Big Problems with a Little Fly: African Rice Gall Midge

AS ITS name might imply, African rice gall midge looks more like a mosquito than a serious plant pest; but, this little bug is an important pest of lowland rice in at least four of WARDA's member states, and has been recorded in a further 16 Sub-Saharan African countries. The larva bores into a rice tiller and eats away its host from the inside. Infestation in a field of a susceptible variety can result in complete yield loss. WARDA has been working on gall midge for some years, and now has some methods for managing it that can be combined for greater effect.

Gall-midge adult: It's only a little fly, but its appetite for rice tillers can lead to total crop loss!

Gall midge has been known as a pest of rice for a long time; however, it was not until the late 1970s that serious damage was recorded in West Africa, and that was in southern Burkina Faso. In 1988, extensive outbreaks occurred over 50,000 hectares of lowland rice in southeast Nigeria. It is now a serious problem in both these countries, and also in Mali and Sierra Leone. In addition, it has been recorded from a further 11 West and Central African countries, and 5 other Sub-Saharan African countries (*see* map, Figure 5). Yield loss assessments in fields with up to 30% tiller infestation suggest that for each 1% increase in tiller infestation, a farmer can expect to lose 2–3% grain yield. Heavily infested fields may produce no grain at all. Thus, the potential for devastation is already great, and is most likely increasing.

Early research by WARDA, the International Institute for Tropical Agriculture (IITA) and their partners concentrated on the basic biology and ecology of the pest. It was not until 1982 that African rice gall midge (*Orseolia oryzivora*) was recognized as being distinct from Asian rice gall midge (*O. oryzae*) of South and Southeast Asia. In 1993, entomologist Charles Williams of the Centre for Agriculture and Biosciences International (CABI, UK) was seconded to WARDA, based at IITA headquarters (Ibadan, Nigeria), to work on African rice gall midge in a project funded by the UK Department for International Development (DFID). The DFID project ran through 1996, and covered the study of pest distribution and economic importance, ecology, alternative hosts and cultural practices, identification

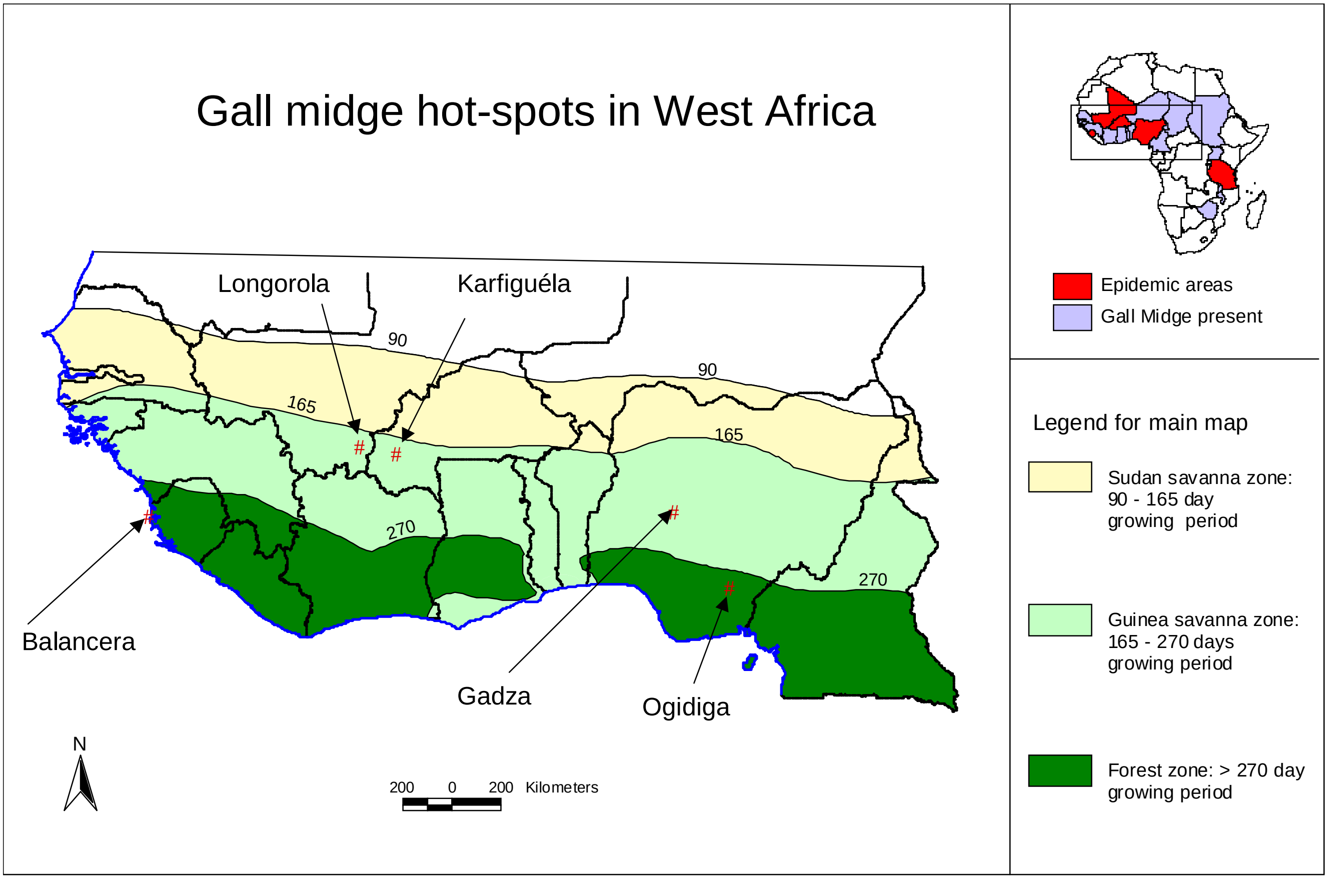

Figure 5. Map of the distribution of African rice gall midge

of natural enemies of gall midge, and screening of rice varieties to assess their resistance to the pest. The work continues today under the supervision of staff entomologist Francis Nwilene, who first came to WARDA (headquarters this time) as a Visiting Scientist in 1998.

Life cycle

A female gall midge lays its eggs scattered on leaves and leaf sheaths of rice. Eggs hatch in 2 to 5 days. The tiny, legless larva crawls onto a rice shoot (tiller) and makes its way (down) between the leaf sheaths to the growing point. After it has shed its first skin, the larva burrows its way into the tiller. Water droplets are needed on the plant surface to allow the larvae to move and penetrate the tiller—if the plant is dry, any larva that hatches will most likely die. The presence of the larva at the growing point causes the plant to produce an oval white gall, in which the larva feeds and develops for 10 to 20 days. When fully grown, the larva becomes a pupa—at this stage the insect is about 5 mm long, it does not feed; it does, however, darken from whitish to dark brown as it develops.

Galls on young plants shortly after transplanting

Toward the end of the pupal stage (usually 3–5 days), the gall elongates rapidly to form a hollow tube of about 3 mm diameter, tapering at the end. At this time, the gall becomes visible as it projects beyond the tiller. The gall's final length is determined by as yet unknown factors, but it may be as long as 50 cm. The pupa wriggles up the gall and cuts an exit hole near the tip using spines on its head. Finally, the pupal skin splits and the adult midge flies away leaving the pupal case protruding from the hole. After emergence of the midge, the gall dies back slowly over a few weeks.

To control a pest...

The adage "beat that big, bad bug with the bug-spray" is not so easy if you're a subsistence farmer. You simply don't have the financial resources to invest in expensive chemicals, or you may not have time to spray the crop even if you have the money to do so. What's more, insecticides are frowned upon by those who pay for development these days, as environmental contaminants and altogether undesirable! So, we have to find another way—or several ways—to "beat the bug."

The cultural way

Cultural, or farm-management, practices are often a cheap and easy entry point for farmers to reduce their risks from insect attack and damage.

For example, when farmers don't all grow their rice at the same time, they make life easy for the gall midge by providing it with a succession of suitable habitats. This allows gall-midge populations to build up through the whole growing season, with most damage being inflicted on the last-sown fields. The converse of this acts as a population control: synchronized and early planting over an area doesn't give the midges a good start to the season, and then gives them only a very short season to multiply in. Unfortunately, the diversity of rice farmers in any given area means that it may not be particularly easy for them to do all their planting at the same time.

African rice gall midge is specific to rice (and its close relatives), so it has to make use of whatever rice it can find during the off-season in order to survive. Crop residues (what's left after harvest of the grain), ratoons (tillers that sprout from rice stubble) and volunteers (self-seeded rice plants that grow up from shed or spilt seeds) all make perfectly good places for midges to survive and multiply. Thus, destruction of crop residues, and careful clearing away of ratoons and volunteers deprives the pest of this alternative and consequently helps limit the population.

A close relative of rice—*Oryza longistaminata*—is also one of the commonest weeds in and around rice fields. The added advantage of this weed to gall midge is the fact that it is perennial, living for more than one season. Gall midge can survive the dry season in the underground parts (rhizomes) of *Oryza longistaminata* ready for an early start to the following rice-growing season. Careful weeding to remove *Oryza longistaminata* plants and their rhizomes should help reduce the gall-midge population that can survive the dry season.

Useful as such cultural practices are, it is often difficult for farmers to find the labor to have the activities carried out at the appropriate time. We must, therefore, seek yet further methods to control the bug.

The search for resistant rice plants

Since resource-poor farmers have problems both with managing labor requirements and with acquiring resources, their ideal solution to any rice problem is to have a variety for which the problem is not a problem. In terms of pests and diseases, we therefore need to find a plant that either *resists* the offending organism, or else *tolerates* the presence of the pest and produces 'normally' despite being infested.

Early work comprised screening of varieties for their resistance to African rice gall midge by teams led by M.S. Alam at IITA and Mark Ukwungwu at the National Cereals Research Institute (NCRI), Nigeria. In 1982, some 90 Asian varieties known to be resistant to Asian gall midge were screened, and only six suffered less than 2% infestation from the African species. The screening work finally yielded two useful Asian varieties. The first of these was Cisadane, a variety from Indonesia introduced in nurseries distributed by the International Rice Research Institute (IRRI). Cisadane *tolerates* gall-midge infestation and was by far the best-yielding variety at infestation levels of up to 30%, in trials in southeast Nigeria. The variety was released in Nigeria as FARO 51 in 1998, for the rice areas with endemic gall midge. On the down-side, Cisadane is susceptible to iron toxicity—another common problem in lowland rice in West and Central Africa—this limits its value for wider use. Variety BW 348-1 from Sri Lanka is also tolerant of gall midge, but has the advantage of also being tolerant of iron-toxic soils. It is currently undergoing field testing in both Nigeria and Burkina Faso.

Galls on rhizome of *Oryza longistaminata*

Meanwhile, a 'traditional' variety from The Gambia, TOS 14519, showed moderate resistance to African gall midge, but has poor yield. It is, therefore, not suitable for direct release, but is being used as a source of resistance in the breeding program. However, to date no high-yielding variety that is resistant to African rice gall midge has been found among the 'Asian' rices (*Oryza sativa*).

"With the paucity of material available in Asian rice, it was clear that the time had come to look elsewhere within Africa," explains WARDA entomologist Francis Nwilene. With the advent of the NERICAs and the technology to generate interspecific progeny more and more rapidly, WARDA switched its search for gall-midge resistance to the African rice species (*Oryza glaberrima*). The results were promising: at least four varieties have been identified that are highly resistant to gall midge. "Of course," explains Nwilene, "these are all typical *glaberrimas*, susceptible to lodging and grain-shattering at maturity. However, they are ideal donors for the breeding program, since they express much higher resistance than anything found so far in the *sativas*."

Progress is being made, but WARDA still has one source 'up its sleeve.' Deputy Director for Research, Monty Jones, explains: "The NERICAs were specifically bred for the upland ecology, but we were so impressed with their performance that we decided just to test them under rainfed lowland conditions." After the initial 'lowland adaptation' trials, some 102 upland NERICAs were screened against gall midge. One of these lines showed moderate resistance to gall midge—this augers well for the possibility of generating gall-midge-resistant NERICAs from lowland-adapted *sativas* and resistant *glaberrimas*.

But not all African rice gall midges are the same

Nwilene takes up the story again, "the screening work [*see* Box] also revealed that resistance or tolerance to gall midge is not stable across sites." The five major pockets with serious gall-midge problems were all used as screening sites. "Varieties that performed well at Ogidiga (southeast Nigeria) did not do so at Gadza (central Nigeria), and those that performed well at Longorola (Mali) did not do so at Balancera (Sierra Leone)." In fact, the behavior of the resistant and tolerant varieties divides the sites into two groups: one resistance is stable among southeast Nigeria, Burkina Faso and Sierra Leone, and the other between central Nigeria and Mali. This difference seems to reflect elevation, with the first three site being low-lying (less than 11 m above sea level) and the remaining two higher (200 to 400 m).

When an insect of the same species can attack a plant that is resistant to that species at another location, scientists say that the insect occurs in 'biotypes,' that is, there are differences between the insect populations that are manifest in the resistance reaction of the host plant. Thus, it seems clear that there are at least two biotypes of African rice gall midge in West and Central Africa, and more may be found in other parts of the region. The UK Department for International Development (DFID) has recently started to fund work to classify the gall-midge biotypes by means of molecular fingerprinting.

Useful 'friendly' bugs

Another avenue of research is to tap into nature's own pest-management brigade.

Modified screening methodology

"One major advantage of doing all this screening work is that we have been able to improve our screening techniques over time," says Entomologist Francis Nwilene. The early work was carried out using conventional 'spreader rows'—that is, rows of a highly susceptible variety grown around the plots of the plants being screened; newly-hatched larvae were deposited appropriately on the susceptible 'spreader' plants. However, such a system is open to the vagaries of chance and it is just possible for a healthy line to be simply uninfested rather than resistant or tolerant to the pest. The new technique involves direct introduction of young larvae to all test plants, and replication of every test entry. This method should be more efficient, and ultimately cheaper than the old one.

There are very few organisms on the planet that have no enemies besides human-beings, and African rice gall midge is no exception. Natural enemies generally fall into two categories—predators and parasites. Predators are not a serious problem for gall midges, as only the eggs and very young larvae are exposed on the outside of the plant and therefore available as predator food. However, a range of insect-eating insects and spiders will happily munch on gall-midge eggs and larvae should the opportunity arise.

Many plant-parasitic bugs have even smaller species that parasitize them. Most of these are what are termed by scientists 'parasitoids.' Parasitoids are merely parasites that develop in or on their host without killing it until they are mature. Our research identified two major parasitoids attacking African rice gall midge, both wasps. The first of these is a 'gregarious endoparasitoid' known as *Platygaster diplosisae*. It lays its eggs within a gall-midge egg. Several *Platygaster* larvae then hatch (within a single midge egg) to eat away the developing gall midge from inside—the *Platygasters* develop within the egg and larval gall midge. The adults then emerge from the fully-grown corpse of the gall-midge larva. Thus, the parasitoid essentially does to the gall midge what the gall-midge larva does to the rice plant!

The second parasitoid is a 'solitary ectoparasitoid' known as *Aprostocetus procera*. The female *Aprostocetus* paralyzes the pupa and then lays her egg close by. The single larva hatched from the *Aprostocetus* egg then feeds on the paralyzed gall-midge pupa. Though neither of the parasitoids prevent the stem-boring activities of the gall-midge larva that inflict the damage on the rice plant, they do have a direct impact on the gall-midge population as a whole.

Both parasitoids are indigenous to Africa, but are apparently ineffective in controlling gall-midge numbers under 'normal' circumstances. They tend to arrive in gall-midge-infested rice fields late in the season, by which time the gall-midge population has already reached damaging levels. Further research, therefore, focused on the biology of these tiny insects as a means of finding ways of 'helping them to help themselves' to gall-midge hosts and thereby aid the farmer.

We discovered that both parasitoids have the same alternative host, a cousin gall midge (*Orseolia bonzii*) that lives on the grass *Paspalum scrobiculatum*—it is consequently known as paspalum gall midge. Now, *Paspalum* itself is a weed and is usually cleared by farmers during their weeding operations. But what if we were to encourage rather than cut *Paspalum*? We have recently started a project to find out. We hope that by maintaining the grass near to rice fields in the non-rice-growing season, we will maintain the population of paspalum gall midge. That, we hope, will enable the two parasitoids to maintain numbers right beside the rice fields, so that they are ready to attack the rice gall midge as soon as it arrives early in the rice-growing season.

Dissected gall with *Platygaster* adults beside corpse of full-grown gall-midge larva

"Another interesting avenue of research has arisen from the parasitoid work," says Nwilene. It seems that any rice plant attacked by a gall midge releases a chemical that attracts the parasitoids to the plant. It may be too late by then for *Platygaster* to get at that particular gall-midge larva, but at least it is likely to find other gall-midge eggs and recently hatched larvae on adjacent plants. "If we can obtain the resources," continues Nwilene, "we will try to identify the chemical, with all the potential spin-offs that that knowledge would offer." If we know what attracts the parasitoids, we can use it early in the season to attract the helpful insects before the gall midges do too much damage.

Integrated pest management

Not so many years ago, the simple answer to pest control was to spray a chemical pesticide on it at the right time and kill the pest. That short-sighted view, however, didn't last very long. Pesticides are poisons that may have direct or indirect effects on human and environmental health. Pesticides are expensive—usually way out of reach of resource-poor farmers. What is more, African rice gall midge is a stem-borer. Once it has found its way inside a rice tiller, it can no longer be reached by chemical spray. That leaves a very small time-window for the farmer to spray in. Then again, the control methods described here are not likely to work in isolation. What is needed is an array of tactics, each one capable of doing some damage to the pest population, and each one having minimal environmental impact. This is what is called integrated pest management.

To date, our armory consists of a couple of tolerant varieties and some crop-management options to minimize off-season survival and seasonal population growth. In the short term, a combination of Cisadane or BW 348-1 with whichever of the recommended cultural practices the farmer can handle will be the best bet for minimizing damage. In the medium term, we have prospects for truly resistant NERICA varieties and management techniques for natural parasitoids. The biotype 'problem' will feed into the breeding program, so that resistance can either be targeted or else 'pyramided' (resistance to all biotypes bred into one variety).

"All in all," enthuses Monty Jones, "we are looking at an exciting time ahead for both entomologists and breeders. Not to mention the prospects for rice farmers in gall-midge infestated areas."

Major elements of integrated management of gall midge