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Effect of Transplanting Period on the Population Dynamics and Parasitism of the African Rice Gall Midge *Orseolia Oryzivora* Harris & Gagné(Diptera: Cecidomyiidae) Under Irrigated Conditions in Boulbi, Central Burkina Faso

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Abstract: **We conducted an experimentation in 2004 and 2005 in Boulbi, central Burkina Faso. Our objective was to evaluate the variation in abundance of the African Rice Gall Midge (AfRGM) and its associated parasitoids in relation to transplanting periods. We used a randomized complete bloc design with three treatments and four replications. Treatments consisted of transplanting periods, two consecutive periods were separated by two weeks. Ten entomological evaluations were performed weekly, from 21 days after transplanting (DAT) to 84 DAT. When rice was planted late, the larval parasitism occurred earlier. The highest larval parasitism (43.10 to 66.57%) was recorded after the maximum tillering. Pupal parasitism got established late for both years. The AfRGM populations and parasitism were significantly affected by rice transplanting date as evidenced by the values of the correlation coefficients between the average number of larvae and their associated parasitoids (0.41 in T1 versus 0.88 in T3 in 2005). Rice transplanting period did not affect significantly pupal parasitism.**

Keywords: **Rice, *Orseolia Oryzivora*, *Platygaster Diplosisae*, *Aprostocetus Procerae*, Burkina Faso.**

1. Introduction

Several insect pest species are associated with rice in Burkina Faso. They are responsible for yield reduction ranging from 2 to 38% according to [1]. African rice gall midge (AfRGM), *Orseolia oryzivora* Harris & Gagné (Dip-tera: Cecidomyiidae) is one of the key insect pests of rice in Burkina Faso. The insect especially prevails in the west and the south-west regions of Burkina Faso where it finds suitable abiotic (rainfall) and biotic conditions (abundance and prevalence of alternative hosts year round). The young larva feeds on tillers at the growing point of the rice plant and induces the plant to form an oval, hollow gall. Each gall prevents the production of a panicle. The amount of yield loss caused by the gall midge larva varies among rice varieties. References [2] and [8], showed that an increase in 1% in the percentage of tillers with galls at the stem-elongation stage reduced yield by 2 to 3%. Following the work of [3] and [4], [2] reported on the pest status of the insect pest in Boulbi, central Burkina Faso. They showed that 1% to 1.3% of damaged tillers was associated with 1% yield loss.

Chemical control of the midge is difficult because of the feeding habit of the insect pest. Several authors have investigated on alternative control methods ([5]; [6]; [7]; [8]; [9]; [10]; [11]). These alternative methods include cultural control. Studing the effect of 4 different planting dates on the population dynamics of the AfRGM, [12], [5], [1] and [13]) clearly showed that rice from the third transplanting date was the most damaged by the midge. Reference [14] drew the same conclusions with regards to late planting. Two parasitoids are known to be commonly associated with the AfRGM. These are *P. diplosisae* (Hymenoptera: Platygastridae) and *A. procerae*(Hymenoptera: Eulophidae). These two parasitoids are the main natural biological control agents of the AfRGM. The cumulative parasitism due to these two hymenopterans can be very high, up to 77% ([5]; [7]; [9]). This paper reports on the effect of transplanting periods on the population dynamics of the midge and its two associated parasitoids.

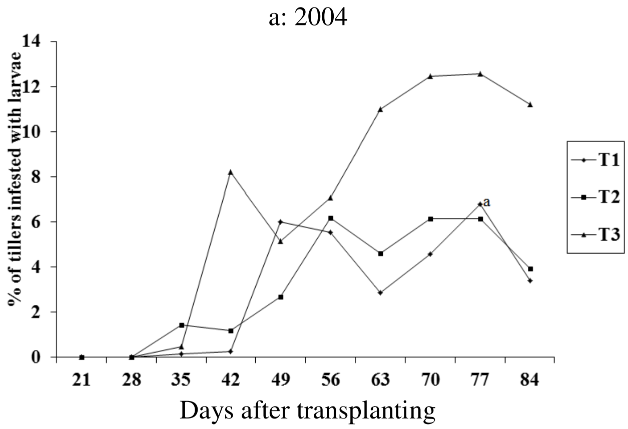
2. Materials and Methods

Fifteen-day-old seedlings of FKR 14, a commercial rice variety with a maturation period of 120 days, were transplanted in Boulbi, central Burkina Faso during the 2004 and 2005 cropping seasons. The planting spacing was 20 cm x 10 cm. Basic fertilizer, NPK (14-23-14) was applied at the dose of 200 kg/ha 10 days after transplanting (DAT) and followed by a top dressing of Urea (46% of N) at the dose of 150 kg/ha equally split into three applications of 50 kg/ha each at 30, 45, 60 DAT respectively. The paddy wasn't permanently flooded and, irrigation and hand-weeding of the plots were done when needed but each treatment was irrigated independently. No pesticides were applied. A randomized complete bloc design was used. Three treatments were arranged randomly within each of the four replications. Treatments were transplanting periods separated by 14 days. These treatments were designed as T1 (first transplanting period: August 9, 2004), T2 (second transplanting period: August 23, 2004), T3 (third planting period: September 06, 2004). The same transplanting periods were used in 2005. Dikes of 1 m and 0.5 m separated respectively two adjacent blocks and two adjacent treatments. Plot area was 50 m²

(10 m x 5 m). The total experimental area was 600 m² (50 m² x 3 x 4). Ten hills were randomly and weekly removed from each plot and dissected in the laboratory for observations, starting from 21DAT to 84 DAT. The following variables were monitored: AfRGM larvae parasitized by *P. diplosisae* and AfRGM healthy larvae, AfRGM pupae parasitized by *A. procerae* and AfRGM healthy pupae. When necessary, the data were transformed as recommended by [15]. The Stat View SAS 4.0 was used for the analysis of variance, while the software Excel 5.0 was used to produce the simple linear regressions. Means were separated using the Student-Newman-Keuls test at 5% significance level.

3. Results

3.1 Larval population of AfRGM



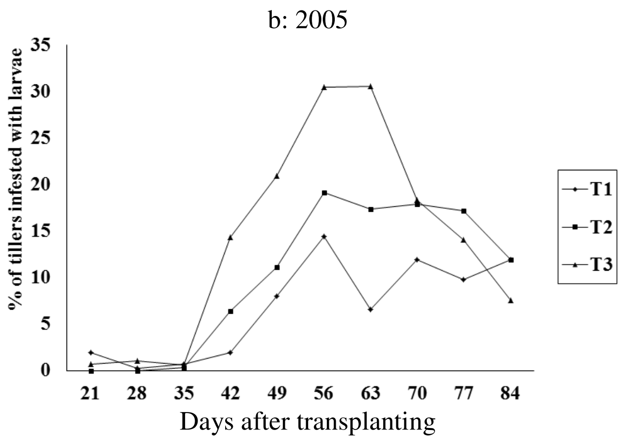


Fig.1. Evolution of the average rate of larval populations of *Orseolia oryzivora* H. & G. based on planting periods, Boulbi Burkina Faso a: 2004; b: 2005

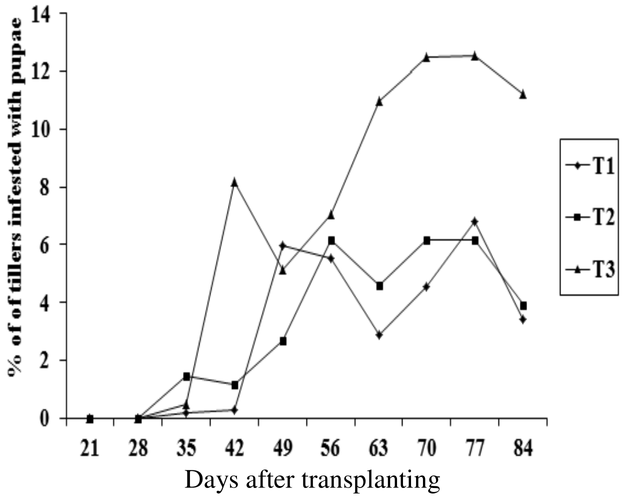
Regardless the treatment, the level of tillers infested with AfRGM larvae was low during the vegetative stage (from 21 to 42 DAT) and relatively high at the ripening stage (Fig. 1). However, the percentage of infested tillers was higher in T3 than the two other treatments. Thus, during the 2004 cropping season, the levels of tillers infested with AfRGM larvae varied from 0.17%, 1.45% and 0.47%, respectively for T1, T2 and T3 (at 35 DAT where first larvae were recorded) to 6.8%, 6.19% and 12.55% respectively for T1, T2 and T3 (at 77 DAT for T1 and T3 and at 56 DAT for T2). In general, the percentage of infested tillers with larvae increased from the vegetative stage to the reproductive stage (from 21to 63 DAT) but drops were observed in T1, T2 and T3 respectively at 49, 56 and 63 DAT. During the 2005 cropping season, the first larvae were recorded at 21 DAT (1.90 and 0.70% respectively for T1 and T3) and at 35 DAT (0.28% for T2). The levels of larval infestations during this season oscillated between 0.23% (at 28 DAT) and 14.43% (at 56 DAT) in T1, between 0.28% (at 35 DAT) and 19.19% (at 56 DAT). The larval infestations in T2 and T3 varied from 0.59% (at 35 DAT) to 30.61% (at 70 DAT). The analysis of variance (Table 1) showed that in 2004, T2 was significantly higher than T1 at 35 and 42 DAT. However, at 49 DAT, T2 was significantly lower than T1. For other observations (56, 63, 70, 77, and 84 DAT) no significant difference was observed between the two treatments. Compared with T1 and T2, T3 was significantly higher at 42, 63, 70 and 84 DAT. In 2005, the analysis of variance showed that the recorded levels of infested tillers in T2 were significantly higher than those recorded in T1 at 42, 63 and 77 DAT. These results also showed that T3 was significantly higher than T1 and T2 at 28, 42, 49, 56 and 63 DAT. But at 84 DAT, it was the opposite case; T1 and T2 were significantly higher than T3.

Table 1. Summary of results of correlation between pre-imaginal populations and parasitoids of *O. oryzivora*

Years	Treatments	Correlation coefficients (R^{2})
		between pre-imaginal populations and parasitoids of *O. oryzivora*
2004	T1	0.55
	T2	0.66
	T3	0.96
2005	T1	0.74
	T2	0.93
	T3	0.56
		between larvae and parasitized larvae of *O. oryzivora*
2004	T1	0.41
	T2	0.41
	T3	0.88
2005	T1	0.01
	T2	0.56
	T3	0.32
		between pupae and parasitized pupae of *O. oryzivora*
2004	T1	0.63
	T2	0.68
	T3	0.94
2005	T1	0.99
	T2	0.88
	T3	0.84

3.2. Pupal population of AfRGM

a: 2004



b: 2005

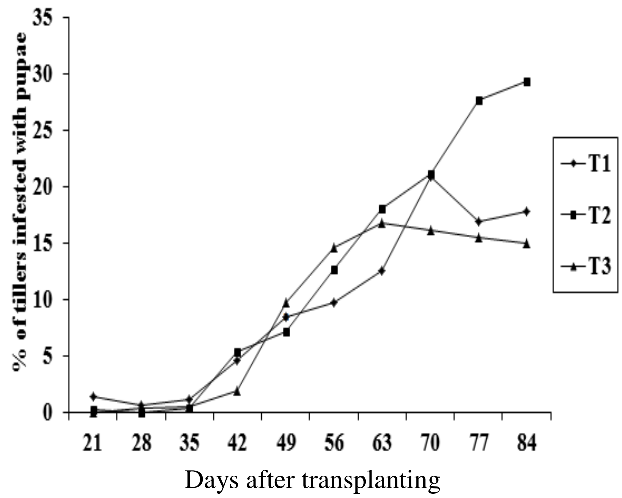


Fig.2. Evolution of the average rate of pupal populations of *Orseolia oryzivora* H. & G. based on planting periods, Boulbi Burkina Faso a: 2004; b: 2005.

The first pupae were recorded during the 2004 cropping season at 35 (0.83% in T2), 42 (2.87% in T3) and 49 DAT (5.5% in T1), which means one to two weeks after the first larvae were recorded (Fig. 2).

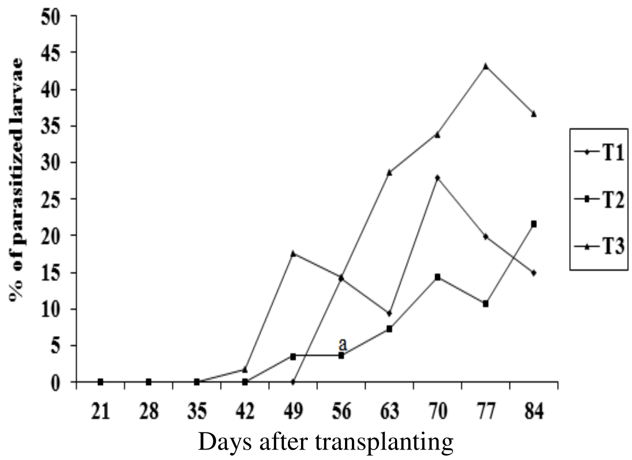
After appearing, T3 was the highest treatment until the end of the samplings (at 84 DAT where it reached its highest pick, 19.34%). T2 reached its highest pick a week before (14.84% at 77 DAT). During the 2005 cropping season, pupae were already found at 21 DAT like the larvae of that season (1.44 and 0.28% respectively in T1 and T2). First pupae from T3 appeared at 28 DAT (0.41%). After 42 DAT, these levels will increase with the superiority of T3 over the two other treatments. After 63 DAT, the level of tillers infested with pupae was lower than the two other treatments. The highest pick of T3 was 16.79% (at 63 DAT). Infestations picks were observed for T2 (29.34%) and T1 (20.86%) at respectively 84 DAT and 70 DAT. In general, the levels of pupal infestations were higher than those of larvae. According to the analysis of variance (Table 1), T2 was significantly higher than T1 at 35, 42, 63, 70 and 77 DAT (during the 2004 cropping season). T3 was significantly higher than T1 at 42, 56, 63, 70 and 77 DAT. T2 was significantly higher than T3 at 35 DAT while the opposite was observed at 56 DAT.

During the 2005 cropping season, T2 was significantly higher than on T1 at 63, 77 and 84 DAT. At 28 DAT, T1 was significantly higher than T2. Significant differences were observed between T3 and T1 at 21 (where T1 was higher than T3) and 56 DAT (where T3 was higher than T1). Finally, significant differences were detected between T3 and T2, at 42, 77 and 84 DAT with T2 higher than T3.

3.3. Larval parasitism of AfRGM

Observed late in 2004 (42 DAT in T3, 49 DAT in T2 and 56 DAT in T1), the first parasitized larvae in 2005 were recorded at 21 DAT in T1 (14.15%), 42 DAT in T3 (1.79%) and 49 DAT

a: 2004



b: 2004

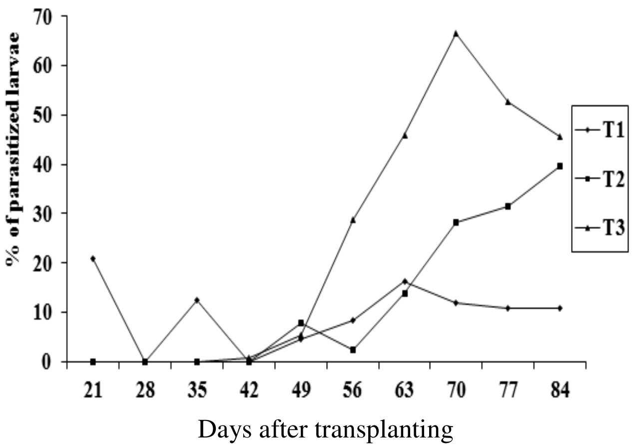


Fig.3. Evolution of the average rate of larval parasitism due to *Platygaster diplosisae* Risbec based on planting periods, Boulbi Burkina Faso a: 2004; b: 2005.

In T2 (3.57%) (Fig.3). In general, the levels of larval parasitism became important after 49 DAT with the highest levels recorded in T3. Thus, in 2004, the levels of

International Journal of Agriculture Innovations and Research
Volume 3, Issue 4, ISSN (Online) 2319-1473

parasitized larvae oscillated between 1.79% (at 21 DAT) and 43.10% (at 77 DAT) in T3. Those from T1 and T2 varied respectively from 9.38 (at 49 DAT) and 3.57% (at 56 DAT) to 27.92% (at 70 DAT) and 21.69% (at 84 DAT). These levels varied from 0.78% (at 42 DAT) to 66.57% (at 70 DAT) in T3 during the 2005 cropping season. During that season, levels of larval parasitism in T2 varied from 2.4% (at 56 DAT) to 39.54% (at 84 DAT). Duringthe 2005 cropping season, the highestparasitism levels in T1 were recorded at 21 DAT (20.83%), meaning at the same date of first AfRGM larvae recording. No significant difference was revealed between T1 and T2 during both cropping seasons except for the last series of observations (84 DAT) in 2005 where T2 was significantly higher than T1. However, compared with T1, T3 was significantly higher at 49 and 63 DAT in 2004 and 56 to 84 DAT in 2005. Compared with T2, T3 was significantly higher only at 77 DAT in 2004 and 56, 63 and 70 DAT in 2005.

3.4. Pupal parasitism of AfRGM

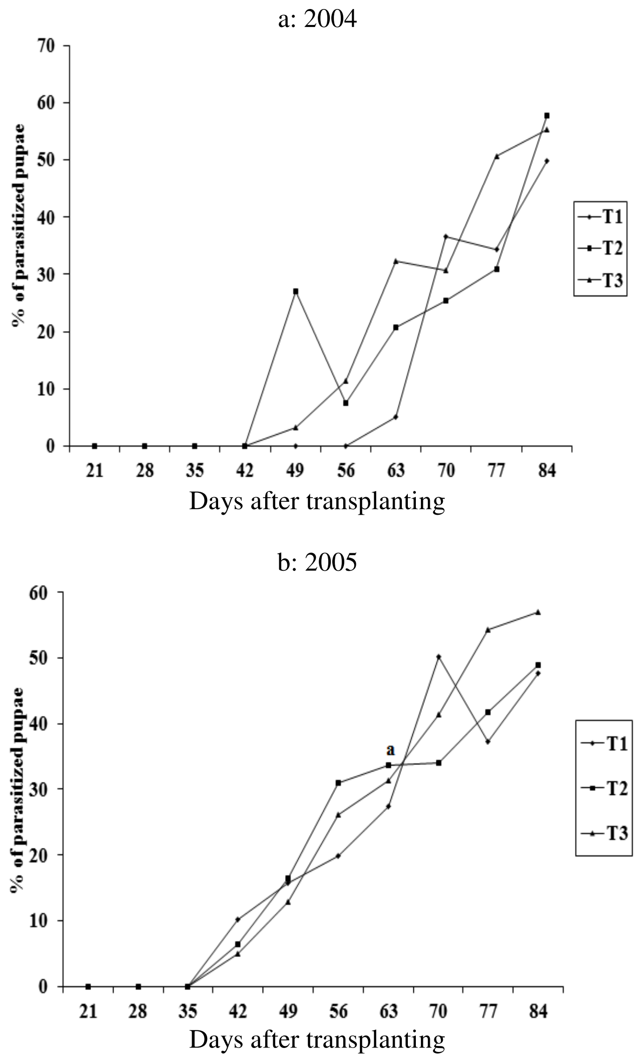


Fig.4. Evolution of the average rate of pupal parasitism due to *Aprostocetus procerae* Risbec based on planting periods, Boulbi Burkina Faso a: 2004; b: 2005.

Pupal parasitism was observed for the first time in 2004 at 49 DAT (in T2 and T3 respectively 27.8 and 3.24%) and 63 DAT (in T1, 5%) while it was noticed in 2005 for the first time at the same time (42 DAT) for all treatments (Fig.4). In general, the levels of parasitized pupae were quite similar in all three treatments irrespective of the year. These levels were 57.73, 55.35 and 49.70% (at 84 DAT) respectively in T2, T3 and T1 in 2004 and 57.08, 48.99 and 47.67% respectively in T3 (at 84 DAT), T2 (at 84 DAT) and T1 (at 70 DAT) in 2005. At 49 and 63 DAT in 2004, T2 was significantly higher than T1. T3 was significantly higher that T2 and T1 at 56 and 63 DAT but was significantly lower than T2 at 49 DAT. For the 2005 cropping season, no significant difference was observed between treatments except for 77 DAT where T3 was significantly higher than T1.

3.5. Combined parasitism of AfRGM

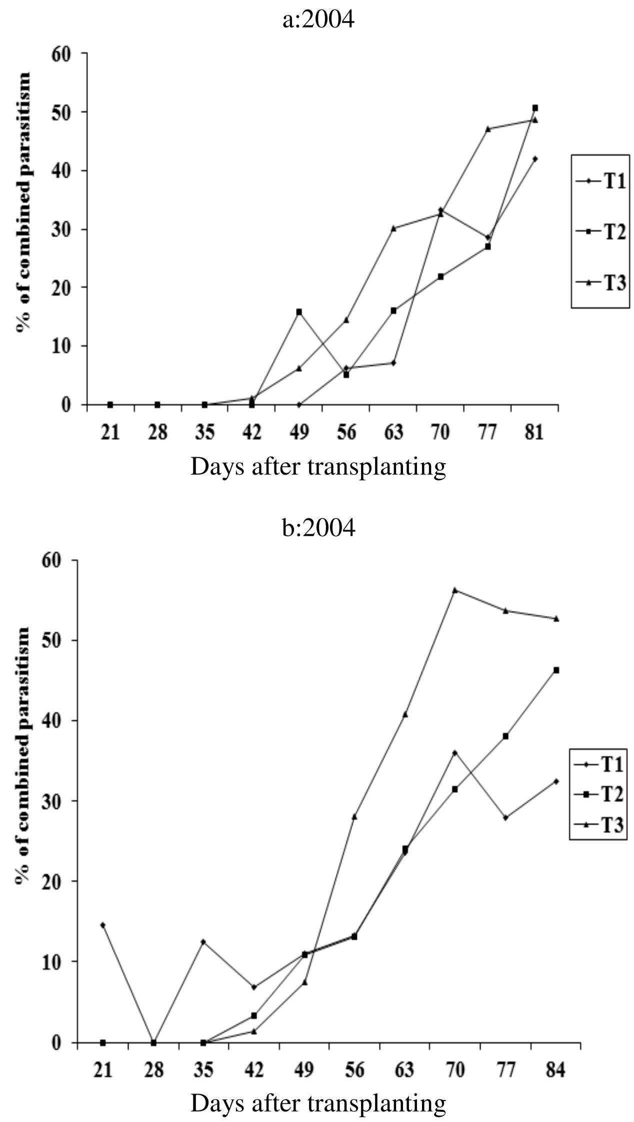


Fig.5. Evolution of the average rate of combined parasitism due to *Platygaster diplosisae* Risbec and *Apros-tocetusprocerae*Risbec based on planting periods, Boulbi Burkina Faso a: 2004; b: 2005.

International Journal of Agriculture Innovations and Research
Volume 3, Issue 4, ISSN (Online) 2319-1473

More than 50% of combined parasitism were recorded during the ripening phase of the rice plant for both cropping seasons (Fig.5). Levels of combined parasitism ranging from 1.14% (at 42 DAT) to 48.70% (at 84 DAT) were recorded in T3 in 2004. In T2 and T1, these levels varied respectively from 5.11 and 6.20% (at 56 DAT) to 50.60 and 41.90% (at 84 DAT). During the subsequent cropping season (2005), the levels of combined parasitism varied from 0 (at 28 DAT), 3.36 (at 42 DAT) and 1.33% (at 42 DAT) respectively in T1, T2 and T3 to 36.07, 46.30 and 56.27% (at 84 DAT, respectively in T1, T2 and T3). Simple linear regressions analysis (Table 2) showed that the average level of combined parasitism was highly and positively correlated to the average number of larvae and pupae. Correlation coefficients (R^2) were 0.55, 0.66 and 0.96 respectively in T1, T2 and T3 in 2004. In 2005, these correlation coefficients were respectively 0.74, 0.93 and 0.56%. Average percentages of pupal parasitism were highly correlated with the average number of pupae but this was not true for the average percentage of larval parasitism and the average number of larvae. In fact, correlation coefficients (R^2) between the average number of pupae and the average number of parasitized pupae by *A. procerae* were 0.63, 0.68 and 0.94 respectively in T1, T2 and T3 (in 2004) and 0.99, 0.88 and 0.84 (respectively in T1, T2 and T3 for the 2005 cropping season). The correlation coefficients between the average number of ARGM larvae and the average percentage of ARGM parasitized larvae were 0.41, 0.41 and 0.88 respectively in T1, T2 and T3 (for the 2004 cropping season) and 0.01, 0.56 and 0.32 (for the 2005 cropping season) respectively in T1, T2 and T3.

4. DISCUSSION

The progressive tillers' production during the vegetative phase of the rice plant, causing the progressive installation of a microclimate (moisture increase), and the availability of young tillers explain the gradual increase in larval population during that period. According to [16], working on *Orseolia oryzae* Wood Mason, the Asian Rice Gall Midge (ARGM), cousin to *O. oryzivora*, a high moisture in rice field after transplanting allows the oviposition and larval infestation into the tillers growing points. *O. oryzae* density, according to them, increased proportionately with the number of tillers and rice plant growing points until maximum tillering. Drop in larval population between 49 DAT and 63 DAT (especially during the 2004 cropping season) corresponds assuredly to panicle initiation period. Indeed, [17] and [18] reported that the larval population declined clearly after panicle initiation and that because no larva can live on panicle primordia. The availability of growing points due to the production of compensatory tillers, the higher the insect attacks the higher the compensatory tillers, explains the increase in larvae number after that period. The decline of larval population at the end of the rice cycle (last observations) is the result of combined effects of lack of growing points and likely the important development of *P. diplosisae* population (larval parasitoid). The early rainfalls could explain the early appearance of larval population during the 2005 cropping season and their superiority as compared with the 2004 cropping season. Reference [19] reported that the most important attacks of the insect occur when the first rains come early and are followed by a dry period which delays the planting. The superiority of pupal levels on larval levels could be explained by the number of larvae which were on the way to the growing points and which were not considered in computing the larval levels. Thereby, pupal infestation is equivalent to the actual larval infestation.

The drop in AfRGM populations (larvae + pupae) in T3 after the reproductive phase (during the 2005 cropping season) resulted in the lack of water in plots caused by the drop in water pressure (in the dam) and the defectiveness of irrigation channels. Regarding the statistical analysis, AfRGM populations' densities fluctuated mostly with transplanting periods. In other words, the period of rice transplanting affects significantly the levels of AfRGM populations' infestations, the later the planting date the greater the AfRGM populations. This is similar to the results reported by [2]. According to them, AfRGM damages were significantly higher in rice fields planted late than those planted early.

The peak observed in larval parasitism at 49 DAT corresponded to a pick in host infestations. Chronological recording of first parasitized larvae according to the transplanting periods showed that when the rice was planted late, the larval parasitism occurred early (2004 cropping season). However, climatic conditions, mainly early rains, favored the appearance of early larval parasitism in rice fields planted early. Unfortunately, that parasitism was low (2005 cropping season). In general, larval parasitism became high after the maximum tillering (around 49 DAT) and reaches its maximum at the end of the cropping season. Thus, larval parasitism ranging from 43.10 to 66.57% was recorded at this period. Reference [5] reported previously on larval parasitism reaching 77% in south-western Burkina. In Malawi, [20] reported similar results. Reference [13] quoted several authors who reported on similar results in Nigeria. AfRGM populations and parasitism were significantly affected by the rice transplanting date as evidenced by the values of the correlation coefficients between the average number of larvae and their associated parasitoids (0.41 in T1 versus 0.88 in T3 in 2005). In general, pupal parasitism got established later than that of larval one. However, pupal parasitism was more important than that of larval one at the end of the cropping season for both years. Some studies ([20]; [21]) also reported on the precocity and even the superiority of *P. diplosisae* over *A. procerae*. The relative importance of pupal parasitism could be explained by the large number of pupae at the end of the cropping season when larvae are scarce because the young plants on which they feed are no longer available. Reference [22] recorded lower pupal parasitism in Karfiguéla, western Burkina Faso under similar irrigated conditions. This author recorded from 0 to 30% of pupal parazitism. The analysis of variance performed showed that rice transplanting period did not affect significantly pupal parasitism. The significant differences observed in 2004 during the maximum tillering and the panicle initiation stage could be explained by the large number of the parasitoids in a single treatment.

In accordance with [23] and [9], the parasitism associated with *O. oryzivora* is that of dependent-density type, that's to say that the development of the parasitism follows that of the host populations. This density-dependence is more clearly evidenced with the pupal parasitism than with the larval one as reflected by the simple linear regressions. The important cumulative parasitism recorded at the end of the cropping season regardless the year got established too late to prevent the damage of the insect pest. Reference [17] drew the same conclusions by stating that if the parasitism associated with the AfRGM reached 50% early in the cropping season, the pest's damage could be reduced. However, the high cumulative parasitism recorded at the end of the cropping season reduced the host surviving populations during the dry season, when no crop was planted in the field which could explain the low AfRGM infestations in early planted fields.

5. Acknowledgment

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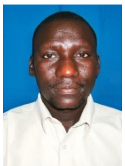
AUTHOR'S PROFILE



Mr. Tankoano was born in Koudougou, Burkina Faso in 1978. He earned a BSc. in biology and chemistry in 2002 at the University of Ouagadougou, Burkina Faso. He also earned a MSc. in agronomy in 2004 at the Polytechnic University of Bobo-Dioulasso, Burkina Faso. Lastly, Mr. Tankoano earned a MSc. in natural resources management in 2007 at the University of Ouagadougou. Mr. Tankoano received several post-graduate training including the 'Simple Measurement of Indicators for Learning and Evidence-based Report' training in 2014 in Ouagadougou, the Field Oriented Training on cotton production in 2013 at the University of Angrau, India, a training on proposals writing in 2013 in Koudougou, Burkina Faso and a training on the analysis of agricultural value chains.

He served as an assistant in charge of monitoring and evaluation at the National Integrated Production and Pest Management Program in Ouagadouogu, from 2008 to 2009. He was the head of the National Cotton Growers' Union office at FadaN'Gourma, East Burkina Faso from 2009 to 2011. From 2011 to 2013, he was in charge of family farming at the headquarters of the National Cotton Growers' Union in Bobo-Dioulasso. He was head of the monitoring and evaluation office of the same union from 2013 to June 2014. Since July 2014, he is the Technology Development Representative of Monsanto in Burkina Faso at the main office of Bobo-Dioulasso.

Mr. Tankoano is a co-author of a scientific paper published in 2006. He received the Prize of the Belgian cooperation to the development.

Souleymane Nacro, Sié Alassane Barro, Lucien Sawadogo, Aboubacar Gnamou and Honoré Tankoano, 2006: The effect of planting date on the African rice gall midge *Orseolia oryzivora* (Diptera: Cecidomyiidae) damage under irrigated conditions in Boulbi, central Burkina Faso. *International Journal of Tropical Insect Science* vol. 26, n° 4 pp. 227-232.

Dr. Nacro was born in 1959 in Abidjan, Côte d'Ivoire. He earned a diploma in Mathematics, Physics, Chemistry and Biology in 1981 at the University of Niamey, Niger. In 1984, he graduated from the University of Ouagadougou with a MSc. in agronomy. He earned a PhD. in biology at the University of Rennes 1, France. In 2012, he received a MSc. in integrated water resources management from the International Institute of Water and Environment engineering, in Ouagadougou Burkina Faso.

He was a research assistant from 1985 to 1994 in Bobo-Dioulasso, Burkina Faso at the Institute of Environment and Agricultural Research (INERA). He was recruited by the West Africa Rice Development Association (WARDA) as an Integrated Pest Management (IPM) consultant from 1995 to 1997. From 1998 to 2000, he was an IPM consultant for the Food and Agriculture Organization of the United Nations (FAO). He was the national coordinator of the IPM program for Burkina Faso from 2001 to 2009. Since 2010, he teaches Entomology and IPM in a Master course at the University of Ouagadougou. From 2009 to 2013 he was the Director of both Fasobio carburant SARL and Fondation Fasobiocarburant respectivelly a biofuel company and an organization that promotes sustainable biofuel production in Léo, South Burkina Faso. He resumed his senior entomologist position at INERA, Kamboinsé, Ouagadougou in August 2013.

Dr. Nacro authors about 50 publications including paper published in peer-review international journals, extension journals, books or book chapters. He supervided the research work of about 30 Master and two PhD. students. Here is a list of selected publications:

Souleymane Nacro and Jean-Pierre Nénon, 2006: Anatomy of the female Reproductive System and the Ultrastructure of the Egg's Envelopes of *Orseoliaoryzivora* (Diptera: Cecidomyiidae). *Journal of Entomology* 3 (1): 16-22.

Souleymane NACRO and Jean-Pierre NENON, 2008: Female reproductive biology of *Platygaster diplosisae* (Hymenoptera: Platygatridae) and *Aprostocetus procerae* (Hymenoptera: Eulophidae), two parasitoids associated with the African Rice Gall Midge, *Orseolia oryzivora* (Diptera: Cecidomyiidae). *Entomological Science* (2008) 11, 231-237.

SouleymaneNacro& Jean-Pierre Nénon, 2009: Comparative study of the morphology of the ovipositor of *Platygaster diplosisae*(Hymenoptera: Platygasteridae) and *Aprostocetus procerae* (Hymenoptera: Eulophidae) two parasitoids associated with the African Rice Gall Midge, *Orseoliaoryzivora* (Diptera: Cecidomyiidae). *Psyche: an entomological journal.* Volume 2009 ; 7 pages.

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Dr. Nacro is member of several professional associations including the Entomological Society of Burkina Faso, the African Association of Insect Scientists, the International Association of Plant Protection Sciences and the Entomological Society of America. He received several scientific awards during the be-annual forum of National Scientific and Technological Research in Burkina Faso.