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Influence of Cotton Crop Types on the Variation of *Phonoctonus lutescens* Population Guérin Meneville and Percheron (Heteroptera: Reduvidae), a Predator of *Dysdercus voëlkeri* (Schmidt 1932) (Heteroptera: Pyrrochoridae) in Burkina Faso

Issa Sow[1]*, Sacamba Aimé Omer Hema[1], Antoine Sanon[2], Issoufou Ouedraogo[1]

[1]Institut de l'Environnement et de Recherches Agricoles (INERA), Bobo-Dioulasso, Burkina Faso
[2]University Joseph KI-ZERBO, Ouagadougou, Burkina Faso
Email: *issaparguisow@yahoo.fr, omerhema@yahoo.fr, yeguere@yahoo.fr, antoine_sanon@univ-ouaga.bf

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Abstract

Phonoctonus lutescens which is a predator of *Dysdercus voëlkeri* (Schmidt, 1932) is present in cotton fields at the same time as its prey, *D. voëlkeri*. The objective of this study was to see which of the biological control or chemical control programs spares and maintains the potentially beneficial insects, especially *P. lutescens*. This study was conducted at three sites: Farako Bâ site located in the southern Sudanian zone and has geographical coordinates between 04˚20' West and 11˚06' North. The site of Kombissiri with 12'04" North and 1'20" West as geographical coordinates. The site of Kouaré with the following coordinates: 11'56" North and 0'17" East. The design was a 2000 m^2 paired trial subdivided into 3 subplots of 640 m^2 on the three sites. The sample area is repeated 4 times in each plot. All data were subjected to analysis of variance (ANOVA) using SPSS software (version 22.0; SPSS Inc., Chicago, IL, Usa). When significance occurred, means were separated by Bonferroni test ($p < 0.05$). All data were presented as the mean ± standard errors with 3 replications. For insect pests, conventional cotton was more affected by whitefly with 0.42 ± 1.10 and organic cotton by jassids with 0.75 ± 1.66 at Farako bâ. The untreated plot was significantly less infested at Kombissiri with 0.25 ± 1.38 *Dysdercus voëlkeri* than at the other sites. In Fada, the organic cotton was more infested by whitefly larvae and jassid flies, with respectively 0.73 ± 2.25 and 0.22 ± 0.54 plants attacked on average. For beneficial insects, the levels of presence in Farako bâ varied from 0.17 ± 0.66 to 0.02 ± 0.1 on organic cotton than on the other treatments. At Kombissiri the levels of beneficial insects varied more on organic cotton from 0.021 ± 0.20 to 0.026 ± 0.15 than on untreated cotton and conventional cotton. These levels ranged from 0.04 ± 0.21 to 0.26 ± 0.86 on organic cotton than on the other treatments. The seed cotton yield ranged from 500.52 to 946.8 for conventional cotton, from 531.25 to 853.13 for organic cotton and from 493.75 to 763.54 for untreated cotton. *P. lutescens* was discreet about the types of cotton grown. Neem oil is positioned as one of the alternatives to biopesticides that can be used in organic cotton cultivation. The results suggest *P. lutescens* is more adapted to integrated cotton pest management program in Burkina Faso.

Keywords

Phonoctonus lutescens, *Dysdercus vöelkeri*, Conventional Cotton, Organic Cotton, Burkina Faso

1. Introduction

Dysdercus voëlkeri (Schmidt, 1932) [1] is a boll-sucking biting insect, a bug of the family Pyrrhocoridae, and is reported to cause serious damage to cotton. It is a phytophagous insect that feeds on cotton bolls and seeds. PR-PICA, 2014 [2] reported intense outbreaks of *D. voëlkeri* in Benin (13.21%), Burkina Faso (29.27%), Côte d'Ivoire (4.51%) and Senegal (28.7%). The nymphs and adults of *D. voëlkeri* feed on the young capsules, the fruits and seeds, causing (capsules abortion and fall off [3]. There is a large reductant notably *Phonoctonus lutescens* Guérin de Meneville and Percheron, which live in the same environment as *D. voëlkeri* with similar physiognomy [4]. *P. lutescens* is a predator of *D. voëlkeri*, of the reduviidae family, which feeds preferentially on *D. voëlkeri* [5], which contributes to a decrease in the level of *D. voëlkeri* outbreaks in the field.

Control measures of *D. voëlkeri* are dependent on chemicals, which are the most widely used in crop pest control [6]. In Burkina Faso, the chemical insecticides used in conventional cotton are organophosphates, pyrethroids, carbamates, oxadiazines and neonicotinoids. Synthetic pesticides are more dangerous than plant extracts [7], although some plant extracts such as nicotine can be toxic at certain doses to living organisms [8]. In addition to chemical control methods in conventional cotton cultivation, there is the use of biological control methods with the use of organic pesticides [9]. In addition to the use of organic compounds, there is also agronomic control, which focuses on fractioned harvesting and consists of harvesting the cotton in a staggered manner in order to prevent *D. voëlkeri* attacks [10]. Organic pesticides used are important in organic cotton production for integrated insect pest management in cotton ecosystem. As stated by Regnault (2007) [11], the use of organic pesticides spares and maintains natural enemies in the fields. In contrast, chemical control in addition to its dangerousness and prohibitive price, is harmful to human and animal health and the environment [12]. Several authors [13] [14] [15] [16], have shown in the laboratory and in a semi-real environment, the real insecticidal potential of organic compounds, including neem oil *Azadirachta indica* A. Juss neem oil, *Bacillus thuringiensis* (Bt), *Capsicum frutescens* L pepper and soap in the control of crop pests, particularly *A. gossypii*, *D. voëlkeri*, *J. fascialis* and *B. tabaci*. But beneficial insects including *P. lutescens* that are not targeted by insecticide and/or biological pesticide applications should maintain their populations at acceptable levels in the field. As a consequence, this study aim to evaluate the effectiveness of the protection program in organic and conventional crops on sucking biting insects: *Jacobiella fascialis* (jassid), *A. gossypii* (aphid) and *B. tabaci* (whitefly) and particularly *D.voëlkeri* on cotton, and to assess the maintenance of populations of beneficial insects including *P. lutescens*.

2. Materials and Methods

2.1. Materials

- **Sites**

This study was conducted in three sites. The first site was the Farako bâ research station (SOFITEX) located in the southern Sudanese zone between 04˚20' West and 11˚06' North. The second site was located in Kombissiri (FASO COTTON) with coordinates 12'04" North and 1'20" West. The third site was Kouaré (SOCOMA) with coordinates 11˚56" North and 0'17" East (Figure 1).

- **Plant material**

At each site, the plant material used was the seed of the conventional cotton

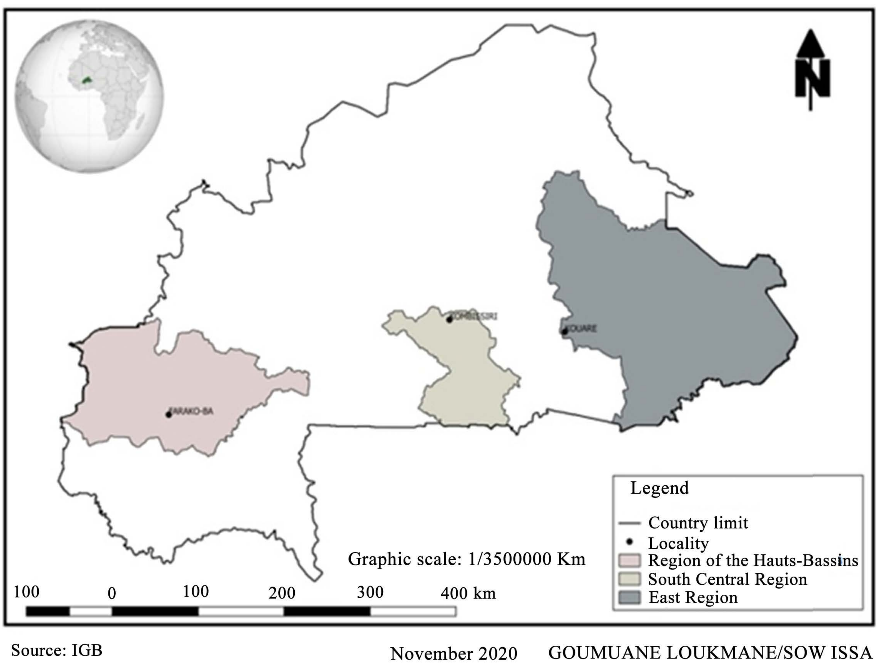


Figure 1. Study sites.

variety FK 37 created by INERA's cotton breeders. The plant material is constituted by the cotton variety FK 37 originating from INERA/Farako-Bâ. It is a variety resulting from the crossing of the H 2784 variety with the IRMA BLT/PF variety. It has a height of 1.50 m and its leaves are medium hairy. The date of appearance of the first flower and the date of opening of the first bolls are respectively the 65th and 112th day after sowing. This variety has the advantage of high productivity in the field. It can be grown on almost all sandy soils and on hydromorphic soils and under a rainfall of 600 mm or more.

- **Insect target**

The study focused on migrating populations of sucking bugs prevailing at the end of the cotton cycle. The sucking biting insects concerned were *Jacobiella fascialis* (jassid), *A. gossypii* (aphid) and *B. tabaci* (whitefly), capsule-sucking biting insects (*D. voëlkeri*). For beneficial insects, we have: *P. lutescens*, ladybird beetle larvae, spiders, ants, praying mantis. The study was carried out on natural populations of sucking and beneficial insects that came from other crops where the feeding conditions were unfavorable.

The larva and adults of biting and sucking insects bite the secondary leaf veins and/or fruiting organs during formation or maturation. Heavy attacks by these biting and sucking insects are likely to stop plant development or the fall of the reproductive organs [17]. At the same time, a high presence of beneficial insects helps to limit pest attacks.

2.2. Methods

- **Experimental design**

The methodology presented was inspired by the work of Gnankiné (2005) [18]. The design used were a paired plot with an untreated control. The design were a 2000 m^2 couple trial subdivided into 3 subplots of 640 m^2.

1) The first sub-plot were a conventional cotton field treated in accordance with the phytosanitary program in conventional cotton cultivation in Burkina Faso;

2) The second sub-plot, a field of organic cotton treated in accordance with the phytosanitary program for organic cotton in Burkina Faso;

3) The third sub-plot, a control that has not received any treatment. The sampling area were replicate 4 times within each of the 3 sub-plots of 640 m^2. The sampling areas selected were 10 meters long by 05 meters wide considered as a repetition. 0.80 meters was observed between 2 lines and 0.40 m between 2 poquets on the same line.

- **Strategy for phytosanitary protection**

We use 6 treatments in conventional cotton cultivation and 8 in organic cotton cultivation. These treatments are the current protection strategy based on insecticide treatments which occurred every 14 days for conventional cotton and 10 days for organic cotton cultivation from the 30th day after emergence (DAL) for conventional cotton and every 10 days for organic cotton. The insecticides used in the study are integrated in the window approach, and could be considered as a grouping of two insecticide treatments with the same insecticide to overcome insect resistance in the field. The insecticide treatments were carried out using products validated by Cotton Research and approved by the Sahelian Pesticides Committee (CSP). Those used in the study are concentrated emulsions (CE) and applied according to the plant protection window approach. In conventional cotton cultivation, Indoxacarb 150 g/l is used in first window from treatment 1 to treatment 2 (T1 to T2). In the second window we used Lambdacyhalothrin-Profenofos 12 g/l - 200 g/ha from treatement 3 to treatement 4 (T3 to T4). For the third window Lambdacyhalothrin Acetamiprid 15 g/l - 16 g/ha is used from treatement 5 to treatement 6 (T5 to T6). In organic cotton cultivation, Neem oil + Pepper + liquid soap from is used from treatment 1 to treatment 4 (T1 to T4). From T5 to T8, *Bacillus thuringiensis* 80 WG were used. The insecticides come from SOFITEX, one of the three cotton companies in Burkina Faso. The neem oil comes from Biotrade Burkina and is concentrated at 1%. Bacillus thuringiens comes from the Société africaine de produits phytosanitaires et d'insecticides (Saphyto). The chilli is obtained from the vegetable garden. It is harvested fresh and dried in the shade before being crushed to obtain the powder. Table 1 summarises the type of cotton cultivation, the active ingredients used by type of cotton cultivation. It also indicates the rates and the frequency of use in conventional and organic cotton cultivation.

- **Rainfall**

The data was obtained from daily rainfall records taken from January to November 2019 from rain gauges installed at Farako bâ, Kombissiri and Fada in the experimental sites (Figure 2). The choice of daily rainfall records is justified by the fact that they include the vegetative periods likely to shelter the populations of harmful and useful insects on the cotton tree. Thus, the cumulative annual rainfall recorded at Farako bâ is 1316 mm, 653 mm at Kombissiri and 469 mm at Kouaré. Heavy rainfall was recorded in May, June and July with respective heights of 87 mm in Kombissiri, 413.5 mm in Farako bâ and 104.5 mm in Fada. Thus, heavy rainfall was observed during June. During this month the rainfall

Table 1. Doses of active ingredients used according to the type of cotton crop.

Types of cotton cultivation	active ingredients used	Doses/ha^{-1}
conventional cotton	Indoxacarbe 150 g/l from T1 to T2	25
(every 14 days)	Lambdacyhalothrine-Profenofos 12 g/l - 200 g/ha from T3 toT4	12 - 200
	Lambdacyhalothrine Acétamipride 15 g/l - 16 g/ha from T5 to T6	15 - 16
Organic cotton	Neem oil + Pepper + liquid soap from T1 to T4	3 l + 60 g + 120 ml
(every 10 days)	*Bacillus thuringiensis* 80 WG from T5 to T8	100 g

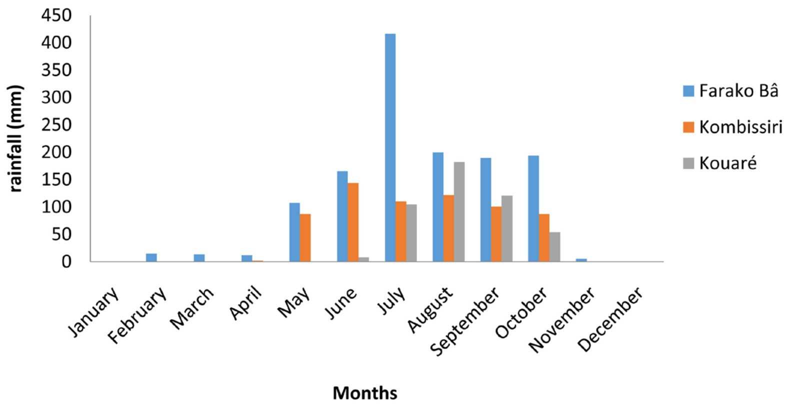


Figure 2. Monthly rainfall recorded in the three study sites.

amounts recorded were respectively 165.4 mm at Farako bâ, 144 mm at Kombissiri and 8 mm at Kouaré. These rains thus enabled the preparation of the plot and the implementation of the trial on 25 June 2019 on all three sites.

- **Collected data**

Under field experimental conditions, the efficacy of synthetic chemical insecticides and/or plant extracts is usually measured through the abundance of pest populations or the severity of damage [19]. On each observation plot, a series of 12 parasite counts were done at regular intervals of one week, from the 30th Day After Emergence (DAE) until harvest. The observation of insect pests and beneficial insects on the plants were done on individual plants of a sample of 30 plants taken in groups of 5 consecutive plants per row, following the sequential method known as the "diagonal" method [20] [21]. For sucking insects (*B. tabaci*, *J. fascialis* and *A. gossypii*), on each selected plant, the 5 terminal leaves were examined. For jassids (*J. fascialis*), the plant is considered attacked when one of its leaves shows damage or symptoms of jassids attack. For *B. tabaci*, the plant is considered attacked when one of its leaves hosts ten adults and one larvae. For beneficial insects (*P. lutescens*, ladybird larvae, spiders, ants, praying mantis), the entire plant was examined and the number of insects for each species was counted. The absence of data for carpophagous and phyllophagous insects is explained by their almost null presence during the observations. This absence did not help to determine the health of the mature capsules.

The cotton yield was estimated on six treated rows of the four 10 meters squares taken from the centre of each experimental unit. Plants were harvested on the 120th DAE when all the boll were opened. The cotton yield was estimated according to the following formula:

$$\text{Yield} = \frac{\text{cumulated weight of the cotton of the 6 lines}(\text{kg}) \times 10000\ \text{m}^2}{6\ \text{lines} \times 10\ \text{m} \times 0.80\ \text{m}}$$

- Conventional cotton is noted Conv cotton
- **Statistical analysis**

All data were subjected to analysis of variance (ANOVA) using SPSS software (version 22.0; SPSS Inc., Chicago, IL, USA). When significance occurred, means were separated by Bonferroni test ($p < 0.05$). All data were presented as the mean ± standard errors with 3 replications.

3. Results

3.1. Insect Pests on Both Types of Cotton Crops

➢ **Farako Bâ**

Analysis of the data on sucking pest infestations by type of cotton production in Farako Bâ indicated a significant difference between treatments (**Table 2**). Whitefly adult infestations were lower in conventional cotton with 0.42 ± 1.10 than in organic and untreated cotton at Farako Bâ. *Jacobiella fascialis* were more important with 0.75 ± 1.66 on organic cotton than on conventional and untreated cotton. Infestations were significantly lower with 0.01 ± 0.08 plant for aphids and significantly higher with 0.3 ± 1.76 individual for *D.voëlkeri* in conventional cotton than in organic and untreated cotton.

➢ **Kombissiri**

Analysis of the sucking insects infestation data by type of cotton production at the Kombissiri site indicated a significant difference between treatments (**Table 3**). Only the level of *D. voëlkeri* infestations was significantly lower on the untreated plot with 0.250 ± 1.38 than on the conventional and organic cotton plot.

➢ **Fada**

Analysis of the data on sucking pest infestation by type of cotton production at the Fada site indicated a significant difference between treatments (**Table 4**). The levels of Whitefly larva and *A. gossypii* infestations on the organic cotton plot and those of *A. gossypii* on the untreated plot were significantly higher than on the conventional cotton.

Table 2. Infestation levels of insect pests at Farako bâ site.

Types of cotton	Whitefly adult	Whitefly larva	*J. fascialis*	*A. gossypii*	*D. voëlkeri*
conv cotton	0.42 ± 1.10*	0.07 ± 0.27	0.47 ± 1.04	0.01 ± 0.08*	0.3 ± 1.76*
organic cotton	0.46 ± 1.06	0.18 ± 0.38	0.75 ± 1.66*	0.03 ± 0.17	0.003 ± 0.05
Untreated cotton	0.57 ± 1.25	0.2 ± 0.40	0.57 ± 1.34	0.05 ± 0.23	0.01 ± 0.08

Farako bâ. ddl = 1290; Probability = 0.05 for organic cotton; Probability = 0.05 for conventional cotton; Probability = 0.05 for untreated cotton; *Significant.

Table 3. Infestation levels of insect pests at Kombissiri site.

Types of cotton	Whitefly adult	Whitefly larva	*J. fascialis*	*A. gossypii*	*D. voëlkeri*
Conv cotton	0.28 ± 0.86	0.011 ± 0.12	0.31 ± 0.77	0.01 ± 0.11	0.31 ± 1.28
Organic cotton	0.119 ± 0.38	0.31 ± 1.284	0.022 ± 0.61	0.001 ± 0.037	0.441 ± 1.77
Untreated cotton	0.011 ± 0.123	0.14 ± 0.452	0.213 ± 0.649	0.006 ± 0.095	0.25 ± 1.38*

Kombissiri. ddl = 1290; Probability = 0.05 for organic cotton; Probability = 0.05 for conventional cotton; Probability = 0.05 for untreated cotton; *Significant.

Table 4. Infestation levels of insect pests at Fada site.

types of cotton	Whitefly adult	Whitefly larva	*J. fascialis*	*A. gossypii*	*D. voëlkeri*
conv cotton	2.86 ± 3.89	0.46 ± 1.70	0.17 ± 0.52	0.16 ± 0.40	0.013 ± 0.12
organic cotton	2.5 ± 3.40	0.73 ± 2.25*	0.2 ± 0.57	0.22 ± 0.54*	0.099 ± 0.73
Untreated cotton	3.99 ± 4.31	0.59 ± 2.05	0.28 ± 0.74	0.22 ± 0.54*	0.17 ± 1.39

Fada. ddl = 1290; Probability = 0.05 for organic cotton; Probability = 0.05 for conventional cotton; Probability = 0.05 for untreated cotton; *Significant.

3.2. Beneficial Insects on Both Types of Cotton Crops

- **Farako Bâ**

There was high significance differences between treatments for the presence of beneficial insects in Farako bâ (Table 5). The presence of adult ladybirds was significantly higher with 0.02 ± 0.1 for organic cotton and 0.01 ± 0.1 for untreated cotton than on conventional cotton. Religious mantises, *P. lutescens,* spiders and ants population were significantly higher on organic cotton than on conventional and untreated cotton. Both organic and untreated cotton had significantly higher number of spiders than conventional cotton.

- **Kombissiri**

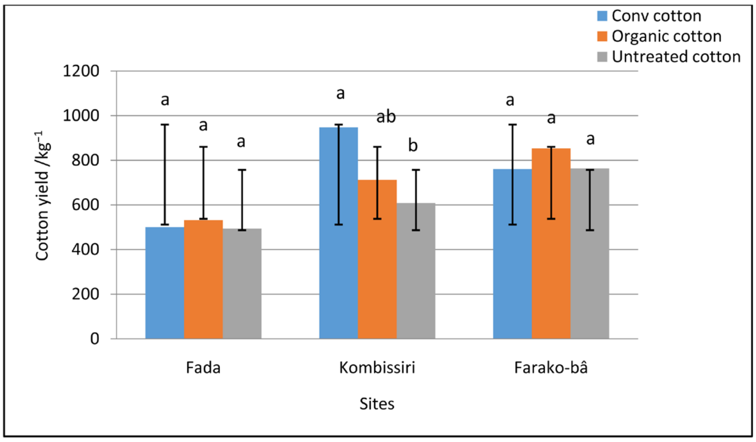
The level of beneficial insects was significantly different between treatments at Kombissiri (Table 6). The level of ladybird adult was higher on the organic cotton plot with 0.021 ± 0.20 individuals than on the conventional and untreated cotton which recorded 0.013 ± 0.16 and 0.01 ± 0.13 respectively. Spider populations were significantly lower with 0.002 ± 0.04 individuals in untreated cotton than in conventional and organic cotton with 0.004 ± 0.08 and 0.005 ± 0.07 respectively. Organic cotton plot registered significantly higher *P. lutescens* populations with 0.026 ± 0.15 individuals as compared to conventional cotton with 0.022 ± 0.15 and 0.018 ± 0.13 for untreated cotton.

- **Fada**

The level of beneficial insects in Fada varied according to the types of cotton production (Table 7). Adult of ladybirds were more present on untreated cotton with 0.02 ± 0.16 individuals than on conventional and organic cotton. Significantly higher spiders were observed on organic cotton with 0.04 ± 0.21 individuals than on conventional and untreated cotton. Ants were significantly more present on organic and untreated cotton than on conventional cotton.

- **Yield performance per location**

The observed seed cotton yields are summarized in Figure 3. The highest yields were 763.54 kg·ha^{-1} in untreated plots at Farako-bâ, 853.13 kg·ha^{-1} in plots treated with organic pesticides at Farako-bâ and 946.88 kg·ha^{-1} on conventional plots with chemical insecticides at Kombissiri. A significant difference was observed between treatments at Kombissiri. In this site, the organic cotton plots obtained higher yield (89.59 kg·ha^{-1}) than the untreated plot. On the other hand, plots treated with chemical insecticides produced more (93.75 kg·ha^{-1}) than the organic cotton plots.



Farako Bâ, F = 0.757, ddl = 9, Probability = 0.4966; Kombissiri, F = 5.320, ddl = 9, Probability = 0.0299; Fada, F = 0.2977, ddl = 9, Probability = 0.1018. Treatments with the same letters are not statistically different.

Figure 3. Cotton yield observed at Kouaré, Kombissiri and Farako bâ.

Table 5. Presence of beneficial insects at Farako bâ site.

Types of cotton	Ladybird adult	Ladybirdlarva	Religious mantises	*P. lutescens*	Spiders	Ants
Conv cotton	0.009 ± 0.09	0.002 ± 0.03	0.01 ± 0.02	0.01 ± 0.02	0.02 ± 0.13	0.06 ± 0.38
Organic cotton	0.02 ± 0.1*	0.010 ± 0.113	0.17 ± 0.66*	0.17 ± 0.66*	0.048 ± 0.21*	0.17 ± 0.66*
Untreated cotton	0.01 ± 0.1*	0.002 ± 0.03	0.002 ± 0.04	0.002 ± 0.04	0.04 ± 0.23*	0.09 ± 0.37

Farako bâ. ddl = 1290; Probability = 0.05 for organic cotton; Probability = 0.05 for conventional cotton; Probability = 0.05; for untreated cotton; *significant.

Table 6. Presence of beneficial insects at Kombissiri site.

Types of cotton	Ladybird adults	Ladybird larva	Ants	Spiders	Religious mantises	*P. lutescens*
Conv cotton	0.013 ± 0.16	0.002 ± 0.04	0.001 ± 0.037	0.004 ± 0.08	0.001 ± 0.02	0.022 ± 0.15
Organic cotton	0.021 ± 0.20*	0.015 ± 0.15	0.001 ± 0.037	0.005 ± 0.07	0.042 ± 0.24	0.026 ± 0.15**
Untreated cotton	0.01 ± 0.13	0.008 ± 0.12	0.001 ± 0.037	0.002 ± 0.04*	0.018 ± 0.17	0.018 ± 0.13

Kombissiri. ddl = 1290; Probability = 0.05 for organic cotton; Probability = 0.05 for conventional cotton; Probability = 0.05 for untreated cotton; *Significant; **highly Significant.

Table 7. Presence of beneficial insect at Fada.

Types of cotton	Religiousmantise	*P. lutesces*	Ladybird larva	Ladybird adults	Spiders	Ants
Conv cotton			0.009 ± 0.09	0.016 ± 0.14	0.01 ± 0.13	0.15 ± 0.49
Organic cotton			0.002 ± 0.04	0.006 ± 0.09	0.04 ± 0.21*	0.26 ± 0.86*
Untreated cotton	0.001 ± 0.02	0.007 ± 0.09	0.008 ± 0.08	0.02 ± 0.16 *	0.01 ± 0.23	0.49 ± 1.10 *

Fada. ddl = 1290; Probability = 0.05 for organic cotton; Probability = 0.05 for conventional cotton; Probability = 0.05 for untreated cotton; *Significant.

4. Discussion

The study on the influence of cotton crop types on *P. lutescens* populations showed that low levels of sucking bugs could be achieved in conventional cotton and acceptable levels of beneficial insects in organic cotton. The pest control program in conventional cotton used synthetic chemical insecticides at all three sites and resulted in lower infestations of *Bemisia tabaci*, jassids, *D. voëlkeri* and aphids. In the recommended cotton protection program, it was use Indoxacarb 25 g/ha, Lambdacyhalothrin-Profenofos 12 - 200 g/ha and Lambdacyhalothrin Acetamiprid 15 - 16 g/ha. However, it is noted that Lambdacyhalothrin Acetamiprid 15 - 16 g/ha which is a pyrethroid is more widely used against a wide range of pests [22]**.** Thus the good control of adults of *Bemisia tabaci*, *Aphis gossypii*, *Jacobiella fascialis* and *D. voëlkeri* in conventional cotton plots points to the mode of action of the Lambdacyhalothrin-acetamiprid combination which acts by contact and ingestion. It penetrates the insect cuticle to disrupt nerve conduction within minutes. This result is in agreement with those of [23] and [24] who showed that contamination of a pest with the combination of Lambdacyhalothrin-acetamiprid disrupts nerve conduction within minutes, leading to cessation of feeding, loss of muscle control, paralysis and eventual death. According to Acta (2015) [25], the combination Lambdacyhalothrin-Acetamiprid is effective in reducing cotton pest infestations by keeping them at low densities. Our experimental conditions indicate that the active ingredients used to control *B. tabaci*, aphids and *D. voëlkeri* populations were effective. This result on the efficacy of acetamiprid is in line with those of [26] [27] who showed the efficacy of acetamiprid in controlling *B. tabaci* and aphids. As for the results of the pest surveys on thresholds, they did not reach 10 infested plants out of 30 plants observed. This result is similar to the infestation threshold defined by [2] to control late cycle insect pests of cotton by keeping them below the threshold of 10 infested plants out of 30 observed plants. The pest survey showed that the presence of sucking bugs was dominated by *B. tabaci* (whitefly) and *A. gossypii* (aphids) and *D. voëlkeri* but did not reach the pest threshold on the three study sites (<10 infested plants out of 30 for the white fly and 21 infested plants out of 30 observed for *A. gossypii*). This observation is different from that of [28] who observed a strong presence of sucking bugs dominated by *B. tabaci* (whitefly) and *A. gossypii* (aphids) which reached the threshold of harmfulness in all the sites of their study (10 infested plants out of 30 observed plants). Concerning the low levels of infestation at the 3 sites, it is possible that the numbers of insect pests (*B. tabaci*, aphids, jassids and *D. voëlkeri*) and beneficial insects (ladybirds, praying mantises, *P. lutescens*, spiders and ants) were not sufficient to cause significant infestations. It is also possible that the action of the insects was limited by the scarcity of trophic support, the period of senescence of the plants and the harvesting of the cotton seed. This result is in harmony with that of [29] who reported that when food was scarce, sucking insects, especially *B. tabaci*, migrated to other host plants to ensure their survival. In the recommended pest management program for organic cotton, the combination of neem oil, chilli, liquid soap and *Bacillus thuringiensis* (*Bt*) was used. In general, the recommended pest control program in organic cotton seems to control jassids. The results of the present study revealed that neem oil has a good control on jassids. This good control of jassids could be explained by the synergistic effect created by the mixture [30]. Azadirachtin and its derivatives in neem seeds are obtained from crushed neem seeds [31]. They have been the subject of several studies. Some of these studies have shown that neem seed compounds contain a high amount of azadirachtin, which is a compound that regulates the dynamics of insect pests of crops and stocks, but also of insect vectors [32] [33] [34] [35] [36]. The effectiveness of neem seed juice in reducing the number of jassids was reported by [37] who showed that this substance reduced the damage of sap- and seed-sucking biters by about 37.9% in Burkina Faso. Sane *et al*., (2018) [38] reported that neem extracts show good efficacy on sap sucking biters. *Bacillus thuringiensis* was positioned to control late cycle pests. Jassids were less important in the organic cotton crop at Farako bâ. This result is in line with the results of other authors [39] [40] who have shown significant entomopathogenic activity of *B. thuringiensis* on several insect species. In the case of *Capsicum frutescens* L, its performance in plant protection results from the presence of alkaloids, saponins and flavonoids contained in the fruits of this botanical species [6]. Concerning beneficial insects, they are represented by ladybirds, spiders, ants, praying mantises and notably *P. lutescens*. In general, these beneficial insects were more present in the organic cotton plot than in the conventional cotton plot and the untreated plot. The use of Lambdacyhalothrin, which is a pyrethroid, must have limited the activity of beneficial insects. This result seems to confirm that of [41] who reported that pyrethroid insecticides could significantly affect the natural enemies (*Pharoscymnus ovoideus*, *P. numidicus* and *Cybocephalus palmarum*) of *Parlatoria blanchardi* in palm groves. Adult ladybird presence levels were higher on the organic cotton plot than on the conventional cotton. Conventional cotton when treated with commonly used insecticides belonging to the pyrethroid family may limit ladybird activity. This result corroborates that of [42] who reported on the toxicity of commonly used pyrethroids on sweet corn and soybeans that this family was harmful to the Asian ladybird beetle. As for the presence of natural enemies, the observed densities were low, however they were higher in the organic cotton crop than in the conventional cotton crop. The pest surveys show that, unlike the protection program recommended for conventional cultivation, the one recommended for organic production can be environmentally friendly. This result is in line with that of [43] who showed that plant extracts and in particular neem oil are biodegradable. For some authors, neem has no adverse effect on beneficial insects [44]. For seed cotton yield, the results showed that neem oil combined with chilli and soap and *B thuringiensis* resulted in 853.53 kg/ha for organic cotton and 531.25 kg/ha for untreated cotton. This result on seed cotton yield is in agreement with that of [6] who showed that Agri-bio-pesticide which is a neem based organic pesticide improved yield compared to the untreated control. Treatments with neem oil in organic cotton crop resulted in a yield increase of 312.28 kg/ha compared to the untreated. The observed yield increase is similar to that of [45] who showed the ability of *Azadirachta indica* extracts for its contribution in increasing the yield obtained on treated okra plots. Similar results on yield increase were obtained by [46] who showed that plots treated with *Azadirachta indica* leaf extracts gave the best marketable cabbage yields. Compared to the three study sites, infestations were almost below the threshold in both the northern and southern Sudanese zones, regardless of the species. The late arrival of rain in Fada, combined with insufficient rainfall at the end of the season, did not allow for a period of intense reproduction of sucking bugs. This result differs from that of [47] who observed that the end of the season is a period of intense reproduction of *A. gossypii* and B. tabaci, in preparation for migration to other crops. Furthermore, in humid areas, cotton plants enter their senescence phase late, which means that nutritive support is available for the sucking bugs, but the high rainfall would explain the low level of infestation of these sucking bugs, which could be washed away by rainwater or killed by runoff. The trials were planted at the same time on all three sites and did not show any influence of sowing dates on pest populations. This is different from some authors such as [48] [49], who stated that the presence of some pests is partly related to the phenology of the plant.

5. Conclusion

In this study the effectiveness of chemical protection as compared to protection provided by biopesticides in organic cotton cultivation. It was found that the conventional phytosanitary practice reduced *B. tabaci* (whiteflies), *A. gossypii* and *D. voëlkeri*. Infestations were lower in conventional cotton and natural enemy activity was high in organic cotton, while an acceptable cotton yield was achieved in the three experimental sites. Organic cotton protection should be promoted and strengthened in the farming environment against the main cotton pests. Producers need to be made more aware to enable them to optimize the use of these biopesticides on pests before damage occurs at the end of the cotton cycle. The results suggest *P. lutescens* is more adapted to integrated cotton pest management program. This could help to improve producers' income and consequently, reduce poverty among farmers in Burkina Faso.

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Conflicts of Interest

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

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