the collaboration with national programs on screening of new material. This latter element will involve the production of further targeted crosses between popular local *O. sativa* varieties and *O. glaberrima*, which will be screened and further advanced at WARDA. However, it will not be the final products of breeding that are sent to national programs from screening against the most virulent local isolates in screen houses. This will enable national breeders to select for adaptation to local conditions in addition to RYMV resistance.

Capacity building for national partners

From the beginning, WARDA's work on RYMV has been conducted through partnerships. The whole issue of multilocation screening of varieties brings a need for partnership in itself. However, as the screening progressed, and especially with the advent of the DFID *in-situ* screening project, it was necessary to upgrade the capacities of some of our partners—to train the national-program technicians to actually conduct the screening in the screen houses. In addition, the development of the polyclonal antibodies for detecting RYMV in plant tissue meant that we had to train laboratory technicians in collaborating countries in their use.

By providing training to our partners, we are not only providing a service to the countries concerned, but rather to the whole region. The information produced from the *in-situ* screening work feeds into the whole RYMV research process, which will ultimately benefit lowland-rice farmers in RYMV-endemic areas throughout Sub-Saharan Africa.

Then again, we are not only interested in today's research-workers. We are also providing input into the training of tomorrow's pathologists. After all, rice systems and RYMV itself are biological entities—the virus will eventually adapt to whatever control measures we put in place, or else another disease could come along to fill the niche of RYMV should we ever come close to eradicating it. Thus, we need an upcoming cadre of pathologists ready to tackle tomorrow's plant-disease problems. Linkages have been established with universities in Côte d'Ivoire and Mali for basic methodologies for screening and scoring, plus research topics such as the variation in pathogenicity (virulence) of Ivorian isolates of RYMV.

“We are at a very exciting stage with the RYMV work,” says WARDA's Director General Kanayo F. Nwanze. “We have nearly reached our short-term goal of seeing improved virus-resistant rice in the fields of farmers in those areas where the disease is endemic, and we have identified certain components to initiate integrated management of the disease at farm level. The next few

years will see an increase in the amount of resistant material available, and some of this will not only have durable resistance, but also be attractive to farmers in other ways, such as plant and grain types and cycle length. We trust that never again will farmers be thrown into despair by the site of their fields devastated by RYMV.”