Research & Development
2022; 3(1): 34-40
http://www.sciencepublishinggroup.com/j/rd
doi: 10.11648/j.rd.20220301.17

Local Cropping Systems and Influence on the Proliferation of Rice Midge (*Orseolia oryzivora*) in Baguinéda, Mali

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To cite this article:
Fatoumata Maïga, Noussourou Moussa, Bernard Sodio, Abdoulaye Hamadoun. Local Cropping Systems and Influence on the Proliferation of Rice Midge (*Orseolia oryzivora*) in Baguinéda, Mali. *Research & Development.* Vol. 3, No. 1, 2022, pp. 34-40.
doi: 10.11648/j.rd.20220301.17

Received: January 3, 2022; **Accepted**: January 25, 2022; **Published**: February 9, 2022

Abstract: Mali is one of the largest rice (*Oryza* L.) producing country in West Africa. However, this production is still confronted with phytosanitary constraints linked to parasitic insects, including the African rice midge (*Orseolia oryzivora*). The African rice gall midge is an important pest in the southern Sudanian zone where conditions are suitable for its development. This study aims to document the influence of cropping systems on proliferation of rice midge. The study was conducted in the Baguinéda irrigated perimeter during 2016, 2017, and 2018 years. Fifty study plots were selected in the four sectors that make up the Baguinéda irrigated perimeter. Twenty galls, ten per diagonal, are collected from each plot after the 40th, 60th and 80th day after each transplanting date for dissection and rearing. The study identified five types of cultivation practices in rice fields. The results show that the monoculture of the Gambiaca variety has the highest average number of galls per clump regardless of the observation date after transplanting. An analysis of variance performed on the year 2018 data revealed a significant difference at the 5% threshold between the average number of galls observed at the 80th day after transplanting and at the 60th day after transplanting but also between the 80th day after transplanting and the 40th day after transplanting.

Keywords: *Orseolia oryzivora*, Crop Systems, African Gall Midge, Rice, Baguinéda

1. Introduction

Rice (*Oryza* L.) farming plays an important role in agriculture and maintaining food security in Mali. Annual rice production in 2010 reached 2,268,054 tons [8]. It is expected to increase due to the growing demand for food in and the sub-region [12]. This crop plays a key role in national poverty reduction strategies [3, 11].

The notable deficiency of rice production can be explained in part by multiple abiotic and biotic constraints, including the increasing water deficit, declining soil fertility, and continued pest aggression [16]. Among these constraints are the damages caused by insects, especially the midge whose causal agent is *Orseolia oryzivora*. The insect is prevalent in several African countries [18]. In Mali, it is very widespread in the areas of Sikasso, Koulikoro and Ségou in lowland areas and irrigated perimeters [7]. The damage is caused by larvae feeding inside the rice tillers, which then thicken and take on the shape of an onion bulb called gall. Infestation levels range from 30% in the lowlands cultivation to 80% in the irrigated conditions, especially at the Office of Baguinéda irrigated perimeter [16]. In some places, nurseries of rice have been completely destroyed, making transplanting impossible for some farmers. The San and Baguinéda irrigated perimeters have experienced upsurges of the pest with production losses of about 55% [8]. Production losses of 60% have been observed in Burkina Faso [5].

In Mali, the new cropping systems were progressively introduced, based on tillage by plowing for land preparation and crop maintenance, mechanization of sowing, use of herbicides for weed control, use of fertilizers and organic manure for soil fertility renewal [2], and application of insecticides for pest control [19].

The influence of cropping systems on variations in pest populations is little documented in country. Understanding these phenomena in the context of the Baguinéda irrigated perimeter, considered the midge hotspot in Mali, is of great importance in completing the components of integrated management to minimize the considerable production losses in these rice ecosystems.

This study is part of this framework and aims to document the influence of cropping systems on rice midge proliferation through the irrigated perimeters of Baguinéda.

2. Material and Methods

2.1. Site of the Study

The study was conducted in the Baguinéda irrigated perimeter Office (OPIB) with the coordinates: 12.62291°N and 007.77896°W. A 45 km long canal drains the waters of the Niger River from Bamako to the study site which has 3000 ha of irrigated land [14]. Baguinéda climate is Sudanian, characterized by a rainy season from June to October and a dry season from November to April. The annual mean rainfall 850 mm at Baguinéda. The temperatures range from 16.5 to 39°C. The soils are mostly clayey, acid with very little organic matter. In some areas, there are large quantities of gravel and coarsely fragmented laterite. The vegetation is composed of orchards with forest recruits more or less developed according to the age and duration of the fallow.

2.2. Characterization of Cropping Systems

The characterization of cropping systems through surveys of rice farmers focused on the description of the landscape in the rainy and off-season, on sociological aspects at the plot level, and on cropping practices. The following variables were documented: the diversity of crop species grown in the rainy and dry seasons, soil preparation and fertilization techniques, sowing and transplanting schedules, crop association and rotation practices, weed and pest control (diseases and insects), and crop residue management (burial, burning or other uses).

2.3. Assessment of African Rice Midge Damage in the Baguinéda Irrigated Perimeter

The study was conducted during three rainy seasons (June to November 2016, 2017, and 2018) and two dry seasons (January to May 2017 and 2018). During vegetative development, observations of *Orseolia oryzivora* damage on rice involved all 50 plots and across the 20 test plots of the 2017 rainy season and the 30 test plots of the 2018 rainy season, beginning 40 days after transplanting. Then, they were performed at the 60th and 80th day after transplanting (DAT). In each plot, the intensity of rice midge damage was assessed on 20 rice clumps, 10 clumps on each diagonal, by scoring the number of tillers per rice clump and the number of galls per rice clump. The intensity and severity of midge attack was recorded once every 20 days after transplanting by counting the number of galls on the total number of stems per plant at 10 plants selected on one of the two diagonals. Also, 10 galls collected from 10 rice plants per plot were observed to record the number of midge larvae and pupae, the number of midge adults and parasitoid species at emergence.

2.4. Data Analysis

For each plot, the results of the gall counts from both diagonals are presented as totals of the numbers. The population sizes of *Orseolia oryzivora* on the 40th day, 60th day and 80th day according to the transplanting dates were established. For cultivation practices, a number of variables were used to develop a typology of cultivation practices for which a multiple correspondence factor analysis and a hierarchical ascending classification were performed. Analyses of variance were performed using R (https://cran.r-project.org/Card), statistical processing software, to establish relationships between the average number of galls per clump and current cultural practices in the Baguinéda irrigation scheme.

3. Results

3.1. Typology of Cultivation Practices in Rice Farms at the Baguinéda Irrigated Perimeter

The analysis carried out on the data collected from the 50 farms monitored during the two rainy seasons (2017 and 2018) shows that the first two factorial axes 1 and 2 explain 25.05 and 14.14% of the results, respectively, or 39.19% of the total variability (Figure 1). The average size of the plots monitored is 1.22 ha in the rainy season and 0.88 ha in the off-season, with great disparities between farms. The vast majority of producers farm an area of between 0 and 2 ha. Surveys conducted over the three years of the study identified nine rice varieties. 66.44% of the farmers surveyed use the adny variety in the rainy season, 10.27% use the BG variety and 9.59% use the IR (Wassa) variety. The other varieties (Gambiaca, BG (SRI), Kogoni, Nènèkala, Sébérang and adny (SRI) represent 13.70% of the varieties used by the producers in our sample.

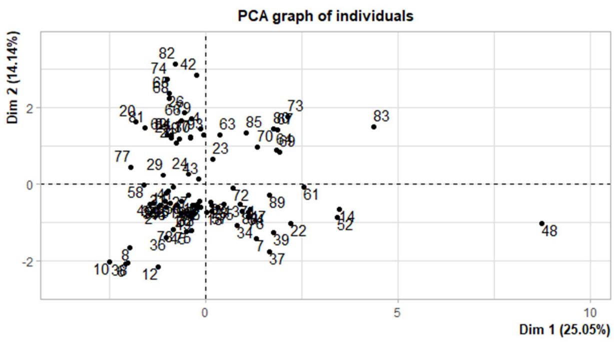

Figure 1. Individuals distribution of farms monitored in Baguinéda irrigated perimeter (2017 and 2018).

A hierarchical ascending classification (HAC) was used to distinguish five types of cultivation practices in rice fields at the Office of the Baguinéda Irrigated Perimeter Office.

Type 1

This type concerns 44% of the farms in the sample. The vast majority of farmers in this group have adopted the rice variety adny and farm an average of 1 ha. They carry out several rotations in the off-season (more than three types of crops). On these farms, plowing and harrowing are favored for soil preparation. They use chemical treatments as a method of pest control and make only one intervention per crop cycle. The doses used are on average 268 kg ha^{-1} of Urea, 136 kg ha^{-1} of DAP and 3.23 L of Roundup.

Type 2

This group includes 32% of the farms in the sample. On these farms, the adny (SRI) variety is grown during the rainy season. As with the first type, several rotations and crop rotations are practiced in the off-season. Rice farmers in this group farm an average of 0.72 ha. To prepare the soil, farmers in this group use burning and harrowing. They also use the chemical method to control the disease. They make one application per crop cycle and apply an average of 166 kg ha^{-1} of Urea, 94 kg ha^{-1} of DAP and 1.63 L ha^{-1} of Roundup.

Type 3

For third type, 14% of the farms monitored at the Baguinéda irrigated perimeter. In these farms, the adny variety is preferred. As off-season crops, rice farmers grow some market gardening (cucumber and onion) in parallel with cowpea cultivation. In this group, plowing and slurrying are the most common soil preparation practices. Chemical treatments are also frequent in this group with very large quantities of Roundup (over 4.89 L ha^{-1} on average). To control *Orseolia oryzivora* attacks on rice, chemical fertilization is also de rigueur in this group (606 kg ha^{-1} of Urea on average, 311 kg ha^{-1} of DAP). Rice farmers in this group farm an average of 2.46 ha.

Type 4

This type includes 6% of the farms in the sample. Farmers in this group grow rice exclusively and the Gambiaca variety is adopted for the rainy season. To prepare the soil, the rice farmers in this group practice burning before plowing. In this group, fertilization and pest control methods are exclusively chemical. The average doses used are 230 kg of Urea, 83 kg of DAP and 2 L ha^{-1} of Roundup. Rice farmers in this group farm an average of 0.86 ha.

Type 5

4% of the farms monitored at the OPIB of Baguinéda. The average area farmed is 3.69 ha. As for the type 1 and 3 farms, the adny variety is preferred by the producers. As off-season crops, the rice farmers in this group grow cowpeas and onions. To prepare the soil, they use plowing preceded by burning. As in Group 4, mineral fertilization and pest control methods are exclusively chemical. The doses used in single application are on average 195 kg ha^{-1} of Urea, 75 kg ha^{-1} of DAP and 9 L ha^{-1} of Roundup.

3.2. Tolerance of Varieties to African Rice Midge Attack

Assessment of varietal tolerance to leaf blast revealed variation in disease severity among rice varieties (Figure 2).

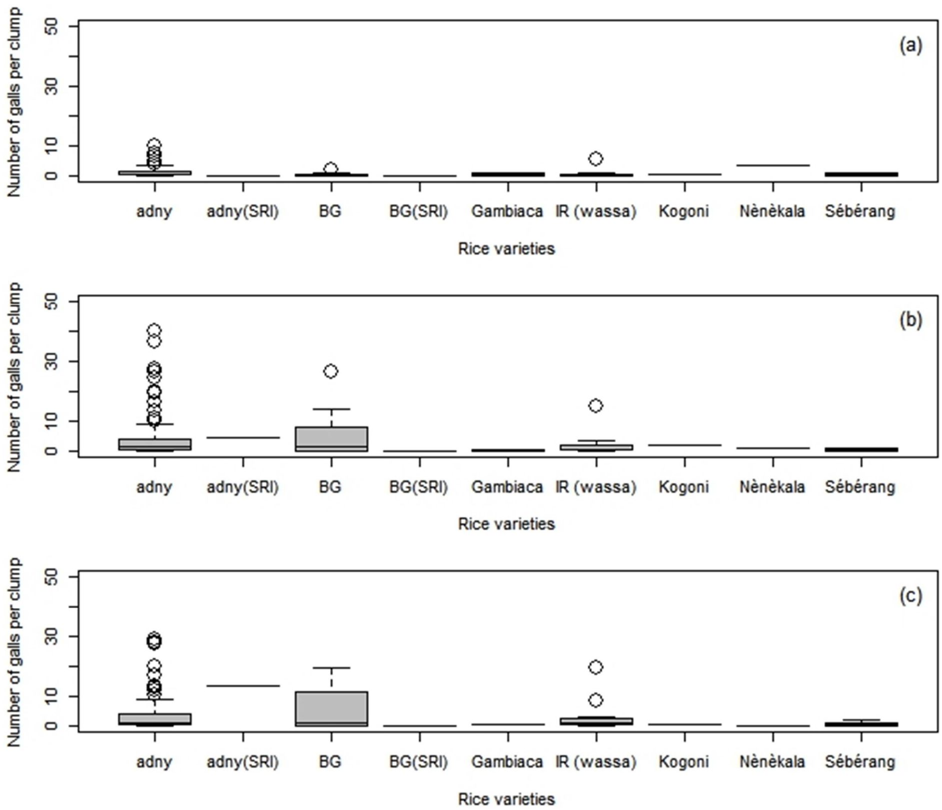

Figure 2. *Varietal tolerance to African rice midge attack in Baguinéda irrigated perimeter.*

On day 40 after transplanting (Figure 2a), the most attacked rice varieties were Nènèkala (3.35), adny (1.32 galls per clump on average), IR (Wassa) (0.64) and BG (0.42 galls per clump on average). The other varieties are moderately attacked with an average of 0.38 galls per clump. The varieties adny (SRI) and BG (SRI) were not attacked at this date.

On the 60th day after transplanting (Figure 2b), all rice varieties were attacked with a high average number of galls per clump. For the variety BG, the average number of galls per clump is 5.16. On the contrary, this number amounts to 0.49 for the variety Sébérang.

On day 80 after transplanting (Figure 2c), the average number of galls per clump was high for BG, adny and IR (Wassa) varieties. On the other hand, there were no attacks on the Nènèkala variety on the 80th day after transplanting. For the other cultivated varieties, the average number of galls per clump is 1.44 with a strong variation from one farm to another.

3.3. Variation of the Average Number of Galls Per Clump According to Number of Day After Transplanting

The average number of galls per clump varied greatly during the rainy season, depending on the date of observation after transplanting (Table 1). During the dry season (Table 2), attacks by *O. oryzivora* were relatively low.

In 2016, this number was 2.23 galls per clump on the 40th day after transplanting for all varieties, rising to 16.77 galls per clump 20 days later (60th day after transplanting) and dropping slightly on the 80th day after transplanting (14.92 galls per clump).

In addition to the intra-seasonal variability, there is also an interannual variability. In 2017, the average numbers of galls per clump were 1.07, 1.85, and 1.72 for the 40th, 60th, and 80th day after transplanting respectively. The average numbers of galls observed in 2018 were 0.37, 0.31, and 0.26 for the 40th, 60th, and 80th day after transplanting respectively.

The analysis of variance performed on the 2018 data revealed a significant difference at the 5% threshold between the number of galls observed on the 80th day after transplanting and the 60th day after transplanting (P=0.001) but also between the 80th day after transplanting and the 40th day after transplanting (P=0.01). But the number of galls did not differ significantly between the 60th day after transplanting and the 40th day after transplanting.

The variation in the average number of galls across decades during the rainy season shows that the transplants made from the 3rd decade of July onwards are the most exposed to *O. oryzivora* attacks. The number of galls per clump was highest on the 60th and 80th and relatively low on the 40th DAT even in 2016 which had a record attack rate.

Table 1. *Variation of the average number of galls per clump according to the transplanting dates (40th, 60th and 80th DAT) in rainy season.*

Statistics/Periods	40th day of transplanting date			60th day of transplanting date			80th day of transplanting date		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
Minimum	0.00	0.00	0.00	0.55	0.00	0.00	5.70	0.00	0.00
Maximum	7.65	9.95	3.35	40.10	9.90	1.05	29.15	10.55	1.05
1st Quartile	0.05	0.20	0.05	6.70	0.55	0.05	8.80	0.75	0.05
Median	0.95	0.45	0.25	15.00	1.30	0.20	12.95	1.13	0.15
3rd Quartile	4.40	1.35	0.55	26.60	2.10	0.48	19.38	2.10	0.30
Average	2.23	1.07	0.37	16.77	1.85	0.31	14.92	1.72	0.26
Variance (n-1)	6.48	2.75	0.30	118.77	4.35	0.09	46.33	3.10	0.10
Standard deviation	2.55	1.66	0.55	10.90	2.09	0.29	6.81	1.76	0.31

DAT = Date After Transplanting.

Table 2. *Variation of the average number of galls per clump according to the transplanting dates (40th, 60th and 80th DAT) in off-season.*

Statistics/Periods	40th day of transplanting date		60th day of transplanting date		80th day of transplanting date	
	2017	2018	2017	2018	2017	2018
Minimum	0.000	0.000	0.000	0.000	0.000	0.000
Maximum	1.050	1.000	1.350	0.550	0.900	0.150
1st Quartile	0.000	0.000	0.000	0.000	0.000	0.000
Median	0.000	0.000	0.000	0.000	0.000	0.000
3rd Quartile	0.000	0.000	0.000	0.000	0.000	0.000
Average	0.084	0.058	0.059	0.021	0.048	0.012
Variance (n-1)	0.071	0.043	0.064	0.011	0.031	0.002
Standard deviation	0.263	0.207	0.252	0.106	0.175	0.041

DAT = Date After Transplanting.

3.4. Frequency of Attacks According to the Phenological Stage

During the rainy season, attacks are more frequent at emergence and tillering respectively 48.12% and 33.83% (Figure 3a).

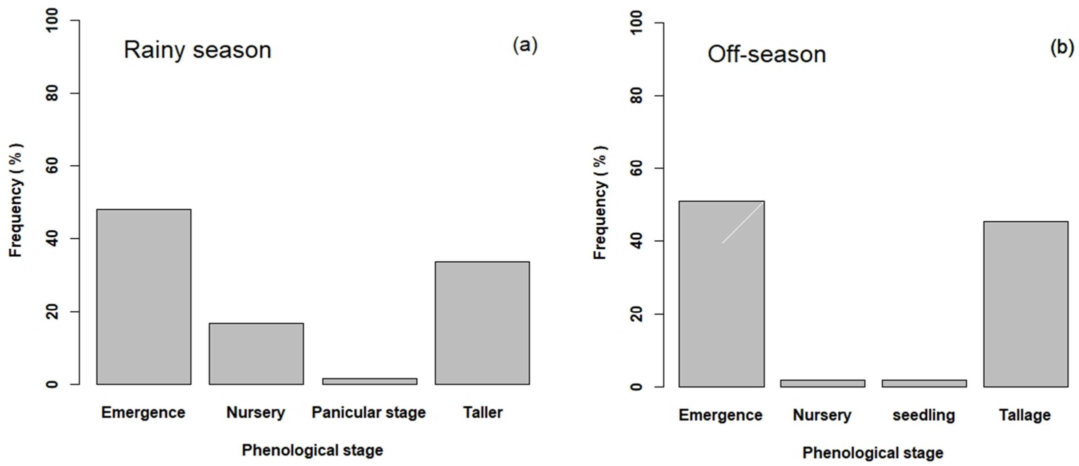

Figure 3. *Variation of the average number of galls according to the phenological stage in the rainy season (a) and the off-season (b).*

The same trend was observed in the off-season with 50.91 and 45.45% respectively at emergence and tillering (Figure 3b). In contrast, they were less frequent at the panicular stage (1.50%) and at sowing time (1.82%). Attacks were moderately frequent in nurseries during the rainy season (16.54%) and low in the off-season with (1.82%).

3.5. Population Dynamics of Orseolia oryzivora and Its Parasitoids

A high rate of *Orseolia oryzivora* population size was recorded from August to September from 2016 to 2017 with an absence of the insect population in 2018 at the same period (Figure 4).

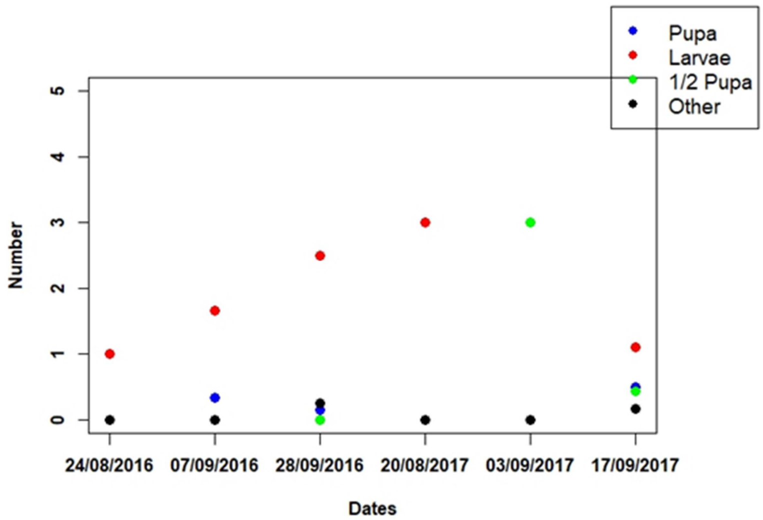

Figure 4. *Population dynamics of Orseolia oryzivora and its parasitoids at OPIB during the 2016, 2017 and 2018 rainy seasons.*

The figure shows a high larval rate of *Orseolia oryzivora* in the second decade of August with 3 larvae out of 10 galls or 30% larvae in 2017 and 25% larvae at the end of the last decade of September in 2016. The same 30% rate of parasitized pupa was obtained in the first decade of September during the 2017 crop year.

3.6. Variation of the Average Number of Galls Per Clump According to the Type of Cultivation Practice

The average number of galls per clump is presented according to the type of cultural practice (Table 3).

Table 3. *Variation of the average number of galls per clump according to the type of cultivation practice.*

Type of practice	Number/type	Average number of galls 40th DAT	Average number of galls 60th DAT	Average number of galls 80th DAT
Type 1	22	0.46 ± 0.74	0.38 ± 0.40	0.28 ± 0.34
Type 2	16	0.36 ± 0.28	0.30 ± 0.21	0.29 ± 0.33
Type 3	7	0.35 ± 0.30	0.39 ± 0.46	0.19 ± 0.22
Type 4	3	1.15 ± 1.91	0.38 ± 0.53	0.10 ± 0.10
Type 5	2	0.58 ± 0.11	0.35 ± 0.28	0.63 ± 0.53

DAT = Date After Transplanting.

The monoculture of the Gambiaca variety (type 4) had the highest average number of galls per clump for the three observation dates (40th, 60th and 80th day after transplanting). To prepare the soil, the rice farmers in this group practice burning before plowing. Type 1, in which farmers have adopted the adny variety and carry out several rotations in the off-season (more than three types of crops, mainly vegetables), has the lowest average number of galls per clump. On the farms in this group, ploughing and harrowing are favoured for soil preparation.

4. Discussion

Results show variation in rice midge population development related to cropping practices. Monoculture of rice would favor infestation levels of *O. oryzivora*. According to EUREKA [9] as a rotation, the best crop precedents for rice are cotton, maize and legumes. And various associated crops such as legumes can be useful for nitrogen fixation in rice soils. The establishment of crops other than rice in the off-season, coupled with the judicious use of plant protection products, would reduce the survival rate of the insect pest during the off-season. Nacro [13] recommends the use of products that would cause less damage to natural enemies.

The study shows that populations of African rice midge are highest during the rainy season. The same trends were observed in Asia by Hjdaka [10], who highlighted the importance of certain meteorological variables such as rainfall, temperature and relative humidity on the growth of rice midge populations. For Bonzi [5]; Nacro [13]; Dakouo et al. [6] and Ba [1], climatic factors can explain the decrease or absence of pest population damage in the dry season.

The evolution of the rice midge population during the four phenological stages shows a significant difference. The highest attack rates were observed at emergence and tillering during the three rainy seasons. These results are in line with those of Tankoano [13] for whom infestation is very often invisible before transplanting.

The variation in the average number of galls across decades during the rainy season shows that the transplanting period plays a large role in the infestation levels of the African rice midge populations. The highest numbers were observed for transplants done after the third decade of July. Similar results have been reported by Nacro [13] and Barro [4] in Burkina Faso.

5. Conclusion and Recommendation

The objective of this study was to document the influence of cropping systems in the control of rice midge. It allowed us to establish a typology of current cultivation practices at the OPIB of Baguinéda and their influence on *O. oryzivora* infestation levels. The results highlight the importance of current cultural practices in the OPIB in the management of the African rice midge. The relationship between transplanting date and average number of galls per clump shows that early transplanting can contribute to the reduction of infestations.

In the context of integrated pest management, it would be desirable to continue investigations in other rice fields, especially those based on floating rice, with the cropping systems identified in this study that are less favorable to *Orseolia oryzivora* infestation.

Acknowledgements

The authors thank the Waapp program for partially funding this study. Authors also thank the rice farmers of the OPIB for their cooperation and support in conducting the work. Finally, the authors thank the reviewers for their many comments.

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