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Review Article
Incidence of Insect Pests on Rice in Nigeria: A Review

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Abstract
Rice is an important cereal crop and is cultivated virtually in all agro-ecological zones in Nigeria. However, production capacity is far below national requirement. One of the major reasons for the low yields of rice in Nigeria is depredation by pests, particularly the insect pests. The rice plant is an ideal host for a large number of insect pests-root feeders, stems borers, leaf feeders and grain feeders. High yield losses associated with these insect pest categories portray the role of the insects in low rice yield in Nigeria and sub-Saharan Africa as a whole. Unfortunately, the potential for proper management of rice insect pests to enhance yield has not been fully realized in Africa. Proper management of rice pests therefore is a pre-requisite for enhanced and sustainable rice production amidst smallholder farmers that typify the rice production industry in Nigeria. In this review, major insect pests of rice were identified with emphasis on their pest status, distribution and control methods. Cultural, biological, host plant resistance and chemical controls and the development of integrated pest management programmes were reviewed. The long-term and wide adoption of integrated insect pest management of rice in Nigeria was advocated, emphasizing the use of host plant resistance and biological control but the current cultural practices should be evaluated from time to time for enhanced efficiency.

Key words: Insect pests of rice, management strategies, increase rice yield, sustainable rice production, stem borers

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INTRODUCTION

Rice is an important cereal crop in the world, providing more calories per hectare than any other cereals food grain[1,2]. It has been reported that rice is one of the most important sources of employment and income generation for rural people[3]. In Nigeria, rice is an important staple food crop grown in almost all the agro-ecologies of the country[4]. At present, rice is competing favourably with such major food crops as cassava, yam and sorghum. The present status of the crop is reflected in an increase in hectareage planted to rice in Nigeria yearly and per capita consumption. Nigeria as at now is the largest producer of rice in the West African region[3,5] and the quantity of rice consumed in Nigeria has increased faster than in any other region of the continent[6,7].

Although rice is a traditional crop in Nigeria and has contributed a significant proportion of the food requirement of the population, local production is limited and has not satisfied the internal demand. To meet the increasing demand, milled rice has been imported. Nigeria ranked among the top rice importers in the world in the recent time[4,8].

Of all the production constraints of rice, one major reason for the low yield in Nigeria, which stand[9] at 3 t ha^{-1} is yield depredation by insect pests, which so far has not been given the full recognition it deserves as a production constraint[10]. The rice plant is an ideal host for a large number of insect pests. All parts of the rice plant are attacked by various insect species. In the world, there are more than 800 insect species damaging rice[11]. In Nigeria, rice is host to about 138 insect pest species and 22 species of parasitoids and predators[12]. These insects attack the rice plant at different growth stages. The severity of their attack differs considerably in different rice ecosystems, cropping systems and technologies.

The study of rice insect pests in Nigeria started in the 1940s, when Golding[13] recorded 11 insect species attacking rice plant. Umeh *et al.*[14] who classified the insects based on the plant parts they damage, which include the stem/bud borers, leaf feeders, grain suckers and root feeders (Table 1). Within these categories some have become serious insect pests of economic importance in Nigeria in the recent time. Most of the studies on insect pests of rice in Africa were reports from Nigeria probably because of the extensive cultivation and use of the crop. Prior to 1980s, there was little specific information beyond the general observations about the few insect pests of rice. In the recent years, much has been reported on different insect pests of rice. Thus, Heinrichs and Barrion[7], Umeh and Joshi[15] and few others have published articles on various insect pests of rice. However, little is yet known about their pest status, probably because of lack of yield loss analysis that justifies the potential of such insect as a key pest. According to Heinrichs and Barrion[7] of the few studies on yield losses associated with pest in Africa, yield losses caused by a combination of insect, diseases and weeds stand at 33.3%. It was estimated that each year, insects destroy between 10 and 30% of all food produced in Africa[16-19], while yield losses in rice attributed to insect pests in Africa were between 10 and 15%[20]. Following continuous changes in the ecosystem alongside the pest status of already established pest of economic importance, there is therefore the need to review the available information on the various insect pest species to identify their present pest status. Studies have also indicated that control of these rice insects alone can cause significant increases in rice production[19].

In this review, attempts were made to harmonize the hitherto fragmented information available on insect pests of economic importance based on literature, their nature of damage, population dynamics and distribution. Also discussed was the various control measures in use in the management of these pests and suggestions for enhanced control.

Table 1: Prevalence of major insect pests of rice in the field in different ecologies in Nigeria

Species	Common name	Upland	Rain fed lowland	Irrigated lowland	Humid tropical	Guinea savanna	Sudan
Orseolia oryzivora	African rice gall midge	0	0	0	-	0	0
Chilo zacconius	Striped stem borer	0	0	0	0	0	0
Maliarpha separatella	White stem borer	+++	+++	+++	0	0	0
Sesamia calamistis	Pink stem borer	0	0	-	0	0	0
Diopsis longicornis	Stalk eyed fly	0	0	+++	0	0	0
Nymphula stagnalis	Case worm	-	+++	0	0	0	0
Trichispa sp.	Hispa	-	0	0			
Hydrellia prosternalis	Whorl maggot	-	0	0	0	0	0
Marasmia trapezalis	Leaf folder	0	0	0	0	0	0
Aspavia armigera	Rice bug	+++	0	0	0	0	0
Stenocoris claviformis	Rice bug	+++	0	0	0	0	0
Spodoptera sp.	Armyworm	0	0	-	0	0	0
Macrotermes spp. (and others)	Termites	0	0	-	0	0	0

+++: Widely abundant, ++: Abundant, +: Present, -: Not recorded, Sources[7,12]

MAJOR FIELD INSECT PESTS OF RICE IN NIGERIA AND THEIR DISTRIBUTION

Although comprehensive information is not yet available on insect pests of economic importance in Nigeria, the rice plant has been reported to be host to so many insect pests. Different insects attack different parts of rice with economic losses. Many species of insects belonging to 8 insect orders have been reported in rice fields in Nigeria. However, the severity varies from location to location[11]. At present, the insect orders of economic importance in the Nigerian ecologies are (Table 1): Coleoptera (beetles), Hemiptera (bugs) and Lepidoptera (moths). Others are the Diptera (midges) and Isoptera (termites)[7]. These are reviewed based on the categories of stem/bud borers, leaf feeders, grain feeders and root feeders. Insects attack rice plant from seedling to harvest and even into storage resulting to yield losses which may be direct or indirect.

STEM/BUD BORERS

African rice gall midge, *Orseolia oryzivora* Harris and Gagne (Diptera: Cecidomyiidae)

Field occurrence and distribution of *Orseolia oryzivora*: The African rice gall midge (AfRGM) is currently one of the most important bud borers of rice in Africa. It is endemic to Africa and is widely distributed South of the Sahara. Gall midges collected from rice in Africa were originally thought to belong to the same species of the Asian rice gall midge, *Orseolia oryzae* (Wood-Mason) that is well distributed in many countries in Asia[11]. However, detailed comparison in the early 1980s showed that *O. oryzae* does not exist in Africa and neither does AfRGM occur outside Africa.

The AfRGM was first recorded in Sudan in 1947, then shortly after in Cameroon in 1953, Nigeria in 1956, Malawi in 1973, Senegal and Burkina Faso in 1980[21,22]. Other countries where *O. oryzivora* has been recorded include Benin, Chad, Côte d' Ivoire, Gambia, Ghana, Guinea Bissau, Mali, Niger, Sierra Leone, Tanzania, Togo, Uganda and Zambia[23,24]. In several of these countries, such as Ghana, Guinea, Sierra Leone, Tanzania, Uganda and Zambia, *O. oryzivora* was recorded for the first time within the last two decades, which suggests that its range in Africa is expanding.

In Nigeria, *O. oryzivora* has been recorded in many states: Abia, Akwa-Ibom, Anambra, Benue, Cross-river, Ebonyi, Enugu, Imo, Kaduna, Niger and Plateau states[25]. The *O. oryzivora* hot spots (area with heavy and perennial infestation) have being identified e.g., Edozhigi in Niger state and Ogidiga in Ebonyi state[23].

African rice gall midge has been reported to exhibit extreme variation in abundance than any other rice insect pests in different parts of West Africa with evidence of a long-term trend of increasing abundance over the last few decades[7]. However, recent surveys have given an indication that rice gall midge infestation in other West African countries appear to be less than in Nigeria. Since its major outbreak in Nigeria in 1988, its pest status has been on the increase.

Nature and extent of damage by *Orseolia oryzivora*: African rice gall midge is a pest at the vegetative stage of rice growths, attacking the growing primordial, destroying the bud and causing the production of tubular gall (silver shoot or onion leaf), which is irreversibly damaged and does not produce any panicle[26,27]. A typical rice gall can be 10-30 cm long or more depending on prevailing situation.

When infestations occur early and the primary tillers are destroyed, the plants are stimulated to tiller profusely but the new tillers often got infested too[28]. The uninfested secondary tillers however, produce panicle, which did not mature at the same time with panicles produced by the primary tillers and this result in reduction in grain yield and weight. The plant eventually presents stunted growth with excessive tillering bearing many galls[15]. After adult emergence, the galls gradually turn yellow and later dry up. From panicle initiation, *O. oryzivora* is no longer able to damage the tillers. Presence of *O. oryzivora* on rice plant usually remain undetected for some time, due to their cryptic and nocturnal habit as well as the late appearance of external damage symptoms[29].

Willams[30] in an on farm yield loss trial recorded a yield loss of 0.5% for every 1% increase in infestation. Nacro *et al.*[31] recorded 22% yield loss at 1 gall m^{-2} and 65% at 25 galls m^{-2}. ARC[25] stated that yield loss assessment in field with up to 30% tiller infestation suggests that for each 1% increase in tiller infestation, a farmer can expect to lose 2-3% grain yield. They further stated that heavily infested fields might produce no grain at all. In general, it has not been possible to fully assess or quantify yield losses due to the attack of *O. oryzivora* in Nigeria due to various factors influencing its infestation.

Stem borers: Stem borers as a group are considered one of the most important economic field insect pests of rice in Nigeria. They are in fact a major problem in almost all the rice growing countries of Africa[26,32]. They are primarily from two insect orders: Lepidoptera (Noctuidae and Pyralidae) and Diptera (*Diopsis* spp. and *Pachylophus).* Of all the stem borer species that attack rice plant, four species are of economic importance in Nigeria. These include African striped stem borer, *Chilo zacconius* Bleszynski and white stem borer, *Maliarpha separatalla* Ragonot of the Pyralidae family, pink stem borer, *Sesamia calamistis* Hampson of the Noctuidae family and stalk eyed fly, *Diopsis longicornis* Macquart of the Diptera insect order[7].

African striped rice borer, *Chilo zacconius* Bleszynski (Lepidoptera: Pyralidae)

Field occurrence and distribution of *Chilo zacconius*: This is one of the most important indigenous rice stem borers, which attack rice from seedling to maturity stage, leading to severe damage to rice plant in different parts of Africa[33]. There are 6 species recorded in Nigeria and are widely distributed. It is second to *M. separatella* in abundance in all the ecologies in different parts of Nigeria and widely distributed in different parts of West Africa[7]. It is the major rice stem borer in the humid forest and savannah zones[33]. It has been recorded in the mangrove swamp of Warri and high rain forest zones of Benin and Abakaliki. It has also been reported to be abundant in the Bende and Badeggi in Niger state. *Chilo zacconius* occurs in the humid tropical, Guinea savanna and Sudanian savanna zones of Nigeria but is most abundant in the Guinea savannah and Sudanian savannah zones. It is widely distributed between February to December with the highest percentage occurring in June[7]. Although it occurs in all ecosystems, it prefers the irrigated rice ecology and then uplands[34]. *Chilo zacconius* has been reported as a polyphagous pest of rice attacking both cultivated and wild gramineous plants with the wild plant species serving as alternate hosts during the off-season when rice is not available and that serves as a reservoir from which they invade rice fields[7,33]. Some of the alternative host plants include *Oryza barthii*, *Echinochloa crusgalli* (L.), *E. pyramidalis* (Lamarck) Hitchcock and Chase, *Pennisetum* spp., *Rottboellia cochinchinensis* (Loureiro) W.D. Clayton, *Saccharum officinarum* L., *Sorghum arundinaceum* (Desv.) Stapf. and *Zea mays* L.[11,33].

Nature of damage: Six species of *Chilo zacconius* have been reported as a polyphagous insect pest of rice attacking both cultivated and wild gramineaceous plants in Nigeria. However, only *C. zacconius* species has been reported on cultivated rice. Upon hatching, the larvae move actively on the plant, feed for a short time on the leave and leaf sheaths and then enters the stem by penetrating the leaf sheath. Feeding occurs at the upper internodes. One rice tiller may contain many larvae at a time. The larvae can move from one stem to another when the stem decays and no longer provides nourishment. Plant damage caused by *C. zacconius* is simila to that of other lepidopterous stem borers. Feeding inside the stem during the vegetative stage prevents the central leaf whorl from opening; instead, it turns brown and withers (deadhearts). Although the lower leaves remain green, the apical reproductive portion of the tiller is destroyed and the tiller fails to produce a panicle. Larval feeding at the panicle initiation stage or thereafter causes a severing of the developing panicle, which prevents the development of the panicle, resulting in unfilled and whitish panicle, rather than filled with grain and brownish panicle, which is referred to as a 'whitehead'. The first generation causes mainly deadhearts, whereas damage by the second generation results in whiteheads. According to Ukwungwu and Odebiyi[35], larval infestation causes a reduction in plant height. Though it has not been possible to fully assess or quantify yield losses associated with stem borer attacks, there was a positive correlation between percentage of deadhearts and reduction in filled grains per panicle and reduction in weight of grains in different rice ecologies. According to Ukwungwu and Odebiyi[35] yield losses due to a mixture of *M. separatella* and *C. zacconius* in a field experiment at IITA in Ibadan, Nigeria ranged from 15% in resistant variety to 55% in the susceptible variety, FARO 11.

African white borer, *Maliarpha separatella* Ragonot (Lepidoptera: Pyralidae)

Field occurrence and distribution of *Maliarpha separatella*: This is one of the major rice stem borers in Africa, consisting of about 70% of the total stem borer population in most parts of the Nigerian ecologies. It is widely distributed in many African countries with its distribution recorded across all seasons of the year. It is more abundant in the humid tropical and Guinea savanna than in the Sudanian savanna zone. It is a monophagous insect specific to *Oryza* species with limited alternate hosts, while rice (stalk) serve as a residual population between rice crops. However, while Delucchi *et al.*[36] reported that hosts other than *Oryza* spp. in West Africa are doubtful, some researchers have reported alternative hosts such as *Andropogon tectorum* Schum. and Thonn, *Sorghum bicolor* (L.) Moench. and the wild rice *O. barthii*, *O. longistaminata* and *O. punctata*[37]. It is more or less a pest of low land rice than upland rice[15] and attack rice plant more at later stages of growth with peak population at the flowering to ripening stages and only about 1% of the species was observed at 15 Days After Transplanting (DAT)[34,38]. However, at 60 DAT, 80% of the larvae was collected and by harvest about 94% was observed. It has also been reported to occur in Asian countries though not regarded as stem borers of rice[7,19].

Nature of damage: Although damage by stem borers is generally indicated by dead heart and white head symptoms, damage by *M. separatella* is insidious, feeding is within the stem without actually cutting the growing plant points at the base that results in the usual dead heart or white head[7,15]. This has been attributed to their habitation of the lower internodes of rice than the uppermost. However, losses (in plant vigour and of panicle weight) associated with the pest is still very severe in many places. On hatching, the larva (usually one per tiller) penetrates a stem and feed on the stem tissues just above the node. Typical damage by the larva is perforated nodes with necrosis inside the internodes and continuous infestation at tillering stage results in reduction in plant height and at booting reduces the number of grains per panicle, prevents panicle from ripening and loss of weight instead of the usual white head from other stem borers. The *M. separatella* has been reported not to be voracious in its feeding and throughout the larval stage, they limit their feeding to one or two internodes and do not move from one tiller to another. According to Delucchi *et al.*[36], *M. separatella* has the potential to cause 22% yield loss at the infestation level of about 59%.

African pink borers, *Sesamia calamistis* Hampson (Lepidoptera: Noctuidae)

Field occurrence and distribution of *Sesamia calamistis*: *Sesamia* species have been reported as the most polyghagous stem borer of rice. About five species have been reported in Nigeria, with *S. calamistis* as the most common and is well distributed throughout West Africa. It has been reported to occur in all the ecologies and is the fourth most abundant stem borer species across ecologies and plant growth stages. It occurs in both the humid tropical and Guinea savannah areas but is more widely distributed in the savannah with longer dry weather than in the forest zone and is the most abundant species in upland rice fields in the Guinea savannah[7]. According to Heinrichs and Barrion[7], the population of *S. calamistis* is highest in upland rice fields very close to maize farm, the most preferred host plant.

Sesamia calamistis infests many wild grass species such as *Andropogon*, *Cenchrus*, *Chrysopogon*, *Coix*, *Cyperus*, *Echinochloa*, *Eleusine*, *Lepturus*, *Lolium*, *Hyparrhenia*, *Kyllingia*, *Panicum*, *Paspalum*, *Pennisetum*, *Phalaris*, *Rottboellia*, *Saccharum*, *Setaria*, *Sorghum*, *Tripsacum*, *Triticum*, *Vetiveria*, *Vossia* and *Zea* in addition to cultivated crops such as rice, maize, millet and sorghum[7,11].

Nature of damage: *Sesamia calamistis* attacks rice plant at all stages but increases with the crop age, thus with the highest incidence mostly at the latter stage of crop growth starting from the booting stage to maturity. According to Hamadoun[39], in a study carried out in Mali, the larvae population of *S. calamistis* starts at the booting stage and doubles from panicle initiation to maturity making their population very high in the field from August to October in different parts of West Africa. Feeding of stem borers during the reproductive stage (panicle initiation to milk grain) causes a severing of the developing panicle at its base. As a result, the panicle is unfilled and whitish in colour, rather than filled with grain and brownish in colour. Such empty panicles are called whitehead, thus causing yield loss by reducing the number of productive tillers.

Stalk-eyed fly, *Diopsis longicornis* Macquart (Diptera: Diopsidae)

Field occurrence and distribution of *Diopsis longicornis*: Of all the *Diopsis* species identified in the rice plant, *D. logicornis* is the most abundant and most important, distributed across different parts of tropical Africa and in the three climatic zones (humid tropical, Guinea savanna and the Sudanian savanna) of Nigeria and West Africa[7]. However, it is most abundant in rainfed lowland and irrigated ecologies. Adult populations based on sweep net counts in the three surveys conducted in Côte d'Ivoire and Guinea in 1995 showed that the population increased from July through October of each season. However, the larvae population in that survey tended to be more during the months of July and August, which represent the highest larvae population of all the stem borer species in upland and lowland rice in August[7]. The *D. longicornis* has been reported to be primarily a rice feeder but may feed on crop plants other than rice such as wild rice and *Cyperus difformis*, a weed commonly found in rice fields.

Nature of damage: *Diopsis longicornis* has been reported as an important pest of rice throughout tropical Africa. Adult populations are responsive to toposequence (being most abundant in the lowlands and least abundant in the uplands) and more in non-weeded plots. Upon hatching, they move down inside the leaf sheath and feed above the meristem on the central spindle of young leaves, causing deadhearts. Larvae move readily from one tiller to another. One larva can destroy up to 10 neighbouring tillers. Later generations feed on the developing flower head. Prior to pupation, the larvae move to new tillers within the same rice hill or stay on the damaged tillers and move to the outer leaf sheaths. Though it can attack all stages of the rice plant, its incidence has been reported to be more on the younger plants than the older ones probably because of low silicon deposits on the younger plant tissues. In Nigeria, it has been reported to appear on transplanted rice as early as about 10 Days After Transplanting (DAT) with its peak at 40 DAT. Generally, only one larva occupies a stem and feeding leads to deadheart symptom. Most authors report that each infested tiller is destroyed. However, Feijen's studies indicated that larval feeding kills the last emerged leaf but the stem is not killed and produces new leaves to compensate for the damage. There is a great variation in the yield losses caused by *D. longicornis.* Several estimates of infestation levels and yield loss have been reported in different parts of Africa. In Côte d' ivoire, *D. longicornis* tiller infestation has been reported to be highest in July with 15% tiller infestation and August 13%. In Ghana up to 66% or more hill infestation have been reported[7].

Leaf feeders: There are many insect species that feed on and within the leaves of rice in West Africa. While some suck leaves sap thereby cause leaf burn and transmit viral diseases [e.g., Rice Yellow Mottle Virus (RYMV)], others defoliate the leaves by feeding directly by cutting leaf parts thereby reducing photosynthetic ability of the plant, which invariably affects crop yields[40]. However, most of the sap sucking insects of rice have been reported as minor rice feeders in West Africa, unlike in Asian countries where in recent decades, infestations have assumed epidemic proportions due to the Green Revolution which resulted in rice intensification and insecticides use[7]. Based on research evidences, leaf-feeding insects are found in the orders Coleoptera, Diptera, Hemiptera, Lepidoptera and Orthoptera[7]. In most cases both the larvae and adults are involved in destroying the leaves. While the larvae tunnels as leaf miners, leaving only a thin layer of epidermal tissue at the top and bottom of the leaves, the adults scrape the upper leaf surface tissue and leave white streaks of uneaten lower epidermis between the parallel leaf veins; still others feed within developed leaf whorls.

Rice caseworm, *Nymphula depunctalis* Guenée (Lepidoptera: Pyralidae)

Field occurrence and distribution of *Nymphula depunctalis*: *Nymphula depunctalis* (Guenée) also referred to as *N. stagnalis* (Zeller) is an important pest of lowland rice in Nigeria. Although other *Nymphula* spp. have been reported as the major casworm of rice plant, *N. depunctalis* is the most important one in Nigeria. It is widely distributed throughout the rice-growing regions of Africa and beyond. It occurs throughout the humid tropical, Guinea savannah and Sudanian savannah climatic zones of West Africa though little of it has been reported in the Sudanian savannah areas. Many alternative host plants have been reported for *N. depunctalis* in Asia, such as *Brachiaria*, *Cynodon*, *Cyperus*, *Cyrtococcum*, *Echinochloa*, *Isachne*, *Leersia*, *Panicum* and *Paspalum* weed species[11,41] but in Africa only *Eragrostis* sp., *Panicum* sp. and *Paspalum* sp. have been recorded as alternative host plants.

Nature of damage: A survey conducted in Côte d'Ivoire in July, 1995 showed that caseworm damage was more severe in the forest (humid tropical) zone than in the Guinea savannah. Defoliation by the caseworm was 34% in the forest and 7% in the savannah zone. The survey also showed that caseworm defoliation was 0% in upland fields and 23% in lowland fields. Caseworm is semi aquatic in nature, hence the larvae occurs only in lowland swamp, mangrove swamp and irrigated environments where they are most abundant. Caseworm damage is most severe when the rice plants are in the vegetative stage of growth. Plants that have recently been transplanted are preferred but larvae may also attack seedlings in the nursery. In a greenhouse study[41], found that moths preferred leaves at 4 WAT for oviposition in comparison with younger or older leaves. They also reported that the caseworm is better adapted to the vegetative stage than the reproductive stage of rice growth as indicated by the rate of larval development, survival, size of larvae and the fecundity of the females.

Generally, several larvae attack the same plant. The first visible sign of caseworm damage in the field is the characteristic cut leaves. Leaf blade tips appear as if they have been cut with a scissors. Leaf damage is caused by the cutting off of the leaf tips for making the characteristic leaf cases and the removal of green tissue. Infested fields are easily identifiable by the cut leaf tips, scraping of the leaves, presence of leaf debris on the water and presence of larvae in tubular leaf cases on the plants and/or floating on the water. All that remains after the removal of the green tissue is a papery epidermis. As larvae feed on the leaves, they leave patches or longitudinal streaks of light-coloured, papery epidermis. Damaged areas appear as patches of whitish foliage.

Rice leaf folders, *Marasmia trapezalis* Guenée (Lepidoptera: Pyralidae)

Field occurrence and distribution of *Marasmia trapezalis*: Two genera of pyralid moths, *Cnaphalocrocis* and *Marasmia* have been reported as the major overlapping leaf folder/leaf roller pest complex in rice throughout the world. Of these genera, only three species, *Cnaphalocrocis medinalis*

Table 2: Examples of average losses attributable to pests of rice in selected West African countries

Country	Pests	Estimated crop loss (%)
Ghana	Stem borers	30
Nigeria	Stem borers	25-30
	African rice gall midge	10-35
	Termites	5-10
Burkina Faso	Stem borers	10-40
	African rice gall midge	20-60
Mali	African rice gall midge	20-35
	Termites	10-15
Cameroon	Stem borers	26-30
	Root aphids	6-11

Source[48]

(Guenée), *Marasmia* (= *Susumia*) *exigua* (Butler) and *M. trapezalis* (Guenée) have been recognized to attained major pest status on rice, with *M. trapezalis* being the major rice leaf folder in West Africa and well distributed throughout tropical Africa[7]. The *M. trapezalis* occurs in low populations in the humid tropical and the Guinea savannah but not in the drier, Sudanian savannah of West Africa (Table 2). Dale[11] reported the presence of low populations of *M. trapezalis* in all three climatic zones of Nigeria. *Marasmia trapezalis* occurs at all sites on the continuum toposequence from upland to rain fed lowland and irrigated fields in Nigeria[11]. Studies in Asia indicate that *M. trapezalis* has several hosts consisting of weeds and crops within the grass family in addition to rice[7].

Nature of damage: The larvae roll or fold the leaves of rice. Severe damage causes a decrease in panicle production and yield.

African rice hispids, *Trichispa sericea* Guerin-Meneville (Coleoptera: Chrysomelidae)

Field occurrence and distribution of *Trichispa sericea*: Several species belonging to the subfamily Hispinae, commonly referred to as 'hispids,' feed on rice in Africa. However, *Trichispa sericea* is the major pest of rice in Nigeria causing severe defoliation and as a vector of Rice Yellow Mottle Virus (RYMV). It is well distributed in many parts of Africa where rice is grown, occurring in the humid tropical and Guinea savanna climatic zones of West Africa but not in the Sudanian savanna zone. Hispids are most abundant during the rainy and in wetland environments or irrigated lowland fields. In addition to rice the most preferred host, a number of grassy weeds have been reported to serve as alternative hosts for *T. sericea*[42]. For instance, in Swaziland, when rice leaves harden and were no more attractive for adult feeding and oviposition, adult *T. sericea* infested other plants such as *Chloris virgata* Sw., *Echinochloa holubii* (Stapf), *Eragrostis aethiopica* Chiov., *Eragrostis heteromera* Stapf, *Digitaria zeyheri* (Nees Hend.) and *Diplachne fusca* (L.) Beauv. ex Stapf[7].

Nature of damage: Hispids are serious pests of rice in some countries. Experiments conducted at M'bé Farm, Côte d' Ivoire indicated that damage caused by *T. sericea* is most prevalent in the lowlands. *Trichispa sericea* attacks the rice crop in the early growth stages. In Côte d'Ivoire, adults are observed in the rice field shortly after transplanting when they attack small seedlings. Larval feeding occurs through the tillering phase. Both the adults and the larvae feed on the leaf tissues of young rice plants[11]. The first attack in a field is highly localized but the infested area spreads rapidly. Attacked plants have narrow white streaks on the leaves and irregular pale brown patches. Adults feed on the green portion of the leaves, leaving only the epidermal membranes. Adult feeding damage is evident by the characteristic narrow white streaks, or feeding scars, that run along the long axis of the leaf. Feeding results in a loss of chlorophyll and the plants wither and die. The most serious damage occurs in nurseries that may be completely destroyed. Severe infestations sporadically occur on transplanted rice and can kill the plants. When the plants survive, they usually recuperate and produce some grain. Percent leaf area damaged by *T. sericea* was about 15% in the lowlands and 1% in the uplands. In addition to defoliation of leaves[43] have reported that *Dicladispa gestroi* (Chapman) and *T. sericea* are vectors of RYMV in Madagascar where the disease has significantly impacted on rice yields.

Rice whorl maggot, *Hydrellia prosternalis* Deeming (Diptera: Ephydridae)

Field occurrence and distribution of *Hydrellia prosternalis*: *Hydrellia prosternalis* is widely distributed in West Africa, occurring in both the humid tropical and the Guinea savanna zones with the highest occurrence in the humid tropical zone. However, it has been reported to occur in the three climatic zones, the humid tropical, Guinea savannah and the Sudanian savannah in some West African countries, including Nigeria[11]. The whorl maggot occurs in aquatic habitats and thus is a pest of both, rain-fed lowland and irrigated lowland rice. In some regions, it has been reported as a pest of both the dry and wet seasons, though more abundant in the lowland throughout the year. In Côte d'Ivoire *H. prosternalis* has been reported to infest other grasses (*Hexandra*, Swartz and *P. purpureum* (Schumacher) as an alternative host.

Nature of damage: *Hydrellia prosternalis* is a pest occurring from seedling stage until booting, being most abundant during the tillering phase of crop growth. On hatching, the larvae begin to feed on the foliar tissue. First-instar larvae mine in the leaves moving parallel to the leaf veins. Feeding damage by this pest retards plant development, reduces plant vigour and renders infested plants less competitive with weeds. Effects of this pest in causing yield loss have not yet been properly determined. However, it is considered a potentially serious pest whose biology and ecology should be studied more.

Grain feeders: Many species of insects feed on rice panicles and can be separated into those that feed on the floral parts (mostly the pollen) and those that suck the milk-like sap from the developing grains or when the grains are fully matured. While some feed on pollen, stamens and pistils of rice when the glumes open, causing abortion and sterility of the grain, others feed on the floral parts of the rice plant. The panicle thrips, *Haplothrips* spp., feed on the rice inflorescence, damaging the lemma and the palea, still others feed on developing rice grains, soft and hard dough rice grains resulting in small and unfilled grains, discoloration or "pecky" rice, thus reducing grain quality rather than weight. However, the relative importance of floral feeding insects in Nigeria is not well known or minimal. The grain feeders of economic importance are discussed below:

Stink bugs, *Aspavia armigera* F. (Hemiptera: Pentatomidae)
Field occurrence and distribution of *Hydrellia prosternalis*: There are four species of *Aspavia* infesting rice in West Africa with similar biology and damage. However, *A. armigera* appears to be the most common and important species in Nigeria. This is distinguished from other species based the characteristic foul odour that is produced by the scent glands, located on the lower side of the body near the middle coxae, which has given the pentatomids the common name of 'stink bug[7]. It is well distributed and equally abundant in the humid forest zone and in the Guinea savannah of West Africa as a whole. It occurs at both upland and lowland ecologies but is more abundant in the latter.

Nature of damage: In studies in lowland fields at WARDA, *A. armigera* was collected throughout the crop growth cycle with a peak at flowering. Studies conducted in Nigeria on the relative abundance of *A. armigera* and *Stenocoris claviformis* on irrigated and upland rice showed peak populations at 70-90 DAT. Field experiments on the damage potential of *A. armigera* indicated that both nymphs and adults attack rice grains as soon as the panicle is exerted and continue to feed until the hard dough stage. Nymphs prefer to feed on grain immediately after flowering and the adults prefer grain in the milk stage. Grains at the hard dough stage are rarely punctured. The glumes are punctured and the bugs suck the contents of the developing grain. *Aspavia* spp., primarily puncture the grain at the apical end. Only part of the milk is sucked out at each feeding and the same grain may be punctured several times. Severity of the damage depends on the stage of grain development and on the number of punctures in the grain. It is believed that *Aspavia* spp., feeding contributes to the incidence of the 'dirty panicle' syndrome mentioned earlier.

Alydid bugs, *Stenocoris claviformis* (Hemiptera: Alydidae)
Field occurrence and distribution of *Stenocoris claviformis*: Various Alydid bugs have been reported as pests of rice worldwide. There are several Alydids in the genera *Riptortus* and *Stenocoris* infesting rice in West Africa and their biology, ecology and damage to plants are similar. Thus, a representative genus, *Stenocoris*, *S. claviformis* which is extremely abundant in many West African countries is discussed. It is distributed across both the humid forest and Guinea savanna zones. It occurs in all rice ecosystems from the uplands to the lowlands with the highest population in the latter. Many grasses do serve as hosts for the alydids with rice and *Echinochloa* being important.

Nature of damage: Both nymphs and adults prefer to feed on the endosperm of rice grains but will also suck plant sap. The presence of *Stenocoris* spp. in the crop at the vegetative stage indicates that they may be feeding on the sap from rice leaves or stems. They have sucking mouthparts. The alydids do not bore a hole through the rice hulls but insert their stylets into the grain through a space between the lemma and the palea. As they feed, they secrete a liquid that forms a stylet sheath that hardens around the feeding point and holds the mouthparts in place. The white stylet sheaths left in the grain are visible to the naked eye. The nymphs and adults both prefer rice at the milk stage but may also feed on soft and hard dough rice grains. Nymphs are more active feeders than adults but adults cause more damage because they feed over a longer period of time. Removal of the milky white endosperm results in reduced grain size. When feeding on the grain at the soft or hard dough endosperm stage, they inject enzymes to predigest the carbohydrate. This process results in the contamination of the grain with microorganisms that cause grain discoloration or pecky rice. Feeding at this stage reduces grain quality but does not reduce grain weight.

Root feeders: There are many insect pest species that attack the roots of rice plant underground. While some attack only the root section, others attack both the root and lower part of the stem, which may cause wilting of the stem. These are well distributed in well drained soils. Because of the cryptic nature of their attack, their infestations many a times are not detected early enough and neither their biology nor ecology is well known. Some attack rice roots by sucking the sap, others have chewing mouth parts through which they devour the entire roots of the plant. Following the nature of the underground environment, the root feeders find it difficult in locating their food, hence many species have adapted various measures to ensure survival, either as social insect living in colonies or as dependents on social insects.

Termites, *Macrotermes natalensis* Haviland (Isoptera: Termitidae)

Field occurrence and distribution of *Macrotermes natalensis* Haviland: Termites have been regarded as the most significant soil insect pests of crops in Africa. There are many species of termites that are of economic importance and well distributed in West Africa. In Nigeria, 20 species have been recorded as pests of crops[44]. Of the important termites species in Nigeria, Macrotermes spp. is the most abundant and destructive species. Termites are social insects living in colonies, preferably in upland ecology, they do not survive/occur under flooded environments. However, little is known of the ecology of termites because their faunas do change with land use[45].

Nature of damage: Termites feed on dead wood, dung and grasses but few are known to feed on living grasses. Among those ones that feed on living grasses, rice is their preferred host[7]. They attack rice plant from seedling to maturity by cutting rice seedlings at the base of the stem just below or above the soil surface, thus reducing the plant population. While macrotermes attack rice seedlings thus reducing the plant populations, microtermes are known to attack rice later in the growth stage, i.e., at maturity by hollowing out their root system and filling it with soil resulting in the lodging of plants, thus predisposing them to secondary pest attack like plant pathogens. Termite damage is more prevalent in the savanna zone as compared with the forest zone. Feeding is generally more severe on plants that have been subjected to abiotic and biotic stresses such as drought, diseases, weeds, lack of fertilizer and mechanical or fire damage[7]. Rice damages attributed to termites are varied across different regions of West Africa. These variations have been attributed to changes in amount of rainfall and altitudes. Termites have been reported to cause yield losses ranging from 50-100%. Termite damage in upland fields in the forest zone near Gagnoa ranged from 0-78% with an average of 14% for 20 farms.

Summary of yield losses caused by insect pests of rice: Results of study to determine the effect of insects on the yield of rice revealed that insect pest is a major factor constraining rice production in Africa. Insect pests attack all portions of the rice plant and all stages of plant growth. Insect pest infestation have resulted in significant yield losses which are typically in the range 10-30% and in some regions or years, may exceed 90%[46,47] (Table 2). Pests cause considerable and unacceptable crop losses in the field and in storage. The very high food losses in Africa attributable to pests highlight their role in causing food shortages that lead to hunger. Thus, it beholds on researchers to make every frantic efforts to help rice farmers reduce the damage caused by these pests to enhance rice productivity in Africa as a whole.

Factors that may affect the extent of yield losses caused by insects: Before attempting to review various control measures of field insect pests of rice in Nigeria, it is necessary to highlight some of the factors that may determine the extent of infestation of some of these insect pests. Although insect pests are a major constraint to rice production in many parts of the world, some species have declined in importance. This has been attributed to several changes both in the environment and human activities that have assisted in the proliferation of the different insect species infestation in the recent time. Agricultural intensification practices currently in vogue have deemphasized some cultural practices that served as control measures and assisted in stabilizing the ecosystem in olden days. In addition, the practice of monoculture, multiple, extensive cultivation and extensive use of improved cultivars and agrochemicals have altered the agro-ecology and natural enemies fauna. Thus, continuous cropping throughout the year has caused shifts in the composition of pest fauna. More so, species that are hitherto constrained by certain environmental factors are now on the increase because of constant supply of irrigation water and other required necessities.

MANAGEMENT OF THE FIELD INSECT PESTS OF RICE

Insect pest infestations of rice as mentioned earlier on is one of the major causes of low rice yield in the tropics, particularly in Nigeria. Similarly, it has become increasingly evident that future agricultural growth hinges on smallholder farmers, which calls for knowledge in all aspects of rice production including the management of pests, if they must meet national demand. Therefore, for rice production to keep pace with increasing demand, effective and sustainable pest management strategies are urgently needed to forestall the menace of these economic pests of rice.

Pest management is a broad ecological approach that requires the consideration of many things-pest sampling and surveillance, forecasting, determination of economic thresholds and other conventional management practices. In order to raise more food and protect man from biting and disease-carrying insects, man has devised methods to alter normal population growth of many insect pests by reducing their chances of survival. Early practices were aimed at minimizing damage but with the advent of synthetic insecticides in the 1940s, attempts became directed at eradication. Unfortunately, no successful eradication story of any pest is known except in the cases of localized areas like islands. In addition, some of these methods have attendant environmental challenges following usage. Hence, the concept of the modern pest management practices that are more environmental friendly. The current pest management practices are emphasizing a departure from heavy reliance on the use of single conventional practice or pesticides that pollute the environment to ecologically based integrated management strategies. Pest management is the practice of regulating insect pest population to prevent pest outbreaks instead of attempting to eliminate them. This implies harmoniously following various management components (cultural or agronomic practices, physical or mechanical methods, host plant resistance or the application of genetic principles, biological control and chemical method) together in order to maintain pest population below economic injury level at the same time without degrading the environment. Hence, in this review, considering the numerous factors involved and the complexity of the interactions among the components of pest management, efforts were made to discuss the various categories of insect pests of rice aforementioned under the above conventional methods of pest control, since each method can control any of those categories of pests. However, before adopting any control measure for the management of any particular pest, one needs a thorough understanding of the identity of the insect, natural, technological and socio-economic conditions and their interrelationships. Furthermore, thorough knowledge of the biology and ecology of the pest in focus and the knowledge of economic thresholds upon which to base the control decisions are paramount. The understanding of these principles is an essential first step in organizing an effective insect pest management.

METHODS OF INSECT PEST MANAGEMENT

Cultural, mechanical and physical control: Cultural method of insect pest management is one of the oldest measures adopted by man in the management of pests. It refers to the purposeful manipulation of the cropping environment to make it less favourable for the pests or more favourable for their natural enemies (predators and parasites. According to Ferro[49,50], cultural control is that broad set of management practices or options, which farmers may manipulate to achieve their crop production, or the alteration of the environment to improve their crop production. It simply means various crop production practices such as land preparation, planting time, crop density, water management, crop residue management, intercropping, fertilizer management, crop rotation etc, which can alter ecological conditions and cause shifts in the status of insect pests in a given ecology. Cultural control is more of a preventive method than curative and is very cheap and may prove more effective and efficient with the adequate knowledge of the life history and habits of the target pest. Today cultural controls are still important management tactics in the integrated management of rice insect pests of economic importance. On one hand, while cultural control involves purposeful manipulation of the cultural practices, mechanical and physical methods complement cultural control. While tillage is a cultural practice, insects are killed by mechanical crushing and physical exposure to heat and many insect pests of rice have been controlled through these means. Cultural control was effective in the management of stem borers, plant hoppers, gall midge, whorl maggot, leaf folder, pink bollworms, rice buds, beetles, etc[27,28,49,51-53]. On the other hand, Ogah *et al.*[54] showed that planting *Paspalum scrobiculatum* (weed) around rice field increased the build up and abundance of *Platygaster diplosisae* that parasitize the *Paspalum* midge, an alternative host of *Platygaster diplosisae*, which in turn enhanced *P. diplosisae* abundance and has been used in the management of Africa rice gall midge below economic level early in the season in Nigeria.

Host plant resistance: Host Plant Resistance (HPR) has generally been considered one of the components of cultural method but because of its importance, it has been given an independent status as a major method of protecting crop against insect damage. Host plant resistance refers to the inherited characteristic of a host plant that reduces the effect of pest attack or to recover from injury caused by its populations[55]. Resistant cultivars can alter the physiology and behaviour of insects and this in turn affect the insects' susceptibility to chemical and biological control[56]. Traits conferring HPR to insects and pathogens are among the most important for crop improvement and their importance is increasing as insecticides loose efficacy due to pest adaptation or is removed from use to protect the environment and human health[57,58]. Resistant cultivars are sought as the major tactics in an integrated approach in the management of insect pests. Incorporation of insect resistance into varieties of crops is a major objective of most breeding programmes in developing countries in the recent time. This method has succeeded in the management of many insect pest species to a limit due to difficulties encountered in identify genes that carry the resistance traits and insect biotypes. However, because of the unique advantage of this method, it is sought as the major control of most key pests and its use is on the increase. The success of Green Revolution cannot be told without attributing it to the adoption and application of host plant resistance technique. Similarly, so many insect pests of rice have been controlled using this method. The Africa rice gall midge is under serious check following the adoption of host plant resistance[32,54,58]. Non-preference and antibiosis appeared to be the mechanism of resistance to *O. oryzivora.* For instance[32], identified anti-xenotic and antibiotic traits associated with resistance to AfRGM in some rice varieties but the traits have yet to be utilized in breeding. The Quantitative Trait Loci (QTLs) or genes conferring resistance to AfRGM have also been identified from (*O. sativa*×*O. glaberrima*) crosses, ITA306×TOS14519 and ITA306×TOG7106. Similarly insect pests such as stem borers, leafhoppers, leaf folders, whorl maggot, termite, etc have been managed effectively through adoption of host plant resistance[59-61]. Presently, genetically modified rice plants (Bt-rice) resistant to striped stem borer, leaf folders and other insects have been developed[62] and two Bt-rice varieties (Huahui 1 and Xianyou 63) were authorized for marketing especially in China, in 2009[63]. However, considering the effect of biotype and the traits exhibited by some insects, which make it difficult to trace gene that could match their resistance trait, crop improvement programmes need to place emphasis on developing germplasm with multiple resistance to key insect pests using biotechnological tools (e.g., marker-assisted selection), because there are often two or more stresses in most rice production ecologies in Africa. Recent advances in biotechnology provide the possibility of solving some of the constraints that have limited the practical use of genetic resistance to insects in pest management programs. Biotechnology provides new possibilities for manipulating germplasm.

Biological control: According to Landis and Orr[64], the present awareness of the impacts of pesticide use on the environment and human health has resulted in efforts to reduce reliance on chemical controls. This call for alternative control measures to pesticides and biologically based technologies such as biological control have been seen with the potential to solve the pressing needs in pest management with little or no side effects. Biological control may be defined as the use of natural enemies of an organism such as parasitoids, predators, pathogens, antagonists or competitors' population to suppress a pest population, making it less abundant and less damaging than it would otherwise be[65]. Practically every crop pest has its natural enemies, which have played significant roles in limiting potential pest populations and have been the focus of several studies in the recent time. Many species of predators, parasitoids and pathogens have been reported to attack rice insect pests. These natural enemies occur everywhere, from the backyard garden to the commercial field, adapted to the local environment and to the target pest.

Biological control as a method of insect pest management in rice began much later than the first success in the control of cottony cushion scale in California in the later 1880s. However, considerable work has been done during the later part of the 20th century and the practices of biological control of rice pest are constantly evolving. At present, the actions of indigenous parasitoids, predators and insect pathogens have formed the cornerstone of modern IPM programmes in rice. Insect pathogens are currently the most manipulated biological control agents. Some of the most important pathogens in use in the management of rice insect pests are *Metarhizium, Beauveria*, *Hirsutella* and *Pacilomyces*, they have been used successfully in the management of many insect species of rice. Others include *Bacillus thuringiensis*, which exist in several commercial formulations but has limited application in field insect pests of rice because of the cryptic nature of some insects. Various methods depending on organism have been adopted in the application of these natural enemies, introduction, augmentation and conservation. Biological control, where successful is the most cost effective, sustainable and environmentally safest way of pest management. Currently, so many insect pests of rice have been controlled below economic injury level using biological control. For instance, the African rice gall midge, different species of rice stem borers, etc. have been effectively controlled using their natural enemies.

Chemical control method: Although the uses of chemicals for the control of pests have been very popular with commercial farmers in different parts of the world, in West Africa, traditional farming methods that served as an alternative to pesticides use were widely practiced. With the introduction of new rice varieties in the past few decades, the use of insecticides for the management of rice pests became widespread, especially in endemic areas where appropriate resistant varieties were not available. At present, various categories of pesticides (starting with chlorinated hydrocarbons, then phosphates and the recent carbamates and pyrethroids) are available for farmers and have been evaluated for use in the management of various rice pests, especially under emergency/heavy infestation situations. Their use has increased grain yield dramatically but since the 1990s, the return on pesticide use has been gradually reducing, unlike the traditional practice whose return was low but stable. This has been attributed to limitations associated with the use of various chemicals to control various field insect pests of rice. Most farmers lack both the financial and technical means for effective use of insecticides[33]. Furthermore, most of the damaging stages of rice pests are protected inside the rice plant and are accessible using foliar insecticides that are prevalent in Nigeria. Therefore, the time of any insecticide application is very important, if the desired aim is to be achieved and that requires technical assistance, which is limited in Nigeria. Considering sustainability and insecticide effects on human health, environment, insect resurgence and natural enemies, the use of insecticides in the management of rice pests become questionable. Hence, developing countries are always advised to borrow a leaf from developed countries where insecticides have been used extensively and often times misused with resultant environmental hazards. This reinforces the recent advocacy for integrated management of rice insect pests.

INTEGRATED PEST MANAGEMENT (IPM)

As rice scientists and farmers have gained experience in the cultivation of the modern varieties and the agronomic practices that have accompanied the "Green Revolution", there has been a shift from a primarily unilateral approach of insect control, with a strong reliance on insecticides to a multilateral approach involving a mix of control tactics. This approach, known as Integrated Pest Management (IPM) is a broad ecological attack combining several tactics including biological, chemical and cultural control methods and insect resistant rice varieties for the economic control and management of pest populations.

The IPM programs have a significant impact on minimizing the adverse effects of insecticides and in increasing the profitability of rice production. Currently, majority of smallholder farmers in Africa rely on the conventional and their traditional knowledge to manage pest problems, mainly by the use of synthetic and botanical pesticides[66]. Unfortunately, in the face of a changing climate, it is obvious that their indigenous knowledge is limited. For effective management of litany of insect pest ravaging crops on sustainable basis, farmers need a combination of indigenous and scientific knowledge. The effectiveness of pest management in the current state is dependent on how the farmer can integrate his known control tactics in a compatible form as possible.

In the context of sustainable agricultural development in Nigeria, Integrated Pest Management (IPM) come to play. Integrated pest management has evolved from pesticide-abatement strategies into analytical approaches to understand pest status within crop production ecologies in order to make informed decisions on appropriate management options that incorporate social, economic, gender and environmental issues. The IPM programmes utilize biological controls, traditional cultural controls, insecticides and pest resistant varieties to varying degrees to achieve the desired results.

CONCLUSION

Nigeria is considered to have all the resources suitable for abundant rice production. However, insect pest damages have been on the high side, with so many key pests recorded in different parts requiring suitable management strategies. Sustainable and efficient pest management practices require scientific expertise to develop, through research and to effectively disseminate to farmers for adoption. Thus, if rice production is to keep pace with increasing demand, effective and sustainable management strategies are urgently needed to tackle these important biotic constraints. Of all the management strategies, host plant resistance has served as a key component and should be integrated with other strategies in IPM programmes. High populations of diverse natural enemies of rice pests have been recorded in different parts of West Africa and should be part of any IPM programme for the management of rice pests. Finally, considering the level of farmers' education in Nigeria, for any strategy to work efficiently, agricultural extension officers are urgently needed for proper dissemination of the modern technologies. It is hoped that this compendium on management of rice insect pests will provide a comprehensive source of information and guidance to researchers for enhanced rice production in years to come.

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