Journal of Biology, Agriculture and Healthcare
ISSN 2224-3208 (Paper) ISSN 2225-093X (Online)
Vol 2, No.8, 2012
www.iiste.org

Effect of Abiotic Factors on the Incidence of African Rice Gall Midge, Orseolia oryzivora and its Parasitism by Platygaster diplosisae and Aprostocetus procerae

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Abstract
African rice gall midge (AfRGM), *Orseolia oryzivora* is one of the most damaging insect pests of lowland rice in Nigeria in the recent time, and could result in total crop failure in endemic areas. Of all the control measures adopted so far biological control is the most promising. Two parasitoids (*Platygaster diplosisae*, Hym: Platygastridae and *Aprostocetus procerae*, Hym: Eulophidae) have been identified with the potential to suppressed AfRGM population. In the current study, we evaluated the effect of abiotic factors (rainfall, relative humidity and temperature) in two eco-sites for two years on the incidence of AfRGM, and on the efficiency of the two parasotioids in the management of AfRGM. The incidence of AfRGM was significantly influenced by abiotic factors (rainfall, relative humidity and temperature). The percentage infestation increased with increase in rainfall and relative humidity. The trend was similar at both locations with the highest infestation recorded in October, and decreased in November. At both locations, percentage tiller infestation was greater in the rainy season of 2006 with more frequent rains than in 2007, with highest infestation recorded at Edozhigi in both years. Percentage parasitisms by the two parasitoids were found to have significant correlation with the abiotic factors. Heavy rains and high humidity significantly reduced the efficiency of the two parasitoids. On the contrast, the population and efficiency of the parasitoids were observed to increase with reducing rainfall, RH, but increasing temperature thus increasing the efficiency of the parasitoids later in the season with up to 70% parasitism when combined, with *P. diplosisae* dominating the field. The results suggest that abiotic factors played significant role on the incidence of AfRGM and the efficiency of these parasitoids and should be considered in the adoption of these parasitoids as bio-control agents of AfRGM.
Keywords: Orseolia oryzivora, Platygaster diplosisae, Aprostocetus procerae, abiotic factors

1. Introduction

African rice gall midge (AfRGM), *Orseolia oryzivora* Harris and Gagné (Diptera: Cecidomyiidae) is an indigenous insect pest of lowland and irrigated rice in Sub-Saharan Africa (Williams et *al*., 1999; Nwilene *et al.*, 2006). It is a serious insect pest of rice in many African countries in the recent time. It attacks the rice plant at the vegetative stage of growth. The infested plant tillers are stimulated to grow into a gall called 'silver shoot' within which the larva develop (Ukwungwu and Misari, 1997). An infested tiller does not initiate new leaves or a panicle. Thus each infested tiller represents a tiller lost. AfRGM outbreaks have been reported in different parts of Nigeria and Africa with significant yield losses recorded in worst affected areas (Ukwungwu and Joshi, 1992a; Heinrichs and Barrion, 2004).

Following resultant significance grain yield losses in many infested rice fields, several studies have been undertaken to identify appropriate control measures for this pest. However some of the methods adopted were hindered by lack of knowledge on factors responsible for its outbreak. Biological control appears to be the most promising controlling measure of AfRGM in the recent time. In the development of biological control techniques hitherto, considerable attention has been paid to what has become known as the classical approach. However, there is a growing realization that much can be gained from the exploitation of naturally occurring enemies of indigenous or long-established pests (Heinrichs and Barrion, 2004). Many natural enemies complexes of AfRGM have been reported both in Nigeria and other West African countries with the potential to reduce AfRGM to tolerable levels (Umeh *et al.,* 1991; Ukwungwu and Misari, 1997). Amongst these, two parasitoids; *Platygaster diplosisae* Risbec (Hymenoptera: Platygastridae), an egg/larval endoparasitoid, and *Aprostocetus procerae* Risbec (Hymenoptera: Eulophidae), a solitary pupal ectoparasitoid have been identified with high potential for the management of AfRGM (Dakouo *et al*., 1988). It has been reported that parasitism caused by these two parasitoids can reach as high as 77% of the pest populations (Williams *et al*., 1999; Ba, 2003). Unfortunately, lack of knowledge of the abiotic factors that triggers the incidence of AfRGM and its effect on the efficiency of these parasitoids can hinder control measures against it and the adoption of these parasitoids as its bio-control agents. Understanding the influence of abiotic factors that may influence the distribution and abundance of an insect is a fundamental issue in insect management especially insects like AfRGM that causes economic damage regularly (Baskauf, 2003; Murua *et al*., 2006).

Climatic factors have a significant impact in the performance of insects either to grow, develop or the ability to catch prey and escape predators. Though there are some information on how environmental factors (rainfall, temperature and relative humidity) influences the incidences of AfRGM, there are paucity of information on the role of these factors in the distribution and abundance of the parasitoids associated with AfRGM in Nigeria. Identifying these factors and their influences on these insects will advance AfRGM biological control efforts in many African countries.

In this study therefore, we assessed the influence of abiotic factors (rainfall, relative humidity and temperature) on the incidences of AfRGM. Secondly, we assessed how these abiotic factors could influence the distribution, abundance and efficiency of identified parasitoids of AfRGM for possible adoption as bio-control agents of AfRGM.

2. Materials and methods

The field experiments were performed at two sites (Ogidiga and Edozhigi) identified as AfRGM hot spots in Nigeria. Both sites have had long history of gall midge outbreaks for the past three decades. Ogidiga is located in the southeastern Nigeria under forest zone and falls within latitude 06°17'N, longitude 08°04'E and altitude 104m above sea level (masl). On the other hands, Edozhigi is located in the north central Nigeria under the Guinea savanna zone with latitude 09°45'N, longitude 06°07'E and altitude 51 masl. Both sites have bimodal rainfall patterns with an average annual rainfall of about 1800–2200 and 900–1050mm per annum for Ogidiga and Edozhigi, respectively, which are distributed between May and October. Their average daily temperature ranges between 20 and 35 8C with an annual mean of 26.5°C and 27.4 °C respectively. Their mean relative humidity ranges from 64–83% and 52–73% for Ogidiga and Edozhigi, respectively. Both sites are known for rain fed lowland rice-growing.

The studies were conducted using farmers' fields at both sites. Two rice varieties (Cisadane and ITA 306) were the major rice varieties grown in the two sites. Both rice varieties are susceptible to the AfRGM. Fields used for the experiments were not sprayed with any insecticides.

Sampling for the incidence of AfRGM was conducted at monthly intervals at both locations from June to December of 2006 and 2007. At each sampling period in each site, 50 plants were randomly selected to assess the level of AfRGM infestation (% tiller infestation). The samplings were selected at set intervals along parallel transects through the crops, while leaving the border rows. The collected galls were dissected for % parasitism (parasitized larvae and pupae and parasitoid species present). Data on environmental factors (rainfall, relative humidity and temperature) were collected from the weather stations in the zones.

Data analysis

Collected data on % tiller infestation and % parasitism were transformed (arcsine transformation) prior to ANOVA using SAS (2003). The mean separation was carried out by Tukey's studentized range test. Pearson correlation coefficient (r) was used to determine the relationship between % tiller infestation and between % tiller infestation and parasitism by *P. diplosisae* and *A. procerae* and abiotic factors.

3. Results

The results indicated that abiotic factors have significance influences on the AfRGM incidences and its parasitism by its parasitoids. At both sites the incidences of *O. oryzivora* were less frequent and insignificant during the earlier part of the season characterized with less frequent rains, relative humidity and higher temperature. With the increase in rainfall, the percentage infestation increased rapidly at both locations with the highest infestation recorded in October and decreased in November (Figs. 1a and 1b) for Ogidiga and Edozhigi respectively. Similarly, it was observed that the percentage infestation of AfRGM at both locations increased with increase in relative humidity (Figs. 2a and 2b) for Ogidiga and Edozhigi respectively. On the contrast, the results indicated that the percentage infestation of AfRGM was decreasing as the temperature was increasing towards the ending of the season at both locations (Figs. 3a and 3b) for Ogidiga and Edozhigi respectively.

At both locations, the percentage tiller infestation was greater in the rainy season of 2006 than in 2007. The 2006 cropping season recorded more rainfall, relative humidity and reduced temperature with a mean of 217.7 mm, 79.1 % and 26.0°C for both locations and gave the highest level of AfRGM infestation than the 2007 cropping season with a mean of 172.9 mm, 71.4 % and 27.4°C for rainfall, relative humidity and temperature respectively. At the location level, Edozhigi recorded less rainfall but slightly higher relative humidity and temperature with a mean of 139.6 mm, 84.9 % and 27. 1°C than Ogidiga with a mean of 250.9 mm, 65.5 % and 26.3°C for rainfall, relative humidity and temperature respectively. Rainfall and temperature but not relative humidity differed significantly between both locations. At Edozhigi, there was a positive correlation between AfRGM infestation and relative humidity ($r = 0.70$, $P < 0.01$), between AfRGM infestation and rainfall ($r = 0.71$, P < 0.01) and negative correlation between temperature and AfRGM infestation (r = -0.74, P < 0.01). At Ogidiga, there were positive correlations between AfRGM infestation and rainfall (r = 0.62, P < 0.01), AfRGM infestation and relative humidity (r = 0.94, P < 0.001) and also negative correlation between AfRGM infestation and temperature (r = -0.58 P < 0.01). Although the levels of AfRGM infestations were more at Edozhigi site throughout the period of the experiments, no significant differences were recorded at both locations.

The results on the influence of the abiotic factors on the efficiency of the parasitoids indicated that the efficiencies of the paarasitoids were dependent on the abiotic factors (rainfall, relative humidity and temperature). When there were more rains and high relative humidity and the population of AfRGM increased significantly in the field, the populations of the parasitoids were low in the field and could not effectively control AfRGM (Figs. 1 and 2) for both locations. This was in contrasted with the observations seen later in the season when the rains and relative humidity were less with an increasing temperature. The populations of the parasitoids were observed to increase very rapidly later in the season and overtook the population of the pest with up to 70% parasitism when combined in October. Data collected from both locations and years showed that *P. diplosisae* was the most abundant and frequent parasitoid encountered attacking AfRGM than *A. procerae*. In the Guinea savanna zone (Edozhigi), *P. diplosisae* was the most abundant parasitoid parasitizing AfRGM larvae during the 2006 and 2007 rainy seasons. The percentage parasitism by *P. diplosisae* peaked in October across the years and sites and dominated the field throughout the 2006 and 2007 rainy seasons suppressing AfRGM infestation below economic injury level. In the forest zone (Ogidiga), percentage parasitism by *A. procerae* was much lower than in the Guinea savanna zone. There were no significant differences in % parasitism between the two locations. However, Edozhigi had higher percentage parasitism during the two-years of study. Beginning from November, populations of AfRGM and both parasitoids were observed to decline slowly indicating the negative effect of total absence of rainfall and relative humidity and high temperature on the insects. There were strong positive correlations between tiller infestation and % parasitism by *P. diplosisae* (r = 0.89, P ≤ 0.0001) and *A. procerae* (r = 0.86, P ≤ 0.0001).

4. Discussion

Generally the incidences of AfRGM and its parasitoids were observed to be more at Guinea savanna zone of Nigeria than at the forest zone. This was in line with Ukwungwu and Joshi (1992) who reported that AfRGM occured in both the savanna and forest zones, they however reported that it was more common in the southern portion of the Guinea savanna region of the country. Insect pests have generally been reported to be most severe in the humid tropical and Guinea savanna zones (Heinrichs and Barrion, 2004). This was consistent with the results obtained in the present study where gall midge incidences were higher in the southern Guinea savanna zone, Edozhigi than in the forest zone, Ogidiga. Studies conducted in Côte d'Ivoire in 1995 also confirmed that AfRGM incidences were higher in the Guinea savanna than in the humid forest region (Heinrichs *et al*., 1995). The present study showed that *Orseolia oryzivora* incidence was generally very rare at the beginning of the wet season, but its infestations increased during the rains and the peak of infestation occurred between August and October of each growing season, which coincides with the period of continuous rains and high RH (Ogah *et al*., 2006). During these months, the mean relative humidity and temperature averaged 75% and 25^{o}C, respectively, and this has been reported as favourable for AfRGM development and reproduction (Umeh and Joshi, 1993; Williams *et al*., 1999). Umeh and Joshi (1993) observed that the peaks in AfRGM populations were positively correlated with increase in relative humidity and regular rainfall. AfRGM larvae require high regular water supply to hatch. Reviewing the influence of climatic conditions on *O. oryzivora*, Heinrichs and Barrion (2004) mentioned abnormally wet weather as a factor contributing to heavy infestation. In addition, rice plants at the susceptible vegetative stage were abundant in the rainy season, providing ample food supply for the larvae. Bonzi (1980) stated that midge activity in Burkina Faso, in general, starts in August and was comparatively higher in years when rainfall exceeds 1500mm during May. This suggests that alteration of the planting period according to climatic factors could affect the incidence of *O. oryzivora*. Ogah *et al*. (2005) have suggested that delayed sowing may reduce the incidence of *O. oryzivora* in southeastern Nigeria, by reducing the period during which rice plants are available for infestation by the midge. Ogah *et al*. (2006) in their study on the effect of time of transplanting and spacing on the incidence of *O. oryzivora,* found that earlier and regular rains accelerated the incidence. That study also found that the incidence of *O. oryzivora* decreased with an increase in temperature, corroborating the relationship observed between infestation and seasonal factors in the present study.

Parasitism is very important in the biological control of AfRGM (Nacro *et al*., 1995, Ogah *et al*., 2010). Generally, *P. diplosisae* was observed to be more abundant than *A. procerae* in the present study, especially at Edozhigi. Ukwungwu and Joshi (1992) reported that *P. diplosisae* was the dominant parasitoid species attacking AfRGM in Nigeria. Similarly Umeh and Joshi (1993) have reported that *P. diplosisae* was the dominant parasitoid of AfRGM at Ogidiga. In the present study, *P. diplosisae* was the first parasitoid species to establish in the field, and it maintained a higher rate of parasitism than *A. procerae* throughout the season and across both years of the study. The decline in gall density observed in November as parasitism increased could be attributed to the parasitoids and influence of climatic factors on it as previously reported by Umeh and Joshi (1993). The observed exploitation of the host earlier in the season by *P. diplosisae* may be advantageous to this species as an effective biological control agent of AfRGM. Thus suggesting that *P. diplosisae* is the only indigenous parasitoid with high potential for biological control of AfRGM.

Conclusion

The highest gall midge infestations recorded during the high raining period with high relative humidity suggests the importance of climatic factors on the incidence of this pest. Similarly, the inability of these parasitoids to control the gall midge earlier in the season despite its population and then do that with easy latter in the season tells on the importance of the climatic factors on the efficiency of these parasitoids as agents of biocontrol for AfRGM. We thus hypothesize that consideration of climatic factors in rice planting will enhance the management of AfRGM especially when using its natural enemies, and is therefore recommended to rural farmers since this will improve their synchrony and may positively contribute towards biological control of AfRGM in lowland rice-based ecosystems in Nigeria.

Acknowledgements

The authors are thankful to Africa Rice Center, IITA Ibadan Nigeria for providing technical assistance. They are also thankful to the farmers that we used their fields for the study. They are also grateful to Mr. Bayo Khinde and Nte Nwafor for their assistance in data collection.

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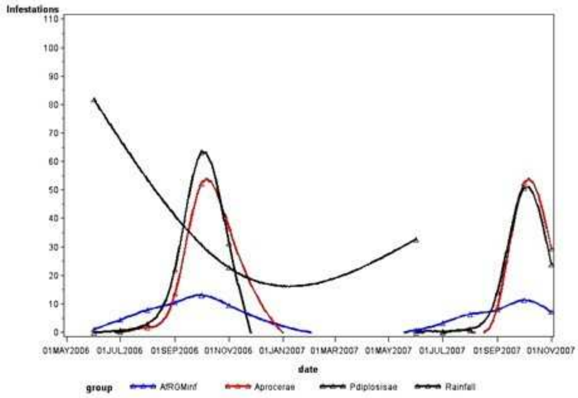

Fig. 1a: Relationship between AfRGM infestation, *A. procerae, P. diplosisae* and rainfall In Ogidiga during 2006/2007 farming seasons

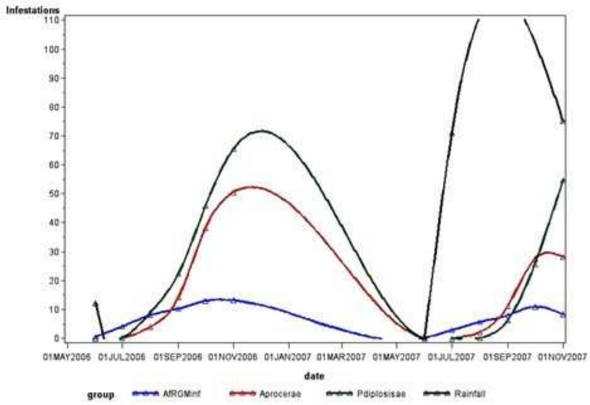

Fig. 1b:Relationship between AfRGM infestation, *A. procerae, P. diplosisae* and rainfall in Edozhigi during 2006/2007 farming seasons

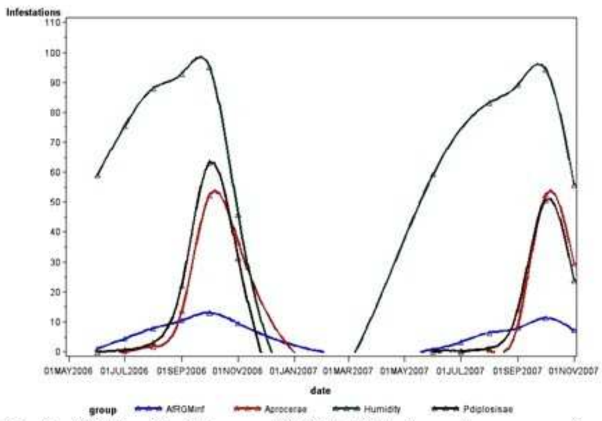

Fig. 2a: Relationship between AfRGM infestation, A. procerae, P. diplosisae and Relative Humidity in Ogidiga during 2006/2007 farming seasons

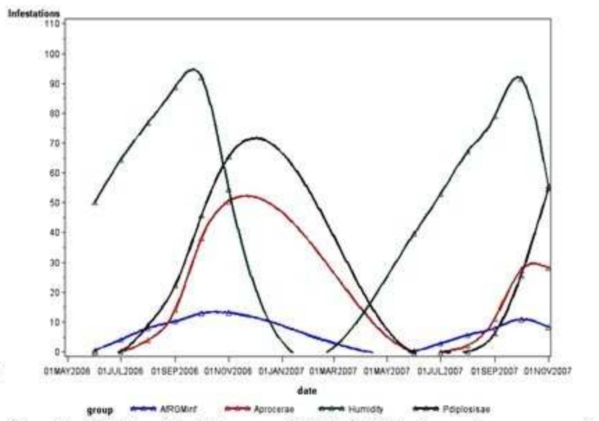

Fig. 2b: Relationship between AfRGM infestation, A. procerae, P. diplosisae and Relative Humidity in Edozhigi during 2006/2007 farming seasons

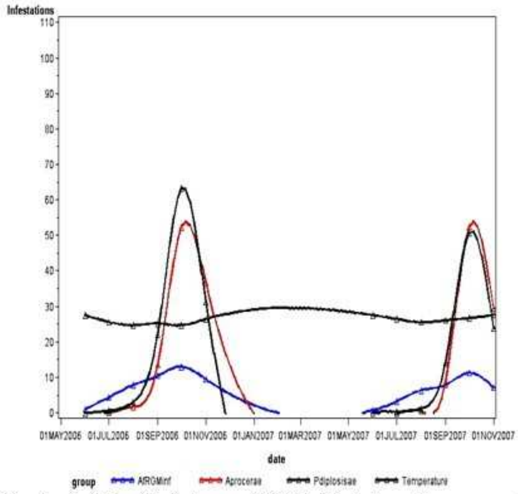

Fig. 3a: Relationship between AfRGM infestation, A. procerae, P. diplosisae and Temperature in Ogidiga during 2006/2007 farming seasons

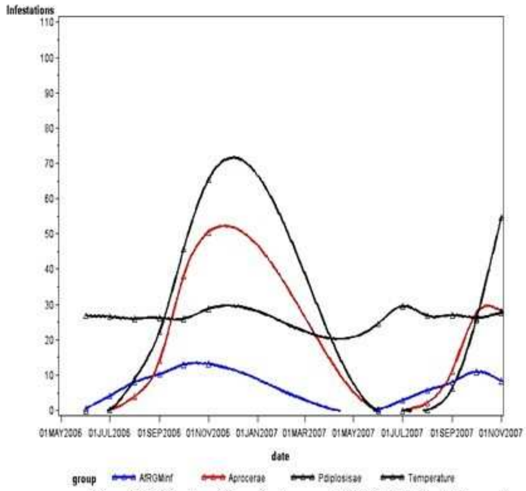

Fig. 3b:Relationship between AfRGM infestation, A. procerae, P. diplosisae and Temperature in Edozhigi during 2006/2007 farming seasons