UNDER PEER REVIEW

Original Research Article

Population dynamics of the mango mealybug *Rastrococcus invadens* Williams (Homoptera: Pseudococcidea) in Western Burkina Faso.

ABSTRACT

Aims: the study aimed at determining the periods of high pest population of the mango tree mealybug *Rastrococcus invadens* Williams with respect to biotic and abiotic factors.

Study design: semiweekly observations were performed on the mango trees with a view of assessing the density of alive, dead or parasitized *R. invadens*.

Place and duration of the study: This study was conducted Western Burkina Faso from May 2014 to April 2015.

Methodology: a set of mango trees was selected in each of the following locations: Toussiana, Bérégadougou and Orodara. The assessment was conducted on 20 leaves (five leaves per cardinal point) that were picked up from each mango tree at each observation date. The parasitized mealybugs were kept inside pill boxes for two weeks and the emerging parasitoids were collected and kept in alcohol 70°. Data were registered and processed with the Mi crosoft Excel 2010 and Genstat Discovery Edition 4 software.

Results: results showed that *R. invadens'* populations were more abundant during the wet season (May-September 2014) than the dry season (November 2014-April 2015) in all study locations. In general, parasitism was low some peaks of abundance were recorded in both wet and dry seasons. The evolution of the mortality of the insect pest was the same in all locations and peaks were observed from December 2014 to April 2015. The impact of abiotic factors and the parasitism due to *Anagyrus mangicola* Noyes and *Gyranusoidea tebygi* Noyes were also assessed and discussed.

Conclusion: *A. mangicola* and *G. tebygi* may be released to control *R. invadens*.

Keywords: Burkina Faso, mango, mealybug, population dynamics, parasitoids, biological control

UNDER PEER REVIEW

1. INTRODUCTION

The mango mealybug *Rastrococcus invadens* Williams (Homoptera: Pseudococcidea) was incidentally introduced in West Africa in the 1980s ([1]). It was observed for the first time in Lomé (Togo) and in Cotonou (Benin) before spreading along the western coast of Africa in Ghana, Côte-d'Ivoire and Eastern Nigeria. In the mid-1990s, it had almost invaded the whole Western and Central Africa, from Senegal to the Democratic Republic of Congo ([2]). This insect pest organism was identified in French Guyana (South America) in September 2014, and was thus reported for the first time on the American continent ([3]). As soon as it was incidentally introduced in Ghana, losses of 80% of crops were reported in the infested mango orchards ([4]). Losses inflicted by *R. invadens* were also reported on some other fruit crops such as citrus and guava trees ([5]). Control methods (mechanical and chemical) that were implemented by farmers since the first years of infestation failed to contain the pest. To that effect, two species of parasitoids (*Anagyrus mangicola* Noyes and *Gyranusoidea tebygi* Noyes) were imported from India and were released in several West African countries from 1987 to 1990 ([6]). Satisfactory results were reported on the of crop losses reduction and on the improvement of farmers' socio economic status ([7]), [8],[9], [10]). According to [2], once the populations of the insect pest drastically dropped under the action of parasitoids, the mealybug restricted itself to mango trees as its major host plant. Nonetheless and despite the settlement of the parasitoids in countries that were not covered by the releases, the insect pest is still a major threat because of its devastating effect. Thus, 53% yield losses were reported on research stations in Korhogo-Lataha (Côte-d'Ivoire) by [11]. These losses at times rise to 100% in farmers' orchads. These same authors reported some constraints in mango production in Burkina Faso because of the mealybug.

Initially observed in the Far West of Burkina Faso, the mango mealybug then spread in all the Western region of the country. This region is the major mango production zone of the country. The insect pest was reported in 2009 in 29 locations distributed in the provinces of Comoé, Houet, Léraba and Kénédougou ([12]). In the course of 2009, a short term monitoring (April to June) addressed the population dynamics of that insect pest within its distribution area (L.C. Otoidobiga, personal presentation). This testifies that the mango mealybug is still a major concern. More comprehensive knowledge is necessary to develop an

UNDER PEER REVIEW

efficient and sustainable control strategy of this insect pest. This study aimed at improving knowledge on the population dynamics of the insect pest within its distribution area. Its objective is to determine the abundance variation of the insect pest populations over time and space in relation with abiotic and biotic factors.

2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY

The study was conducted in Western Burkina Faso, in the distribution area of the insect pest ([12]). The provinces of Comoé, Houet, and Kénédougou (Fig. 1) that are the most representative ones in mango production in that region were selected to host this study. Thus, a prospection was conducted to set up a location for this study in each province. The selected locations were Bérégadougou (Comoé), Toussiana (Houet) and Orodara (Kénédougou). These three locations are circumscribed within a radius of 50 km and are part of the same agro-ecological zone. The climate of the region is tropical and Sudanian type with an alternation of two distinct seasons: a wet season that extends on five to six months (from May to October) with a yearly rain accumulation beyond 900 mm and a dry season ([13]). The monthly mean temperatures are occasionally above 35° C. The vege tation is a savanna woodland with open woodland forest and islets of dry tropical rainforests and gallery forests. Figure 1 indicates the geographical position of the three study locations.

Figure 1. Study locations of *Rastrococcus invadens* Western Burkina Faso

2.1. Selection of orchards for the study

The selected orchards for the study equate to a stand of six mango trees infested by *R. invadens* in each location. *R. invadens*' infestations were confined to agglomerations and to the surroundings of highways and streets' facilities ([12]). Mango trees that were selected in our study were in the agglomerations and were therefore not submitted to the rule of spacing that was applied in the orchards. On the Toussiana and Bérégadougou locations, the stand was composed of three varieties (that is 2 trees/variety) of mango trees. The varieties that were found in these locations included Amélie/Kent (Tousssiana/Bérégadougou), Lippens and green Mangot. On the Orodara site, the stand was solely composed of the green Mangot

UNDER PEER REVIEW

variety. All these mango trees were distributed within an area of two hectares. No chemicals were applied throughout the duration of this study.

2.2. Data collection and climate characteristics of the study locations

Climate data included temperature, relative humidity and rainfall recorded in the course of our study. In each location, rainfall data were recorded daily between 8 A.M. and 6 P.M. using a direct reading rain gauger (Brand S.P.I.E.A-Patented S.G.D.G N°1 269 2 77). Similar profiles of rain periods were recorded in all locations. The wet season was effective from May to October with a cumulated rainfall of 968.8 mm recorded in Bérégadougou; 1037.78 mm in Orodara and 1215.5 mm in Toussiana. As for other climate data, only the Bérégadougou location had a comprehensive weather forecasting station where temperature and relative humidity were recorded. Temperature was recorded using the thermographer PRECIS-MECANIQUE, 95870 BEZONS-FRANCE and relative humidity was recorded using the hygrographer JULES RICHARDS and PEKLY. These two tools recorded on daily basis the hourly changes of temperature and hygrometrics, under shelter, on charts that were specifically conceived for that purpose. Daily means were computed according to the following formula: $\frac{mini+maxi}{2}$; mini being the minimal temperature or minimal relative humidity and maxi being the maximal temperature or maximal relative humidity recorded on that day. From the computed values, monthly means were determined. Relative humidity was high (81-87%) from June to October and low (39 to 41%) from December to March. As for temperature, it was low from December to January (25 to 26℃) and high from February to April (29 to 32℃).

2.3. Monitoring *R. invadens*' populations

R. invadens' population's densities, living insects, dead ones and parasitized ones were assessed during the in situ study. These data were collected every 15±1days in all three locations. During theses observations, leafed small branches were collected outside the frondescence of each tree respective the four cardinal points (East, West, North, South). Then five leaves were randomly collected (three old leaves + two young leaves and vice versa) on each young branch according to the method used by Pitan (2008) and Hala et al. (2011). These leaves were carefully examined under hand magnifying glasses in order to register the values in line with the above mentionned parameters. After these observations, the

UNDER PEER REVIEW

parasitized insects were collected and put inside pillboxes. The sampled leaves were incubated inside A4 format enveloppes: approximatively 8½ by 11 inches (one enveloppe per tree) to allow the insects to complete their developmental cycle. Four weeks afterwards the emerged insects were collected and were identified using a binocular microscope.

2.4. Entry and statistical analysis of data

Data were entered on the Excel software and were organized per tree for each variable. The values that were entered were divided by 120 (20 leaves per tree for six trees) in order to get the overall means expressed in number of per leaf insects, wether they were alive, parasitized or dead. Parasitism and mortality were expressed in percentage according to the formula used by Boavida et al. (1995) and Pitan (2008). *R. invadens* populations' fluctuations and parasitism and mortality evolution were translated by curves using the coresponding total means. For the purpose of correlation analysis, the density of living *R. invadens* was transformed into log(x+1) whereas parasitism and mortality levels were transformed into Arcsin $(p)^{1/2}$; x being the mean number of *R. invadens* per leaf and p the level of parasitism or mortality per leaf. Data transformation and correlation analysis were performed using Genstat Discovery Edition 4 software. Correlations were established every two weeks between the insect pest's populations and temperature, relative humidity, rainfall and parasitism.

3. RESULTS AND DISCUSSION

3.1. Fluctuation of *R. invadens*' populations and of parasitism level in Toussiana

Fig. 2 illustrates the evolution of the population density of and parasitized *R. invadens* in the Toussiana location. The alive insect pest's populations increased from mid-May to mid-September 2014 with a mean of 31 to 132 individuals per leave of mango tree. After two first peaks that were observed at the end of May (60 living insect pest per leaf) and at the end of June 2014 (80 living insect pest per leaf), the insect pest's populations' density gradually reached a maximum of 132 individuals per leaf at the end of August 2014. The populations decreased as from mid-September until mid-November 2014 with a density varying from 102 to 12 individuals per leaf. A slight increase in populations density (18 to 49 individuals per leaf) was then observed between the end of November 2014 and the end of April 2015.

UNDER PEER REVIEW

The peaks of abundance of parasitized *R. invadens* were generally similar to those of living mealybugs. Thus, a first peak (6% of parasitized *R. invadens* per leaf) was observed in mid-June 2014. After that first peak, parasitism ratio moved from 3.61 to 1.39% between June and August 2014. A gradual increase in parasitism (3.38 to 8.04%) was recorded between mid September and mid-November 2014. Then parasitism ratios decreased (3.70 à 2.90%) until end of December 2014 before fluctuating between 2.81 to 4.40% between mid-January and the end of April 2015.

3.2. Fluctuation of *R. invadens* populations and parasitism level in Bérégadougou

Fig. 3 portrays the evolution of the population density of *R. invadens* and of parasitism level in Bérégadougou location. A first peak was observed amidst *R. invadens*' populations at the end of May 2014 with a mean of 50 living insects per leaf. Other populations peaks appeared in August and September 2014. During these periods, a mean of 57 to 102 living *R. invadens* were recorded per leaf. The density of the insect pest's populations dropped after mid-September (5 to 40 living individuals per leaf) between the end of September 2014 and the end of April 2015.

A mean parasitism of 2.5 to 8.6% was registered between May 2014 and April 2015. The first peak of abundance was observed at the end of June with 8.54% of parasitized scale insects per leaf. Three other peaks were observed in mid December 2014 (5.9%), mid-Januaryr (6.8%) and mid-April 2015 (6.2%).

3.3. Fluctuation of *R. invadens*' populations and of parasitism level in Orodara

A first peak of abunbance of the insect pest' populations was observed at the end of May 2014 with a mean of 51 individuals per leaf (Fig. 4). As from the ending of June 2014 (51 living insects per leaf), the insect pest's populations increased gradually and reached maxima numbers of 164 and 159 individuals per leaf at the end of August and at mid-September 2014. Afterwards, a continuous decrease of the populations (82 to 40 living individuals per leaf) was observed between September and November 2014. Three peaks of abundance (85, 48 and 21 living individuals per leaf respectively) were recorded at the end of December 2014, mid-February and mid-March 2015. The parasitism level varied from 1.7 to 6.9% from May 2014 to April 2015. Two first peaks were observed during the wet season, at the end of June (6.9%) and at the end of July (6.8%) 2014. These were followed by a decrease of 6.3 to 1.7% parasitism between mid-August 2014 and the end of September 2014. Four other peaks were observed at the end of November 2014 (4.15%), end of January (4.33%), mid-March (5.62%) and mid-April (5.02%) 2015.

UNDER PEER REVIEW

3.4. Fluctuation of *R. invadens*' populations' mortalities in the study locations

R. invadens' populations mortalities were found low in all three locations from mid-May to mid September 2014 (Fig.5). During that period, these mortalities varied from 0.7 to 5.6%. A peak of mortality was observed in each location in mid October for Toussiana (44%) and Bérégadougou (18%) and at the end of October for Orodara (18%). After that period, a decrease (31.92 to 1.82%) in the populations' mortalities of the insect pest was observed between September and November 2014. In Toussiana, the mortality ratio varied from 13.33 to 27.01%. These ratios were observed around four peaks of abundance that appeared between mid-December 2014 and end of April 2015. The same period of decrease was observed in Bérégadougou where the mortality ratio dropped from 15.43 to 6.65%. Mortality ratio then increased from 7.79 to 33.6% including three peaks between mid-December 2014 and the end of April 2015. In Orodara, a 15-day period of decrease (2.4%) was observed. After that period, the mortality ratio fluctuated around 5 to 30.52% with 2 peaks observed between the end of November and the end of April 2015.

3.5. Impact of abiotic factors and parasitism on *R. invadens*' populations in study locations

This is a matter of showing the relationship between the number of *R. invadens* (living and dead insects) with biotic (parasitism) and abiotic factors (temperature, relative humidity and rainfall) in the study locations (Table 1. and 2.). The density of living *R. invadens* was positively correlated ($0.58 \leq r \leq 0.73$) with rainfall in all study locations. But rainfall had no significant impact ($0.28 \leq r \leq 0.3$) on *R. invadens*' mortalities. As ($0.58 \leq r \leq 0.73$). As for temperature and relative humidity in Bérégadougou location, the correlation was respectively negative and positive with living *R. invadens*. These two factors did not significantly affect the insect pest mortality. No significant relationship was evidenced between the density of living and parasitized *R. invadens* in all locations. The correlation between these two factors was positive in Bérégadougou and Orodara and negative in Toussiana. The number of living *R. invadens* was positively correlated with the number of *A. mangicola* in all locations. That correlation was significant in Orodara. A contrario, the number of *G. tebygi* were not significantly correlated with the number of living *R. invadens*.

The populations of *R. invadens* evolved in a saw tooth pattern as from May 2014 moving towards peaks of abundance which highest were observed during the wet season in all study locations. The lowest population densities of the insect pest were observed during the dry season. These results are similar to

UNDER PEER REVIEW

[14]'s findings in Northern Côte d'Ivoire where climate conditions are close to those of our study zone. A contrario, in southern Benin where the climate is of the bimodal type, the highest densities of the insect pest were observed during the dry season ([8]). Our study revealed a a significant and positive correlation between rainfall and the population density of living *R. invadens* in all three locations. According to [14], rainfalls can negatively or positively impact the populations of the insect pest. The positive effect results in the origination of new leaves which present interesting physicochemical traits for the insects. But rainfalls can have a negative effect through a mechanical action which displaces the insect's young larvae on the leaves. In this study, the negative effect of rainfalls was significant because there was an increase in the populations of the insect pest during periods of heavy rains. Besides, rainfalls did not significantly correlate with the density of dead *R. invadens*. As for temperature and relative humidity which were recorded only in Bérégadougou, they were correlated respectively positively and negatively with *R. invadens* populations. A contrario with [14]'s findings, the impact of temperature was not significant on *R. invadens*' populations. The negative coefficient of correlation for this abiotic factor could mean a decrease in the population density of living *R. invadens* as from a specific temperature level and vice-versa. This phenomenon was evidenced by [15]'s work which observed in the laboratory a drop of fecundity of *R. invadens* when temperature rises above 30℃. Besides, they concluded that temperatures between 20 and 30℃ are supportive of the insect's development. In the field, [16] also observed a high fecundity of *R. invadens* in September; a period when temperatures varied between 26 and 30℃ and relative humidity from 82 to 90%. That trend was observed during the wet season in our study. Relative humidity was significantly correlated with the density of living *R. invadens*. This positive effect that was observed could therefore explain that an increase of relative humidity induces a high fecundity of the insect pest. With the cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero, [17] observed an increase in the number of leg eggs at different increasing relative humidity (respectively 60, 65 and 95%) with a constant temperature of 27℃. In a previous study, [18] reported that extreme values of relative humidity inflict high mortality to larval stages of *P. manihoti*.

The number of parasitized *R. invadens was* not significantly correlated with the number of living *R. invadens* in all the study locations. Also, the parasitism was low (≤11%) meaning the failure of parasitoids to control *R. invadens*. The insect pest being mostly confined into agglomerations, parasitoids are less

UNDER PEER REVIEW

efficient because of air pollution due to human activities. In our study, the number of living *R. invadens* was not significantly correlated with the number of *A. mangicola* and *G. tebygi* except in the Orodara location. In addition to the negative impact of pollution, hyper parasitoids like *Chartocerus hyalipennis* Hayat and *Marietta leopardina* Motschulsky were suspected of being limiting factors for *A. mangicola* and *G. tebygi* in some studies ([14]).

The first peaks *R. invadens*' mortality followed those of living individuals of the insect after a period of one to two months. Rainfall, temperature and relative humidity did not significantly impact on the mortalities cases. The major factor of mortality would probably be the density of living *R. invadens*. Actually, when the density of living *R. invadens*, that of dead insects follows the same trend, resulting in a decrease in the populations of the insect pest within four months (May-August). The mortality of the insect pest decreased one or two months later (September-November), but the populations increased again before reaching a steady state between December and April. Some biotic factors such as pathogens and predators also contribute to naturally regulate the populations of the insect pest. That is the case of insect pests such as *Dicrodiplosis sp*., *Exochomus troberti* Mulsant and *Nephus flavomaculatus* Fürsch which we observed in our study. Fungi like *Hirsutella sphaerospora* ([19]), *H. cryptosclerotium* ([20]) and *Neozygites fumosa* ([21]) are potential pathogens of *R. invadens*.

UNDER PEER REVIEW

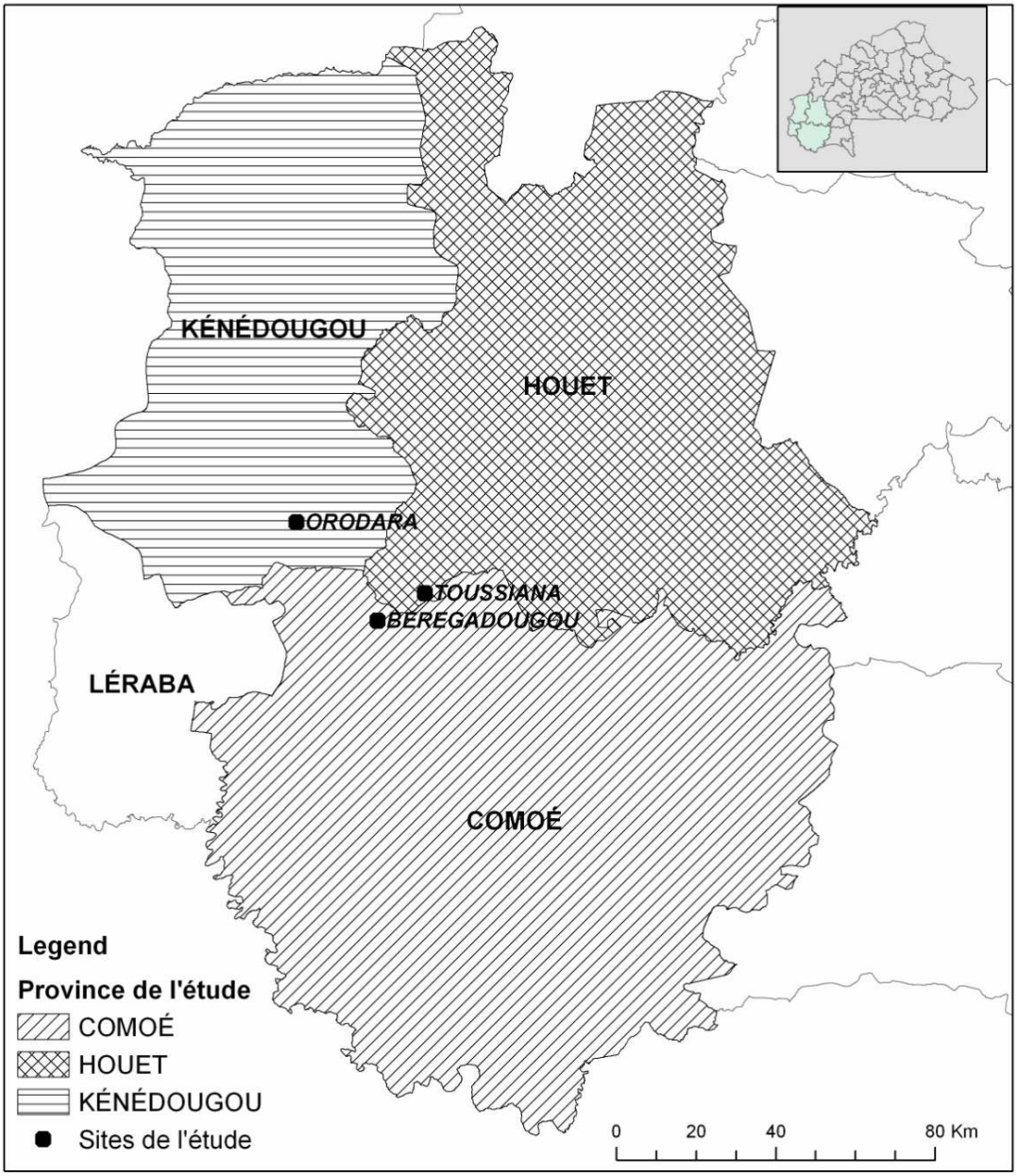


Figure 1. Geographical situation of the study locations of R. invandens in Western Burkina Faso.

UNDER PEER REVIEW

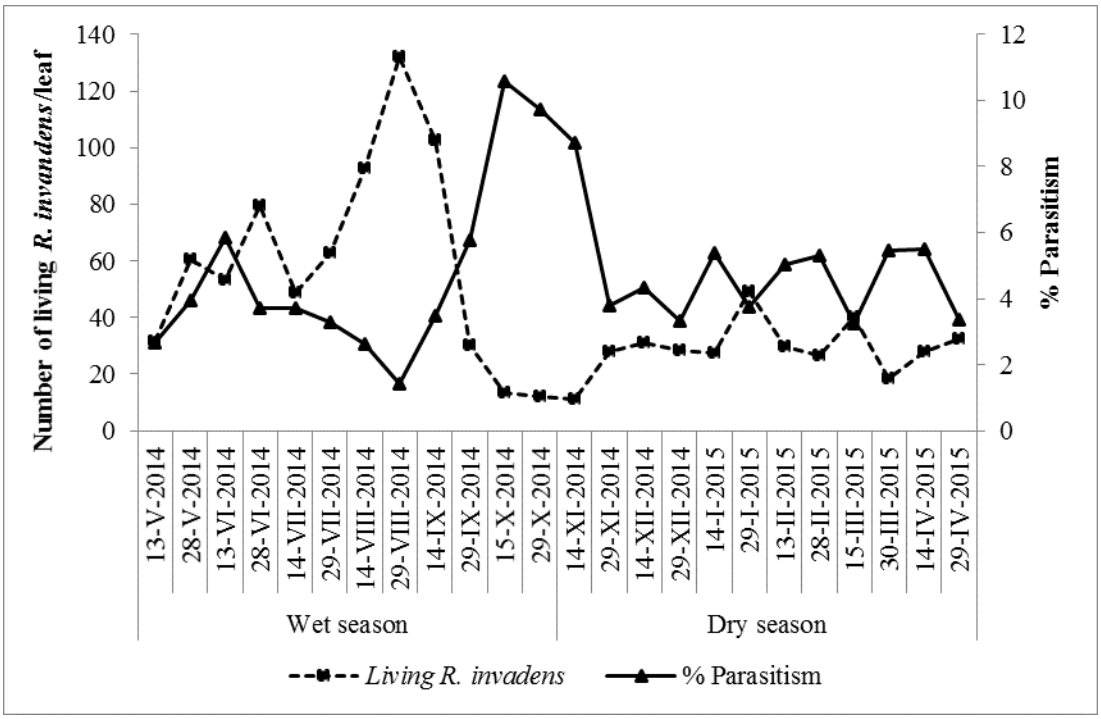
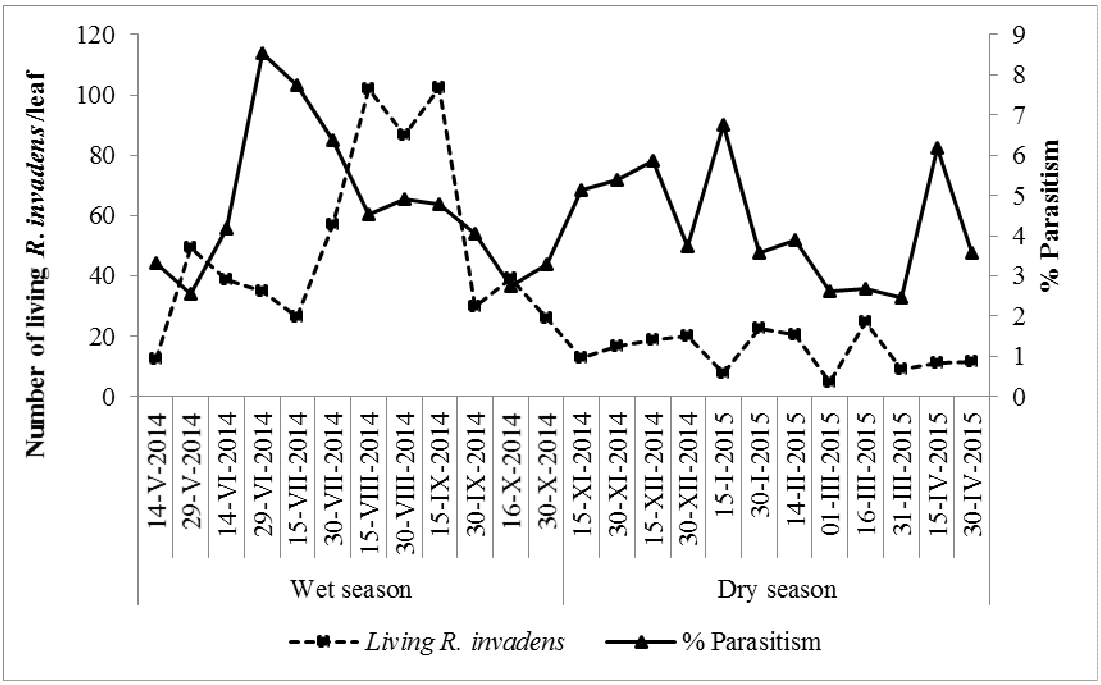


Figure 2. Fluctuation of living *R. invadens*' populations and parasitism level in Toussiana, Western Burkina Faso.



UNDER PEER REVIEW

Figure 3. Fluctuation of living *R. invadens*' populations and parasitism level in Bérégadougou, Western Burkina Faso.

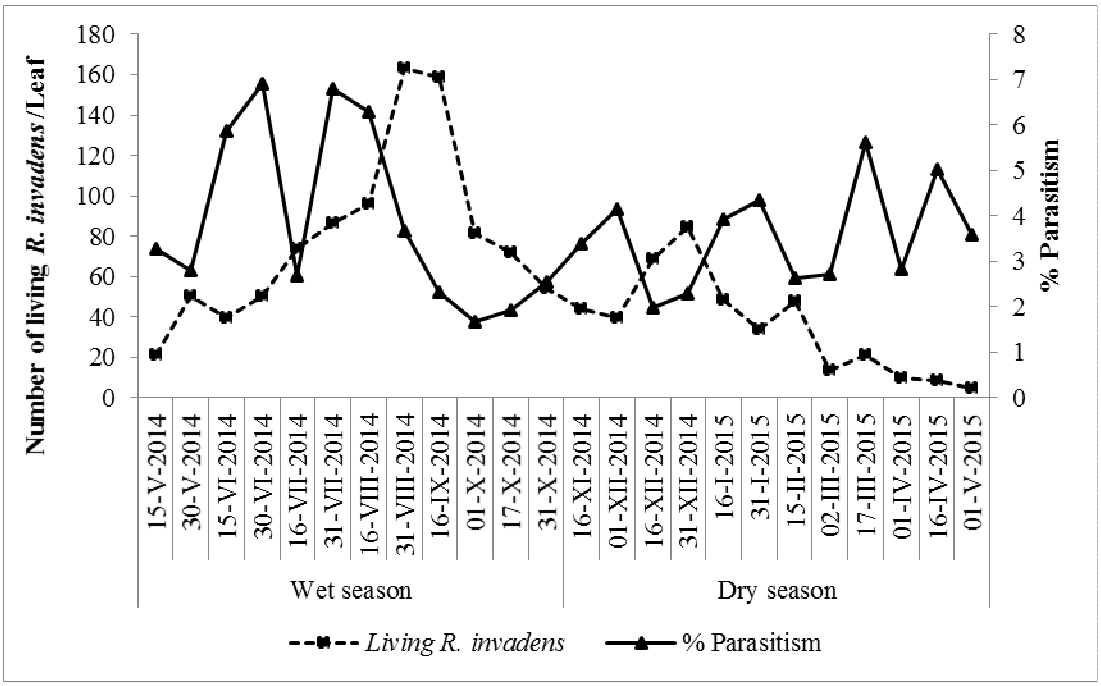


Figure 4. Fluctuation of living *R. invadens*' populations and parasitism level in Orodara, Western Burkina Faso.

UNDER PEER REVIEW

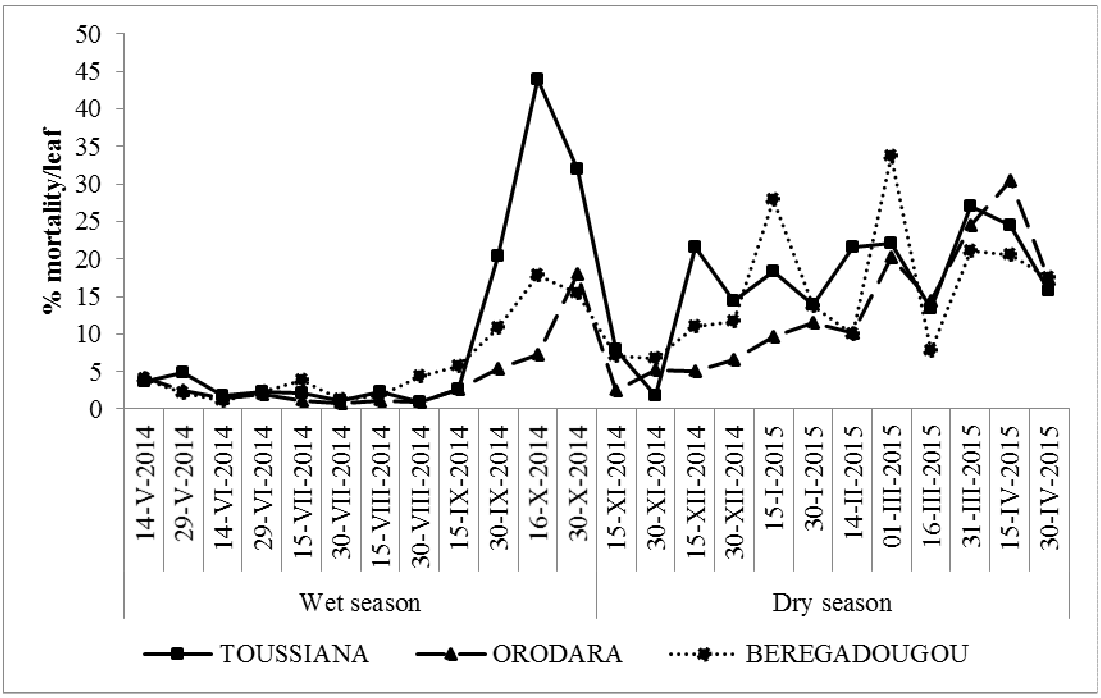


Figure 5. Fluctuation of *R. invadens*' mortalities in all three study locations, Western Burkina Faso.

Table 1. Data on linear regression of the density of *R. invadens* (living and dead) and abiotic factors in Bérégadougou, Orodara and Toussiana

	Locations	Rainfall	Relative humidity	Temperature
Living *R. invadens*	**Bérégadougou**	y = 0.005x + 1.196 r = 0.73**	y = 0.011x + 0.692 r = 0.68**	y = -0.075x + 3.518 r = -0.45(NS)
	Orodara	y = 0.004x + 1.431 r = 0.58*		
	Toussiana	y = 0.003x + 1.475 r = 0.67**		
Dead *R. invandes*	**Bérégadougou**	y = 0.021x - 1.527 r = 0.31(NS)	y = 0.058x - 4.447 r = 0.38(NS)	y = 0.051x - 2.125 r = 0.03(NS)
	Orodara	y = 0.008x + 0.023 r = 0.28(NS)		
	Toussiana	y = 0.074x - 5.661 r = 0.29(NS)		

r: Correlation coefficient; *, significant r; **, highly significant r; NS, non significant r; x: Mean semiweekly temperature, Mean semiweekly relative humidity or Total semiweekly rainfall; y: log [(Mean number of living scale insects / leaf)+1] or arsin (mortality ratio/leaf)$^{1/2}$.

UNDER PEER REVIEW

Table 2. Data on linear regression of the density of *R. invadens* (living and dead) and parasitism in Bérégadougou, Orodara and Toussiana

Biotic factors	Living *R. invadens*		
	Bérégadougou	**Orodara**	**Toussiana**
Parasitized *R. invadens*	y = -0.035x + 1.475 r = -0.25 (NS)	y = -0.172x + 1.859 r = -0.19 (NS)	y = 0.027x + 1.556 r = 0.25 (NS)
Anagyrus mangicola	y = 0.051x - 0.035 r = 0.49(NS)	y = 0.063x - 0.047 r = 0.50*	y = 0.045x - 0.008 r = 0.17 (NS)
Gyranusoidea tebygi	y = 0.060x - 0.039 r = 0.47 (NS)	y = 0.089x - 0.053 r = 0.43(NS)	y = -0.012x + 0.055 r = -0.22(NS)

r: Correlation coefficient; *, significant r; NS, non significant r; x: arsin (parasitism ratio/leaf)$^{1/2}$ or log [(Mean number of parasitoids/leaf)+1]; y: log [(Mean number of living scale insects / leaf)+1].

4. CONCLUSION

This study determined the variations in the abundance of *R. invadens*' populations in time and space in Western Burkina Faso. The populations of the insect pest were more during the wet season than the dry one and were significantly influenced by the effect of rainfalls on all study locations. Temperature and relative humidity had more or less influence on the insect pest's populations. Parasitism due to *Anagyrus mangicola* and *Gyranusoidea tebygi* remained low on all study locations. The knowledge of the ecology of *R. invadens* supports the formulation of a sustainable control strategy with a view of improving mango production in Burkina Faso. In that perspective, the two associated parasitoids, *Anagyrus mangicola* and *Gyranusoidea tebygi* could be mass reared and released for the biological control of *R. invadens*.

REFERENCES

[1] Agounké, D., U. Agricola, and H.A. Bokonon-Ganta. 1988. *Rastrococcus invadens* Williams (Hemiptera: Pseudococcidae), a serious exotic pest of fruit trees and other plants in West Africa. Bulletin of Entomological Research 78: 695-702.

[2] Neuenschwander, P. 2003. Biological control in IPM Systems in Africa. CABI, first edition, 448 p.

[3] ANSES, 2015. Analyse de risque phytosanitaire express *Rastrococcus invadens*, la cochenille asiatique identifiée récemment en Guyane française. ANSES, Cayenne, Guyane.

[4] Moore, D., 1992. Lutte biologique contre la cochenille farineuse du manguier, pp.95-125. In : Markham R. H., Wodageneh A. et Agboola S. (eds.), Manuel de lutte biologique, tome 2 :Etudes de cas de lutte biologique en Afrique., IITA/CLBA, Cotonou, Bénin.

UNDER PEER REVIEW

[5] Agounké, D., U. Agricola, et A. Bokonon-Ganta. 1989**.** *Rastrococcus invadens* Williams (Homoptera, Pseudococcidae), un ravageur exotique des arbres fruitiers en Afrique de l'Ouest. Bulletin du Service de la Protection des Végétaux 11: 17-29.

[6] Neuenschwander, P., C. Boavida, A. Bokonon-Ganta, A. Gado, and H. R. Herren. 1994. Establishment and spread of *Gyranusoidea tebygi* Noyes and *Anagyrus mangicola* Noyes (Hymenoptera: Encyrtidae), two biological control agents released against the mango mealybug *Rastrococcus invadens* Williams (Homoptera: Pseudococcidae) in Africa. *Biocontrol Science and Technology*, 4 : 61-69.

[7] Vogele, J.M., D. Agounké, and D. Moore. 1991. Biological control of the fruit tree mealybug *Rastrococcus invadens* Williams in Togo: A preliminary sociological and economic evaluation. *Tropical Pest Management* 37(4): 379-382.

[8] Boavida, C., and P. Neuenschwander. 1995. Population dynamics and life tables of the mango mealybug, *Rastrococcus invadens* Williams,and its introduced natural enemy, *Gyranusoidea tebygi* Noyes in Benin. Biocontrol Science and Technology 5: 489–508.

[9] Pitan, O.O.R., T.A. Akinlosotu, and J.A. Odebiyi. 2000. Impact of *Gyranusoidea tebygi* Noyes (Hymenoptera: Encyrtidae) on the mango mealybug *Rastrococcus invadens* Williams (Homoptera: Pseudococcidae) in Nigeria. *Biocontrol Science and Technology* 10(3): 245-254.

[10] Bokonon-Ganta, A. H., H. De Groote, and P. Neuenschwander. 2002. Socio economic impact of biological control of mango mealybug in Benin. *Agriculture, Ecosystems and Environment*, 93: 367-378.

[9] Pitan, O.O.R., T.A. Akinlosotu, and J.A. Odebiyi. 2000. Impact of *Gyranusoidea tebygi* Noyes (Hymenoptera: Encyrtidae) on the mango mealybug *Rastrococcus invadens* Williams (Homoptera: Pseudococcidae) in Nigeria. *Biocontrol Science and Technology* 10(3): 245-254.

[11] Hala, N., M. Kehe et K. Allou. 2004. Incidence de la cochenille farineuse du manguier *Rastrococcus invadens* Williams, 1986 (Homoptera ; Pseudococcidae) en Côte d'Ivoire. *Agronomie Africaine* 16 (3) : 29-36.

UNDER PEER REVIEW

[12] Dakouo, D., L.C. Otoidobiga, N.S. Ouedraogo, M. Guira, R. Dabire et G. Kambou 2011. Rapport de synthèse des activités conduites pour la lutte biologique contre les insectes ravageurs du manguier. Projet PADL/CLK, INERA, Programme CMFPT, 01 BP 910 Bobo-Dioulasso, Burkina Faso, 33p.

[13] Lerebours P., A., Menager, M-T. *et al.* 2005. Atlas de l'Afrique : Burkina Faso : Groupe Jeune Afrique : les editions du Jaguar, Paris, France. 62p.

[14]Hala, N., B. Dembele, A. A. N'Da, F. Coulibaly, M. Kehe, Y.A. N'Goran, and M.

[15] Kemabonta, K.A., and J.A. Odebiyi. 2002. Comparative studies on the effect of temperature on life tables of *Rastrococcus invadens* Williams (Homoptera :Pseudococcidae) and *Gyranusoidea tebygi* Noyes (Hymenoptera : Encyrtidae). *Ghana Jnl agric. Sci.* 35, 23-31.

[16]Sahoo A.K., and A.B. Ghosh. 2000. Biology of the mealybug *Rastrococcus invadens* Williams. Environment & Ecology 18(3): 752-756.

[17] Obame Minko, D. 2009. Influence des facteurs écologiques (température et hygrométrie) sur le développement de la cochenille farineuse du manioc (Phenacoccus manihoti Matile-Ferrero, Homoptera: Pseudococcidae). Tropicultura, 27 : 21-25.

[18] Le Rü, B., and B. Papierok. 1987. Taux intrinsèque d'accroissement naturel de la cochenille du manioc, *Phenacoccus manihoti* Matile-Ferrero (Homoptera, Pseudococcidae). Intérêt d'une méthode simplifiée d'estimation. Acta Oecologica, oecol. Appl. 8, 3-14

[19] Fernandez-Garcia, E., and D. Moore. 1988. *Hirsutella sphaerospora* as a potential biocontrol agent of *Rastrococcus invadens* Williams. -- *Brighton Crop Prot. Conf.* -Pests and Diseases, 1988, 1125-1130.

[20] Akalach, M., E. Fernandez-Garcia, and D. Moore. 1992. Interaction between *Rastrococcus invadens* (Hom.:Pseudococcidae) and two natural enemies. Entomophaga 37: 99-106.

[21] Keller, S. 1997. The genus *Neozygites* (Zygomycetes, Entomophthorales) with special reference to species found in tropical regions. Sydowia 49: 118-146.