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Research Article

DAMAGE ASSOCIATED WITH THE AFRICAN RICE GALL MIDGE (AFRGM), *ORSEOLIA ORYZIVORA* HARRIS AND GAGNE (DIPTERA : CECIDOMYIIDAE) IN AN INTEGRATED CROPPING SYSTEM AT BAMA, WESTERN BURKINA FASO

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ABSTRACT

Orseolia oryzivora is a major insect pest of rice in Burkina Faso. This study aimed at assessing the incidence of this pest on an integrated irrigated rice cropping system in Bama, western Burkina Faso. The work was carried out during two consecutive wet cropping seasons, 2020 and 2021. The experiment was conducted using a randomized split-plot design in a latice design. The main plots (MP) were divided into secondary plots, made up of a combination of two factors: two rice varieties (FKR64 and Orylux6) and four types of crop management before rice (Mucuna, cowpea forage, organic matter and a no-crop control); the third factor, mineral fertilization (F0, F1, F2, F3) was distributed in secondary plots (SP). Weekly entomological assessments were carried out from day 28 after transplanting (DAT) to DAT 84. Symptoms of *O. oryzivora* damage were assessed during the vegetative and reproductive phases of rice and examined in the laboratory. Results showed that all rice varieties were infested with *O. oryzivora*. The higher amount of NPK, the higher the damage caused by the insect pest. The FKR64 variety recorded the highest average rate of pre-imaginal *O. oryzivora* populations. The results of this study could contribute effectively to the sustainable management of *O. oryzivora* in Bama.

Keywords: Rice, integrated system, AfRGM, Burkina Faso.

INTRODUCTION

Rice is one of the most widely consumed cereals in Burkina Faso. As a result, it has become a strategic crop in terms of the country's trade balance. To meet the demand for rice, the Burkinabè government has made efforts to promote rice growing through intensification and the construction of hydro-agricultural infrastructures. These initiatives include agricultural research activities such as the introduction of improved varieties, and the improvement of cultivation techniques and practices. However, the gap between national demand and supply is closely linked to the various constraints facing rice growing. These include abiotic constraints (capricious rainfall and low soil fertility), socio-economic constraints (poor farmer equipment) and biotic constraints (diseases, nematodes, weeds, insect pests, etc.). These constraints lead to production losses of 2 to 38%, depending on the growing season (Ba, 2008).

The African rice gall midge (AfRGM), *Orseolia oryzivora*, is one of the major insect pests of rice in Burkina Faso. It is also a major pest in sub-Saharan Africa (Ukwungwu *et al.*, 1989; Dale, 1994; Williams *et al.*, 2002; Nacro *et al.*, 2008). In Burkina Faso, *O. oryzivora* occurs in areas with high rainfall, such as the west and south-west of the country, and is known to occur in all three rice-growing ecologies (rainfed, irrigated and lowland). Attack occurs during the vegetative stage, when plants are actively

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tillering. The larva causes a bulbous thickening at the crown, known as a gall. The thickening of hollow tubular galls has the appearance of an onion leaf, hence the name "onion leaf" given to this symptom on young tillers whose internodes have not yet formed (Nacro *et al*., 2008). Severe infestations lead to reduced plant development and stunting (Dale, 1994). The damage caused can result in crop losses of 70% or even 100% if no phytosanitary treatment is adopted (Dakouo *et al*., 1988). Following damage by the pest, the only intervention available to farmers is chemical control. However, despite its effectiveness, this method leads to an imbalance in the rice-growing environment through its effects on natural enemies, pest resistance and farmers' health. It has also revealed its limitations with regard to the biology of the insect pest, which spends most of its cycle inside the gall.

Research on this insect pest has shown that irrational use of nitrogen fertilization, the presence of alternative host plants and staggered sowing or transplanting are all factors that favor the development of *O. oryzivora* populations (Dakouo *et al*., 1988 ; Nacro, 1995). In addition, this research has also revealed the presence of two parasitoids associated with this midge. These include a gregarious endo-parasitoid of the eggs and larvae, *Platygaster diplosisae*, and a solitary ecto-parasitoid of the pupae, *Aprostocetus procerae*, whose combined action results in 70% mortality of the African rice midge at the end of the cropping season (Dakouo *et al*., 1988, Nacro *et al*., 1995). Other studies have shown that *O. oryzivora* populations are decimated by a cohort of indigenous predators and parasites, some of which can destroy up to 50% of the pest's larvae at the end of the cropping season. This study was conducted with the objective of assessing the level of damage of *O. oryzivora* and its' associated parasitism in an integrated irrigated rice cropping system of western Burkina Faso.

MATERIALS AND METHODS

Presentation of the study area

The study was carried out on the irrigated rice-growing scheme of Bama, western Burkina Faso. Bama is the capital of a rural district located in the province of Houet, 25 km north-west of Bobo-Dioulasso, between parallels 10°20' north latitude and 4°20' west longitude; of a total developed area of 1,260 ha, only 1,100 ha are farmed by 1,300 growers (Sanou *et al*., 2016). Thanks to total water control, rice is grown during two seasons a year: from January to May, on 800 to 900 ha planted with rice, maize, tubers and vegetables, corresponding to the dry season; from June to November, on 1,200 ha planted mainly with rice, corresponding to the wet season. The average annual yield is 4.5 to 5.5 tons of rice paddy/ha, with annual production estimated at around 842,065 tons of rice paddy (MAAH-HOUET, 2020).

Plant material

The plant material consisted of two irrigated rice varieties, Orylux 6 and FKR 64, a cowpea forage variety and a cover crop variety, *Mucuna pruriens*. The Orylux6 variety has a 100-day cycle and a potential yield of 6.5 tons/ha; as for FKR 64, it has a 120-day cycle; its potential yield can reach 8 to 10 t/ha (INERA, 2018).

Animal material

The pre-imaginal or imaginal stages of the *O. oryzivora* constituted the animal material.

1.1.4. Technical and laboratory equipment

Field equipment included :

- Jute bags for storing and transporting samples to the laboratory for dissection;
- Knives for sampling the plants under study;
- Protective equipment (boots).
- Dissecting equipment (knives and forceps).
- 70% titrated alcohol to preserve larvae and pupae from dissecation;
- A pipette for transferring alcohol from vials;
- Paper tape for labeling;
- Spatula-tipped forceps for handling insect larvae or pupae;
- Bottles for preserving insect specimens;
- Binocular magnifier for insect observation and identification;
- Distilled water to dilute the alcohol in the bottles;
- Pens for taking notes;
- Field and laboratory data collection sheets.

Sampling methods for rice midge damage

Sampling consisted in observing damage caused by the gall midge. Observations were made from 28 days after transplanting (DAT) to 84 DAT with a frequency of 14 days. Galls were sampled during the vegetative and reproductive phases of the rice plant. Samples were taken randomly from 20 hills per sub-plot. Pre-imaginal midge populations were obtained after laboratory dissection of rice tillers showing damage symptoms (galls). The number of dissection series was the same as the number of visual observations made in the field.

Rearing of pre-imaginal midge stages

The rearing of pre-imaginal stages of the midge was carried out in the entomology laboratory of the rice program at the Farako-Ba station. The biological material consisted of pupae and larvae of various stages obtained during dissections of tillers showing gall symptoms. Incubation of these specimens was carried out in jars or flasks containing water-soaked cotton; one individual was placed per flask. Rearing took place under ambient laboratory temperature conditions. Daily observations were made until complete emergence of either the midge or its associated parasitoids. Identification of emerged insects enabled us to monitor the level of parasitism of pre-imaginal populations and the rate of parasitism of the midge.

Experimental set-up

The experiment was conducted on the rice-growing scheme of Bama over two consecutive wet cropping seasons (2020 and 2021) using a randomized split plot design. The main plots (MP) were divided into sub-plots (SP) made up of a combination of two factors: two rice varieties (FKR 64 and Orylux6) and four crop management practices prior to rice (Mucuna, cowpea forage, organic matter and a no-crop control). A total of 96 SP were obtained, including 32 SP repeated 3 times, corresponding to 32 treatments. The third factor, mineral fertilization (F0, F1, F2, F3), was distributed in SP: F0: Control without fertilization; F1: NPK (200 kg/ha) + Super Granulated Urea (72 kg/ha); F2: NPK (100 kg/ha) + Simple Urea (100 kg/ha); F3: NPK (200 kg/ha) + Simple Urea (150 kg/ha).

Yield evaluation

At maturity, rice was harvested manually, using a sickle, from a 3.5 m² yield square. After harvesting, the paddy was sun-dried, threshed, winnowed and weighed, and the moisture content measured and corrected to 14% in order to estimate grain yield.

Calculation methods

The parasitism rate was calculated using the method of January *et al*. (2018) and the relative abundance of pre-imaginal *O. oryzivora* populations using that of Rahaman *et al*. (2014).

- % larval parasitism = (Number of parasitized larvae) / (Total number of larvae) x100
- Relative abundance of pre-imaginal populations (%) = (Total number of individuals of each species) / (Total number of individuals of all species) x100
- Average gall rate = (Σ of galls) x 100 / Σ of tillers ;

The yield obtained in the yield square (3.5 m²) was corrected to 14% humidity before being extrapolated to the hectare (10000 m2) using the following formula:

- Yield = (m× correction factor×10000) /4.5 ; with Yield = rice yield (in kg/ha), m= paddy mass in grams

Statistical analysis

Data collected were entered and grouped using Microsoft Excel 2010. The database was then imported into R software version 3.6.0 for various statistical analyses. The data were first tested for normality using the Shapiro-Wilk test. To determine the individual effect of the explanatory variables (variety, previous crop and mineral fertilization) and their interactions on the response variables (gall midge, galls), the data were then subjected to the Kruskall-Wallis (K-W) test at a significance level of 5%. Finally, to determine the combined effects of the factors studied, the data were subjected to a multi-factor analysis of variance at the 5% level. The analyses focused on descriptive statistics (percentages, averages and graphical treatments).

RESULTS AND DISCUSSION

Table 1 presents the results of the analysis of variance of the factors studied on rice gall formation. These results revealed a very highly significant difference between subplots for the number of days after transplanting (DAT) factors. Highly significant differences were also revealed between the interactions Fertilization*DAT, and Variety*DAT; a significant difference for the interaction Fertilization*Var and finally a significant difference was observed for the triple interactions Fertilization*Var*DAT.

Tableau 1. Effect of factors on the formation of galls.

Sources of variation	Probabilities Percentage of galls (%)
Days after transplanting (DAT)	< 2.2e-16***
Fertilization (F)	0.003126**
Previous crops (PC)	0.2954^{ns}
Varieties (Var)	0.1618^{ns}
Fertilization*DAT	0.000002647***
Fertilization*PC	0.4120849^{ns}
Fertilization*Var	0.0118412*
Previous crops*DAT	0.467^{ns}
Previous crops *Var	0.07789^{ns}
Varieties*DAT	0.001661**
Fertilization*PC*DAT	0.998890^{ns}
Fertilization*Var*DAT	0.04*

Fertilization*PC*Var	0.3747682^{ns}
Previous crops*Var*DAT	0.110495^{ns}
Fertilization*PC*Var*DAT	0.8877252^{ns}

*** : Very highly significant; ** : Highly significant; * : Significant; ns : Not significant.

Based on the results of the analyses of variance, only those sources of variation for which significant differences have been identified will be considered in the following presentation of results.

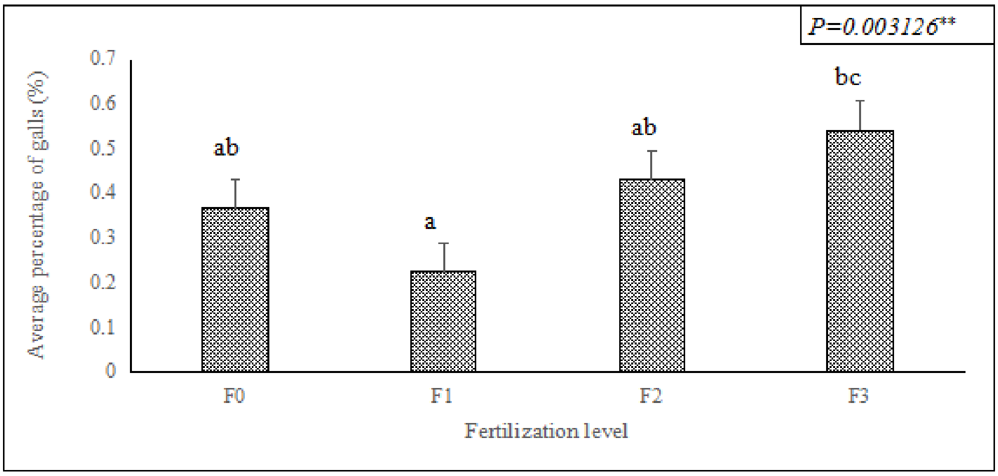

Figure 1. Effect of rice mineral fertilization level on gall formation.

Figure 1 illustrates the impact of fertilization level on average gall rates observed on rice plants. The results of the analysis of variance revealed a significant difference between the four levels of fertilization at the 5% probability threshold. Damage to rice tillers was significantly higher in plots receiving the highest dose of NPK and simple urea (F3=0.540), followed by plots F2 (0.430) and F0 (0.366). Plot F1 (0.225) recorded the lowest gall rate. The combined effect of mineral fertilization and number of days after transplanting on gall formation is recorded in figure 2. No galls were recorded on the 28th and 42nd DAT. Galls began to be observed from the 56th DAT (0.137%) in the control plot (F0). These rates increased for all mineral fertility combinations from 70 to 84 days. The highest average gall rates at 70 days were recorded with F2 (1.04%) and F3 (1.03%). With regard to the level of mineral fertilization, the plots that received F2 (1.11%) and F3 (1.67%) fertilization had the highest gall rates, followed by the F0 control plot (1.27%) at 84th DAT. The lowest gall rates were recorded in plots receiving F1 (0.44%) and F0 (0.42%) fertilization.

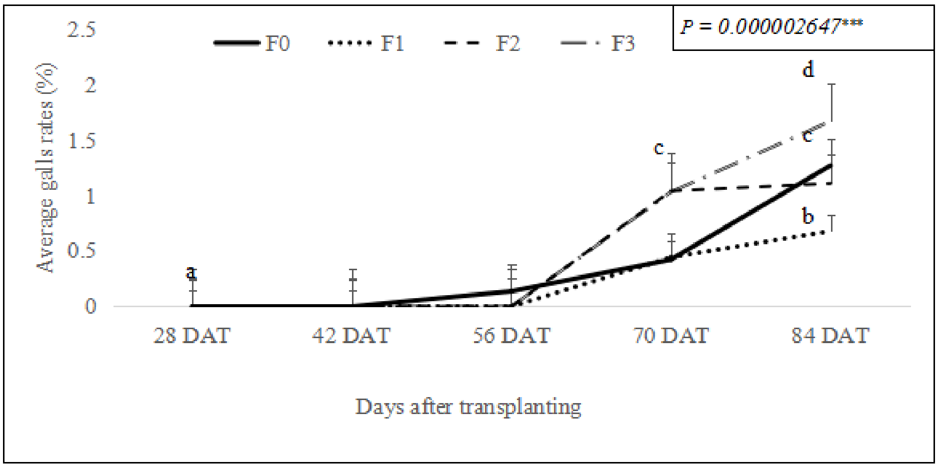

Figure 2. Combined effects of mineral fertilization and number of days after transplanting on gall formation.

Figure 3 shows the combined effects of fertilization and rice variety on onion tube formation. Analysis of variance reveals a significant difference in mean gall rate for fertilization*variety interactions. At F0, FKR64 with 0.52% galls proved to be more susceptible to the pest than Orylux6 with 0.23% galls. For F1, no significant difference was recorded in average gall rates for the 2 varieties, FKR64 (0.26%) and Orylux6 (0.18%). With F2, the two rice varieties were not significantly different from each other. With F3, the average gall rate was 0.611% for FKR64 and 0.480% for Orylux6. Figure 4 shows the combined effect of rice variety and number of days after transplanting on gall formation. The results of the analysis of variance revealed a significant difference between varieties and number of days after transplanting. Galls were observed from the 56th DAT with the variety FKR 64 (0.07% galls). At 70 and 84 days after transplanting, 0.64% and 1.42% galls respectively were recorded with FKR 64. The Orylux6 variety recorded 0.82% galls on the 70th DAT and 0.96% galls on the 84th DAT.

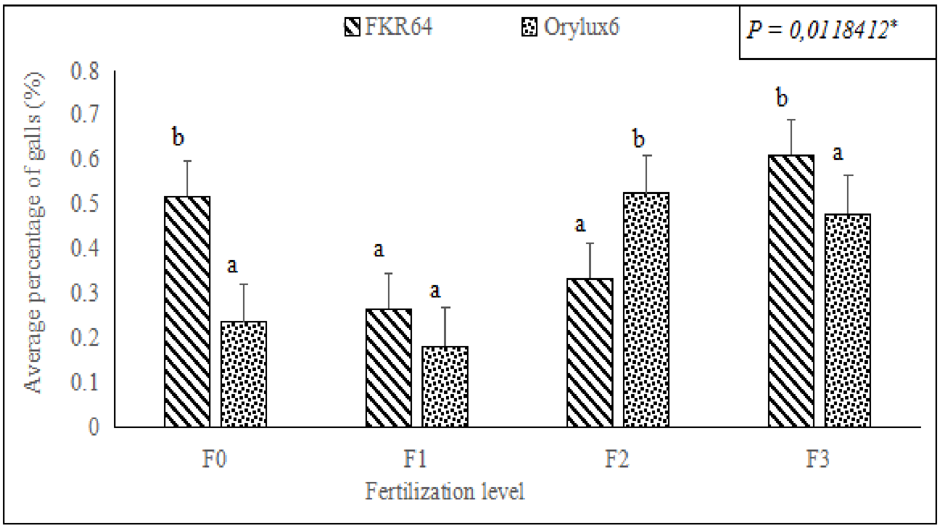

Figure 3. Combined effects of fertilization and rice variety on gall formation.

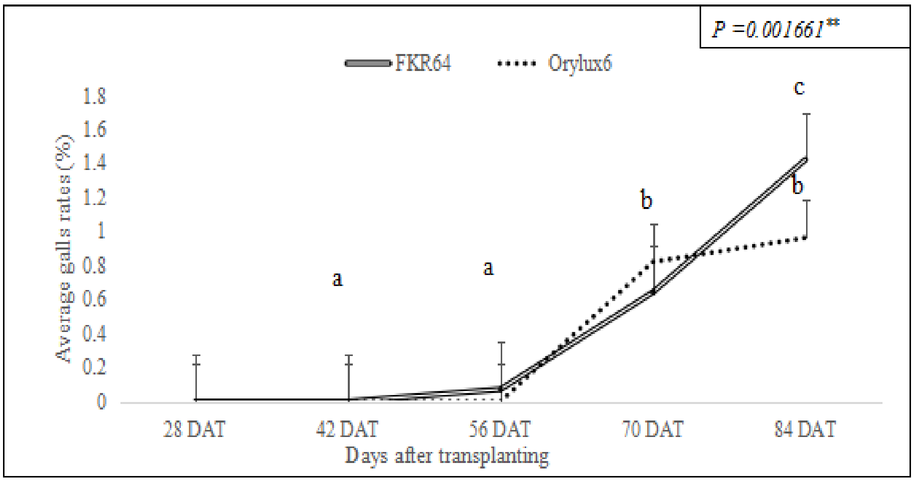

Figure 4. Combined effect of variety and number of days after transplanting on gall formation.

The results of the combined effects of fertilization*variety*DAT on gall formation are presented in Table 2. Analysis of variance revealed a significant difference between treatments at the 5% threshold. The damage recorded was low from the 56th DAT with the FKR64* F0 combination (0.30%); it then increased at the 70th and 84th DAT. The highest average gall rate (2.15%) was recorded on the 84th DAT with the FKR64*F3 combination, followed by the FKR64*F0 combination (1.86%). On the other hand, the lowest average gall rate (0.41%) was observed on the 70th DAT with the FKR64*F1 combination. In addition, the fertilization*variety combination (Orylux6) was more susceptible to midge attack. The highest average gall rates were observed on the 70th (1.28%) and 84th DAT (1.35%) with the Orylyx6*F2 combination. The Orylyx6*F3 combination recorded 1.13% and 1.26% galls on the 70th and 84th DAT respectively. The lowest average gall rates were observed at 70 DAT with the Orylyx6*F0 combination (0.41%) and the Orylyx6*F1 combination (0.45%).

Figure 6 shows the evolution of pre-imaginal rice midge populations according to the different phases of plant development. The results of the insect damage dissection showed a significant difference between the two seasons and between varieties. During the 2020 wet season, a relatively abundant pre-imaginal midge population was observed during the vegetative phase, with 88 individuals for FKR64 and 123 for Orylux6. During the 2021 wet season, the numbers recorded were 92 for FKR64 and 112 for Orylux6. Subsequently, there was a decline in pre-imaginal populations of the insect during the rice breeding and ripening phases for the two consecutive seasons, 2020 and 2021. The lowest pre-imaginal midge populations were recorded during the rice maturation phase with the FKR64 variety in 2020 (13 individuals) and the Orylux6 variety in 2021 (12 individuals).

Table 2. Combined effects of fertilization, variety and number of days after transplanting on gall formation.

Sources of variation		Average percentage of galls (%)				
Varieties	Fertilization	28 DAT	42 DAT	56 DAT	70 DAT	84 DAT
FKR64	F0	0	0	0.30	0.44	1.86
	F1	0	0	0	0.43	0.90
	F2	0	0	0	0.80	0.87
	F3	0	0	0	0.91	2.15
Orylux6	F0	0	0	0	0.41	0.77
	F1	0	0	0	0.46	0.46
	F2	0	0	0	1.28	1.35
	F3	0	0	0	1.14	1.26

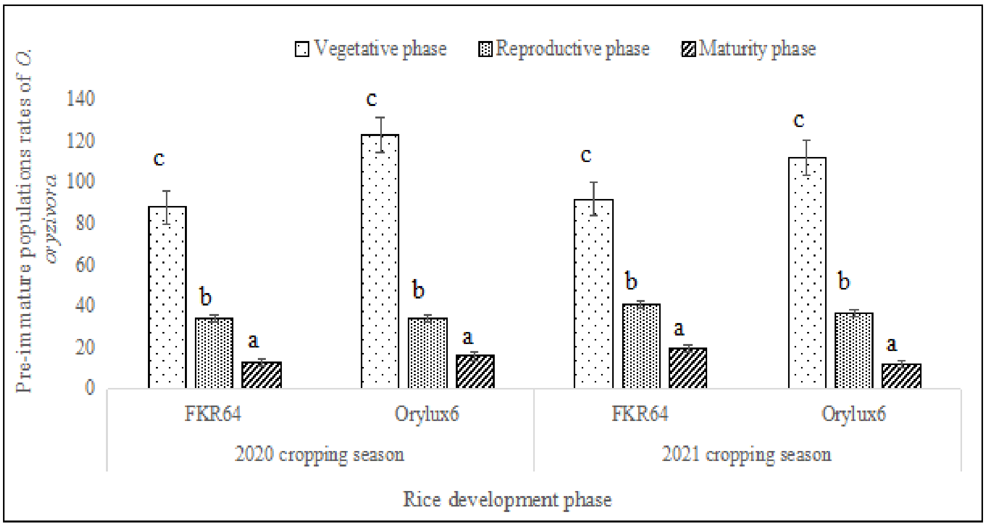

Figure 6. Variation in pre-imaginal rice midge population levels according to rice plant development phases.

Midge larval parasitism was higher on FKR64 in both 2020 (19.48%) and 2021 (31.44%). Pupal parasitism was lower in 2020 (5.72%) than in 2021 (30.92%) on the same variety. Pupal parasitism was higher on the Orylux6 variety in the 2020 wet season (9.88%) than in the 2021 wet season (3.25%). Overall, larval parasitism was higher in 2021 (14.05%) than in 2020 (8.403%). During these two consecutive wet seasons, the average rate of cumulative parasitism was higher on FKR64 (25.20% in 2020 vs. 62.37% in 2021) than on Orylux6.

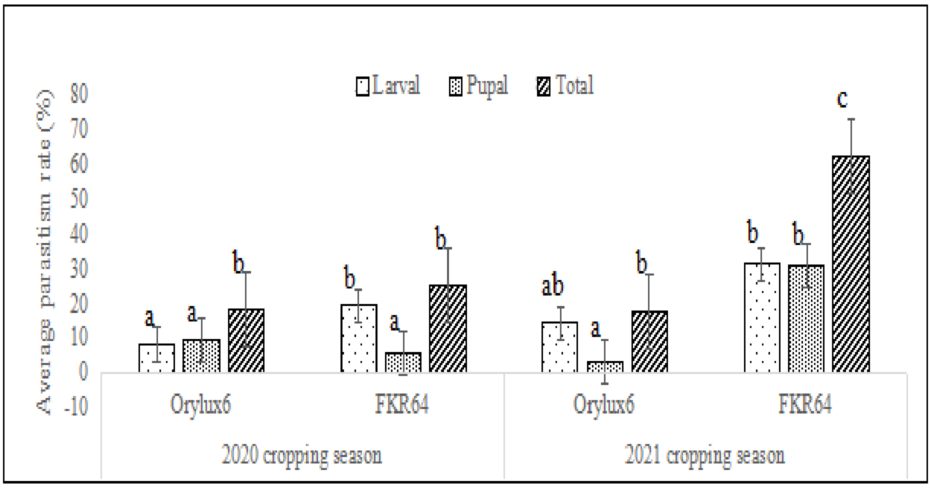

Figure 7. Evolution of the average rate of parasitism affecting pre-imaginal populations of rice midge.

The results of the analysis of variance on paddy rice yield are shown in Table 3. Fertilization and variety had a very highly significant effect, and the previous crop*variety interaction a significant effect, on rice yield in the 2020 wet season. For the 2021 season, fertilization and variety had a very highly significant effect on yield.

Table 3. Yield analysis results.

Sources of variation	**Probabilities**	
	Yield 2020	**Yield 2021**
Fertilization	0.0000001534***	7.61e-13 ***
Previous crops	0.1434710^{ns}	0.136 ^{ns}
Varieties	0.0006308***	0.000404 ***
Fertilization* Previous crops	0.6195088^{ns}	0.71873^{ns}
Fertilization* Varieties	0.0144960*	0.3174^{ns}
Previous crops* Varieties	0.9311673^{ns}	0.1092365^{ns}
Fertilization* Previous crops * Varieties	0.5975340^{ns}	0.790779 ^{ns}

*** : Very highly significant; * : Significant; ns : Not significant.

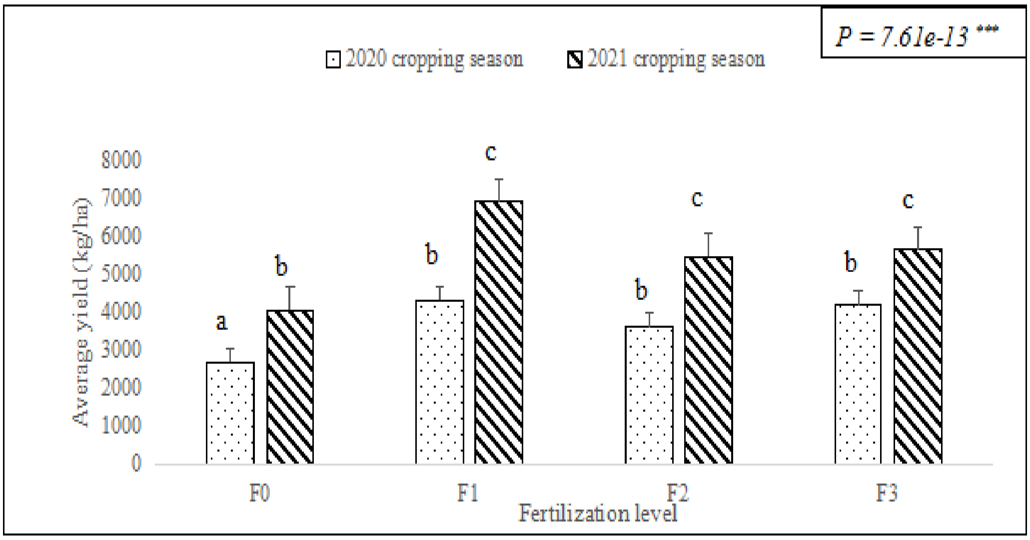

Figure 8. Effect of fertilization levels on average rice yields.

The effect of fertilization levels on paddy rice yield is shown in figure 8. Analysis of variance revealed a highly significant difference between treatments at the 5% threshold. The highest average yield in the 2020 wet season was obtained with F1 (4,321 kg/ha), followed by F3 (4,182 kg/ha) and F2 (3,613 kg/ha). The lowest average yield was recorded for F0 (2,683 kg/ha). During the 2021 wet season, the highest yield was observed with F1 (6,912 kg/ha), followed by F3 (5,665 kg/ha), F2 (5,481 kg/ha and finally F0 with 4,058 kg/ha. Figure 9 shows the average paddy rice yield by variety. Analysis of variance revealed a highly significant difference between treatments at the 5% threshold from one season to the next. Over the 2 consecutive seasons of the study, the FKR64 variety recorded the highest average yields (4,043 kg/ha in 2020) and (6,049 kg/ha in 2021).

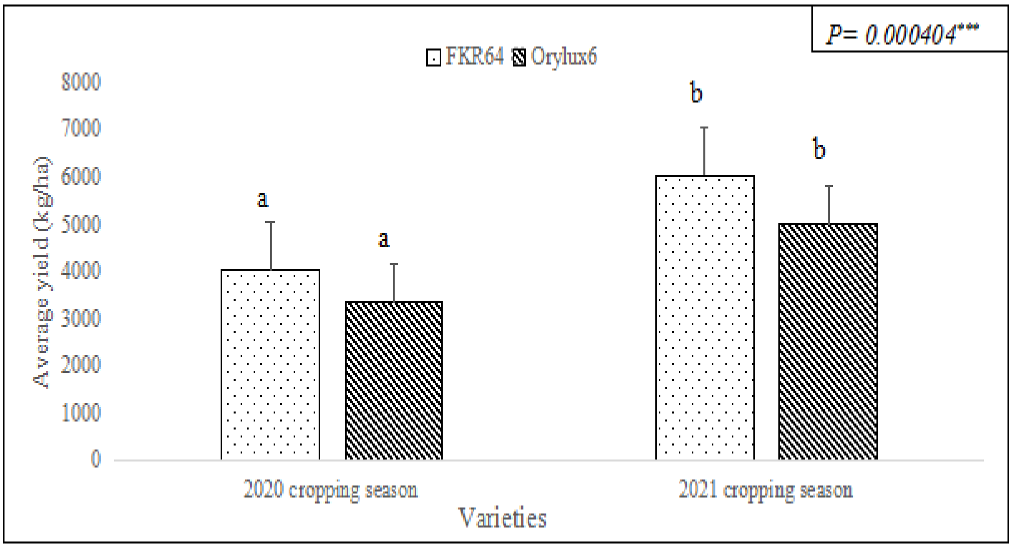

Figure 9. Average paddy rice yield by variety

Overall, the incidence of *Orseolia oryzivora* on rice in Bama during the two consecutive years of this study was low, with less than 3% galls recorded. The highest damage was observed with the Fertilisation*DAT and Variety*DAT interactions from the 56th DAT. Average gall rates were significantly higher in plots receiving high doses of NPK and simple urea. Plots receiving F2 and F3 fertilization recorded the highest average gall rates. Similar observations were reported by Dakouo *et al*. (1988) and Nacro (1994), who noted that high doses of nitrogen favored the appearance of galls symptoms in rice plots. Our results are comparable to those reported by Ouattara (2003). The Orylux6 variety was more susceptible to the gall midge than FKR 64. In addition, the interaction between variety and the number of days after transplanting revealed that damage appeared from the 56th day after transplanting. Our results are similar to those of Ganou (2021), who reported that most insects are dependent on the vegetative development stage of the crop.

The evolution of pre-imaginal midge populations depended on the varieties used. The Orylux6 variety recorded more pre-imaginal midge populations during the 2020 wet season, while FKR64 hosted more pre-imaginal midge populations during the 2021 season. A high pre-imaginal midge population during the vegetative phase was observed for FKR64 in the 2020 and 2021 seasons. These results corroborate those of Ogha *et al*. (2012); Nacro *et al*. (2008); Williams *et al*. (1999) who showed that midge incidence is generally very rare at the start of the wet season, but infestations increase during the rains and peak between August and October of each growing season. Otieno *et al* (2006) reported similar results. The high rate of parasitism during the two wet seasons could be linked to the high rainfall and relative humidity, which were favorable to midge development. Ogah *et al*. (2006) showed that the period of continuous rainfall, high relative humidity and average temperature are reported to be favorable for midge development and reproduction. Umeh and Joshi (1993) observed that midge population peaks were positively correlated with increased relative humidity and regular rainfall. Parasitoids are specialized and act on their hosts according to their density. Nacro *et al* (1995) reported similar results when studying parasitism associated with *O. oryzivora*. Parasitoids are able to locate their hosts even at low pest densities (Yu and Byers, 1993; Boivin, 2001).

In 2021, fertilization and variety had a highly significant effect on yield. Grain yield was influenced by variety, fertilization and the crop precedent*variety interaction in both cropping seasons. The results showed that the lowest yields were recorded in the control plots, while the highest yields were observed in the plots that benefited from mineral fertilization. Increasing doses of NPK had an effect on yield. This could be explained by the multiple roles played by this nutrient in stimulating root development, tillering, flowering and grain ripening. Our results corroborate those reported by Sanogo *et al*. (2010), who concluded that the use of high-performance varieties and appropriate doses of mineral elements in irrigated lowland rice maximized yield.

CONCLUSION

The study revealed the presence of the African rice midge in the integrated rice-growing system. Onion tubes were present irrespective of rice variety and type of treatment. Midge damage was highest in plots receiving higher NPK levels and in control plots. The highest damage was recorded at 70 days before harvest. The highest average rate of pre-imaginal midge populations was recorded on the FKR 64 variety. The rate of associated parasitism was average for the two cropping seasons. The main parasitoids associated with midge belonged to 02 families: platygastridae and eulophidae of the order hymenoptera. Grain yield was influenced by variety, fertilization and the crop precedent*variety interaction and the best yield was obtained in the FKR 64 plots during the 2021 season.

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