

Effect of Temperature and Rainfall on the Proliferation of Cocoa Mirids in the Yamoussoukro District in Central Côte d'Ivoire

N'Dri Norbert Kouamé^{1*}, Walet Pierre N'Guessan¹, Kouamé François N'Guessan¹, Klotioma Coulibaly¹, Acka Jacques Alain Kotaix¹, Yao Tano²

¹National Center for Agronomic Research (CNRA), Research Station of Divo, Divo, Côte d'Ivoire

²Laboratory of Zoology and Animal Biology, Biosciences UFR, Félix Houphouët Boigny University, Abidjan, Côte d'Ivoire
Email: *ndri_norbert@yahoo.fr

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Abstract

Mirids are a major concern for cocoa producers in Côte d'Ivoire. These biting and sucking insects feed on pods, buds and orthotropic branches. They cause 30% of crop losses per year. This study was carried out to determine the different species of mirids and their outbreak periods in the Yamoussoukro district of Côte d'Ivoire. Mirid outbreaks were assessed by sampling twice a month using the tarpaulin technique. Cocoa trees containing mirids or mirid outbreaks that were identified and covered were treated with a high dose of registered insecticide with the active ingredient acetamiprid and bifenthrin. Mirids killed by the spray were counted on the tarps 5 hours after treatment. Rainfall and temperature data were also collected in the study areas. The results revealed the presence of 3 species of mirids in Yamoussoukro district: *Sahlbergella singularis*, *Distantiella theobromae* and *Helopeltis* sp. *Sahlbergella singularis*, with a rate of 99.82% of the mirids counted was the main species in the area. The curve revealed a period of high mirid outbreaks in the district. This period extends from May to March with a population peak in August or September depending on the year. The outbreak of mirids in the district starts during rainy periods and gradually stops with dry periods. Also, the periods of high mirid outbreaks in the district seem to coincide with low temperatures of the year. However, the Spearman correlation test at the 5% threshold showed that there is no significant correlation between mirid outbreaks and the climatic parameters of temperature and rainfall.

Keywords

Pullulation, Mirids, Cocoa, Yamoussoukro District

1. Introduction

Cocoa is strategic for Ivory Coast, which is the world's leading producer. Ivorian production is estimated at around 2.2 million tonnes for the 2020/2021 campaign and represents more than 40% of the world market [1]. Cocoa constitutes 15% of Ivorian PIB and more than 50% of export revenues and supports approximately five (5) million people in Côte d'Ivoire [2]. Despite this prowess, cocoa cultivation faces numerous biotic problems (pests and diseases) [3]. Diseases such as brown rot, the pathogen of which is *Phytophthora* sp and Swollen shoot, cause significant damage in cocoa orchards [4] [5]. Stem borers, bedbugs and mealybugs contribute to the destruction of production [6] [7]. Added to this are pests such as mirids which constitute the major insects of the cocoa tree. These insects attack young and adult cocoa trees. They cause significant damage to young cocoa trees, buds, young shoots, cherelles (young pods) and mature pods (Figure 1).



Figure 1. Mirid damage on cocoa tree: (a) On branch; (b) On mature pod.

They cause a loss of around 30% of annual production. Currently, climate change occurring in different regions is causing food disruption for these insects. Several methods have been developed to combat mirids. These are agronomic, biological, genetic and chemical struggles. Chemical control is the main method of combating these pests. Today, to ensure good productivity of cocoa farming in Yamoussoukro in particular and of Ivorian cocoa farming in general, we must fight effectively against these pests. The following problem therefore emerges: What are the effects of temperature and rainfall on the proliferation of mirids in the cocoa production district of Yamoussoukro in central Côte d'Ivoire? To answer this question, it would be important to determine the proliferation of mirids in the Yamoussoukro district based on climatic values. Specifically, this will involve:

- Identify the importance of different species of mirids in the district.
- Establish the geographical distribution of species.
- Establish the dynamics of mirids as a function of rainfall and temperature.

2. Materials and Methods

1) Study Site

The district of Yamoussoukro is located in the center of Côte d'Ivoire. It is located between 06°49 and 06°47 North latitude and 05°16 and 05°15 West longitude. It is bordered to the north by the department of Tiébissou, to the south by the departments of Toumodi and Oumé, to the east by the department of Dimbokro and to the west by the departments of Bouaflé and Sinfra. The Yamoussoukro district covers an area of 3500 km². The climate is equatorial with four seasons. A long dry season from mid-November to mid-March, characterized by the presence, in December and January, of the harmattan. The harmattan is a dry and powerful wind coming from the Sahara, which lowers the humidity considerably. A long rainy season, from mid-March to mid-July. A short dry season from mid-July to mid-September and a short rainy season from mid-September to mid-October. Average rainfall amounts vary from 900 to 1100 mm per year with a very variable spatial distribution during the year and from one year to another. The average temperature of the region is about 26°C. Relative humidity varies between 75 and 85% with drops to 40% during the harmattan period and is between 80 and 85% during rainy periods. The Yamoussoukro district benefits from a hydrographic network essentially composed of the Bandama whose two main tributaries are the Marahoué (or red Bandama) and the N'Zi.

2) Study Material

The study material is composed of plant material and animal material. The plant material is composed of cocoa trees belonging to the species *Theobroma cacao* L. The animal material was represented by the larvae and adult of mirids.

3) Experimental Device

Determination of the different mirid species in the district

A survey was conducted in Yamoussoukro district from July 2018 to December 2018. Ten localities were selected in the district. In each locality 3 high dose treatments were carried out. For the treatments, a 1 ha plot was delineated per site. In each plot, 12 cocoa plants were selected. Each cocoa tree received 1 liter of insecticide spray containing acetamiprid and bifenthrin. A total of 30 cocoa farms were visited. In the district, 360 cocoa trees were treated. The treatment of the selected cocoa plants was done between 6:00 and 8:00 am.

Determination of mirid outbreaks in the Yamoussoukro district

Sampling was carried out in six (6) cocoa farms in the Yamoussoukro district on three (3) different axes from January 2019 to December 2023. These are the Yamoussoukro-Sinfra, Yamoussoukro-Toumodi and Yamoussoukro-Bouaflé axes. On each axis, two cocoa trees were chosen. Double dose treatments are carried out in each plot on 12 cocoa trees every two weeks. Or 2 treatments per axis per month. The cocoa plant treatments were done between 6 a.m. and 8 a.m.

4) Mirid Enumeration

Before each treatment, a white percale fabric tarpaulin measuring 16 m² (4 × 4 m) is placed directly above each chosen cocoa tree. All insects killed during treat-

ments are collected on the tarpaulins. The mirid count was done 5 h after treatment. First, before collecting on the tarpaulin, the cocoa tree is shaken in order to remove all the mirids killed and still clinging to the foliage. The mirids were collected and put into the Petri dishes. The mirid count was done on the tarpaulin. The collected mirids were preserved in alcohol at 70°C.

5) Data Analysis

The rate of the different mirid species in the Yamoussoukro district was determined by the formula:

$$\text{Percentage (\%)} \text{ of mirid species collected} \\ = \frac{\text{Total number of species collected} \times 100}{\text{Total number of mirids collected}}$$

Correlation between variables

The Excel software was used to calculate the means for the determination of the outbreak.

The Spearman correlation test at the 5% threshold was performed with the XLSTAT software. This test allowed to study the degree of link between the variables (mirid outbreak, temperature and rainfall).

3. Results

Different species of mirids causing damage in cocoa orchards in Yamoussoukro district

Three (3) species of mirids causing damage in cocoa orchards were encountered in the Yamoussoukro district. These are *Sahlbergella singularis*, *Distantiella theobromae* and *Helopeltis sp* (Figures 2-4). A total of 7368 mirids were collected during the surveys in Yamoussoukro district. Two (2) *Helopeltis sp*. representing 0.03% of the district's mirids were collected during the survey. *Distantiella theobromae* represented 0.15% of the mirids encountered. *Sahlbergella singularis* with 99.82% of the mirids in the district was the most abundant species (Table 1). The mirids *S. singularis* were found in the 10 surveyed localities. The species *D. theobromae* was collected in Zatta and Kokumbo. *Helopeltis sp* was found in Attiégouakro (Figure 5)



Figure 2. *Sahlbergella singularis*.



Figure 3. *Distantiella theobromae*.



Figure 4. *Helopeltis* sp.

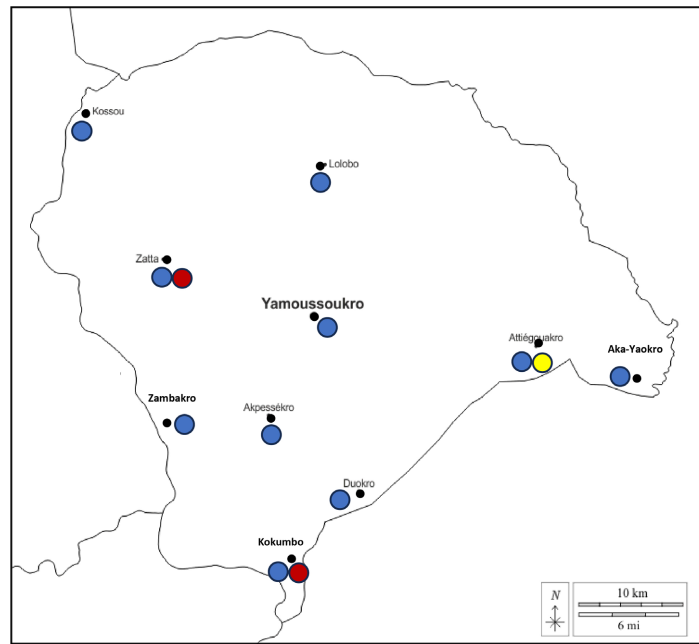
Table 1. Mirid species in the Yamoussoukro district.

Species of mirid	Attendance rate
<i>Sahlbergella singularis</i>	99.82%
<i>Distantiella theobromae</i>	0.15%
<i>Helopeltis</i> sp	0.03%

Mirid outbreak in the Yamoussoukro district

In the Yamoussoukro district, a period of proliferation was determined during the five years of study. The period extends from May 2019 to March 2020, from May 2020 to March 2021, from May 2021 to March 2022 and from May 2022 to March 2023 (Figure 6). The mirids were in the plots of Yamoussoukro every month of the year. But the number of mirids per cocoa tree was significant during the months of August, September, October, November and December 2019. With successively 10.98; 12.61; 9.23; 11.11 and 10.28 mirids/cocoa tree.

In 2020, the number of mirids/cocoa trees was significant in January (10.46 mirids/cocoa tree), February (6.42 mirids/cocoa tree), August (6.71 mirids/cocoa tree), November (5.09 mirids/cocoa tree), cocoa tree) and December (5.39 mirids/cocoa tree). During the year 2021, 10.41 mirids/cocoa tree were recorded



- *Sahlbergella singularis*
- *Distantiella theobromae*
- *Helopeltis* sp

Figure 5. Geographical distribution of mirids in the Yamoussoukro district.

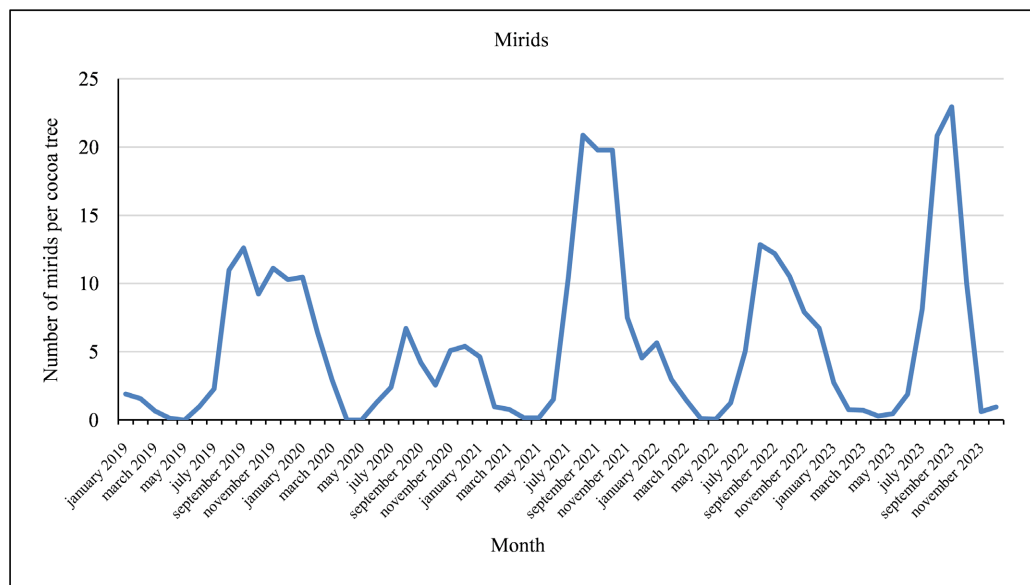


Figure 6. Mirid outbreak in the Yamoussoukro district.

in July, 20.86 mirids/cocoa tree in August, 19.77 mirids/cocoa tree in September and October and 7.5 mirids/cocoa tree in November. In 2022, the number of mirids/cocoa trees was 5.03 in July, 12.85 in August, 12.20 in September, 10.52 in October, 7.90 in November and 6.74 in December. In 2023, there were successively

in July, August, September and October 8.12; 20.83; 22.95 and 10.04 mirids/cocoa tree. The months of August 2021 (20.86 mirids/cocoa tree), September 2021 (19.77 mirids/cocoa tree), October 2021 (19.77 mirids/cocoa tree), August 2023 (20.83 mirids/cocoa tree) and September 2023 (22.95 mirids/cocoa tree) recorded the highest number of mirids per year (Figure 6).

Mirid proliferation depending on rainfall in the Yamoussoukro district

In March 2019, April 2019 and May 2019, less rain was recorded. During this period, the mirid population was low. From June 2019 to November 2019, the district was irrigated with more than 50 mm of rain except September 2019 with 47.76 mm of rain. During this period, the number of mirids was high in the district's plantations with an average of 10 mirids/cocoa trees. From March 2020 to June 2020, the rain was significant in the plantations with a monthly height of 100 mm. During this period, the mirid population was low. During the periods March 2021 to May 2021, March 2022 to May 2022 and March 2023 to May 2023, more than 50 mm of rain was recorded with the exception of April 2023 with 46.48 mm of rain. During these periods, mirid populations were low on cocoa plantations. In August 2021, September 2021, October 2021, August 2022, September 2022, October 2022, August 2023, September 2023 and October 2023, there was enough rain. During these months, the number of mirids was high in the cocoa plantations of the Yamoussoukro district. The months of December and January are the driest months during which the amount of rain is very low, generally less than 20 mm. The analysis of the mirid outbreak curve in relation to the rainfall regime shows that the outbreak begins during rainy periods and gradually stops when precipitation decreases (Figure 7).

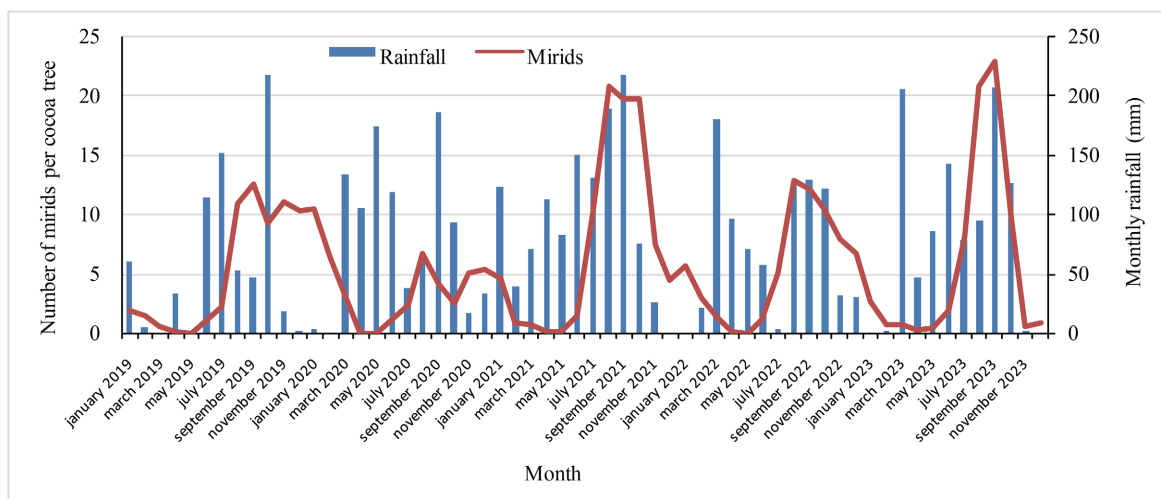


Figure 7. The proliferation of cocoa tree mirids in relation to precipitation in the district of Yamoussoukro Côte d'Ivoire.

Mirid proliferation depending on temperature in the Yamoussoukro district

Average temperatures over the five years of study ranged from 24.9°C to 29.1°C. High temperatures were recorded from January 2019 to May 2020, from January

2020 to May 2020, from January 2021 to May 2021, from January 2022 to May 2022, and from January 2023 to May 2023. During these periods, mirid populations increased in the cocoa plantations. The low temperatures were from June 2019 to December 2019, from June 2020 to December 2020, from June 2021 to December 2021, from June 2022 to December 2022 and from June 2023 to December 2023 during the 5 years of study. During these periods, mirid populations were high in the cocoa plantations of the Yamoussoukro district. Unlike rainfall, the relationship between variations in mirid populations and temperature was not obvious. However, we note that periods of high population growth seem to coincide with the lowest temperatures of the year. In fact, the population gradually decreases from February when the temperature is higher (**Figure 8**).

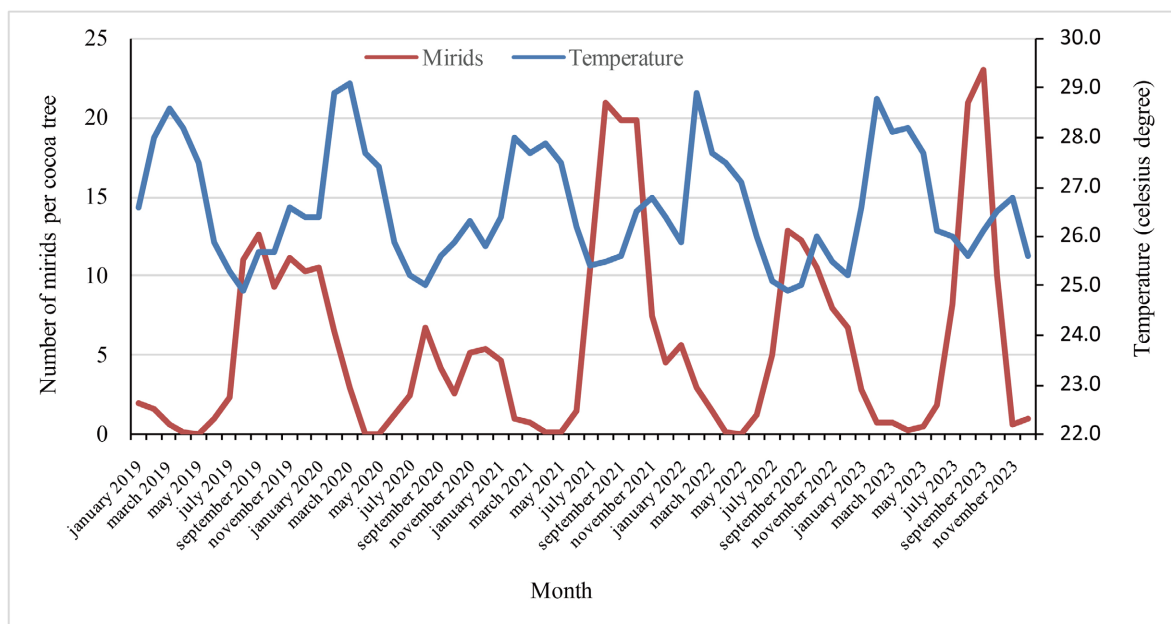


Figure 8. The proliferation of cocoa tree mirids in relation to temperatures in the district of Yamoussoukro Côte d’Ivoire.

Correlation between the proliferation of mirids and climatic parameters (rainfall and temperature) of Yamoussoukro

The Spearman correlation test at the 5% threshold showed that there is no significant correlation between the proliferation of mirids and the climatic parameters of temperature and rainfall (**Table 2** and **Table 3**).

Table 2. Descriptive statistics

Variable	Observations	Minimum	Maximum	Mean	Standard deviation
Month	48	43101.00	44531.00	43815.46	426.27
Temperature	48	24.90	29.10	26.61	1.137
Mirids	48	0.00	20.87	5.19	5.36
Rainfall	48	0.00	251.97	79.08	68.34

Table 3. Proximity matrix (Spearman correlation coefficient) between temperature, rainfall and mirid proliferation.

	Temperature	Mirids	Rainfall
Temperature	1	-0.4865	-0.2710
Mirids	-0.4865	1	-0.0614
Rainfall	-0.2710	-0.0614	1

4. Discussion

Three species of mirids were collected in the cocoa orchard of the Yamoussoukro district. These are *Sahlbergella singularis*, *Distantiella theobromae* and *Helopeltis sp.* The presence of these species would be due to the favorable conditions offered by the cocoa trees in the Yamoussoukro district. But for [3] there are four species of mirids in the Ivorian cocoa orchard, namely *S. singularis*, *D. theobromae*, *B. laticollis* and *Helopeltis sp.*

S. singularis had a very high population in the Yamoussoukro district. These results would confirm those of [8] and [9]. According to these authors, *S. singularis* would be the most predominant and widespread species in the orchard.

The study showed that mirids were present all months of the year in the Yamoussoukro district. The proliferation of these insects was very significant during the months of July, August, September, October and November of all the years of study. This proliferation was weak during the months of January, February, March, April, May and June. The significant number of mirids during the months of July, August, September, October and November can be explained by the favorable conditions during this period. Indeed, during the months of July, August, September, October and November the cocoa trees would have many pods which would constitute a source of food for these insects. But according to [10] and [11] the factors which would trigger the proliferation of mirids would not be the presence of the pods themselves, but the physiological state of the cocoa trees during fruiting and vegetative growth. In this period. For these authors, during this period, the cocoa tree would be rich in sap and therefore favorable to the development of mirids. The low numbers of mirids in January, February, March, April, May and June are due to a latency period [12].

The combined studies of rainfall and mirid abundance showed that during the months of March, April, May and June constituting the periods of heavy rains in the 4 years of study with the exception of 2020. During this period there were fewer mirides. On the other hand, the periods of July, August, September, October and November of the study years with the exception of 2021 recorded less rain. This same period recorded more mirids. The low population of mirids during the months of March, April, May and June can be explained by the heavy rains which dislodge these insects from the cocoa trees [13]. According to [14], heavy rains would negatively affect the behavior and development of small organisms such as insects. The high number of mirid populations in July, August, September, October and November could be explained by the amount of rain that fell during this

period, which would favor the development of these insects. In fact, the amounts of rain during this period would be low.

The proliferation of mirids as a function of temperature showed that during high temperatures there were fewer mirids. Periods of low temperatures recorded high populations of mirids. The low population of mirids at high temperatures is believed to be due to the rapid death of these insects due to severe thermal injury [15].

When the ambient temperature exceeds the upper temperature threshold, thermal stress sometimes leads to the death of individuals or even the extinction of local populations in insects, which would explain the low level of mirids during high temperatures.

5. Conclusion

The results showed that the population level of mirids was high at relatively low temperatures. The reproductive capacity of mirids would be higher at an average temperature of 25°C. As mirids are insects and therefore cold-blooded invertebrates, they depend on external sources such as the sun to raise their body temperature.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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