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Kouakou Malanno

National Center for Agronomic
Research, Cotton Research
Station of Bouake, Entomology
Laboratory, 01 BP 633 Bouaké
01, Côte d'Ivoire

Bini Kouadio Kra Norbert

National Center for Agronomic
Research, Cotton Research
Station of Bouake, Entomology
Laboratory, 01 BP 633 Bouaké
01, Côte d'Ivoire

Ouattara Bala Mamadou

Department of Physical
Geography, University Alassane
Ouattara, Côte d'Ivoire

Ochou Ochou Germain

National Center for Agronomic
Research, Cotton Research
Station of Bouake, Entomology
Laboratory, 01 BP 633 Bouaké
01, Côte d'Ivoire

New subdivision of cotton production area of Côte d'Ivoire based on the infestation of main arthropod pests

Kouakou Malanno, Bini Kouadio Kra Norbert, Ouattara Bala Mamadou and Ochou Ochou Germain

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Abstract

Variations in populations of arthropod pests, under the influence of climate change, compromise the effectiveness of the cotton phytosanitary protection strategy in Côte d'Ivoire. This study aims to establish a new classification of cotton production areas, on the basis of predominant pests. A monitoring was therefore carried out from 2016 to 2019 in 400 farmers' fields. In these fields, surveys were conducted weekly, from the 30th to the 122nd day after emergence. Data analysis, through Principal Component Analysis, identified four groups of localities. The first group includes the northeastern localities (4°W to 5°W: 8°N to 10.5°N) such as Kong, Ouangolodougou, Sordi, Tiékpè, Kaouara. This area is characterized by high infestations of most pests (jassid, white flies, exocarpic lepidoptera, endocarpic lepidoptera, phyllophagous lepidoptera and mites). The second group is intermediate between northeast and central (5.5°W to 6.2°W: 8.3°N to 10.5°N). This area is characterized by infestations of jassid, white flies and exocarpic lepidoptera (*H. armigera* and *D. watersi*). It remains less infested by endocarpic lepidoptera (*T. leucotreta* and *P. gossypiella*). The third area is located in the South (4.5°W to 8.5°W: 6°N to 8.5°N). It is essentially infested by endocarpic lepidoptera *T. leucotreta* and *P. gossypiella*. Jassid and whitefly infestations are less important in this part, compared to the northern part. The fourth and last area extends from the center to the west (6°W to 8°W: 8°N to 10.5°N). Pest infestations are lower in this area compared to other areas.

Keywords: cotton, pests, infestation, strategy

1. Introduction

In Côte d'Ivoire, cotton is grown by more than 100,000 people in the center and north of the country, on an area of about 350,000 hectares. National production over the last three years (2017 to 2019) has been between 413,000 and 490,000 tons of seed cotton, with an average yield of about 1.2 t/ha^[8]. Despite this performance, current yields remain below the record yields of 1.4 t/ha achieved in the past. Indeed, cotton cultivation is subject to many constraints. Firstly, there is the reduction of land and declining soil fertility. Secondly, climate change, through the variability of rainfall, has a negative effect, resulting in: disruption of the cropping season^[3-4], unsuitability of cotton varieties and modification of the spatiotemporal dynamics of pest and disease^[11].

Cotton fields face attacks from many arthropod pests. The pest complex includes several orders of insects such as Heteroptera (*Dysdercus voëlkéri*), Homoptera (*Aphis gossypii*, *Jacobiella fascialis*, *Bemisia tabaci*), Lepidoptera (*Helicoverpa armigera*, *Earias* spp, *Diparopsis watersi*, *Thaumatotibia leucotreta*, *Pectinophora gossypiella*). In addition to these insects, there is the Tarsonemus mite *Polyphagotarsonemus latus*^[20]. Crop losses due to these pests can reach more than 30% in case of insufficient phytosanitary protection^[21].

For the control of pests, a phytosanitary protection strategy has been proposed since 1998-1999. Its aim is to manage the resistance of *Helicoverpa armigera* to pyrethroids and to prevent this problem with other pests^[14]. This strategy suggests a restriction on the use of pyrethroids. Insecticides and miticides are recommended depending on the stage of the crop, production areas and pest emergence periods^[18, 15, 13].

The effectiveness of the protection strategy may be influenced by ongoing changes in arthropod pest populations.

Corresponding Author:**Kouakou Malanno**

National Center for Agronomic
Research, Cotton Research
Station of Bouake, Entomology
Laboratory, 01 BP 633 Bouaké
01 (Côte d'Ivoire)

Systematic monitoring has therefore been initiated to detect variations in time. In recent years, data have revealed the emergence or recrudescence of certain pests such as cotton jassids [11], whiteflies [5], *Helicoverpa armigera*, *T. leucotreta*, *P. gossypiella* [16, 17], etc. The spatiotemporal dynamics of these pests highlight major changes that can compromise the effectiveness of the protection strategy. The objective of this study was therefore to establish a classification of cotton production areas based on the predominance of the main pests. This will allow a better adaptation of the phytosanitary protection strategy to the current situation.

2. Materials and Methods

2.1. Study area

The study was carried out in the cotton production areas of Côte d'Ivoire, which cover the northern half of the country. The study was carried out in the cotton producing areas of Côte d'Ivoire, which cover the northern half of the country (7°5N to 12°N: 3°W to 8.5°W) (Figure 1). The production zone can be subdivided into two parts according to rainfall.

The northern part, located above the 9th parallel, is characterized by a Sudanian-type climate with 6 to 8 months of dry season (October to May) and a rainy season with maximum rainfall in August. Rainfall ranges from 1150 to 1350 mm/year. The southern part (below the 9th parallel) is characterized by a sub-Saharan climate with two rainy seasons (March to July and October to November) and two dry seasons (August to September and December to February). Precipitation varies between 1300 and 1750 mm/year [6].

On the basis of previous studies (1999-2000), the cotton production area has been subdivided into three parts, according to the dominant pests (Figure 1): zone 1-1 is located in the extreme North. The main pests are *H. armigera*, *Earias* spp, *D. watersi* and *B. tabaci*. Zone 1-2 in the north contains *H. armigera*, *Earias* spp, *D. watersi*, *T. leucotreta*, *P. gossypiella* and mites. Zone 2 in the South contains the same species as zone 1-2, with a predominance of endocarpic lepidoptera (*T. leucotreta*, *P. gossypiella*) [19].

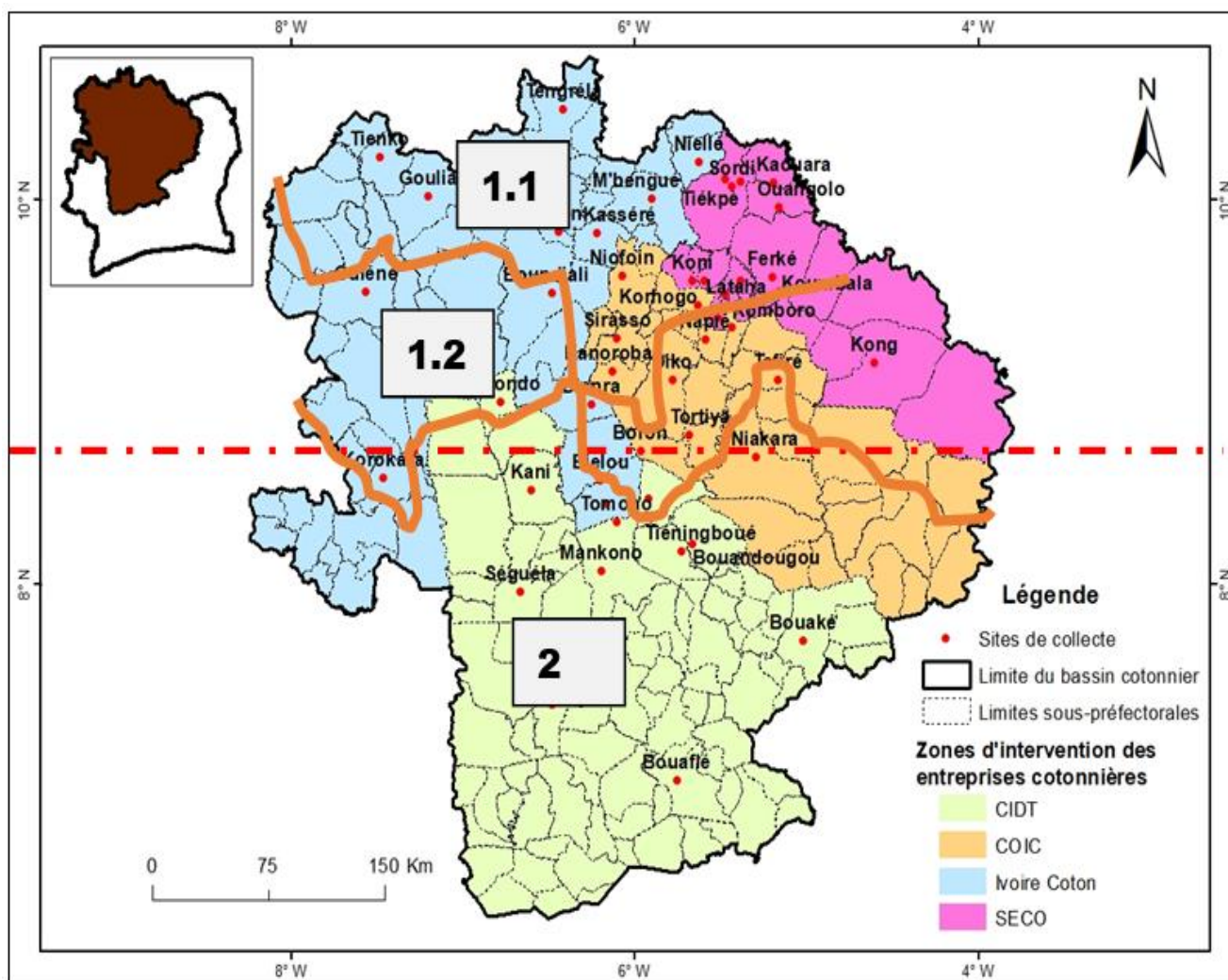


Fig 1: Geographic location of the Study Area showing the boundaries of pest zones according to Ochou and Martin (2001)

2.2. Main Pests Studied

The study focused on the main pests of cotton: *Aphis gossypii* Glover (Homoptera: Aphidididae), *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae), *Jacobiella fascialis* Jacobi (Homoptera: Cicadellidae), *Dysdercus* spp Guerin-Meneville, *Spodoptera littoralis* Boisduval (Lepidoptera: Noctuidae), *Anomis flava* Fabricius (Lepidoptera: Noctuidae),

Haritalodes derogata Fabricius (Lepidoptera: Crambidae), *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae), *Earias insulana* Boisduval and *Earias biplaga* Walker (Lepidoptera: Noctuidae), *Diparopsis watersi* Rothschild (Lepidoptera: Noctuidae), *Pectiophora gossypiella* Saunders (Lepidoptera: Gelechiidae), *Thaumatotibia leucotreta* Meyrick (Lepidoptera: Tortricidae), *Polyphagotarsonemus*

latus Banks (Acari : Tarsonemidae).

2.3. Monitoring design

Data collection was done in collaboration with the Research and Development (R&D) departments of the cotton companies. Each year, the monitoring system involved about 400 fields in the farming environment throughout the production region. These fields were selected in 40 localities,

with ten (10) fields per locality. The fields were chosen according to the most representative sowing dates in each locality (Table 1). An area of 0.25 ha was delineated in the center of the field for data collection. Each field is subject to the recommended technical practices for cotton production in Côte d'Ivoire (variety, sowing density, fertilization, weeding, etc.).

Table 1: Method of choosing fields according to geographical location and sowing period

Planting dates	Geographic location	
	North	South
1st sowing period (D1): 20-31 mai	1	-
2nd sowing period (D2): 01-10 juin	2	1
3rd sowing period (D3): 11-20 juin	3	3
4th sowing period (D4): 21-30 juin	2	3
5th sowing period (D5): 01-10 juillet	1	2
6th sowing period (D6): 11-20 juillet	1	1
Total	10	10

2.4. Surveys of pests on cotton plants and bolls

Surveys were carried out weekly from the 30th to the 122nd day after emergence, on 30 plants taken in groups of 5 plants consecutively, following the diagonal ^[11, 5]. For lepidopteran species (*Helicoverpa armigera*, *Earias* spp., *Diparopsis watersi*, *Spodoptera littoralis*), larvae were counted. For the whitefly *B. tabaci*, the number of adults was estimated by gently stirring each plant beforehand. For jassids (*J. fascialis*), aphids (*A. gossypii*) and mites (*P. latus*), the number of plants attacked was determined by examining the presence of symptoms on five (5) well-developed terminal leaves. For *Thaumatotibia leucotreta* and *Pectinophora gossypiella*, larvae develop inside cotton bolls, some bolls were taken weekly and stripped. The larvae encountered were counted.

2.5. Data analysis

Data were recorded in Excel, and then, the following parameters have been determined per locality over the weekly surveys: average number of larvae on 30 plants (for *H. armigera*, *Earias* spp, *D. watersi*, *H. derogata*, *S. littoralis* and *A. flava*), average number of individuals on 30 plants (for *B. tabaci* and *Dysdercus* spp), average number of larvae found in 30 cotton bolls (for *T. leucotreta* and *P. gossypiella*). After the determination of annual infestation levels, the three-year averages were determined for each locality.

A Principal Component Analysis (PCA) was also performed on the average infestation levels. The purpose of this multivariate descriptive analysis was to summarize

information on infestations of the pest complex in the cotton production areas and to classify the localities according to the types of pests that characterize them. This analysis was performed using the XLSTAT 2015.4 software.

3. Results

3.1. Average infestation levels of major pests during the study period

Table 2 shows the average level of infestation of the different pests over the study period. The most representative species were *B. tabaci* and *J. fascialis*. The infestation levels of phylophagous lepidoptera were low to medium (less than 1 damaged plant or 1 larva per 30 plants). The infestation levels of bollworms were also low or medium. Approximately 0.23 and 0.17 larvae/30 plants were observed for *H. armigera* and *Earias* spp, 0.66 and 0.33 larvae/100 cotton bolls, respectively for *P. gossypiella* and *T. leucotreta*.

3.2. Variations in infestation levels between North and South

Table 3 shows the average levels of pest infestation in the northern and southern parts. Three groups of pests can be distinguished. The first group consists of *D. watersi*, *B. tabaci* and *J. fascialis* whose infestations are significantly higher in the north. The second group of pests is composed of endocarpic lepidoptera (*T. leucotreta* and *P. gossypiella*) whose infestation levels are significantly higher in the South. The other pests form the third group. Their infestation levels in the North and South do not differ significantly.

Table 2: Average infestation levels of major cotton pests during the study period (2016-2019)

Ravageurs	Unit	Min.	Max.	Average	E.T
<i>Diparopsis watersi</i>	Larvae/30 plants	0,00	0,87	0,08	0,02
<i>Helicoverpa armigera</i>	Larvae/30 plants	0,00	1,159	0,23	0,04
<i>Earias</i> spp	Larvae/30 plants	0,03	2,57	0,17	0,05
<i>Spodoptera littoralis</i>	Larvae/30 plants	0,00	0,35	0,02	0,01
<i>Cosmiphylia flava</i>	Larvae/30 plants	0,00	0,11	0,01	0,03
<i>Dysdercus voelkeri</i>	Nb/30 plants	0,00	51,70	2,44	1,08
<i>Bemisia tabaci</i>	Nb/30 plants	0,21	259,11	29,73	6,30
<i>Syllepte derogata</i>	D.P/30 plants	0,00	5,30	0,18	0,11
<i>Jacobiella fascialis</i>	D.P/30 plants	0,00	17,59	5,34	0,70
<i>Aphys gossypii</i>	D.P/30 plants	0,16	6,03	1,22	0,15
<i>Polyphagotarsonemus latus</i>	D.P/30 plants	0,00	2,30	0,17	0,06
<i>Thaumatotibia leucotreta</i>	Larvae/100 Bolls	0,00	5,10	0,33	0,11
<i>Pectinophora gossypiella</i>	Larvae/100 Bolls	0,00	18,90	0,66	0,39

Table 3: Average levels of pest infestations in the northern and southern production zones over the study period (2016-2019)

Ravageurs	Unit	North	South	t	p
<i>Diparopsis watersi</i>	Larvae/30 plants	0,11 ± 0,03	0,02 ± 0,00	3,82	0,045
<i>Helicoverpa armigera</i>	Larvae/30 plants	0,25 ± 0,05	0,18 ± 0,06	0,76	0,388
<i>Earias spp</i>	Larvae/30 plants	0,13 ± 0,03	0,25 ± 0,14	0,98	0,326
<i>Spodoptera littoralis</i>	Larvae/30 plants	0,02 ± 0,00	0,03 ± 0,00	0,51	0,480
<i>Anomis flava</i>	Larvae/30 plants	0,01 ± 0,00	0,02 ± 0,00	3,14	0,083
<i>Dysdercus vöelkeri</i>	Nb/30 plants	1,78 ± 0,38	3,63 ± 1,01	0,66	0,420
<i>Bemisia tabaci</i>	Nb/30 plants	42,11 ± 9,00	7,17 ± 1,81	8,10	0,007
<i>Haritalodes derogata</i>	D.P/30 plants	0,06 ± 0,01	0,39 ± 0,31	2,03	0,161
<i>Jacobiella fascialis</i>	D.P/30 plants	6,81 ± 0,87	2,66 ± 0,86	9,44	0,004
<i>Aphys gossypii</i>	D.P/30 plants	1,12 ± 0,20	1,42 ± 0,23	0,93	0,350
<i>Polyphagotarsonemus latus</i>	D.P/30 plants	0,14 ± 0,04	0,22 ± 0,14	0,60	0,444
<i>Thaumatotibia leucotreta</i>	Larvae/100 Bolls	0,14 ± 0,04	0,66 ± 0,30	5,47	0,024
<i>Pectinophora gossypiella</i>	Larvae/100 Bolls	0,18 ± 0,05	1,55 ± 0,90	2,91	0,047

D.P: Damaged plants

3.3. Principal component analysis of the spatial distribution of pests

The first two components of the PCA (Table 4) express about 76% of the variance, which is acceptable. The first component (F1), which expresses 56.11% of the variance, is correlated with species such as *T. leucotreta*, *P. gossypiella*, *D. vöelkeri*. These are the species with higher levels of infestation in the southern part. The second component (F2) expresses 19.5% of the variance. It is particularly correlated with *B. tabaci* and *J. fascialis*. These species are more abundant in the northern part.

The projection of individuals on the first two components (F1, F2) determines four (04) groups of localities (Figure 2).

- **Group 1**, which is positively located on both axes, includes localities such as Karakoro, Kong, Ouangolodougou, Sordi, Tiékpè. This area is characterized by high levels of infestation for the main pests, including whiteflies (*B. tabaci*), jassid (*J. fascialis*), bollworms (*H. armigera*, *D. watersi*, *P. gossypiella*, *T. leucotreta*, *Earias* spp), phyllophagous lepidoptera (*H. derogata*) and mites (*P. latus*).
- **Group 2** is located positively on F2 and negatively on

F1. It includes localities such as Diawala, Kaouara, Komboro, Sédiogo, Sinématiali, Tafiré, Niellé, Niofoin, Korhogo, Koumbala, Lataha, Bielou, Boron, Dikodougou. These localities are subject to high pressure from white flies (*B. tabaci*) and jassid (*J. fascialis*) and low pressure from endocarpic lepidoptera.

- **Group 3** is located positively on F1 and negatively on F2. It includes localities such as Bouaké, Tomono, Vavoua, Sharala. These areas are characterized by infestations of endocarpic lepidoptera (*T. leucotreta*, *P. gossypiella*), *Earias* spp, *H. derogata*, *Dysdercus* spp and tarsonemous mites (*P. latus*). On the other hand, they recorded lower infestation levels of whiteflies (*B. tabaci*) and jassid (*J. fascialis*) compared to Group 1.
- **Group 4** is negatively located on both axes F1 and F2. It includes the largest number of localities (Boundiali, Dianra, Gbon, Goulia, Kani, Kanoroba, Kasséré, Korokara, Mankono, Marandala, M'bengué, Morondo, Napié, Odiéné, Séguéla, Sirasso). The plots in these localities are less infested by pests compared to the localities in groups 1, 2 and 3.

Table 4: Eigenvalues and contribution of variables to the first three axes of the Principal Component Analysis

	Axe F1	Axe F2	Axe F3
Eigenvalues	5,611	1,950	0,969
Variance (%)	56,107	19,504	9,692
% Cumulative Variance	56,107	75,612	85,304
Dip	0,093	0,576	0,704
Hel	0,394	0,565	0,319
Ear	0,967	0,024	0,059
Jass	0,005	0,752	-0,515
Syl	0,982	-0,080	-0,099
Aca P	0,879	-0,004	0,048
Dysd	0,979	0,060	-0,046
Bem ad	-0,079	0,835	-0,269
Crypto	0,924	-0,106	-0,069
Pectino	0,977	-0,118	-0,105

Dip : *Diparopsis watersi*, Hel : *Helicoverpa armigera*, Ear : *Earias* spp, Jass : Jassides, Syl : *Haritalodes* (= *Syllepte*) *derogata*, Aca P : Acarien *Polyphagotarsonemus latus*, Dys: *Dysdercus vöelkeri*, Bem ad : *Bemisia tabaci*, Crypto : *Thaumatotibia* (= *Cryptophlebia*) *leucotreta*, Pectino : *Pectinophora gossypiella*.

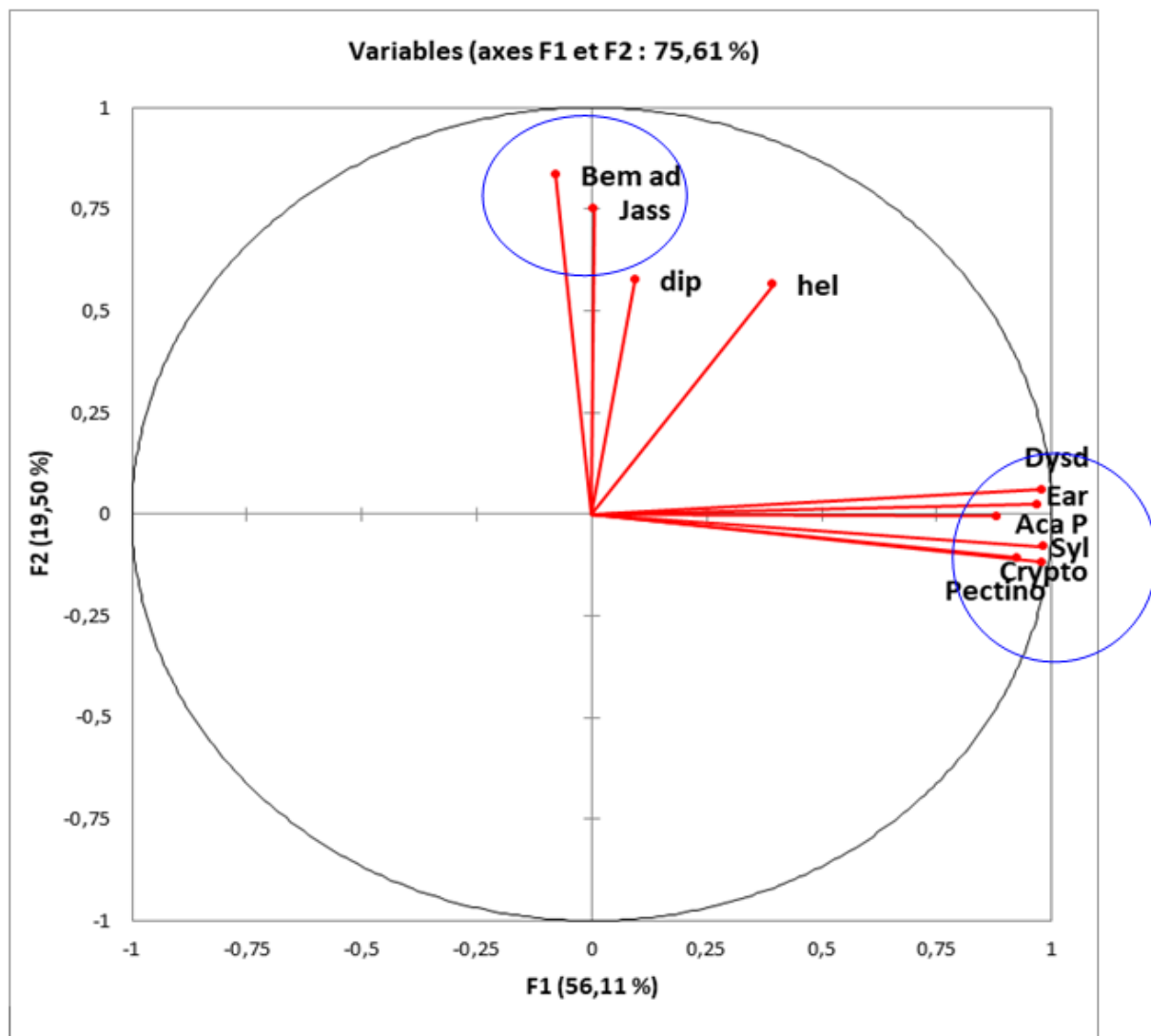
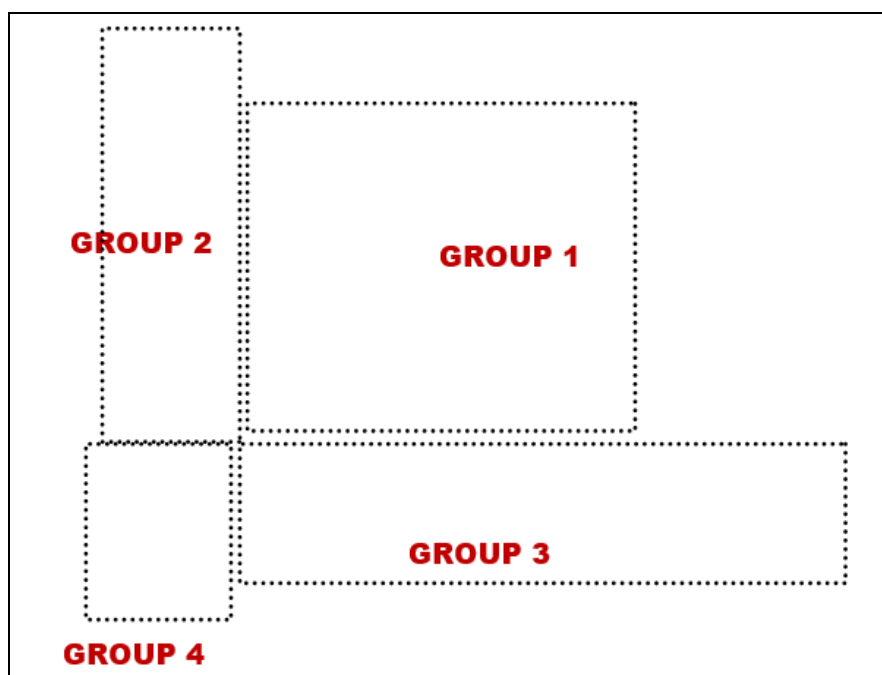


Fig 2: Projection of variables on the first two components (F1, F2) of the Principal Component Analysis

Dip : *Diparopsis watersi*, Hel : *Helicoverpa armigera*, Ear : *Earias* spp, Jass : Jassides, Syl : *Haritalodes* (= *Syllepte*) *derogata*, Aca P : Acarien *Polyphagotarsonemus latus*, Dys :

Dysdercus vöelkeri, Bem ad : *Bemisia tabaci*, Crypo : *Thaumatotibia* (= *Cryptophlebia*) *leucotreta*, Pectino : *Pectinophora gossypiella*..



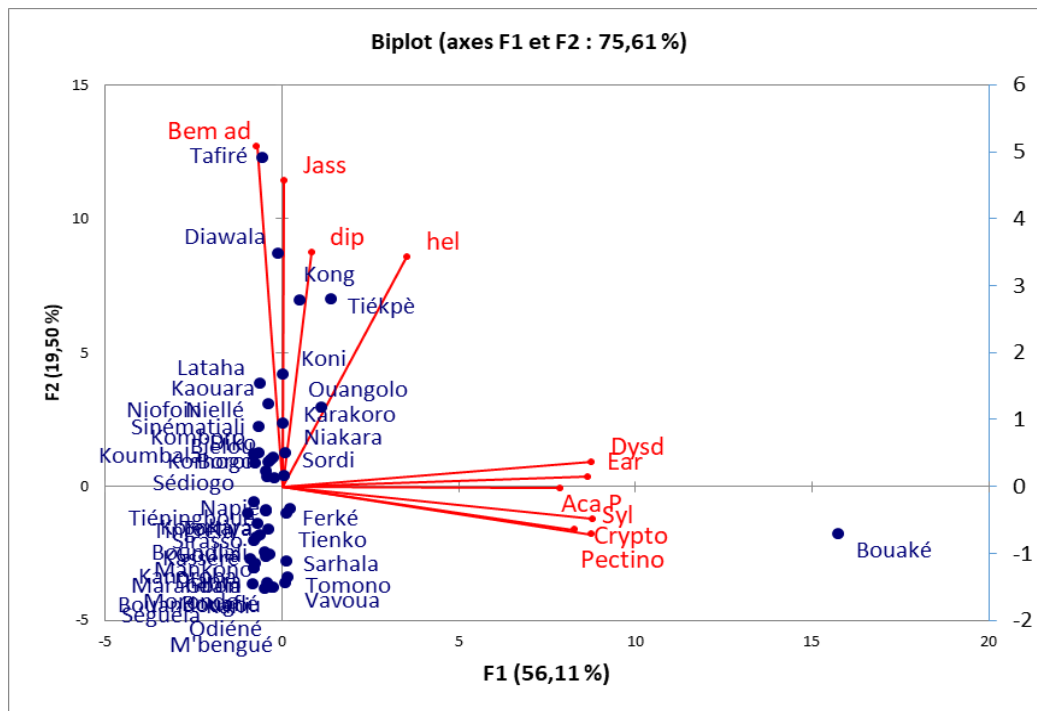


Fig 3: Projection of individuals (localities) on the first two components (F1, F2) of the principal component analysis

3.4. Mapping and delimitation of new pest areas

Based on the results of the Principal Component Analysis, a simplified mapping of the pest complex in the production area was proposed (Figure 4). four geographical pest areas (P.A) have been defined. The first pest area (P.A1) is located in the northeast (4°W to 5.5°W and 8°N to 10.5°N). It includes Kong, Ouangolodougou, Sordi, Tiékpè and Kaouara. This area is under strong pressure from all major pests (jassids, whiteflies, exocarpic lepidoptera, endocarpic lepidoptera, phyllophagous lepidoptera and mites). The second pest area (P.A2) is intermediate between the Northeast and the Center (5.5°W to 6.2°W and 8.3°N to 10.5°N). This pest area is also

subject to pressure from jassids, whiteflies and exocarpic lepidoptera (*H. armigera* and *D. watersii*). However, it remains less infested by endocarpic lepidoptera (*T. leucotreta* and *P. gossypiella*). The third pest area (P.A3) is located in the South (4.5°W to 8.5° W and 6°N to 8.5°N). It is the preferred zone for endocarpic lepidoptera (*T. leucotreta* and *P. gossypiella*) and is under less pressure from whiteflies and jassides. The fourth pest area (P.A4) extends from the center to the west (6°W to 8°W and 8°N to 10.5°N). It is the area with the lowest levels of infestation, compared to the other areas.

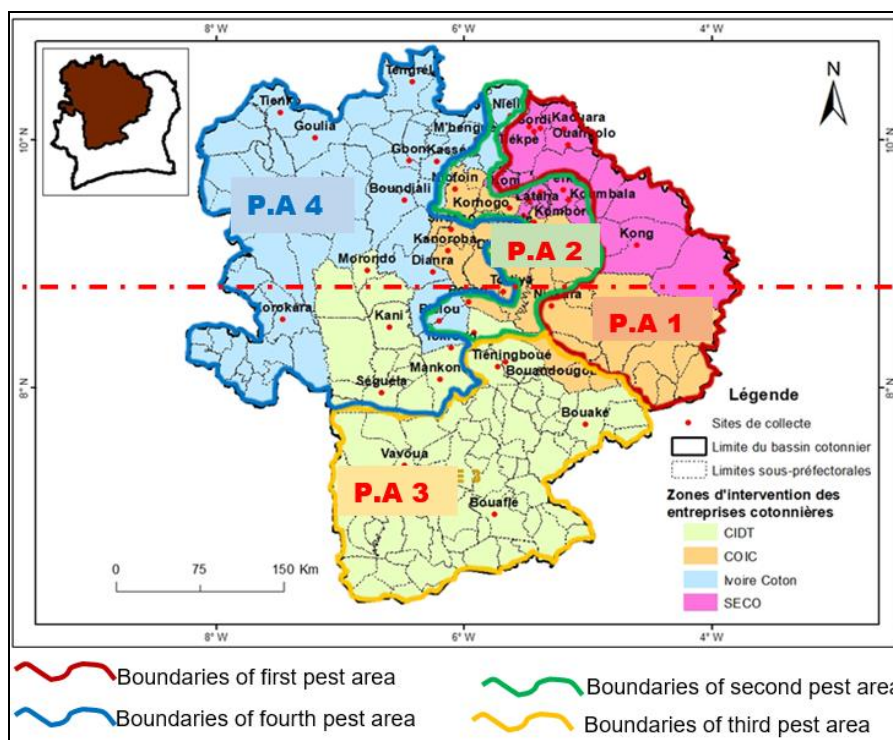


Fig 4: Classification of production areas based on dominant pests

4. Discussion

Phytosanitary monitoring carried out in the fields from 2016 to 2019 revealed spatial variations in pest infestation levels. The species *B. tabaci*, *J. fascialis* and *D. watersi* were more abundant in northern localities (beyond the 9th parallel). Endocarpic lepidoptera, *T. leucotreta* and *P. gossypiella*, were more abundant in the southern areas. Infestations of the cotton bollworm *H. armigera* do not show a clear difference between North and South. However, the northeast appears to have higher infestations.

The analysis also shows an East-West gradient in the spatial distribution of pests. Infestation levels of most of the pests appear to be particularly high in the northeastern localities (Kong, Ouangolodougou, Sordi, Tiékpè, Kaouara). These levels decrease from the northeast to the northwest. The same results have been observed in recent publications on jassid and whiteflies^[11,5].

The contrasting spatiotemporal evolution of rainfall in the cotton production area resulting from climate change^[3] could partly explain this disparity between the North-East, North-West and South. The beginning of the rainy season is later in the Northeast and the end of the season is earlier. This region is experiencing a decline in total rainfall, number of rainy days and average daily rainfall^[4]. These conditions are conducive to the development of populations of most species, especially jassids^[11]. Other reasons could explain the high abundance of pests in northeastern communities. Indeed, biochemical analyses carried out in the laboratory on several jassid samples showed that those coming from Ouangolodougou (North-East) produce high quantities of α -esterases and β -esterases, compared to samples coming from Bouaké (South)^[9, 10]. This result means that jassid populations in the northeast would be better able to degrade some insecticides such as Carbamates, Pyrethroids and Organophosphorus, which are widely used by farmers^[2, 7, 12]. Four groups of localities were defined from the multivariate analysis. These groups thus define four homogeneous parasite zones. Whereas the previous data had defined three parasite zones^[19]. This new classification is more precise and reveals a change in the spatial distribution of the pest complex. It highlights the particular status of the area located in the North-East, where all insect pests and mites have a significant impact. The new mapping should have implications for the phytosanitary protection strategy. This means that it will be essential to develop integrated management strategies specific to each defined pest area. For example, the progression of mites towards the Northeast suggests its consideration, through the integration of effective acaricides in the phytosanitary protection program. In parasite zone 3 located in the South, more effective products against endocarpic lepidoptera (*T. leucotreta* and *P. gossypiella*) should be identified and recommended.

5. Conclusion

The objective of this study was to update the status of cotton pests in the different production areas. The study revealed major changes in the spatial distribution of the main arthropod pests. Based on the knowledge gained from this study, four pest areas were determined. The main pests in each zone were also identified. These results are useful for the adaptation of the cotton protection strategy in Côte d'Ivoire. Thus, a special phytosanitary protection program adapted to each pest zone must be proposed. In addition, the monitoring of arthropod pest populations must be continued in order to detect changes

in time and to continuously adapt the protection strategy.

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