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Research Article

ECOLOGY OF *PLATYGASTER DIPLOSISAE* (HYMENOPTERA: PLATYGASTERIDAE) AND *APROSTOCETUS PROCERAE* (HYMENOPTERA: EULOPHIDAE), PARASITOIDS OF *ORSEOLIA ORYZIVORA* (DIPTERA: CECIDOMYIIDAE)

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A B S T R A C T

Platygaster diplosisae and *Aprostocetus proceraea*re two parasitoids associated with the rice gall midge *Orseolia oryzivora* rice. The population of both parasitoids was monitored in three irrigated rice schemes including Banzon, Karfiguéla and Vallée du Kou, Western Burkina Faso during two consecutive wet cropping seasons 2017 and 2018 and two consecutive dry cropping seasons 2018 and 2019. The objective of this study was to investigate the ecology of the two parasitoids in the perspective of the development of a biological control strategy. In each irrigated rice scheme, four plots of 500 m² each, spread 50 m apart were randomly selected in farmers' fields and used for the study. In each plot, a light trap was implemented along one of the diagonals of the plot. Each light trap consisted of a yellow plastic round bowl containing soapy water almost at half the bowl and a torch. The bowl had a capacity of 4.5 l, a diameter of 28 cm and a height of 10.5 cm. The torch had 3 batteries of 1.5 V each, 30 cm long and 1 cm diameter. The torches were lit every night at 6 pm and off at 6 amplots and collection was weekly. One hundredrice tillers were randomly removed along the two diagonals of each sampled plot and brought back to the laboratory. The tillers were dissected and the pre-immature populations of *O. oryzivora* and its associated parasitoids were recorded. Four hundred tillers were randomly removed per month from each of the alternative hosts of *O.oryzivora* in order to evaluate the monthly gall count, pre-imaginal populations and parasitism associated with *O. oryzivora* and its cousin, *O. bonzii* that is hosted by *Paspalum scrobiculatum*. The results showed that the two parasitoids associated with *O. oryziovora* can reduce the attacks of the midge by 42% (pupal parasitism) and 30% (larval parasitism) on cultivated rice. By providing hosts for the two parasitoids, *Paspalum scrobiculatum* and *Oryza longistaminata* ensured their survival in the absence of cultivated rice.

INTRODUCTION

Two hymenopteran parasitoids are associated with the African rice gall midge (AfRGM), *Orseolia oryzivora*. These include *Platygaster diplosisae* Risbec (Hymenoptera: Platygastridae) a gregarious egg and larval parasitoid and *Aprotocetus procerae* (Hymenoptera: Eulophidae) a solitary parasitoid of the pupa. The two parasitoids may account for 70% of the midge mortality during the wet season (Dakouo *et al*., 1988, Nacro *et al*., 1995). Unfortunately, such a level of parasitism occurs too late to prevent damage from the pest; but that parasitism is almost absent during the dry season (Nacro *et al*., 1995).

The question is how do parasitoids survive between two rainy seasons? Studies conducted in Nigeria and Burkina Faso reported the presence in the rice environment of alternative plants of the genus Oryza that are hots for the AfRGM. So, these plants also harbor the parasitoids of the pest (Williams *et al*., 1999, Ba, 2003). Some studies reported the presence of a species of midge, *Orseolia bonzii* different from *O. oryzivora* and of which *Paspalum scrobiculatum*, a wild grass is the host. *Orseolia bonzii* does not attack cultivated rice but is host for *P. diplosisae* and *A. procerae* (Harris *et al*., 1999, Ba 2003, Ba *et al*., 2007). The midge of *P.scrobiculatum* could thus ensure the survival of the parasitoids associated with the AfRGM in inter-season and increase their action against the pest. Such information could lead to an integrated pest management strategy involving the management of rice ratoons and wild hosts.

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The present study aims at exploring the ecology of the two parasitoids associated with the AfRGM in the context of Burkina Faso.

MATERIAL AND METHODS

Material

Study site

Our study was conducted in Western Burkina Faso in the South Sudanese climatic zone. This zone is the most watered one of the country with an annual rainfall ranging from 900 mm to 1,200 mm. The vegetation is characterized by the presence of woodland savanna, clear forests and gallery forests along the perennial rivers and valleys with permanent humidity (Thiombiano and Kampmann, 2010).The study sites are irrigated schemes, with two cropping seasons per year, the first one (dry season) starting in January and ending in May and the second cropping season (wet season) running from July to November.

- The Banzon rice scheme is located in the Hauts-Bassins region, 65 km from Bobo-Dioulasso between parallels 4° 30' and 5 ° 30' West longitude and 10° 10' and 12° 05' latitude North. This scheme includes a total area of 454 ha that are farmed by 632 farmers (Fig. 1). The relative humidity varies between 58 and 66.46%. Temperatures range from 28.5 to 30.35° C while the average annual rainfall is 966.6 mm.
- Karfiguéla is located at 10°70' North latitude and 4°8' West longitude, 10 km North-West of Banfora in the Cascades region, 95 km South of Bobo-Dioulasso, the second largest city of Burkina Faso. About 400 farmers share this irrigated rice scheme of 332 ha. The area is under cul-tivation since 1977. Irrigation is done from the Cascades of the Comoé River. The wet season is characterized by a relatively high monthly rain-fall between May and September ranging from 957 mm to 1226.0 mm. The humidity levels are between 14% and 88%. Maximum temperatures range from 28.5 to 30.35 ° C while minimum temperatures range from 20.1°C to 24.8°C.
- The rice-growing area of the Kou Valley is located 25 km North-West of Bobo-Dioulasso in the Hauts-Bassins region between the parallels 10° 20' North and 4° 20' West longitude. With a total area of 1,260 ha, the Vallée du Kou with total water control is part of a vast plain of 9,700 ha of which 2,300 ha are under cultivation. This scheme is currently operated by 1,300 farmers (Fig. 1). The relative humidity varies between 56 and 75.3%. Temperatures range from 26 to 28.5 ° C. The annual average rainfall is 1,154 mm.

Field material

- Jute bags were used to carry samples (cultivated rice, wild rice, rice ratoons, *P.scrobiculatum*) from the field to the laboratory; knives were for sampling the plant material; empty bottles (250 ml) served to collect insect pests and their associated parasitoids; a sieve with fine mesh (0.1 mm) was used to separate captured insects with soapy water; a brush served for collecting insects in the sieve.
- Light trapping consisted of implementing one trap at the center of one of the diagonals of each selected plot. Each light trap consisted of a round plastic bowl of yellow color (capacity: 4.5 l, diameter: 28 cm and height: 10.5 cm) containing soapy water almost at half the bowl. The bowl was placed on a wooden support at 1 m from the ground, a torch of 3 1.5 V batteries was suspended on the bowl. The torches were lit every evening (at dusk). Each morning, the content of each cuvette was removed, sieved and stored in empty bottles (250 ml) containing alcohol diluted to 70 °.

Plant material

- *Paspalum scrobiculatum* Linnaeus: it is a perennial wild grass with broad stems bushy from 15 to 100 cm high. Its inflorescence is a terminal pani-cle carrying spikelets. It is found in rice-growing areas on separation bunds or fallow fields.
- Rice ratoons are encountered on rice fields after rice harvest of the wet cropping season and at the end of the dry season in April.
- *Oryza longistaminata* is present in rice ecosystems in various habitats (canals, irrigation, bunds and lowlands). It is a perennial plant that grows thanks to its rhizomes. The plant has a spongy stem up to two meters high. Its inflorescence is an erect panicle with barbed spikelets.
- *Oryza sativa*: it was used in all 3 rice schemes and the varieties used in-cluded FKR 58N, FKR 60N, FKR 62N and TS2.

Animal material

The biological material included the two parasitoids *P. diplosisae* and *A. procerae*.

Platygaster diplosisae (Risbec, 1956) is a parasitoid of the egg and the larva of *O. oryzivora*. It belongs to the family Platygasteridae. The black adult, is about 1.17 mm tall. Its wings are russet and quite long. Males and females are the same size; but males are distinguished from females by the presence of longer hairs on antennas (Hidaka *et al*., 1988).

-*Aprostocetus procerae* Risbec is a pupla parasitoid of *O. oryzivora*. It belongs to the super family of Chalcidoidea and the family of Eulophidae. The adult female measures 2.4 mm. It has a black-blue color with testaceous red spots, russet wings and quite long. Males are smaller in size and measure 0.8 to 1.4 mm.

METHODS

Sampling methods

Sampling was done monthly to monitor the ecology of the two parasitoids *P. diplosisae* and *A.procerae* affecting *O. oryzivora* in farmers' fields. Four elementary plots with an area of 500 m² each and 50 m apart from each other were chosen in farmers' fields. The four elementary plots represented four replications. All plots were subjected to the same cultural and irrigation practices. A light trap was implemented in each elementary plot. In each sampled field and at each observation, a quadrat of 1m² was implemented randomly and 100 rice tillers were removed in the same fields following the two diagonals each week, ie a total of 400 tillers per month. These tillers were packed in bags made of jute that were taken from field to the laboratory for dissection (cultivated rice, wild rice, *P. scrobiculatum*). Once in the laboratory, the tillers were dissected and all insects were removed and identified. The wild rice, *O. longistaminata* and *P. scrobiculatum* were sampled on the bunds and fallow fields. At each sampling, 100 tillers of these grasses were taken and brought back to the laboratory for dissection. The tillers were sorted to count the number of galls before dissection; the number of healthy or parasitized larvae, healthy or parasitized pupae were counted.

Calculation methods

The following formulas were used to calculate the level of larval or pupal parasitism in *O. longistaminata* and *P. scrobiculatum*.

$$\text{Larval parasitism level} = \frac{\text{Number of parasitized larvae}}{\text{Total number of larvae}} \times 100$$

$$\text{Pupal parasitism} = \frac{\text{Number of parasitised pupae}}{\text{Total number of pupae}} \times 100$$

Method of data processing and analysis

The data was entered into the Microsoft Excel 2010 spreadsheet and a statistical analysis was performed with the 2010.7.02 version of the XLSTAT software. Data that did not conform to the normal distribution were first transformed (to normalize) using one of the following mathematical formulas: Log 10 (x + 1) or Arcsin (x +1) for variables continuous, discontinuous or percentage, before performing the analysis of variance. The transformed data were subjected to a non-parametric test (the Kruskal Wallis test) with the SPSS software version 23. The averages were separated using the Fisher test at the 5% threshold, when significant differences were revealed.

RESULT

Adult catches of the two parasitoids with light traps varied with the four seasons and sites. Overall, catches were higher during the wet season than during the dry one (Table 1). The analysis of variance showed a highly significant difference between sites during the two wet seasons 2017 and 2018 on the average number of *P. diplosisae* captures (P <0.0001). figures were recorded: 52.08 and 57 individuals in 2018 and 2019 respectively. A significant difference was observed between sites during the 2017 and 2019 wet seasons (P = 0.001).

The average number of *A. procerae* individuals recorded during the two wet seasons was higherthan that of *P. diplosisae* (Table 1). The highest numbers of *A. procerae* individuals were recorded in Karfiguéla (106.94) during the 2017 wet season and in Vallée du Kou (331.04) during the 2018 wet season. In contrast, the lowest numbers of *A. procerae* individuals (34.94 and 39.92) were recorded in Banzon during the same period. The average number of *A. procerae* individuals was low during the dry season as compared to *P. diplosisae*. During the 2019 dry cropping season, 46.47 individuals were recorded in Vallée du Kou, 43.71 in Karfiguéla and 24.44 individuals in Banzon.

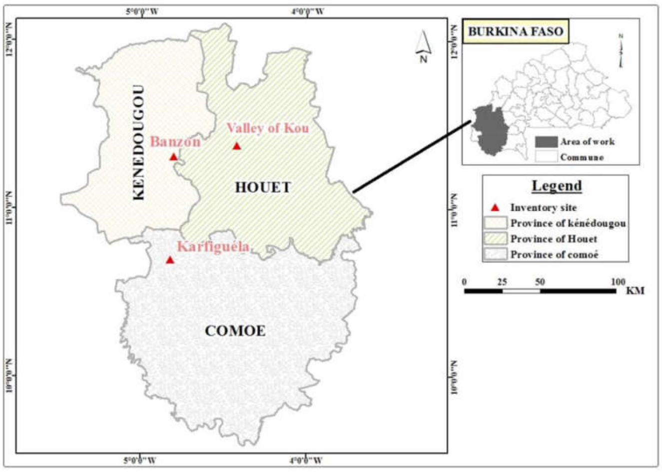

Figure 1 Study sites in western Burkina Faso

Evolution of parasitism affecting pre-imaginal populations of Orseolia oryzivora on cultivated rice, Oryza sativa Banzon

The parasitism associated with *O. oryzivora* started in July in Banzon. Parasitism due to *Platygaster diplosisae* was higher than that of *A. procerae*.

Evolution of the imaginal populations of the two midge parasitoids

Table 1 Results of the analysis of variance on the average number of adults of the two parasitoids caught from 2017 to 2019.

	Platygaster diplosisae				*Aprostocetus procerae*			
Sites	Wet season 2017	Dry season 2018	Wet season 2018	Dry season 2019	Wet season 2017	Dry season 2018	Wet season 2018	Dry season 2019
Banzon	30.71 ± 19.71b	18.77 ± 9.69	35.58 ± 19.52 b	23.67 ± 9.57	34.94 ± 24.58 b	19.48 ± 13.63	39.92 ± 24.45 c	24.44 ± 13.83
Karfiguéla	80.48 ± 11.79a	50.20 ± 44.05	85.38 ± 11.71 a	57.17 ± 44.1	106.94 ± 29.85 a	38.44 ± 28.97	112 ± 29.91b	43.71 ± 28.87
Vallée du Kou	94.42 ± 6.3 a	52.08 ± 49.37	100.92 ± 5.7 a	57 ± 49.24	98.19 ± 28.58 a	41.56 ± 38.13	331.04 ± 85.99 a	46.47 ± 37.84
Probability	< 0.0001	0.257	< 0.0001	0.254	0.001	0.379	0.001	0.372
Significance	HS	NS	HS	NS	S	NS	S	NS

* Within a column, the numbers followed by the same letter are not significantly different from each other at the 5% probability level.

The Banzon site had the lowest average number of captures during these two seasons (30.71 and 35.58 individuals respectively). However, the highest average number of *P. diplosisae*was collected at Vallée du Kou site during the two wet seasons (94.42 and 100.92 individuals respectively) but did not differ from the average number of Karfiguela (80.48 and 85.38 individuals respectively). During the dry seasons 2018 and 2019 no statistical difference was observed between the sites. The average numbers of *P. diplosisae* recorded in Karfiguéla rice scheme were 50.20 and 57.17 individuals in 2018 and 2019 respectively; in Vallée du Kou, the following

The highest level of larval parasitism (22%) was observed in October of the 2017 wet season and that of pupal parasitism (20%) was recorded in the same month (Figure 2). During the 2018 wet season, larval and pupal parasitism followed the same trend from August to October. During the 2019 dry season, cumulative parasitism (larval and pupal) was recorded in November (38%) (Fig 2). However, no parasitism was recorded during the 2018 and 2019 dry seasons 2018 and 2019 starting from January.

Karfiguela

Parasitism in Karfiguéla was observed in July during the 2017 wet season. Two peaks were observed in August (28%) and October (38%) during the 2018 wet season. In the 2018 dry season, larval and pupal parasitism levels were 26% and 24% respectively in November; 21 and 27% respectively in December and nil to the next 4 months. During the 2018 wet season, parasitism was observed in July. While larval parasitism was higher in August (30%) during the 2018 wet season, it was relayed by pupal parasitism in September and October of the 2018 wet season. Parasitism was observed early 2019 dry season and then decreased to nil during the following months. In addition, the cumulative parasitism was higher (69%) in October (Fig 3).

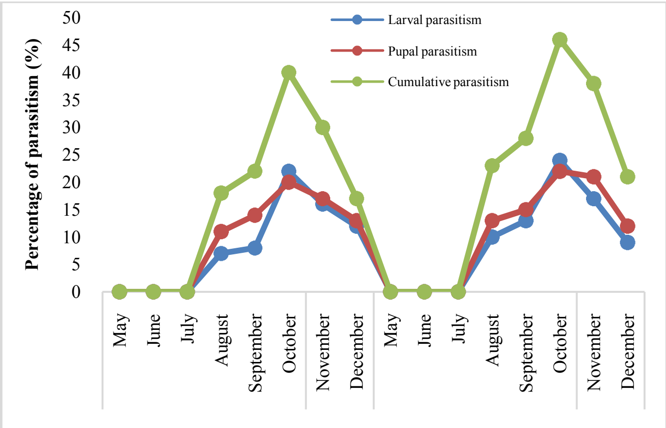

Figure 2 Evolution of average larval and pupal parasitism level associated with pre-immature populations of *Orseolia oryzivora* at Banzon during four consecutive rice cropping seasons.

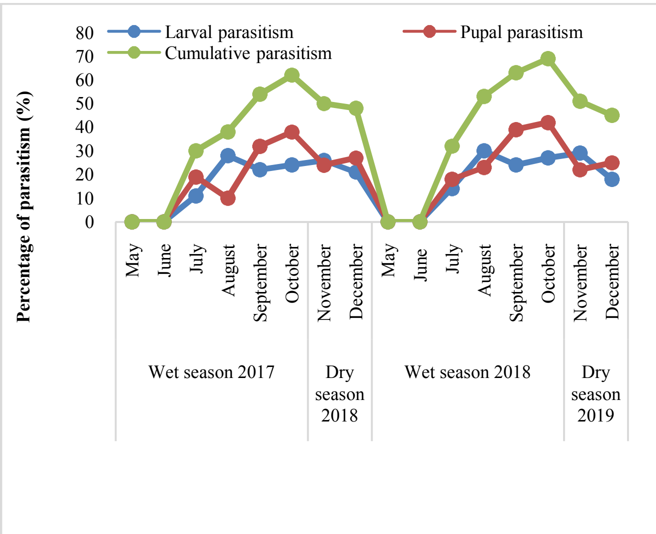

Figure 3 Evolution of average larval and pupal parasitism levels associated with pre-immature populations of *Orseolia oryzivora* at Karfiguéla during four consecutive rice cropping seasons.

Vallée du Kou

During 2017 the dry season in Vallée du Kou, parasitism was recorded in June. Pupal parasitism was higher from September of the 2018 wet season to the first months (October and November) of the 2018 dry season. The highest level of pupal parasitism was recorded in October (42%). Larval parasitism evolved into a sawtooth from August of the 2017 wet season to December of the 2018 dry season. Pupal parasitism was higher during the 2018 wet season 2018 and the 2019 dry season. The cumulative parasitism was amounted 68% in Vallée du Kou (Fig 4). No parasitism was observed from January to April of the two dry seasons.

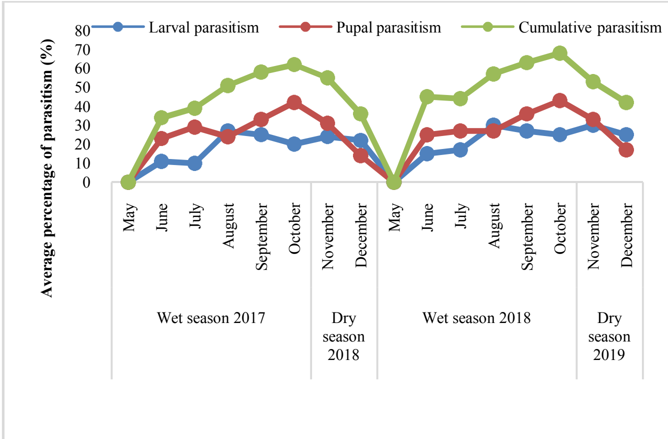

Figure 4 Evolution of average larval and pupal parasitism level associated with pre-immature populations of Orseolia *oryzivora* at Vallée du Kou during four consecutive rice cropping seasons.

Evolution of parasitism affecting pre-imaginal populations of Orseolia oryzivora on wild rice, Oryza longistaminata

Both parasitoids were observed on *O. longistaminata* (Table 2). Their presence was recorded in Karfiguéla during the three consecutive years 2017, 2018 and 2019. During the year 2017, larval parasitism was important in September (21.01%), while pupla parasitism was high in October (34%) and November (38%). The pupal parasitism was higher than the larval parasitism in 2018. For example, it was 45% in October 2018. In 2019, 8.55% of larval parasotism and 11.66% of pupal parasitism were recorded (Table 2).

Table 2 Evolution of the average parasitism associated with the pre-immature populations of *O. oryzivora* on *Oryza longistaminata* in Karfiguéla from 2017 to 2019.

	Year 2017		**Year 2018**		**Year 2019**	
Months	**PL**	**PP**	**PL**	**PP**	**PL**	**PP**
January	1.16	4.35	14.83	7.43	8.55	11.66
February	0.25	0.50	0.21	20.16	1.50	2.50
September	21.01	10.09	28	0.54	0.75	0.50
October	14	34	30	45	1.50	1.75
November	2.50	38	32	20	1.25	1.25

*PL= Parasitized Larvae; PP= Parasitized Pupae

Evolution of parasitism affecting pre-imaginal populations of Orseolia bonzii

Parasitism affecting pre-imaginal populations of *O. bonzii* was negligible in Vallée du Kou. No parasitism affecting the pre-imaginal populations of the *O. bonzii* was observed in Banzon. Pupul parasitism associated with *O. bonzii* was higher than larval parasitism. During the 2017 wet season, 22% of larval parasitism recorded was recorded in August while 12% pupal parasitism was observed (Fig 5). During the 2018 dry season, larval parasitism was 18% in November and 28% in December. On the other hand, pupal parasitism level was22% in November and 42% in December. During the 2018 wet season, larval parasitism was observed in August at 28% and in October at 38%. During the 2019 dry season pupal parasitism was was as 64% in November and 37% in December. Parasitism was mostly observed in Karfiguéla. In general, pupal parasitism was more higher, while larval parasitism was more frequent.

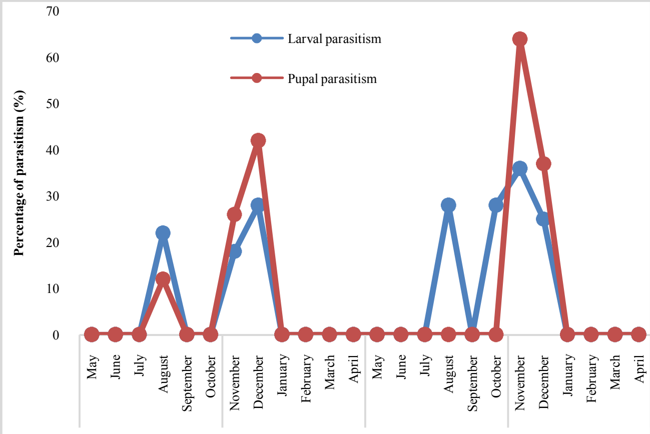

Figure 5 Evolution of parasitism associated with pre-imaginal populations of *Orseolia bonzii* from 2017 to 2019.

Evolution of parasitism affecting alternative host plants

Figure 6 shows the evolution of parasitism affecting *O. oryzivora*on cultivated rice (*Oryza sativa*), wild rice (*O. longistaminata*) and parasitism affecting *O. bonzii*. During the 2017 wet season, parasitism was recorded from July to October on *O. sativa*and *P. scrobuculatum*; from August to October on *O. longistaminata*. During the 2018 dry season in November and December, parasitism was observed in all three plant species (Fig 6). During the months of January and February, parasitism was recorded only on *O.longistaminata*. No parasitism was observed on both *O. sativa* plant species and *P. scrobuculatum* during the 2018 dry season (January to April). During the 2018 wet seasonfrom July to October, parasitism was observed on all three host plants. During the 2019 dry season, from November to January; parasitism was also observed on *O. sativa*, *P. scrobuculatum*, and *O. longistaminata*. In November, the parasitism peak was recorded on *P. scrobiculatum* (100%). Parasitism was not observed during the 2019 dry season, from February to April (Fig 6).

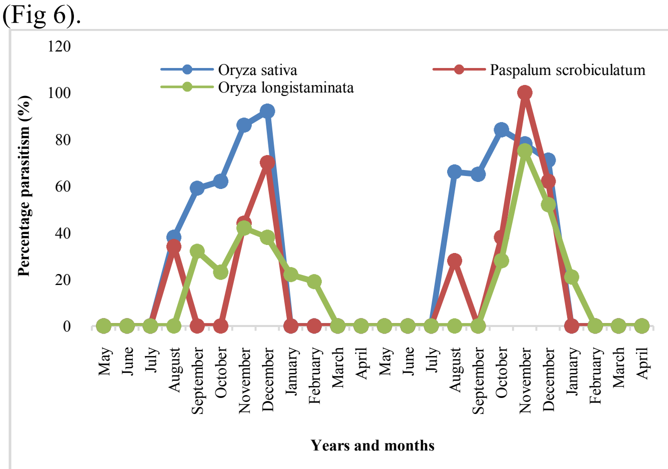

Figure 6 Evolution of parasitism associated with pre-imaginal populations of *Orseolia oryzivora* and *Orseolia bonzii* on *O.ryza sativa*, *P. latygaster scrobiculatum* and *O. longistaminata* from 2017 to 2019.

DISCUSSION

Evolution of the imaginal populations of the P. latygaster and A. prostocetus

The results on the variation in abundance of the adult populations of the two parasitoids *P.diplosisae* and *A. procerae* showed clarly that the hymenopterans were present during the wet season and scarce during the dry season. Indeed the peak of the adult catches of *A. procerae* (165 individuals) was observed in October 2017 in Karfiguéla. Adults of *P. diplosisae* (116 individuals during the 2017 dry season 2017), (121 individuals during the 2019 dry season) were observed in Vallée du Kou. This could be explained by the fact that part of the first part of the pre-imaginal populations (eggs and larvae) of the midge were able to escape the parasitism of *P. diplosisae*. Nacro (1994) reported that in reality this parasitism may have been exercised earlier since the evaluations took into account only the completed parasitism. The climatic conditions (rainfall and relative humidity) favorable to the development of their host (*O. oryzivora*) could explain the gradation of their numbers during the wet cropping season but especially by the availability of this same host. In addition, the availability of alternative host plants could also explain these results. However, during the dry season, the activity of both parasitoids was low due to the scarcity of their host and alternative host plants for *O. oryzivora*.

Evolution of parasitism affecting pre-imaginal populations of O. Orseolia Oryza sativa, Oryza longistaminata and rice ratoons

Parasitism affecting *O. oryzivora* was higher during the wet season than the dry season. Parasitism was observed on both *O. sativa* rice and the wild rice, *O. longistaminata* and rice ratoons during the 2017 and 2018 wet seasons. On *O. sativa*, it was also observed during the two dry seasons. Peak pupal parasitism (42%) was recordedin October 2017 in Karfiguéla and that of larval parasitism (30%) was observed in August 2017 in Vallée du Kou. Our results corroborate those of Ba (2003) who showed a predominance of pupal parasitism over larval parasitism. A similar situation was reported by Feijen and Schulten (1983) in Malawi in relation to the importance of pupal parasitism. This was also supported by Tankoano (2005) who reported that the parasitic activity of *A. procerae* was higher than that exerted by *P.diplosisae*in central Burkina Faso.Likewise, Sibomana (1999) also reported on a higher parasitismof *A. procerae* over *P. diplosisae* but in the proportions of four to fifteen times. However, our results do not coroborate previous observations made by Nacro *et al.* (1995) in Karfiguéla where they reported a higher level of larval parasitism as compared to pupal parasitism. In the same line, Umeh and Joshi (1993) observed the predominance of *P.diplosisae* over *A. procerae*. In addition, parasitism affecting *O. oryzivora*on *O. sativa*was more important than parasitism affecting, *O. longistaminata* and rice ratoons. The pupal parasitoid, *A. procerae* was the most observed on *O. longistaminata* in the case of our study. This observation tells us that *O. longistaminata* ensures the survival of the *O. oryzivora*and its parasitoids in the absence of cultivated rice.

Evolution of parasitism affecting the African rice midge on its host plants (Oryza sativa, rice regrowth and O. ryza longistaminata) and parasitism affecting the midge of Paspalum, Orseoliabonzii.

The parasitoids associated with *O. oryzivora*were recorded on cultivated rice, rice ratoons and *O. longistaminata*. The same parasitoids were also observed on *O. bonzii*. The cumulative parasitism can affect 50% of the pre-imaginal populations of *O. bonzii*. This result is lower than that reported by Ba (2003) who recorded over 70% of parasitism associated with *O.*

bonzii. This difference could be explained not only by the scarcity of*O. bonzii* host plant but also by the lack of water on these sites at the end of the wet season. Our results show that both parasitoids can cause more than 50% mortality of *O. oryzivora*during the wet season. But they are below those reported by Dakouo *et al*. (1988) and Nacro *et al*. (1995). According to these authors, *P. diplosisae* and *A. procerae* together cause more than 70% mortality of the midge in southwestern Burkina Faso during the wet season. Moreover, in our study, pupal parasitism was more important than that affecting the larvae of the insect pest. These results therefore make it possible to assert the role that *P. scrobiculatum* plays in the survival of the parasitoids of the *O. oryzivora*.

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