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# Biological Control of African Rice Gall Midge (*Orseolia oryzivora*, Harris and Gagné) in Nigeria: A Review

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## Authors' contributions

*This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.*

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## ABSTRACT

African rice gall midge (AfRGM), *Orseolia oryzivora* Harris and Gagné (*Diptera: Ceccidomyiidae*) is a serious insect pest of lowland rice in Africa, and is capable of causing total crop failure in endemic areas. Of all the control measures adopted in the management of African rice gall midge in the recent years, biological control has been advocated. Unfortunately, so far, only few biological control agents e.g. *Platygaster diplosisae* Risbec and *Aprostocetus procereae* Risbec have been identified with high potentials for the control of the pest. Hence, there is paucity of information on the bio-control agents associated with AfRGM, and the efficiency of the identified ones in the management of African rice gall midge. In this review therefore, efforts were made to put together the hitherto fragmented information available on the distribution, host range, biology/life-cycle, ecology and the potentials of various bio-control agents associated with rice gall midge. The effects of abiotic and biotic factors on the efficiency of the bio-control agents were also discussed. The aim is to enhance farmers' knowledge about these agents with intent to assist them in the use/adoption of bio-control agents or integrating them with other control methods for improved management of rice gall midge.

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## 1. INTRODUCTION

Rice is one of the prominent cereal crops grown in Nigeria. Nigeria is the largest producer of rice in the West African countries [1]. In Nigeria, rice is an important source of livelihood, food security and income and has been cultivated for over 3,500 years. Rice is cultivated virtually in all agro-ecological zones of the country either as upland, irrigated, swamp or as fadama (low-lying fertile soil with water on or near the surface during most of the year) rice. In 2000, 6.4% of the 25million hectares of land cultivated to various food crops was grown to rice [2,3]. The quantity of rice consumed in West Africa; especially in Nigeria has increased faster than in any other region of the continent, with the average per capita consumption of 25 kg yr<sup>-1</sup> by 1997 [2,3]. Today, rice is no longer a luxury food to millions of Nigerians, and has become the cereal that constitutes a major source of calories for both the rural and urban poor. Presently, rice is competing favourably with such major food crops as cassava, yam and sorghum. Unfortunately, the production capacity and the average yield of rice have not increased significantly to keep pace with national demand since the mid of 1970s. Hence, the importation of milled rice to bridge the gap between domestic demand and supply. Nigeria ranked among the top rice importers in the world with more than 1.8 million tons of rice imported in 2006 [4].

Though Nigeria has the potential and suitable agro-ecologies to attain self sufficiency in rice production, it is evident that; in order to meet the current demand for rice, the domestic production requires an intensification of rice cultivation through increasing production per unit area and by increasing further the area planted to rice. Increasing production per unit area will require among other practices, a decrease in the yield losses to insects and other stress factors without altering the agro-ecology for sustainability.

One of the major reasons for the low yield of rice in Nigeria is depredation by insect pests, which so far has not been given the full recognition it deserves as a production constraint [5,6]. 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. These insects attack the rice plant at different growth stages. Of all the insect pests of rice, the most serious insect pest of rice in Nigeria in the recent time is the infestation of rice by various species of stem borers and African rice gall midge, *Orseolia oryzivora* Harris and Gagné [3]. African rice gall midge (AfRGM), *O. oryzivora* is indigenous to Africa and is one of the major constraints in achieving the yield potentials of wide varieties of rice that are susceptible to rice gall midge. Presently, AfRGM is the most serious insect pest of lowland rice in Africa [3,7,8,9]. AfRGM attacks rice plant at the vegetative stage. Its larvae feed on the growing primordial, destroying the bud and causing the production of tubular gall (silver shoot or onion leaf) [3]. Feeding on seedlings by the larva leads to profuse tillering and stunting of plants. Any tiller bearing a gall is irreversibly damaged and does not produce any panicle [4].

Losses caused by this pest have reached 100% in worst affected areas [10,11,12]. Since its major outbreak in Nigeria, its pest status has been on the increase in all the fields [7].

Until recently, the management of *O. oryzivora* in Nigeria has been dominated by the use of insecticides and other cultural practices [9]. Unfortunately, these measures have not given the desired control [13]. Following the unreliability of these control measures, and the economic importance of the AfRGM with high threshold, led to more serious consideration of

the potential role of natural occurring biological control agents as a sensible, if not an essential alternative.

Many indigenous bio-control agents (predators and parasitoids) have been identified and recorded in the field in Nigeria and other West African countries. According to [7,11] these indigenous naturally occurring bio-control agents have the potential to reduce AfRGM populations to a tolerable level. Unfortunately there is paucity of information on these bio-control agents. In the development of biological control techniques, understanding the lifecycle of the organisms is necessary to determine which agent is to be used for efficiency and factors that may be limiting the abundance of the organism understood. The lack of information on these natural enemies associated with AfRGM, their potentials, distribution and abundance in Nigeria in relation to the population dynamics of AfRGM obstruct its adoption in the management of AfRGM. Understanding the factors that influence their distribution and abundance is a fundamental issue in insect ecology and is a practical concern with insects that cause economic damage [14,15]. Identifying AfRGM natural enemies and determining their temporal distribution will advance AfRGM biological control efforts.

The purpose of this review is therefore, to update the list of major bio-control agents associated with AfRGM in Nigeria. Information on the biology, host range, distribution, ecology and potentials of these agents were discussed. However, in the case of a few minor or newly recorded species, little or no information on their lifecycle is available for inclusion. This information is necessary because it will consolidate our understanding on natural enemies' biology, ecology, insect-plant interactions and pest status and yield losses, and of course will enhance the adoption of bio-control agents by farmers for improved management of AfRGM and increased rice yield.

## 2. NATURAL ENEMIES OF RICE GALL MIDGE

Natural enemies of rice insect pests have been reported to greatly influence the multiplication of insect pests of rice and consequently damages in crop at any particular period. Natural biological control of rice pests and particularly rice gall midge has been recorded in the field [11,16]. These natural enemies include parasitoids, predators and even pathogens that attack various stages of the pests.

## 3. PARASITOIDS

There are a number of parasitoids that have been recorded for rice pests [3]. Also several parasitoids have been recorded for rice gall midge. Studies at Africa Rice Center (Africa Rice) and Asia have recorded several species of parasitoids of rice gall midge in different parts of the world where gall midge is an issue of importance. Table 1 gives an account of parasitoids recorded on rice gall midge in different countries. These parasitoids attack different stages of their hosts; ranging from egg-larval or either larval or pupal parasitoids. These parasitoids have been reported to have a direct impact on the gall midge population as a whole [2,16,17]. However, most of the parasitoids recorded on rice gall midge are non-host specific and majority of them are opportunistic feeders being present only at high density. Of all these, two have been identified as the most common and serious parasitoids of *O. oryzivora* in Nigeria. They are *Platygaster diplosisae* Risbec (*Hymenoptera: Platygastrids*) and *Aprostocetus procerae*, Risbec (*Hym. Eulophidae*) [2,9,16,18], hence, emphasis on the discussion was based on *P. diplosisae* and *A. procerae*.

**Table 1. Major natural enemies (Parasitoids) of rice gall midge**

<b>Natural enemy</b>	<b>Host stage</b>	<b>Continent/country</b>
<i>Platygaster diplosisae</i>	Egg-larval	Africa
<i>Platygaster oryzae</i>	Egg-larval	Asia
<i>Aprostocetus procræ</i>	Pupal	Africa
<i>Eupelmus</i> sp.	Larval	Nigeria, Asia
<i>Neanastatus circitventris</i>	Larval	Cameroon
<i>Aplastamorphia</i>	larval	Cameroon
<i>Camerunus tetrastichus</i> sp.	pupal	Cameroon
<i>Elaphipeza</i> sp.	pupal	India
<i>Eurytoma setitibia</i>	larval	Indonesia
<i>Trichorpia</i> sp.	Larval	Indonesia
<i>Nabis grallarius</i>	Larval	Indonesia
<i>Casonoides interstitialis</i>	Larval	Indonesia
<i>Nabis capisformis</i>	Pupal	Srilanka
<i>Ophionia indica</i>	Pupal	Srilanka
<i>Gyrcampia</i> sp.	Pupal	India
<i>Celis areator</i>	Pupal	India
<i>Propicroscystus nurificus</i>	Egg- larval	India
<i>Obtusilava orquare</i>	Egg- larval	India
<i>Amblyseius imbricatus</i>	Egg	India
<i>Anisopteromalus camerius</i>	Egg	Cameroon
<i>Bracon annulicomis</i>	Egg	Cameroon
<i>Telenomus israeli</i>	Egg	Asia
<i>Tetrastichus</i> sp.	Pupa	Cameroon
<i>Eurytoma setitibia</i>	Larva	Nigeria

Sources: [2,3,9,19]

#### 4. TAXONOMY OF *Platygaster diplosisae* RISBEC (HYM.: PLATYASTRIDAE)

*Platygaster diplosisae* Risbec belongs to the genus *Platygaster* in the Subfamily *Platygastrinae* of the family *Platygastridae*, Suborder *Apocrita* of the order *Hymenoptera*, a *Pterygota* of the class *Insecta* of the Phylum *Arthropoda* [20].

##### 4.1 The Biology and Ecology of *Platygaster diplosisae*

*P. diplosisae* has been reported as the most important parasitoid of African rice gall midge [2,18]. The female adult of *P. diplosisae* is shiny black and bigger (Fig. 1), while the male was dark brown and smaller than the female with paler legs [21]. The adult measures 1.6 mm long for females and 1.3mm long for males. An adult *P. diplosisae* has short antennae which are 10-segmented with moderately long scape, and at least four antennal apical segments which are light brown. The posterior part of the thorax was densely setose laterally, whereas the forewings are without veins. Legs are pale yellowish brown and have tibiae II and III with one long spur. The longevity of the adult female wasps was 4.1 days, while for the male it was 3.0 days. The duration of the complete life cycle from egg to adult emergence averaged 27.3 days. *P. diplosisae* is a gregarious endoparasitoid and reproduction was facultative parthenogenetic. Male adults mate several times while the female mate only once. However, regardless of mating status both mated and unmated females oviposited within 24hr of emergence. The progeny of unmated females produced

entirely males, whereas mated females produced only female progenies. *P. diplosisae* is a prosynovogenic species (i.e. a species for which the process of maturation of its eggs starts during the pre-immature stages and continues after the adult has emerged from its host) [21]. It lays its eggs into the eggs or neonate larvae of AfRGM on the surface of plant leaves [19] Fig. 2. *P. diplosisae* parasitizes both the egg and larval stages of *O. oryzivora*. However, the percentage parasitism was significantly different between the two host stages, with the newly laid eggs of *O. oryzivora* as the most acceptable host stage.

The pattern of oviposition was similar in mated and unmated females, except that mated females laid more eggs per day (average 31.7 eggs) and had shorter longevity (average 3.0 days) than unmated ones (average 25.5 eggs per day and longevity of 4.1 days). The mean reproductive period of mated females take on average 3.2 days. The mean number of eggs laid per female *P. diplosisae* declined with the parasitoid's age with a mean total of 95.2 eggs laid per female during her life time [21].

Following oviposition, the eggs were free within the host egg, but later attached to the nervous system or midgut of the host larva. Shortly after egg development commenced, many paranuclear masses were formed and the developing *P. diplosisae* embryo became encysted within host tissues, where it obtained nutrients and the host larva became paralyzed, body swelled, and cylindrical in shape with a mean length  $0.07 \pm 0.01$  and width of  $0.04 \pm 0.01$ . According to [21], dissections made 7 days following parasitism showed that none of the parasitoid eggs in *O. oryzivora* eggs or larvae had hatched. Hatching mostly occurred on the 13th day after parasitism. When *P. diplosisae* laid its eggs in the *O. oryzivora* eggs, they did not develop into first instar larvae until the third larval instar stage of *O. oryzivora* was reached. The egg stage lasted about 13 days in total. When the first instars were fully formed, they broke away from the surrounding trophamnion and initiated feeding. *P. diplosisae* hibernate during the early embryonic stage in the first instar of the host. As the host larva developed, the parasitoid's eggs hatched into larva.



**Fig. 1. Adult female of *Platygaster diplosisae***

Source: [21]

Many people have reported on the polyembryony of *P. diplosisae*, in which case a single egg develops to hatch and releases so many adults [7] reported the release of 25 to 30 adults

within a single host. [2,16] have also reported the release of multiple adult within a single host larva. While [21] recorded 40 to 65 parasitoids emerging from each parasitoid host and the parasitoids were dominated by the same sex from the particular parasitoid host. Adult wasps emerge from their cocoons by cutting tiny individual emergence holes (0.3mm in diameter) in the gall through where they escape [16,18,19]. Emergences of adult parasitoids take 2 to 3 days. After emergence, empty cocoons were seen inside the gall. The newly emerged adults remained in the host for about four additional days before escaping from the galls. The sex ratio was 8 female to 1 male.

*P. diplosisae* had three instars. When fully developed the larva was white and ovoid, devoid of setae or hymenopteriform, with three thoracic and seven abdominal segments and about 0.84mm length and 0.37mm wide. The larva attached itself either to the ganglion or stomach of the host larva. As *P. diplosisae* began to feed, the host progressively lost its power of locomotion, and eventually died. The parasitoid larva increased in size, developed fat bodies and moulted. The larvae's mouth was a simple transverse orifice. After killing the host larvae by consuming its entire body contents, the *P. diplosisae* larvae entered the prepupal stage within the oblong, yellow-brown integument of the host puparium and formed ovoid cocoons before pupation. Parasitized *O. oryzivora* larvae were filled with wasp cocoons and were much bigger than unparasitized larvae. The larval stage lasted for an average of 5.2 days followed by the prepupal stage.

The prepupal stage takes on the average 2.4 days. They then form pupae, inside the corpse of the host. Initially the *P. diplosisae* pupa is white; the eyes soon darken, and the entire body, with the exception of the integuments between the abdominal plates which gradually assumes the shiny black colouration of the adult. The pupa stage takes on average of 6.7 days. The mean length was  $1.01 \pm 0.03$ mm and width  $0.30 \pm 0.01$ mm.

Though *P. diplosisae* is the acclaimed most important natural enemy of African rice gall midge in Nigeria, specific details are not known about its ecology in relation to that of its hosts. However, the geographical and temporal distribution of any parasitoid and their importance within the local natural enemy complex vary considerable anywhere in the world. For example, in Kenya it was observed that in small holder crops (rice, maize and cotton) in several agro ecological zones, occurrence of parasitoids varied greatly between seasons and sites which of course affect their potentials as bio-control agents. *Platygaster* species has been reported to be widely distributed to all rice gall midge endemic areas [22]. In Nigeria, *P. diplosisae* has been recorded both at the guinea savannah and forest zones of the country where rice gall midge are endemic. However, higher percentage parasitism has been recorded in the guinea savannah than in the forest zone. The research results conducted in Nigeria during the 2006 and 2007 rainy seasons showed that *P. diplosisae* was the most abundant parasitoid parasitizing AfRGM larvae [21]. According to him *P. diplosisae* came to the field late when the gall midge must have been well established, but however increases in population rapidly that it overtakes the midge within two months of its presence. Probable that is why it comes into the rice field late when AfRGM has fully developed. In 1991 in Southern Nigeria [16] recorded its appearance in the rice field after 35 days. [22] recorded the appearance of *P. oryzae* at the second generation of *O. oryzae* in the rice field. His reports showed that the parasitoid was more abundant with increase in temperature than both rainfall and humidity, suggesting the observed increase in percentage parasitism later in the season than at the peak of the raining season. Research results from Nigeria showed that *P. diplosisae* has been reported in *Orseolia bonzii* occurring on *Paspalum scrobiculatum* during the non-rice cropping season and thus *P. scrobiculatum* serves as a bridge between rice crops [23].

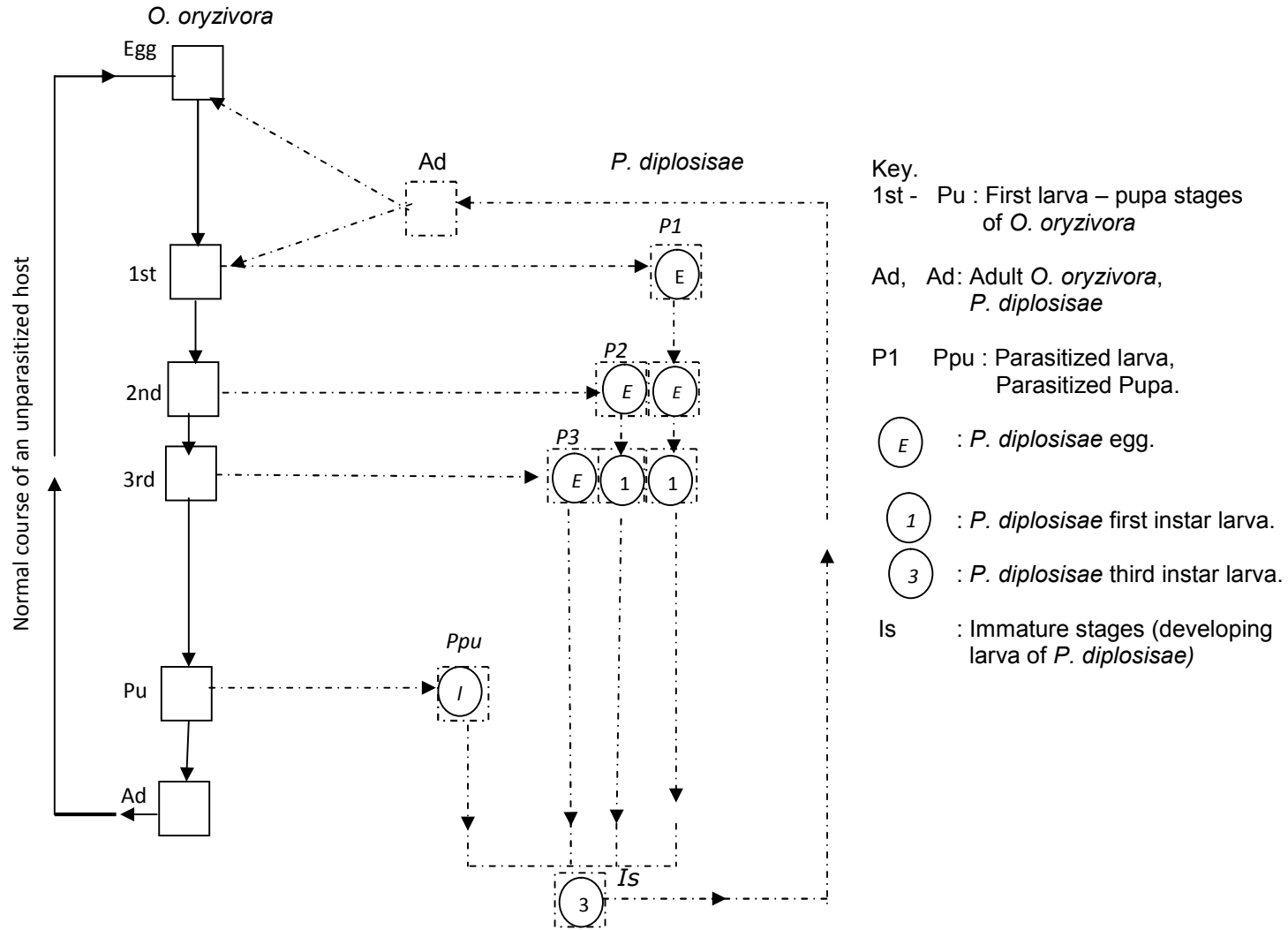


Fig. 2. Diagrammatic representation of the developmental relationship between *Platygaster diplosisae* and the stages of *Orseolia oryzivora*. Source: [21]

## 5. *Aprostocetus procerae* RISBEC (HYMENOPTERA: EULOPHIDAE)

### 5.1 Biology and Ecology of *Aprostocetus procerae*

*Aprostocetus procerae* is the second most important parasitoid of AfRGM [3]. It is a solitary ecto-parasitoid of AfRGM pupae Fig. 3. The female finds a rice gall containing AfRGM pupae using her long ovipositor; it lays a single egg close to the pupa after stinging and paralyzing it. As the parasitoid egg hatches, the larva finds the paralyzed pupa and attaches itself to the abdomen of the pupa from where it sucks up the pupa body fluid from outside. The abdomen of the pupa gradually collapses and loses its shape. As the pupa dies, it turns brownish in colour. Fully developed larva moves clear of the dead AfRGM and pupates. Emerging *A. procerae* cuts a hole in the rice gall and escapes. Unfortunately, presently, much have not been done about the lifecycle of the parasitoid to correlate it with that of the gall midge.

Like *P. diplosisae*, *A. procerae* is well distributed in all rice fields that are hot spots for the gall midge. Similarly, it comes into the rice field when AfRGM is fully established. According to [18], *A. procerae* comes into the field about 3 weeks after *P. diplosisae* has become established. However, its population remains lower than that of *P. diplosisae* throughout the season [16,19,22]. However, combined effort of the two parasitoids has been recorded to be quite high in parasitizing AfRGM in many countries.



Fig. 3. A female adult of *Aprostocetus procerae*

Source: [9]

## 6. PARASITISM LEVEL OF AFRGM BY *P. diplosisae* and *A. procerae*

*P. diplosisae* and *A. procerae* are both important parasitoids of the African rice gall midge in West Africa and Nigeria in particular. These two parasitoids share the same resource by infesting in different life stages of the host, AfRGM [24]. Of the two parasitoids, *P. diplosisae* has been reported as the most important parasitoid of AfRGM [16,18,19]. According to [16] *P. diplosisae* is the dominant natural enemy of AfRGM in south east Nigeria. It was the first to establish in the field and maintained a higher percentage parasitism than *A. procerae*



throughout the season. *P. diplosisae* is capable of parasitizing up to 80 % of AfRGM eggs in unsprayed rice ecosystem [11]. According to [18] combined effect of *P. diplosisae* and *A. procerae* may result in up to 98% parasitization of AfRGM late in the season. [11] reported that field sampling and experiments have shown that in some situations *A. procerae* and *P. diplosisae* can find and kill a high percentage of AfRGM even when the pest population is low. And that towards the end of the rainy season on farmers field that these parasitoids commonly kill well over 50% of AfRGM larvae and pupae. Survey carried out in the South eastern parts of Nigeria showed that in late planted rice crops and ratoon, parasitism by the two parasitoids averaged 42% and 44%, respectively [7,25]. According to [25], percentage parasitism by *P. diplosisae* in sites near Bida and Uyo increased from July to December with 50% to 70% by December. According to [2] parasitism of *O. oryzivora* by *P. diplosisae* ranged from 38 to 60% and *A. procerae* was 20% in studies conducted in Cameroon. Combined parasitism by the two species can be as high as 77% [25,26,27].

*Platygaster oryzae* has also been recorded as the dominant natural enemy of Asian rice gall midge Wood -Mason, *Orseolia oryzae* in different parts of Asian countries where *O. oryzae* is a pest [22]. They recorded 75% parasitism in India and 37.8% parasitism on ratoon rice during off season of Jamu Nadu.

However, most of the times, such high levels of parasitism recorded occur late to prevent large population of AfRGM from building up and causing serious yield loss. Given these facts, there is need for a continuous search in order to improve on these parasitoids for effective control of AfRGM in Africa.

## 7. PREDATORS

Predators are often the most important group of biological control agents in rice. Predators occur in almost every part of the rice environment. Predators identified preying on *O. oryzivora* however is not many. [11] reported predatory mites, *Neaseiulus* sp as attacking and feeding on eggs of *O. oryzivora*. They also reported that spider *Orb* and *lynx* feed on the adults of the midge. [26] reported that predation of *O. oryzivora* pupae in galls was low and did not increase with gall densities in the wet seasons with the average mortality of 1.5 % in October. [28] reported that laboratory test have identified *Cyrtominus viridis* (Miridae), sward tailed cricket, *Anaxipha longipennis* (Gryllidae) and long horned grasshopper, *Conocephalis* sp. that ate the eggs among other predators of *O. oryzivora* in lowland rice fields. *O. oryzivora* larvae and pupae are well hidden from predators inside galls and so only about 5 % of pupae are preyed upon and most of this is accidental predation by larvae of stalk eyed flies and other stem borers, and makes predators ineffective as bio-control agent of *O. oryzivora*. On the other hands, a lot of predators have been identified preying on the Asian species of the gall midge. In Asia it has been reported that *Casonoides interestitatis* Shen and *Nabis capsiformis* are the major larval and pupal predators, respectively. *Taub* was observed to be predacious on pupae and adults in Thailand [22]. [22] Observed a predacious mite, *Amblysius* sp. on eggs of rice midge in Thailand. The lists of predators that have been identified on rice gall midge in different places are as presented in the Table 2 below.

**Table 2. Major predators of rice gall midge**

<b>Predator species</b>	<b>Prey stage</b>	<b>Country/Continent</b>
<i>Cyrtorhinus viridis</i>	Egg	Nigeria
<i>Conocephalus longipennis</i>	Adult	Nigeria
<i>Casonoides interstitialis</i>	Larva/pupa	Asia
<i>Nabis capsiformis</i>	Larva/pupa	Asia
<i>Anaxipha longipennis</i>	Larva	Nigeria
<i>Neanastatus circitventris</i>	Egg	Nigeria
<i>Oxyopes javanus</i>	Adult	Nigeria
<i>Argiope catenulata</i>	Adult	Nigeria
<i>Trigonidium cicindeloides</i>	Egg	Africa
<i>Neoscona theisi</i>	Adult	India
<i>Tetragnatha mandibulata</i>	Adult	Asia
<i>Argiope catenulate</i>	Adult	Asia
<i>Amblyseius imbricatus</i>	Egg	Asia

Sources: [2,3,9,18,20]

## 8. CONCLUSION

It has been observed that African rice gall midge is an important insect of rice with very high potential to cause economic losses especially in endemic areas. Fortunately, this important insect pest has many natural enemies that can be used in the management of the pest. Amongst the natural enemies, two parasitoids (*P. diplosisae* and *A. procerae*) have been identified to have very high potentials in reducing the incidences of the pest instead of relying on pesticides that have not given the desired result since its inception. It has been reported that repeated use of insecticides to control insects have resulted in development of resistance particularly in sub tropical and tropical countries. Research results have also demonstrated significant increase in yields with increased parasitism by these parasitoids. Unfortunately still, these parasitoids with high potential have not been able to control this pest most of the time below economic level early enough to avert economic losses. Studies have showed that the peak incidence of parasitism either coincided with or followed peak pest incidence, but never preceded the latter, indicating that these native natural enemies became effective only under high pest densities and late in the season. This has been attributed to their late arrival in the field. From research results reported by [21], therefore farmers are encouraged to enhance their rice productivity through the conservation of these natural and indigenous parasitoids on *Paspalum scrobiculatum* to ensure their early synchronization with that of the AfRGM population for enhanced management of the rice gall midge in lowland rice-based ecosystems in West Africa especially in the face of absence of any exotic natural enemies. Furthermore, local farmers are encouraged to form an association through which they can develop local techniques for mass rearing and releasing of these parasitoids in times of the outbreak of the pest. Finally the adoption of biological control as an integral part of any integrated control programme for AfRGM will enhance rice productivity and income to farmers' family.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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