CAB International

AFRICAN RICE GALL MIDGE

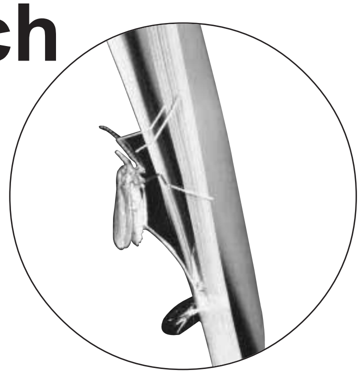
Research Guide

West Africa Rice Development Association

CABI Bioscience

AFRICAN RICE GALL MIDGE

Research Guide



Charles T. Williams *WARDA/CABI*
Keith M. Harris *Consultant*
Mark N. Ukwungwu *NCRI*
Souleymane Nacro *INERA*
Dona Dakouo *INERA*
Francis E. Nwilene *WARDA*
B.N. Singh *WARDA*
Olusegun Okhidievbie *WARDA/CABI*

West Africa Rice Development Association

CABI *Bioscience*

Centre for Agriculture and Biosciences International

2002

Authors' affiliations

Charles T. Williams
(formerly WARDA/CABI, Nigeria)
c/o Makerere University Institute of Environment and Natural Resources (MUIENR)
P.O. Box 7298, Kampala, Uganda
[UK contact address: c/o 24 Durdham Park, Westbury Park, Bristol, BS6 7JA, UK]
E-mail ctwilliams30@hotmail.com

Keith M. Harris
Consultant Entomologist, 81 Linden Way, Ripley, Woking, Surrey, GU23 6LP, UK
E-mail kmharris@lineone.net

Mark N. Ukwungwu
National Cereals Research Institute (NCRI)
Badeggi, P.M.B. 8, Bida, Niger State, Nigeria

Souleymane Nacro
Institut de l'environnement et de recherches agricoles (INERA)
Station de Farako-bâ, 01 B.P. 910,
Bobo-Dioulasso, Burkina Faso
E-mail Alsanou@fasonet.bf

Dona Dakouo
Institut de l'environnement et de recherches agricoles (INERA)
Station de Farako-bâ, 01 B.P. 910,
Bobo-Dioulasso, Burkina Faso
E-mail Ddakouo@fasonet.bf

Francis E. Nwilene
West Africa Rice Development Association (WARDA/ADRAO)
01 B.P. 2551, Bouaké 01, Côte d'Ivoire
E-mail F.Nwilene@cgiar.org

B.N. Singh
(formerly WARDA, Côte d'Ivoire)
Director, Central Rice Research Institute (CRRI)
Cuttack 753 006, Orissa, India
E-mail bnsingh@bol.net.in

Olusegun Okhidievbie
West Africa Rice Development Association (WARDA/ADRAO)
c/o International Institute of Tropical Agriculture (IITA)
P.M.B. 5320, Ibadan, Nigeria
E-mail O.Okhidievbie@cgiar.org

Williams, C.T., K.M. Harris, M.N. Ukwungwu, S. Nacro, D. Dakouo, F.E. Nwilene, B.N. Singh and O. Okhidievbie, 2002. *African Rice Gall Midge Research Guide*. Bouaké, Côte d'Ivoire: West Africa Rice Development Association, and Wallingford, UK: CAB International. 28 pp.

ISBN 92 9113 197 0

Edit/design by *BluePencil Editing & Design*, Hyderabad, India; http://bluepencil.indiaa.com
Printed at *Pragati Offset Pvt. Ltd.*, Hyderabad, India. www.pragati.com

Contents

Acknowledgments

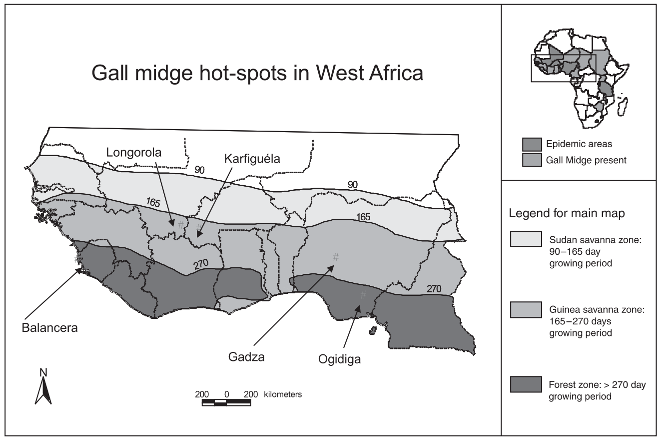
The authors and publishers gratefully acknowledge the funding provided by the UK Department for International Development (DFID) for the WARDA/CABI gall midge project in general—through ODA Holdback Project R5619(H)—and for the publication of this guide in particular.

The authors also wish to thank the members of the WARDA–NARS Task Forces on Integrated Pest Management and Lowland Breeding, and other NARS staff, for collaboration within the project; the management and staff (past and present) of WARDA and CABI Institutes of Biological Control and Entomology, for providing administrative and technical support to the project; the management and staff of IITA (1993–1996) for providing office, lab and field facilities, and administrative support to the project.

Finally, special thanks go to the following individuals, each of whom contributed to the project (and ultimately this book), and without whom this book would not exist: M.O. Adumike, A.M. Alghali, E.A. Bamidele, A.K. Camara, M. Cock, J.R. Dias, S.N. Fomba, A. Hamadoun, E.A. Heinrichs, A.A. Kehinde, J. La Salle, I.W. Meyen, S. Moore, N.Q. Ng, J. Nnabo, O. Oreke, A. Polaszek, D.J. Salami, and M. Sidibe.

Introduction

The African rice gall midge, *Orseolia oryzivora* Harris & Gagné (Diptera: Cecidomyiidae), is an insect pest indigenous to Africa. It was generally considered a minor problem before the 1970s, but has caused increasingly severe damage to rice crops since then. Serious losses were reported from southern Burkina Faso in the late 1970s; ten years later, extensive outbreaks occurred in central and southeast Nigeria, involving over 50,000 ha of rice and causing total yield loss in the worst-affected fields. African rice gall midge (AfRGM) remains a major pest in both of these countries and, since 1990, outbreaks have also been reported from parts of Ghana, Guinea, Guinea Bissau, Mali, Sierra Leone, Tanzania and Uganda. Several possible causes for the increase in AfRGM damage have been suggested, most linked to recent changes in rice production.



The effective management of AfRGM has presented a major challenge to rice scientists of the West Africa Rice Development Association (WARDA) and the national agricultural research systems (NARS) of the countries affected. Since the late 1970s, research has been focused on understanding the biology and ecology of the pest, and developing a range of management options.

A collaborative research project on AfRGM was started in 1993, involving WARDA, the NARS of West and Central Africa, and the Centre for Agriculture and Biosciences International (CABI), funded by the United Kingdom Department for International Development (formerly the Overseas Development Administration).

This guide on AfRGM is one output of the collaboration within the framework of this project. The guide provides up-to-date information on the biology, ecology, recognition and management of the pest, including results obtained before and during the project. It also outlines some basic research techniques. It will be useful to entomologists unfamiliar with AfRGM and is also intended for other agricultural researchers, trainers and extension staff involved with rice production. Technical terms have been kept to a minimum, and those that are used have been explained. A list of further reading is given for readers who need more technical detail. Emphasis has been placed on explaining those aspects of the biology and ecology of AfRGM that have important implications for its pest status and management. The management options described include some that are already recommended to farmers, and others that are still under development.

Biology and Ecology of African Rice Gall Midge

Distribution

Gall midges collected from rice in Africa were originally thought to belong to the same species already known as a pest of rice in Asia—*Orseolia oryzae* (Wood-Mason). However, detailed comparison in the early 1980s showed that the midges from Africa and Asia are structurally different. Two species are now recognized: African rice gall midge, *Orseolia oryzivora* Harris & Gagné, and Asian rice gall midge *Orseolia oryzae* (Wood-Mason) (formerly, *Pachydiplosis oryzae*).

Asian rice gall midge has never been found in Africa, and all earlier reports of this species from Africa are now known to be misidentifications of *O. oryzivora*. African rice gall midge (AfRGM) is widely distributed south of the Sahara, particularly in West Africa, but it has not been found outside this continent. The pest has been recorded from the following countries:

> Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, The Gambia, Ghana, Guinea, Guinea Bissau, Malawi, Mali, Niger, Nigeria, Senegal, Sierra Leone, Sudan, Tanzania, Togo, Uganda and Zambia.

In several of these countries—including Ghana, Guinea, Sierra Leone, Tanzania, Uganda and Zambia—AfRGM has been recorded for the first time since 1970, which suggests that its range in Africa is expanding. However, in some localities it may simply have been overlooked until infestation levels increased.

In West Africa, heavy AfRGM infestation is more common in the Guinea savanna, derived savanna and humid forest agro-ecological zones than in the Sudan savanna. The pest is rare in the Sahel zone. Upland rice fields are occasionally attacked, but AfRGM is mainly a pest of lowland (swamp) rice, whether rainfed or irrigated. Hydromorphic rice fields (with the water table lying close to, but usually below, the soil surface) are also at risk. African rice gall midge is rare on tidal mangrove rice fields, but 'associated mangrove' fields can have infestation levels similar to those on other types of lowland rice.

Life cycle

The adult AfRGM is a reddish-brown fly similar in shape and size to a small mosquito (Figure 1, *see* inside front cover). The female midge lays eggs, about 0.5 mm long, scattered on the leaves and leaf sheaths of the rice plant. The eggs hatch after two to five days (Figure 2). The legless, white to pale-yellow larva which emerges from each egg crawls into a rice shoot (tiller) and makes its way down between the leaf sheaths to the growing point (apical meristem). Water droplets are needed on the plant surface to allow the larva to move across it. If conditions are dry, many larvae die before they can penetrate into the tiller.

At the tiller's growing point, the larva makes the plant form an oval, hollow gall (Figure 3), within which it feeds and develops for about 10 to 20 days. During this period, the gall is short and hidden between the leaf sheaths. When the larva is fully grown, it changes into a pupa, about 5 mm long. The pupa does not feed, but darkens from whitish to dark brown as it develops (Figure 4).

Normally towards the end of the pupal stage, which lasts three to five days, the gall elongates rapidly to form a hollow tube about 3 mm in diameter, tapered at one end. The top part of the gall can then be seen projecting out of the tiller. The color and length of AfRGM galls are quite variable (Figure 5). Typically they are silvery white for most of their length with a green tip, but on older plants they are often mainly green (Figure 6). They may even be purplish on some rice varieties. Their length can vary from a few centimeters to over 50 cm. Because of their tubular shape and white color, they are often called 'onion leaf' or 'silver shoot' galls.

The AfRGM pupa is mobile and wriggles up to the top of the gall when it has completed its development. It then cuts a hole near the tip of the gall using the spines at its head end. The front of the pupa emerges through this exit hole, the pupal skin splits and the adult midge crawls out. The empty, transparent pupal skin is left protruding from the exit hole (Figure 7, *see* inside back cover) and can remain there for several days before being brushed or knocked off. Galls gradually die off from the top after the adult has emerged, normally taking a few weeks to die back completely.

Adult midges usually emerge at night and are nocturnal (active at night). During the day, they rest near the bases of the rice plants. Males and females can mate within a few hours of emerging. The female lays most of her 100 to 400 eggs within the next day or two, and only lives for about three days. As with other insects, the duration of the life cycle is partly dependent on temperature. Development is slower in cooler weather. At temperatures that are normal in AfRGM outbreak areas in West Africa, the life cycle from egg to adult usually takes three to four weeks.

Yield loss

The African rice gall midge is only a pest at the vegetative stage of crop growth, because larvae cannot produce galls on tillers that have already started to form a flower head (panicle). Severe

AfRGM infestation in the nursery bed can kill rice seedlings soon after transplanting, but the pest normally causes damage without killing the plant. In this case, the infestation causes grain yield loss, because a tiller cannot produce any more leaves or a panicle after a gall has been formed. In response to midge infestation, the plant normally produces extra tillers that can help to compensate for the damage. However, these tillers often become infested as well and, even if they escape attack, they may be formed too late to contribute to grain yield. Fields that are heavily infested may produce no grain at all.

The percentage of tillers on which galls can be seen (percent tiller infestation) is commonly used as a measure of the level of midge infestation in a rice crop. Trials under rainfed lowland conditions in Nigeria have shown that percent tiller infestation recorded when rice plants are at stem-elongation stage is reasonably closely related to yield loss. Infestation levels recorded at earlier or later growth stages are less useful in assessing the effect on yield.

The amount of yield loss caused by a particular level of AfRGM infestation can vary from one rice variety to another: 'tolerant' varieties, like Cisadane (see 'Varietal resistance' on page 12), show lower yield loss than more susceptible ones.

For a particular rice variety, the amount of yield loss caused by a given level of midge infestation varies with the growth stage of the crop. This is probably because growth stage affects the plant's ability to compensate for midge damage by producing extra panicle-bearing tillers. Trials on farmers' rainfed lowland fields in southeast Nigeria showed that even moderate infestation levels can result in heavy yield loss. Over a range of midge infestation levels from 0 to about 30%, an increase of 1% in the percentage of tillers showing galls at stem-elongation reduced yield by 2 to 3%. However, losses under more favorable, irrigated conditions are likely to be lower. In addition to reducing grain yield, AfRGM attack also results in delayed and uneven grain maturation, which makes harvesting difficult.

Recognizing gall midge damage in the field

Long, silvery AfRGM galls on young rice plants are very noticeable. However, on older plants the galls are often less conspicuous, since they are more easily hidden by the leaves and may be short and green, particularly if growing conditions are poor. Additionally, galls become harder to see as they grow older, because they die back from the top and the gall-midge pupal skins drop off. Thus, as the season progresses, one has to examine the plants closely to see the galls, even in a heavily infested field.

As a result of rice plants producing extra tillers in response to AfRGM infestation, severely attacked plants usually have a stunted, bushy appearance with as many as 50 or 100 small tillers per hill. At the flowering stage, a heavily infested rice crop can look like a grass field, with very few panicles showing. However, other pests and soil problems sometimes produce similar stunting, so one must find galls to confirm AfRGM as the cause of damage.

The 'deadhearts' produced by stem-boring caterpillars or the larvae of stalk-eyed flies (*Diopsis* spp.) are sometimes mistaken for midge galls. Typically, the youngest, central leaf of a deadheart fails to unfold because of the stem-borer damage near its base. It also turns pale yellowish as it dies off, so it can resemble a midge gall. However, when cut horizontally, a deadheart never shows the hollow, tubular structure of a gall. Also, the central leaf of a deadheart caused by a stem-boring caterpillar is often easy to pull away from the rest of the tiller because of the damage at its base, whereas a gall is not.

Adult gall midges are usually quite difficult to find, even in rice fields with many galls, because they only live for a few days and are active at night.

Alternative host plants

Results of recent field sampling and laboratory tests strongly suggest that cultivated and wild rice species (*Oryza* species) are the only host plants on which AfRGM can develop. Earlier reports of 'onion leaf' galls on other grasses in Asia and Africa refer to other species of gall midge. In Nigeria, AfRGM has been tested on the following grass species common around lowland rice fields: *Leersia hexandra*, *Echinochloa colona*, *Echinochloa stagnina*, *Acroceras zizanioides*, *Paspalum scrobiculatum* and *Ischaemum rugosum*. It could not form galls on any of these.

'Onion leaf' galls are quite commonly found on *Paspalum scrobiculatum* in rice-growing areas of Nigeria and Burkina Faso. However, detailed examination and laboratory host-transfer tests have shown that these galls are produced by a different species of gall midge which cannot infest rice. There are small structural differences in the pupae and adult males of the two species that can be seen under a low-powered microscope or a hand lens.

Rice species on which AfRGM can develop include the cultivated species *Oryza sativa* and *O. glaberrima*, and the wild species *O. longistaminata*, *O. barthii*, *O. punctata* and *O. stapfii*. Other wild rices have not yet been tested, and may be hosts. *Oryza sativa* appears to be the most favorable host.

Annual cycle

African rice gall midge is generally very rare in the dry season, but builds up during the rains. This is mainly because the newly hatched larvae need water droplets on the plant surface to allow them to move into the tillers. In addition, rice plants at the susceptible vegetative growth stage are normally much more abundant in the rainy season, except where irrigation allows dry-season rice crops to be grown. Where there is a dry-season rice crop, AfRGM can persist on it at low levels. Where only one rice crop is grown each year, the way in which AfRGM survives from one cropping season to the next depends on the length of the dry season and the alternative host plants available.

The gall midge normally survives on rice fields for some weeks after harvest by infesting 'ratoons' of cultivated rice. These are the new tillers which sprout from cut stubble after harvest. Later, 'volunteer' rice plants germinating from seed that has accidentally fallen on the field are also infested. In the humid forest zone, where the dry season is short and some live ratoons and volunteers are always present, gall midge can persist from one cropping season to the next on these hosts even if no wild rices are present.

In savanna areas, where the dry season is longer, there is usually a period of several months when no live ratoons or volunteers are present. Here, the wild rice *Oryza longistaminata* is important for the survival of AfRGM. Unlike the other rice species found in Africa, it has underground stems (rhizomes) which remain alive through the dry season after all the leaves have died. Gall-midge larvae can survive dry conditions in a dormant state inside these rhizomes. When the first rains fall, the rhizomes start to grow again and produce new tillers, and the larvae complete their development. Their galls elongate and the new adults emerge and disperse.

Even where *O. longistaminata* is necessary for the dry-season survival of AfRGM, ratoons and volunteers of cultivated rice are also important in the annual cycle. Ratoons are important for several weeks after harvest until they die. Volunteers are important early in the rainy season, after the first generation of adults has emerged from *O. longistaminata*, but before the first rice crops have been planted. Annual species of wild rice, such as *O. barthii*, can play a similar role to volunteers in the rainy season.

In central and southeast Nigeria, in most of the AfRGM outbreak sites that have been studied so far, the great majority of alternative AfRGM host plants (wild rices, volunteers and ratoons) grow on rice fields. When these fields are not being used for rice, they are either left fallow or are cultivated with other crops; in either case, alternative AfRGM hosts can persist on them. Though some AfRGM host plants are present in other habitats, such as ditches, bunds and ponds, these are a small proportion of the total.

In some northern outbreak sites, for example in southern Burkina Faso, there are large uncultivated swamps in which *O. longistaminata* is abundant close to the rice fields. These swamps are probably important habitats for AfRGM.

Field sampling in Nigeria has shown that, though ratoons, volunteers and wild rice species are important in the annual cycle of AfRGM, populations on these hosts early in the rainy season are relatively small. The large populations that can build up later in the rainy season are primarily the result of very rapid reproduction over several generations on the rice crop itself.

Natural enemies

The natural enemies of AfRGM feed on the pest, and often succeed in keeping it under natural biological control, reducing the population so much that rice crops do not suffer yield loss. The two main types of natural enemies are predators and parasitoids. Parasitoids are generally more specialized than predators. They feed either inside or on the body of their host during development, but are free-living as adults.

Parasitoids

By far the most common parasitoids of AfRGM are *Platygaster diplosisae* Risbec and *Aprostocetus procerae* (Risbec) (formerly called *Aprostocetus pachydiplosisae* or *Tetrastichus pachydiplosisae*). Both are very small wasps (Hymenoptera). Adults of *Platygaster* are less than 1 mm long and are black with pale legs. Adults of *Aprostocetus* are stout and about 3 mm long; they occur in a variety of colors, from mainly orange-brown with some black marks on the body to almost entirely black. Several other species of parasitoid attack AfRGM, but these are too rare to play an important role in the biological control of the pest.

Platygaster diplosisae lays its eggs inside the eggs of AfRGM, and the parasitoid's larvae hatch inside the young AfRGM larva. They feed inside it and kill it when it is fully grown. They then form pupae inside the corpse, from which the tiny adults emerge. The adults cut one or more very small exit holes in the gall and disperse.

The adult female *Aprostocetus procerae* usually lays its eggs onto AfRGM pupae, or occasionally onto large larvae. It does this by piercing through the wall of the gall with the tip of its abdomen. The host is stung and paralyzed by the female parasitoid as the egg is laid. *Aprostocetus* larvae feed on, rather than inside, their hosts, and only one larva develops on each host. After it has finished feeding, the parasitoid larva changes into a pupa inside the gall. The adult that emerges cuts an exit hole in the gall to escape. More detail on how to recognize the two main parasitoids is given later in this book (Gall dissection to assess parasitism levels, page 20).

Field sampling and experiments have shown that in some situations *Aprostocetus procerae* and *Platygaster diplosisae* can find and kill a high percentage of AfRGM, even when the pest's population is low. Towards the end of the rainy season on farmers' fields these parasitoids commonly kill well over 50% of the AfRGM larvae and pupae. However, sometimes such high levels of parasitism occur too late to prevent large AfRGM populations from building up and causing serious yield losses.

Predators

Little is known about the predators of AfRGM. Laboratory tests have identified several predators common in lowland rice fields, which feed readily on the exposed eggs of the pest. These include tiny predatory mites (*Neoseiulus* sp., Phytoseiidae), the bug *Cyrtorhinus viridis* (Miridae), and the sword-tailed crickets *Anaxipha longipennis* and *Trigonidium cicindeloides* (Gryllidae). Several other small bugs (Heteroptera) common in rice crops are predatory and may feed on AfRGM eggs. But some larger predators such as ladybird beetles (Coccinellidae) and the long-horned grasshopper *Conocephalus* (Tettigoniidae) ate few AfRGM eggs in laboratory tests.

Gall-midge larvae and pupae are well hidden from predators inside galls. Only about 5% of pupae are killed by predators, and most of this is accidental predation by larvae of stalk-eyed flies (*Diopsis* spp.) and other stem-borers.

The main predators of adult midges that are abundant enough in lowland rice crops at the vegetative stage to be important are spiders—in particular, long-jawed spiders (Tetragnathidae)—and damsel flies (Zygoptera).

Management of African Rice Gall Midge

Researchers working to reduce crop losses caused by AfRGM have adopted an integrated pest management (IPM) approach. That is, they are developing a variety of compatible methods that can be used in combination to reduce AfRGM damage. Emphasis is being placed on the development of methods that do not involve insecticides, such as cultural and biological control methods, and varietal resistance. This is because the use of insecticides to control AfRGM is difficult and has several drawbacks. These include financial cost, risks to human health, and the possible destruction of natural enemies, which could result in new pest outbreaks. The sections below describe the AfRGM management methods already recommended to farmers, and also some others that are under development and not yet ready for implementation.

Cultural control

Cultural control methods involve changing the way the crop is grown in order to reduce pest damage. For AfRGM there are several options.

Early and synchronized planting

Gall-midge populations are normally at a low level at the beginning of the cropping season and build up during the rains. Therefore, rice fields planted early are usually less likely to suffer serious damage than those planted late. Field surveys have shown that this is certainly the case in the Abakaliki area in southeast Nigeria.

If the fields in an area are planted over several months, the AfRGM population has a long period in which to build up on the crop, first on early-planted and then on late-planted fields. Synchronized planting, that is, planting all the rice fields in an area at about the same time, prevents this.

Early and synchronized planting are important cultural control measures that are appropriate in many outbreak areas. However, two points should be considered before recommending them to farmers in a particular area.

- Studies by researchers at the National Cereals Research Institute (NCRI) in Nigeria have shown that, at some sites, early planting may result in higher AfRGM infestation. This is likely to be due to differences between sites in seasonal weather patterns, cropping calendars and AfRGM ecology. Therefore, if it is not already known, the relationship between planting date and AfRGM infestation level in a particular outbreak area should be investigated using surveys or experimental plots before a general recommendation is made to farmers in that area.
- In many situations where early, synchronized planting does reduce AfRGM infestation, farmers may have difficulty in implementing these recommendations fully, because of agronomic or socio-economic problems. For example, different inland valleys in an area may become wet enough for transplanting at different times, or farmers may lack the family labor, cash or fertilizer to plant early. Nevertheless, AfRGM damage can often be reduced even if these measures are only partly implemented, by shifting the average transplanting date earlier and reducing the period during which transplanting is carried out.

In some outbreak areas, fields planted very late may be at lower risk of serious AfRGM damage than those planted in mid-season, because rainfall is less frequent and natural enemies of AfRGM have had time to build up. However, late planting is only advisable if there will be enough water to ensure that the crop will not suffer drought stress.

Destruction of wild rices, and the ratoons and volunteers of cultivated rice

Gall midge can only develop on cultivated and wild rice species and, in many outbreak areas, these host plants are mainly found in rice fields. These facts suggest that the management of AfRGM through the control of its host plants is feasible, at least in some locations. During the cropping season, rice crops themselves are by far the most abundant and important hosts for AfRGM. Therefore, the main aim must be to reduce AfRGM hosts at those times of the year when no rice crops are growing.

Ratoons and volunteers of cultivated rice species are important hosts for AfRGM at times when rice crops are not present. Often, ratoons are destroyed routinely during the dry season when fallow rice fields are burnt off, grazed, or prepared for planting of dry-season vegetable crops. In outbreak areas where this is not done, it may be worth recommending the destruction of ratoons, particularly if the dry season is short. Where the dry season is long, nearly all ratoons die well before the next cropping season even if they are left undisturbed.

The removal of volunteer rice plants early in the year is probably more important. Farmers normally hoe rice fields—burying volunteers along with other weeds—just before transplanting the new rice crop. This allows some AfRGM to move from the volunteers on unprepared fields onto nearby nurseries or newly transplanted seedlings. Destroying the volunteers two weeks or more before the first new rice nurseries are sown should reduce this carry-over, because AfRGM adults only survive a few days.

For many farmers, hand-pulling of volunteers a few weeks before hoeing is probably the only option available. This is feasible if there are a few volunteers, but where volunteers are abundant it will probably be too labor-intensive at such a busy time of the year. If this is the case and herbicide use is not practical, farmers should be encouraged to reduce volunteers by altering their harvesting and threshing practices to reduce the amount of grain dropped in or near the fields.

Most African wild rice species can be controlled in the same way as volunteers, but *O. longistaminata* is more difficult to control because its underground rhizomes, on which AfRGM can survive a long dry season, are hard to kill. In some rice-growing areas, *O. longistaminata* is so abundant, both in rice fields and in adjacent uncultivated swamps, that controlling it is not feasible, but in others where it is limited to small patches, control may be worthwhile. Hand-pulling is not effective because the rhizomes remain alive in the soil. A systemic herbicide such as glyphosate, which moves from the leaves through the whole plant, will kill the rhizomes. The best time to apply this is after the beginning of the rains, but before rice crops are planted. At this time, new *O. longistaminata* tillers will be growing vigorously, and will transfer the herbicide to the rhizomes quickly. The herbicide can be spot-sprayed with a knapsack sprayer, or wiped onto the leaves with a cloth or sponge. Glyphosate kills crop plants, so care must be taken if it is being applied close to them. However, it does not remain active in the soil.

Increasingly, farmers are growing vegetables and other non-rice crops on rice fields in the dry season. This helps to control weeds and should reduce *O. longistaminata* if repeated over several years. However, a survey in one southeast Nigerian outbreak area has suggested that the effect on *O. longistaminata* is slow and that dry-season cultivation may actually increase the abundance of volunteer rice early in the rainy season, so more specific measures are probably needed to reduce these AfRGM hosts. Results of the same survey also suggested that if the area of lowland rice is large or neighboring rice areas are only a few hundred meters apart, then the removal of alternative host plants will have to be carried out over a wide area (probably several square kilometers) to be effective. If tried on a smaller scale, AfRGM adults will be able to move in quickly from adjacent untreated areas. More on-farm testing of this cultural control option is needed.

Fertilizer application

Adequate application of fertilizers is needed to allow the crop to compensate for AfRGM attack, but studies at the National Cereal Research Institute (NCRI) in Nigeria and the *Institut de l'environnement et de recherches agricoles* (INERA) in Burkina Faso have shown that high doses of nitrogen increase AfRGM infestation. Fertilizers should therefore not be used at rates above those recommended by agricultural extension service staff, and they should be applied in split doses at the correct crop growth stages.

Movement of seedlings

Rice seedlings can be infested by AfRGM in the nursery. However, the infestation is often invisible before transplanting, because the galls remain small and hidden until shortly before AfRGM adults emerge. Therefore, moving seedlings between rice-growing areas should be strongly discouraged because it risks spreading the pest, even when the plants involved appear to be healthy. This risk is likely to be significant in areas where farmers often exchange or sell rice seedlings.

Varietal resistance

A crop variety is resistant to a pest if the pest has a less-damaging effect on the resistant variety than it does on other (susceptible) varieties. The resistance may be the result of the pest being less able to colonize, grow or multiply on the variety, or it may be due to the variety's ability to grow and yield better than susceptible varieties despite the presence of the pest. The latter form of resistance is known as 'tolerance.'

Field sampling has shown that AfRGM can increase very rapidly on many of the improved, high-yielding rice varieties currently grown by farmers. This allows serious outbreaks to develop quickly, even though only small numbers of adult midges migrate onto rice crops at the beginning of the cropping season from other hosts, such as wild rice species and volunteers. Thus, developing new rice varieties with higher levels of resistance to AfRGM is very important for improved management of the pest.

No high-yielding rice variety with strong resistance to AfRGM is yet available for release to farmers. However, 'Cisadane,' a variety with some tolerance to the pest, has recently been released in Nigeria as FARO 51. Though its yield is reduced by AfRGM infestation, the effect is less severe than on other varieties. In on-farm trials in southeast Nigeria, Cisadane gave, on average, 28% higher yield than farmers' current varieties. The yield benefit was apparent at sites where more than about 10% of tillers had AfRGM galls.

BW 348-1 is another variety that has shown some tolerance to AfRGM. It has the added advantage of being quite tolerant to iron toxicity, which is a common soil problem in AfRGM outbreak areas. In 1998, this variety was being tested in on-farm trials in Nigeria.

Many varieties of the main cultivated rice species, *Oryza sativa*, that are resistant to Asian rice gall midge have proved to be susceptible to the African species. But several traditional African and Asian varieties that have moderate or weak resistance to AfRGM have been identified. Some of these are now being used in resistance breeding programs. Up to 1998, the variety showing the strongest resistance in Nigeria was the traditional variety TOS 14519 from The Gambia.

The indigenous African cultivated rice, *Oryza glaberrima*, shows more resistance to AfRGM than does *O. sativa*. Several traditional varieties have been identified that show strong resistance in Nigeria. The recent success of WARDA rice breeders in producing fertile hybrids between *O. glaberrima* and *O. sativa* (NERICA varieties) should allow this strong resistance to be bred into high-yielding varieties.

Recent studies by the WARDA Integrated Pest Management Task Force have shown that the resistance of rice varieties to AfRGM can differ markedly from one location to another. This is probably due to genetic differences between the AfRGM populations at different locations.

This has important implications. It means that resistance screening and breeding at several locations will be necessary to develop varieties with AfRGM resistance that is stable across Africa.

Biological control

Parasitoids and predators of AfRGM provide natural biological control of the pest for much of the time. Most of these natural enemies are active on the external surfaces of the rice plants. They are therefore more susceptible to insecticide sprays than AfRGM, which spends most of its life cycle protected within galls. At present, the main way in which farmers can assist natural biological control of AfRGM is to avoid the excessive use of insecticides. When necessary, insecticides and insecticide application methods that produce the greatest effect on AfRGM and the least effect on parasitoids and predators should be used. More details are given below (Control with insecticides).

Possible new methods to improve natural biological control are now being studied and involve the gall-midge species that attacks the grass weed *Paspalum scrobiculatum*. Several of the parasitoids that attack AfRGM, including the two commonest species (*Aprostocetus procerae* and *Platygaster diplosisae*), have also been reared from the *Paspalum* gall midge and appear to use it as an alternative host. In laboratory tests, *Aprostocetus procerae* reared from the *Paspalum* midge readily attacked and developed on AfRGM. Tests are being carried out on the other main species. By adjusting agricultural practices, it may be possible to increase populations of the *Paspalum* gall midge and its parasitoids early in the rainy season, and so improve the carry-over of parasitoids from this species to AfRGM on young rice crops. However, this approach needs further research before it can be recommended to farmers.

Control with insecticides

The use of insecticides to control AfRGM is difficult and has drawbacks, such as the cost, risks to human health, and the destruction of natural enemies. Therefore, insecticides should only be used when economic damage by AfRGM is likely and cannot be prevented by other methods. Recommendations on the use of insecticides to control AfRGM differ from country to country, so only some general principles are given here.

Though the natural enemies that help control AfRGM are usually exposed on leaf and stem surfaces, the pest itself is well protected inside galls for most of its life cycle. Therefore, a 'systemic' insecticide that is taken up and transported around the plant should be used. To minimize its effect on natural enemies, it should be applied to the soil in a granular formulation, rather than as a spray on the leaves. If the granules can be incorporated into the soil, they will have a longer-lasting effect than if they are scattered on the water surface. Poor water control will reduce their effectiveness, because water running off the field will carry away some of the insecticide. The systemic carbamate and organophosphorus insecticides usually recommended against AfRGM should be effective for about two or three weeks after application under good conditions. Therefore, they may have to be applied more than once.

The ‘economic injury level’ of a pest is the level of infestation above which the cost of applying a control measure against it is less than the value of the crop yield that will be lost if no action is taken. The ‘action threshold’ is the level of infestation at which the control measure should be applied to prevent the pest reaching the economic injury level. For AfRGM, these concepts are mainly relevant to the application of insecticides, because nearly all the other control methods (see above) have to be implemented before the rice crop is planted. Accurate economic injury levels and action thresholds for the use of insecticides against AfRGM are not available. They are likely to vary considerably according to the conditions in each outbreak area. Those suggested for Asian rice gall midge in different areas vary greatly, for example: 0.3 galls per hill; 5 to 10% of hills with galls; or 1 gall per square meter.

In addition to being applied to rice crops in the field, insecticide can be applied to seedlings before transplanting. This can be done by using granules or sprays on the nursery bed, or by soaking the roots in a container of insecticide solution for several hours just before transplanting. Advantages over application on the field after transplanting are: (i) a smaller amount of insecticide will be needed to protect a given area of crop; (ii) the plants are protected earlier; (iii) natural enemies are less likely to be affected. The main drawback is that application before transplanting will have to be an ‘insurance’ treatment because galls cannot be seen until about three weeks after AfRGM eggs are laid. Therefore, it is only recommended when the risk of heavy AfRGM damage is known to be high.

Assessing the risk of gall midge damage

At present there is no way of accurately predicting AfRGM outbreaks. Developing a prediction system will be difficult because of the great speed with which AfRGM can multiply on rice crops when conditions are favorable. Work in southeast Nigeria suggests that prediction based on the sampling of galls on volunteers and wild rice before rice crops are transplanted will not be practical, at least in the locality studied. This is because, even in years with serious outbreaks, the number of galls on alternative hosts early in the rainy season is very low. Even crops showing very few galls at three weeks after transplanting can become very heavily infested by the stem-elongation stage and suffer severe damage.

To make a rough assessment of the risk of AfRGM damage, one has to rely partly on information about AfRGM levels at the site in previous years. This can be combined with consideration of the factors which, based on field observations and knowledge of the pest's biology, seem to be associated with a higher risk. The main factors are summarized below.

- Planting date and pattern: Late-planted fields are usually at higher risk, especially if planting in the locality is staggered over several weeks or months.
- Weather conditions: Cloudy, humid weather with frequent rain or mist favors rapid AfRGM build-up.
- Rice ecology: Hydromorphic and lowland rice ecologies, with the exception of tidal mangrove rice, are at higher risk than upland rice.
- Agro-ecological zone: Sites in the Guinea savanna, derived savanna and humid forest zones (having relatively long rainy seasons) are at higher risk than those in the Sudan savanna or the Sahel. Most of the worst-affected areas are in Guinea or derived savanna.

Other possible factors are the following.

- Method of planting: Transplanted crops seem at higher risk than direct-seeded ones.
- Rice variety: Many of the currently used short- and medium-duration improved varieties are very susceptible to AfRGM.
- Nitrogen dose: High rates of nitrogen fertilizer increase infestation.
- Parasitoids: Low levels of parasitism in AfRGM galls in the early- to mid-rainy season increase the risk of high peak populations of the pest later.
- Water depth: Shallow swamps, with water depths of about 30 cm or less, may be at higher risk than deep swamps.
- Size of rice-growing area: Small, isolated areas probably have a lower risk of being colonized by AfRGM, though damage can be severe if they are.
- Presence of *O. longistaminata*: Where there is a long dry season, rice crops in localities in which *O. longistaminata* is present are more likely to be colonized early.
- Abundance of volunteers and ratoons: Sites where many live ratoons and/or volunteers of *O. sativa* are present early in the rainy season, before rice crops are planted, are likely to be at higher risk. This point and the previous one only apply if a dry-season rice crop is not grown.

There is no good evidence that rice–rice double-cropping increases the risk of AfRGM damage, even though the pest can persist on the dry-season rice crop. Most of the worst AfRGM outbreaks have been at single-cropped sites with staggered planting. One reason could be that at double-cropped sites more AfRGM parasitoids are available early in the rainy season because they survive with the pest on the dry-season crop.

Selecting suitable gall midge management options

The conditions under which rice is grown in Africa are very varied. Therefore, AfRGM management options that are practical in one area may be impossible to use in another. For example, synchronized planting may be easily organized on an irrigation scheme with good water control, but impossible where no irrigation is available and neighboring valleys become wet enough for transplanting at different times. Similarly, where *O. longistaminata* is limited to a few patches on farmers' fields, it may be feasible to eliminate it, but this is impractical if rice fields lie next to a large uncultivated swamp dominated by *O. longistaminata*.

Selecting those AfRGM management options that are practical in a particular situation will depend on a good knowledge of the local conditions. This will require direct observations in the field and discussions with farmers. Rapid, informal surveys of local farmers in an outbreak area are worthwhile. They are an efficient way of gathering information on local conditions, currently used control methods, and farmers' experience and knowledge of the pest. Combined with direct observations, this information will provide a good basis for a realistic assessment of the opportunities for, and constraints to, new AfRGM management options.

Sampling and Screening Techniques for African Rice Gall Midge

Surveys

This section provides some guidelines for surveys designed to estimate AfRGM infestation levels in a country or district. The guidelines are aimed mainly at researchers planning a rapid, extensive survey involving a single visit to each sampled site, and with infestation-level estimates based on gall counts. However, they could be adapted for more intensive, multi-visit surveys. To increase the value of a survey, information can also be recorded on other rice pests and on AfRGM parasitoids (see below).

To obtain unbiased estimates of AfRGM infestation, rice fields within an area—and plants within a field—must be selected for sampling in such a way that the chance of a field or plant being selected is not influenced by its level of infestation. In many cases, the simplest way to select fields in an unbiased way is to drive or walk predetermined routes through a rice-growing area, sampling at predetermined intervals (for example, one field every 10 km). The routes and sampling interval can be chosen to give the desired number of sampled fields in an area. If time is limited, it is probably best to restrict the survey to hydromorphic and lowland rice ecologies, which are at higher risk than upland rice.

To find all the galls on a rice plant, including those that have not yet elongated, one must dissect the tillers. Just counting elongated galls is much quicker and does not involve destroying any plants, so this is the method normally used for surveys. Ideally, a survey based on gall counts without tiller dissection should be timed so that fields are sampled at about the stem-elongation stage, because the percentage of tillers showing galls at this growth stage is a better index of yield loss than infestation recorded earlier or later. In practice, the range of growth stages sampled will probably have to be wider. Because of the three-week delay between AfRGM eggs being laid and the resulting galls elongating, do not sample fields with plants that are less than about three-weeks old. A survey undertaken when most rice crops are at or past the flowering stage is also of limited value, because galls present at this stage may have little effect on yield.

When survey assistants examine plants at random, the resulting sample may be biased towards the field edge, one part of the field, large hills, or even hills on which galls can be seen. It is therefore better to follow a pre-determined sampling pattern. An easy method is to select hills by walking transects across the field and sampling at predetermined intervals (for example, one hill every 5 steps), with the interval selected to give the required number of samples. The exact transect pattern does not matter as long as it covers the field fairly evenly. Two possibilities are: (i) several parallel transects, or (ii) a zigzag pattern. Aim to examine at least 20 hills in each sampled field, and preferably 30 or more.

For each sampled hill, record: (i) the total number of galls, and (ii) the total number of tillers (that is, tillers with galls plus those with none). These figures are used to calculate the percentage of infested tillers for all the hills sampled in the field. Numbers of other pests or their damage symptoms can be recorded from the same hills if required.

Other variables that should be recorded for each sampled field include:

- sampling date
- field location (including latitude and longitude, if possible)
- crop growth stage and/or age
- rice ecology.

If one aim of the survey is to investigate factors that may affect the risk of AfRGM damage, then extra information should be recorded, such as rice variety, planting method (direct seeded/ transplanted), date of transplanting or seeding, water depth, and fertilizer and insecticide use. Some of this information will only be available from the farmers.

Interviews with local farmers and extension staff are useful additions to a field survey, particularly because AfRGM damage varies greatly from year to year. Local people may be able to provide some information on past years. Even if time is limited, quick informal group interviews in a few places along the survey route are worthwhile.

Screening rice varieties for resistance to gall midge

Trials in outbreak areas to screen rice varieties for resistance to AfRGM are perhaps the most common type of experiment undertaken on this pest. With the recent discovery that the AfRGM resistance reactions of varieties can vary from one location to another, trials of this type are likely to be even more important in the future. Though a detailed discussion of the design and analysis of such experiments is beyond the scope of this guide, some general principles are given below.

If information on crop yield is not required, small one- or two-row experimental plots of each variety with a minimum of about 20 hills each are adequate. The experimental design used will depend on the trial site, the number of varieties to be screened, the amount of seed available, and the exact objectives of the trial. If the number of varieties to be tested is small, a randomized complete block design can be used, but incomplete block designs are more usual. When hundreds of test entries are to be compared, a single plot of each can be used, with plots of one or more 'check varieties' repeated systematically across the trial.

It is best to use at least two check varieties: a 'susceptible check' to assess the AfRGM pressure, and a 'resistant check' to provide a known resistant 'standard' with which to compare the test entries. Both checks can be used to assess variations in AfRGM pressure across the trial. ITA 306 is a commonly used susceptible check, and Nhta 8 is a commonly used resistant check. Including them in a trial will allow the results to be compared easily with results of many previous trials. ITA 306 is highly susceptible to AfRGM. Nhta 8 is not highly resistant, but it is one of the most resistant *O. sativa* varieties identified so far.

Whatever trial layout is selected, it should be used on the nursery bed as well as in the field, because AfRGM infestation often starts in the nursery. To ensure high AfRGM infestation, the trial should be sited in a reliable AfRGM hot-spot and timed to maximize the chance of high infestation. This will normally mean planting late. A large dose of nitrogen fertilizer can be used to increase the chances of heavy infestation.

The infestation level on each plot should be scored two or three times if possible. Commonly used scoring times are about 21, 42 and 63 DAT (days after transplanting). If the trial can only be scored once, it should be done 63 DAT. The AfRGM infestation level is usually highest at this time, variations in infestation pressure across the trial are lower, there are more tillers per hill, and the infestation level recorded at about 63 DAT is more closely related to yield loss than infestation scored earlier is.

A commonly used sample size is 20 hills per plot. If the plot contains more than this, the hills to be sampled must be a representative sample of the whole plot. For each sampled hill, record:

- the number of galls, and
- the total number of tillers (those with galls plus those with none).

After all plots have been scored, calculate for each plot:

- the percentage of tillers infested, and
- the percentage of hills infested.

In assessing resistance, percentage tiller infestation is more useful because it is more closely related to yield loss and is a more sensitive index of resistance, particularly when AfRGM pressure is high and nearly all hills have some galls.

The infestation level on each entry is often converted to a simple 'Standard Evaluation System' (SES) score. This internationally agreed scale was developed for assessing resistance to Asian rice gall midge. The SES scale for field trials is as follows:

SES score	SES description	Percent tiller infestation
0	Highly resistant	0
1	Resistant	less than 1
3	Moderately resistant	1–5
5	Moderately susceptible	6–10
7	Susceptible	11–25
9	Highly susceptible	more than 25

This scoring system should only be used if the percent tiller infestation on the susceptible check is above 15%. Trial results are considered unreliable if the level is lower.

Though the SES scale provides a simple, standardized way of summarizing results, it cannot take the full effect of variations in AfRGM pressure into account. For example, a test entry that shows 4% infestation when that on the susceptible check is 16% will rate as 'moderately resistant' on the SES scale. But in a trial under much higher AfRGM pressure, in which the susceptible check shows 50% infestation, a test entry with 6% will be classified as 'moderately susceptible' and may be overlooked if only the SES scores are considered. Therefore, comparing percent tiller infestation levels on test entries and checks in the same trial is a more reliable way of identifying entries with useful levels of resistance.

Before percent infestation data are analyzed using statistical procedures that assume the data is normally distributed, such as analysis of variance, they should be transformed using the angular transformation (also known as arc sine transformation).

It is important to remember that the type of trial outlined here will not detect varietal tolerance to AfRGM. This is because tolerance does not reduce the level of pest infestation on the plant, unlike other kinds of resistance. Instead it enables the plant to produce more yield at a given level of infestation. A trial to assess tolerance must involve the measurement of yield and will require larger plots.

Gall dissection to assess parasitism levels

Galls can be collected and dissected to estimate the proportion of AfRGM killed by parasitoids, the pest's most important natural enemies. When collecting galls for this purpose, the following guidelines should be followed.

- Collect a random sample of both new and old galls. If you collect only new, intact galls from which no midge or parasitoid has emerged, you will overestimate the parasitism level. This is because parasitoids, particularly *Aprostocetus*, take longer to complete development after galls elongate than do unparasitized AfRGM. Therefore, parasitized galls remain intact longer than unparasitized ones.
- Take at least 50 galls to get a rough estimate of parasitism, and collect from all parts of the field.
- Use a knife to cut tillers with galls away from the rest of the plant. Be careful to cut below the base of the gall because the AfRGM or parasitoids are usually there. To avoid damaging the insect inside, it is best to remove the whole tiller with some roots attached.
- Do not squeeze the galls or let them become too hot after collection, or you may kill any live AfRGM or parasitoids they contain. Transfer galled tillers to a plastic bag in the shade immediately after collection, or keep them in an insulated cool box.

Dissect the galls on the day they are collected. It is best to use a scalpel, a fine pair of forceps and a hand lens or, ideally, a dissecting microscope with a good light source. Galls can be dissected with your fingers in the field, but the contents may be damaged and some parasitoids will be missed. Use the scalpel to cut away the surrounding leaf sheaths and then carefully open the gall along its length with the forceps and examine the contents.

In a newly elongated gall from which no insects have emerged, you will usually find one of the following:

- A healthy, unparasitized AfRGM pupa that will wriggle when touched. Occasionally the AfRGM is still a larva when the gall elongates.
- A dead final-instar AfRGM larva containing many *Platygaster* pupae. These are whitish for a day or two when first formed, and then turn black. After the adult *Platygaster* have emerged, the pupal cases are transparent. Tiny black adults of *Platygaster*, less than 1 mm long, may also be found. Galls containing *Platygaster* are often rather fatter and shorter than unparasitized galls.
- A paralyzed or dead AfRGM pupa with an *Aprostocetus* egg, larva or pupa on or near it. The parasitoid's eggs and young larvae are small and difficult to see without a microscope. The larva is fat, legless, up to about 3 mm long and either mainly bright red (probably due to the color of the gut contents) or whitish. The oval pupa is white at first, darkening to orange-brown or dark brown before the adult emerges. If the gall contains a large *Aprostocetus* larva or pupa, the AfRGM pupa will be dark and shrivelled as a result of the parasitoid's feeding.

In an older gall from which an adult AfRGM or parasitoids have already emerged, you will usually find one of the following.

- Nothing, if the AfRGM was not parasitized. An oval, ragged-edged AfRGM exit hole about 2 mm long will be found near the top if the gall has not been damaged or started to die back. The exit hole may still have part or all of the translucent AfRGM pupal skin attached to it.
- A dead final-instar AfRGM larva containing some empty, transparent *Platygaster* pupal skins and/or some black, dead pupae from which adult parasitoids have failed to emerge. A few dead *Platygaster* adults are often present in the gall also. This parasitoid's exit holes are distinctive. They are neat, circular and much smaller than those of AfRGM or *Aprostocetus*. There may be more than one per gall.
- A dead, shrivelled AfRGM pupa and fragments of an *Aprostocetus* pupal skin. These fragments are pale, translucent orange-brown, and can be difficult to see. Before pupating, the *Aprostocetus* larva empties its gut. The waste matter leaves a blackish spot on the inside

of the gall. This can be easier to see than the pupal skin. An *Aprostocetus* exit hole is round, but bigger and less neat than that of *Platygaster*.

Quite often, the top of a gall becomes damaged or starts to die back soon after it has elongated, so that it is impossible to tell whether it still contains insects (either AfRGM or parasitoids) until it is dissected.

When a dead AfRGM pupa is found in a gall with no sign of a parasitoid, the likely cause of death is usually evident from its appearance.

- If the AfRGM pupa has been pulled apart or there are pieces missing, it has probably been killed by a predator, which is sometimes still in the gall.
- If it is in a water-filled gall, the pupa probably drowned when the gall was damaged.
- If stuck tight in the gall, it was probably trapped so the adult could not emerge.
- If freshly squashed, it was probably damaged accidentally during collection.
- If immobile but apparently healthy, it was probably recently paralyzed by *Aprostocetus*. Check again for a parasitoid egg or small larva nearby.

The percentage of the dissected galls containing parasitoids or their remains gives an estimate of the proportion of the AfRGM population killed by these natural enemies. If both new and old galls are included in the sample to prevent parasitism being overestimated (as explained above), this estimate relates to all the galls that elongated in the roughly three- or four-week period up to the sampling date, because a gall takes about this length of time to die away.

In gall samples from rice crops, at least 95% of the parasitoids found are normally *Platygaster diplosisae* or *Aprostocetus procerae*. Others recorded occasionally include species of *Neanastatus*, *Eupelmus* and *Eurytoma*. These are all roughly the same size as *Aprostocetus* and have similar life cycles. *Neanastatus* is distinctly slimmer than *Aprostocetus* as a larva, pupa and adult. The others are more similar and are very difficult to distinguish as larvae or pupae. The adults are darker than *Aprostocetus*, which normally has pale orange-brown patches on the body.

Collecting gall midges and parasitoids for identification

The precise identification of gall midges and their parasitoids requires detailed examination by specialists. Fresh specimens should be preserved in labeled specimen tubes containing 80% alcohol. When sending specimens for identification, pack plenty of padding around the tubes. One or two small pieces of thin tissue or polyethylene can also be placed inside each tube to reduce the risk of specimens being damaged. Do not use cotton wool for this because specimens become tangled in it. For both gall midges and their parasitoids, a series of specimens is more valuable for identification than just one or two.

Unlabelled specimens are of little use. Ideally, labeling should be in permanent ink on thin card, but labels in pencil on slips of paper are adequate. Do not use a pen with water- or alcohol-soluble ink. Place the label inside the tube, taking care not to damage the specimens. Information on the label should include:

- country and location
- scientific name of the host-plant species on which the gall was found
- other relevant biological information (e.g. 'reared from gall on lowland rice')
- date of collection
- collector's name
- a reference number.

If any 'onion shoot' galls are found on plants other than rice (*Oryza*) species or *Paspalum scrobiculatum*, keep a dried, pressed specimen of the plant for identification, and preserve the dissected gall, as well as the insects reared from it, in 80% alcohol.

For gall midges, the fully developed larvae, pupae and adults are all useful for identification. Pupae and adult males are the most useful. Males can be distinguished from females by their longer, more hairy antennae and smaller, slimmer abdomen with a pair of claspers at the tip. To rear adults from pupae collected from dissected galls, place several pupae in a beaker or similar container about 7 cm diameter and 10 cm high. Put a piece of damp tissue down the side to keep the humidity high, and close the top. Keep the container in the shade at room temperature. Most of the adults should emerge within one or two days. Keeping the humidity at the right level is important. If the container dries out, the adults will fail to emerge. If it is too wet, they will get trapped in water droplets and become damaged. Adult midges resting on the container's walls can be carefully collected into specimen tubes. They are fragile and should be put in alcohol as soon as they have fully emerged and hardened, which is usually about 2–3 hours after emergence from pupae.

For the parasitoids, adults are needed for identification. Pupae and large larvae can be reared to adults in specimen tubes with a small piece of moist tissue to keep the air humid. Small larvae are difficult to rear successfully. Large larvae should be left in a piece of gall with the AfRGM corpse they are feeding on. The gall section will stay healthy for longer if it includes the base. Preventing the tube's contents from becoming either too wet or too dry is important.

Adult males of *Aprostocetus procerae* can be distinguished quite easily from females under a hand lens or low-powered microscope. The male's antennae are much longer than the female's and they bear long hairs. However, it is difficult to separate males and females of *Platygaster diplosisae* without greater magnification, because of their very small size.

Gall midges and parasitoids can be collected from galls without dissection by keeping fresh, field-collected galls in a small bucket or similar container with a few centimeters of water in the base and a fine net or cloth bag tied over the top. The adults can be collected from the bag as they emerge. Care must be taken that no insects other than gall midges and their parasitoids are present on or in the plant material, as this could lead to incorrect parasitoid host records. For example, if the plant material contained larvae or pupae of stalk-eyed flies (*Diopsis*) or lepidopterous stem-borers, parasitoids emerging from these insects could be mistaken for those of AfRGM.

Further Reading

This list is not exhaustive but includes some of the main references on rice gall midge biology, ecology, management and varietal screening techniques. Those marked with an asterisk are available in both French and English. The list includes some references on Asian rice gall midge that are also relevant to AfRGM. *Note:* In some references information on the host range of AfRGM is inaccurate.

Bouchard, D., A. Ouedraogo, G. Boivin and K. Amadou, 1992. Mass rearing and life-cycle of the African rice gall midge, *Orseolia oryzivora* H. & G., in Burkina Faso. *Tropical Pest Management* 38: 450–452.

Brenière, J., 1983. *The Principal Insect Pests of Rice in West Africa and Their Control* (2nd Edn). West Africa Rice Development Association, Monrovia, Liberia.*

Dakouo, D.S., S. Nacro and M. Sie, 1988. Evolution saisonniere des infestations de la cecidomyie du riz *Orseolia oryzivora* H. et G. (Diptera: Cecidomyiidae) dans le sud-ouest du Burkina Faso. *Insect Science and its Application* 9: 469–473.

Harris, K.M. and R.J. Gagné, 1982. Description of the African rice gall midge, *Orseolia oryzivora* sp. n., with comparative notes on the Asian rice gall midge *O. oryzae* (Wood-Mason). *Bulletin of Entomological Research* 72: 467–472.

Harris, K.M., C.T. Williams, O. Okhidievbie, J. LaSalle and A. Polaszek, 1999. Description of a new species of *Orseolia* (Diptera: Cecidomyiidae) from *Paspalum* in West Africa, with notes on its parasitoids, ecology and relevance to natural biological control of the African rice gall midge, *O. oryzivora* Harris & Gagné. *Bulletin of Entomological Research* 89: 441–448.

Heinrichs, E.A., F.G. Medrano and H.R. Rapusas, 1985. *Genetic Evaluation for Insect Resistance in Rice*. International Rice Research Institute (IRRI), Los Baños, The Philippines.

IRRI (International Rice Research Institute), 1996. *Standard Evaluation System for Rice* (4th Edn). IRRI, Los Baños, The Philippines.

Nacro, S., 1994. *Analyse d'un Systeme Tritrophique: la Cecidomyie du Riz et ses Parasitoides au Burkina Faso*. Thèse de Doctorat de l'Université de Rennes I.

Nacro, S., E.A. Heinrichs and D. Dakouo, 1996. Estimation of rice yield losses due to the African rice gall midge, *Orseolia oryzivora* Harris and Gagné. *International Journal of Pest Management* 42: 331–334.

Okocha, P.I., M.N. Ukwungwu and R.C. Joshi, 1992. Field varietal screening against African rice gall midge. *IITA Research Guide* 34. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.*

Reissig, W.H., E.A. Heinrichs, J.A. Litsinger, K. Moody, L. Fiedler, T.W. Mew and A.T. Barrion, 1986. *Illustrated Guide to Integrated Pest Management in Rice in Tropical Asia*. International Rice Research Institute (IRRI), Los Baños, The Philippines.

Ukwungwu, M.N., 1987. Effects of spacing and nitrogen fertilizer on infestation by the rice gall midge *Orseolia oryzivora* Harris and Gagné (Diptera: Cecidomyiidae) in Nigeria. *Tropical Pest Management* 33: 164–165.

Ukwungwu, M.N. and R.C. Joshi, 1992. The distribution of the African rice gall midge, *Orseolia oryzivora* Harris and Gagné and its parasitoids in Nigeria. *Tropical Pest Management* 38: 241–244.

Ukwungwu, M.N., C.T. Williams and O. Okhidievbie, 1998. Screening of African rice, *Oryza glaberrima* Steud, for resistance to the African rice gall midge, *Orseolia oryzivora* Harris and Gagné. *Insect Science and its Application* 18(2): 167–170.

Umeh, E.D.N. and R.C. Joshi, 1993. Aspects of the biology, ecology and natural biological control of the African rice gall midge, *Orseolia oryzivora* Harris & Gagné (Diptera, Cecidomyiidae) in south east Nigeria. *Journal of Applied Entomology* 116: 391–398.

Williams, C.T., O. Okhidievbie, K.M. Harris and M.N. Ukwungwu, 1999. The host range, annual cycle and parasitoids of the African rice gall midge *Orseolia oryzivora* Harris & Gagné (Diptera: Cecidomyiidae) in central and southeast Nigeria. *Bulletin of Entomological Research* 89: 589–597.

Williams, C.T., O. Okhidievbie, M.N. Ukwungwu, D. Dakouo, S. Nacro, A. Hamadoun and S.I. Kamara, 1999. Multilocational screening of *Oryza sativa* and *O. glaberrima* for resistance to African rice gall midge *Orseolia oryzivora* in West Africa. *International Rice Research Notes* 24(1): 26–27.

Williams, C.T., M.N. Ukwungwu, B.N. Singh, O. Okhidievbie and J. Nnabo, 1999. Farmer-managed trials in south-east Nigeria to evaluate the rice variety Cisadane and estimate yield losses caused by the African rice gall midge, *Orseolia oryzivora* Harris & Gagné. *International Journal of Pest Management* 45: 117–124.

Williams, C.T., M.N. Ukwungwu, B.N. Singh and O. Okhidievbie, 2001. Assessment of host plant resistance in *Oryza sativa* to the African rice gall midge, *Orseolia oryzivora* Harris & Gagné (Diptera, Cecidomyiidae), with a description of a new method for screening under artificial infestation. *Journal of Applied Entomology* 125(6): 341–349.

About WARDA

The West Africa Rice Development Association (WARDA) was formed as an autonomous intergovernmental research association in 1971 by 11 countries, with the assistance of the United Nations Development Programme (UNDP), the Food and Agriculture Organization of the United Nations (FAO), and the Economic Commission for Africa (ECA). Today, the Association comprises 17 member states: Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, the Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo. Since 1987, WARDA has also been a member of the Consultative Group on International Agricultural Research (CGIAR), a network of 16 international research centers supported by more than 50 public- and private-sector donors.

WARDA's mission is: to contribute to food security and poverty eradication in poor rural and urban populations, particularly in West and Central Africa, through research, partnerships, capacity strengthening and policy support on rice-based systems, and in ways that promote sustainable agricultural development based on environmentally sound management of natural resources.

WARDA's research and development activities are carried out in collaboration with the national agricultural research systems of members states, academic institutions, international donors and other organizations, to the ultimate benefit of West and Central African farmers—mostly small-scale producers—who cultivate rice, as well as the millions of African families who eat rice as a staple food.

WARDA Headquarters are at M'bé, 25 km north of Bouaké, a major commercial center in Côte d'Ivoire. WARDA also operates research stations at N'Diaye, near Saint Louis, Senegal, and at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

Donors to WARDA in 2001 were: the African Development Bank, Belgium, Canada, CGIAR (Finance Committee), Common Fund for Commodities (CFC), Côte d'Ivoire, Denmark, the European Union, the Food and Agriculture Organization of the United Nations (FAO), France, the Gatsby Foundation (UK), Germany, the International Development Research Centre (Canada), the International Fund for Agricultural Development, Japan, the Netherlands, Norway, the Rockefeller Foundation (USA), Sweden, the United Kingdom, UNDP, the United States of America, the World Bank and WARDA member states.

About CGIAR

The Consultative Group on International Agricultural Research (CGIAR) was founded in 1971 as a global endeavor of cooperation and goodwill. The CGlAR's mission is to contribute to food security and poverty eradication in developing countries through research, partnership, capacity building and policy support, promoting sustainable agricultural development based on the environmentally sound management of natural resources. The CGIAR works to help ensure food security for the twenty-first century through its network of 16 international and autonomous research centers, including WARDA. Together, the centers conduct research on crops, livestock, fisheries and forests, develop policy initiatives, strengthen national agricultural organizations, and promote sustainable resource management practices that help provide people world-wide with better livelihoods.

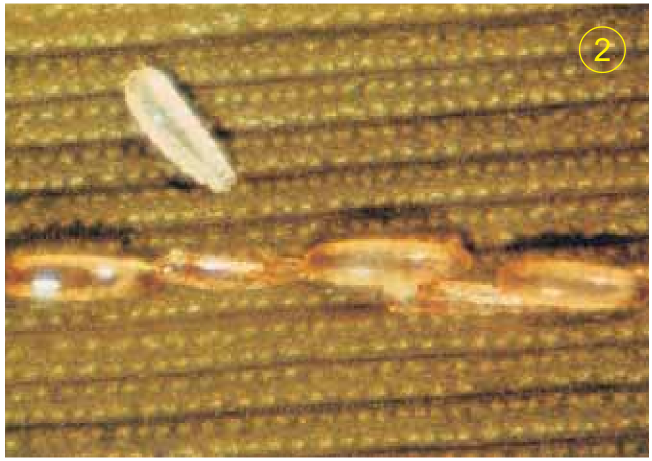
The CGIAR works in partnership with national governmental and non-governmental organizations, universities and private industry. The United Nations Development Programme, the United Nations Environment Programme, the World Bank, and the Food and Agriculture Organization of the United Nations sponsor the CGIAR. The CGlAR's 58 members include developing and developed countries, private foundations, and international and regional organizations. Developing world participation has doubled in recent years. All members of the OECD (Organisation for Economic Co-operation and Development) Development Assistance Committee belong to the CGIAR.

The CGIAR is actively planning for the world's food needs well into the twenty-first century. It will continue to do so with its mission always in mind and with its constant allegiance to scientific excellence.

About CABI

CAB International is a leading global not-for-profit organisation, specialising in sustainable solutions for agricultural and environmental problems.

African rice gall midge adult



Midge eggs with newly hatched larva on leaf surface

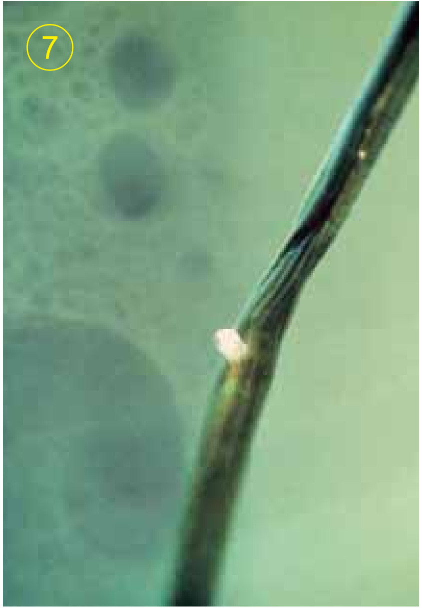
Midge larva in a dissected gall

Midge pupa

Galls on young plants shortly after transplanting

Galls on older plants at mid- to late tillering

Continued inside back cover

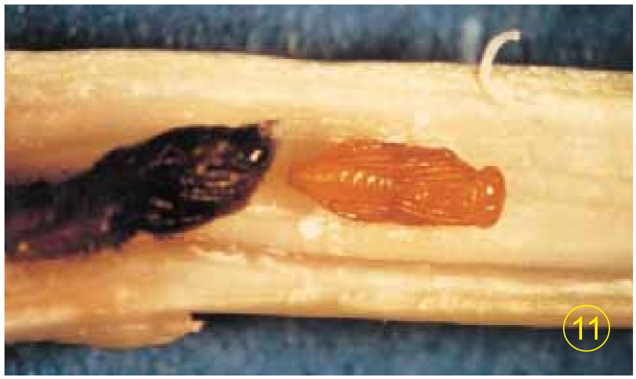


Close up of gall showing African rice gall midge pupal skin in exit hole

Galls on rhizome of *Oryza longistaminata*

Dissected gall with some *Platygaster* adults and parasitized midge larva containing empty *Platygaster* pupal cases

Dissected gall with parasitized midge pupa and *Aprostocetus* larva



Dissected gall with parasitized midge pupa and *Aprostocetus* pupa

Close up of tops of three galls showing exit holes of midge (center), *Platygaster* (right) and *Aprostocetus* (left)

West Africa Rice Development Association (WARDA)
01 B.P. 2551 Bouaké 01, Côte d'Ivoire
Telephone: (225) 31 65 93 00
Fax: (225) 31 65 93 11/22 41 18 07
E-mail: *warda@cgiar.org*
Web-site: *http://www.warda.cgiar.org/*

CAB *International*

CABI Bioscience
Bakeham Lane, Egham, Surrey TW20 9TY, UK
Telephone: (44) 0 1491 829000
Fax: (44) 0 1491 829100
E-mail: *bioscience.egham@cabi.org*
Web-site: *http://www.cabi.org/*

ISBN 92 9113 197 0