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Farmers knowledge and control of two major pests: *Helicoverpa armigera* (Hübner) (Lepidoptera, Noctuidae) and *Aphis gossypii* (Glover) (Homoptera: Aphididae) in five agroecological zones in Benin (West Africa)

Maurille T. Elégbédé[1,2], Isabelle A. Glitho[3], Elie A. Dannon[1], Orou K. Douro Kpindou[1], Martin Akogbéto[2,4], Manuele Tamò[1]

[1]*International Institute of Tropical Agriculture, Tri Postal, Cotonou, Benin*

[2]*Faculté des Sciences et Techniques de l'Université d'Abomey-Calavi, Cotonou, Benin*

[3]*Laboratoire d'Entomologie Appliquée, Faculté des Sciences, Université de Lomé, Lomé, Togo*

[4]*Centre de Recherche Entomologique de Cotonou (CREC), Cotonou, Benin*

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Abstract

A survey study was performed in five agro-ecological zones in Benin to assess farmers' knowledge and perception on the identification, damage recognition, applied control methods of two cotton insect pests *Helicoverpa armigera* Hübner and *Aphis gossypii* Glover. A total of 200 farmers were interviewed in the five agroecological zones in Benin, using semi-structured questionnaire interviews. Results revealed sound knowledge of farmers on the identity of *H. armigera* and *A. gossypii*. Farmers easily recognized *H. armigera* through its damage on different plant organs while *A. gossypii* was known only at high infestation stage. Moreover, many crops are listed as host plants for *H. armigera* and *A. gossypii* with different economic injuries. Control of these insect pests was done mainly by the use of chemicals with various application numbers and frequencies. The most applied chemicals for the control of *H. armigera* on cotton were Nurelle D 236 EC in zone 4 and 6, Thunder145 O-Teq in zone 5 and Tihan 175 O-Teq in zone 2, while protection against *A. gossypii* was done using mostly Thian 175 O-Teq except in the zone 6 where Fanga was used. The time interval between two treatments was 3-14 days depending on the product in use, the target insect and the agro-ecological zone. The effectiveness of the different products was diversely appreciated. Farmers claimed to be aware of the so many side effects of chemicals application. In organic cotton area, alternative method consisting of the use of botanical extracts was being experimented.

* **Corresponding Author:** Maurille T. Elégbédé ✉ melegbede@yahoo.fr

Introduction

Cotton (*Gossypium hirsutum* L., Malvaceae) is a main cash crop that contributes to socioeconomic development of Benin. It is the largest foreign exchange earner in this country (Morris, 1990). In 2009, its production accounts for 13% of the national Gross Domestic Product (GDP) in terms of added value and 60% of the industrial products in Benin (PMC, 2008). From 1993 to 2005, cotton production increased and rose a peak of 427,709 metric tons of cotton (lint and seed taken together) (MEF, 2010). But during the past years, the cotton sector has experienced a significant crisis, resulting in a drastic decreased production (Togbe *et al.*, 2012). Moreover, in Benin, this production is primarily due to extension of growing surface. From 1988 to 1998, cotton acreage increased by 400% (Sinzogan *et al.*, 2004). Various factors such as soil fertility (Van der Pol and Traore, 1993; Quak *et al.*, 1996), low and erratic rainfall, world market prices, high pest occurrence (Togbe *et al.*, 2012), insect resistance to pesticides (Martin *et al.* , 2000; Sinzogan *et al.*, 2004) affect the yield. The high pressure from insect pests remains the main factor that affects cotton production. According to Matthews and Tunstall (1994) more than 1326 species of insects cause damage to cotton plant at different stage of its development. More than five hundred (500) insect species and fifty pathogens were identified damaging cotton in sub-Saharan Africa, (Celini, 2001). In Benin, a dozen of insects belonging to four groups have been reported as major cotton pests. Of these, *H. armigera* and *A. gossypii* are two of the most important pests (Brevault, 2010). Control of these pests has been done mainly by applying synthetic pesticides through a calendar-based spraying (Togbe *et al.*, 2012). To control cotton pest, important quantity of pesticides are used. From 1993 to 2000, pesticides used in cotton production have risen from 1,972,764 litres to 2,314,127 litres representing an increase of 17.30% (OBEPAB, 2002). In 2010, cotton producers applied about 2,453,880 litres of pesticides (MEF, 2010). Despite the increment of pesticides quantities, the yield was not increased. On an average yield above 1500 kg per hectare in 1980s, the productivity decreased steadily, settling currently around 1100–1200 kg (Togbe *et al.*, 2012). To improve yields and reduce the amount of pesticides used, research has suggested the Staggered Targeted Control (in French Lutte Etagée Ciblée, known by the French acronym LEC) as an alternative to the conventional spraying strategy (CRA-CF, 2009).

The LEC is partly based on the estimation of the economic threshold of the targeted pest. The strategy then requires the recognition of pest for an assessment of damaging levels. The challenge of farmers is to know how to scout their own fields, identify each targeted pest in order to assess whether the economic threshold has been reached. Thereby, the success of LEC depends on the individual competence of farmers. Furthermore, when the threshold is reached, specific pesticide is applied to lower the population of the targeted pest (Sylvie *et al.*, 2001). Several studies show that farmers do not respect the institute recommendations such as pesticides quantities to manage pest (Sinzogan *et al.*, 2004; Togbe et al., 2012).

Beside chemical control, alternative method consisting of organic cotton production technique has been introduced by Non-Governmental Organizations (NGOs) in 1996/1997. Organic techniques are environmental sound and may avoid human hazards.

Thus, despite the Staggered Targeted Control, conventional spraying strategy and organic method, the cotton production has decreased. Efficiency of such method is not well establish as some key insect pests were difficult to control using organic techniques or synthetic pesticides as well. Indeed, beside their wide geographic distribution, *H. armigera* and *A. gossypii* are extremely polyphagous. Their infested several plants including vegetables. To their management, farmers used apply significant and increasing amounts of pesticides generally without respect of recommendations. To improve the production, it is essential that producers actively participate as true partners in the development of pests control programs (IRAM, 1998) through consideration of their socio-economic realities.

The present study aims at assessing the methods applied to control *H. armigera* and *A. gossypii*. Specifically, this study (1) evaluated farmers' knowledge and perception of *H. armigera* and *A. gossypii* in five agroecological zones in Benin*;* (2) surveyed farmers' current practices in managing these pests; and (3) summarized farmers' appreciations on production mechanism in order to improve control strategies.

Materials and methods

Study area

This study was conducted from March to June 2012 in five (out of the eight) agro ecological zones of Benin which differ in environmental characteristics and cropping system. Then, the sites choice was related to the cropping system. In fact, some major cotton pests (*H. armigera* and *A. gossypii*) also cause damage to vegetable crops such as tomatoes, okra, cabbage, cucumber, etc. The agro ecological zones 2, 4, 5 and 6 were selected in cotton production areas while zones 6 and 8 were chosen in vegetable production area. In the four cotton zones, zone 6 was a low cotton production zone. The zone 5 belongs to the transition zone between the subequatorial climate and the sudano climate of Benin. The characteristics of the different zones were as follow:

- The Borgou northern cotton-production area (Zone 2) with 20,930 km2, accounts for 18% of Benin surface. The climate was a Sudanese type with one annual rainfall season. Rainfall ranges from 1000 to 1300 mm per year and the average temperature was 27 °C (PANA-Benin, 2007). Soils were highly diverse and of ferruginous type ranging from clay loam soils or lateritic gravel to sandy soils supported by wooded savanna.

- The Atacora northern zone (zone 4) of 16,936 km2 was characterized by a Sudanese climate with different rainfall patterns varying from 1000 to 1500 mm per year and an average temperature of 27°C. Soils, usually ferruginous, support wooded or shrubby savannas and grasslands.

- The center cotton producing zone (zone 5) of 32,163 km2 was characterized by a Sudano-Guinean climate with two rainy seasons in the south and a Sudano-Sahelian type climate in the north with one rainy season. Rainfall ranges from 1000 to 1400 mm and the average temperature was 27° C. Various soil types were distinguished ranging from tropical ferruginous soils, sandy or sandy clay soils to hydromorphic black soils. Vegetation consisted of wooded or shrubby savannas and forest galleries.

- The "Terre de barre" zone (zone 6) of 6,391 km² was characterized by climate a Sudano-Guinean climate with a bimodal rainfall patterns (800-1400 mm). The average temperature was 27.6 °C. Soils were ferralitic. Usually red, they could be clayey sandy, structurally stable with low water holding capacity. Vegetation was frequently forest galleries.

- Fishing Zone (Zone 8). It extends over 3280 km² with a Sudano-Guinean climate. This climate was characterized by two rainy seasons. The rainfall varies from 1000 to 1400 mm and the annual average temperature is 27.2 °C. Soil were alluvial and colluvial. They are also hydromorphic or sandy. The main vegetation types were grassland, meadows and shrubby thicket.

In each agro-ecological zone, three villages were selected for a total of fifteen villages. In addition to these, organic cotton producers were interviewed at Kassakou (zone 2) and Wantéou (zone 4). Within each area, villages were chosen with the help of extension or research agents working in the area.

Data collection and analysis

Data were collected through survey involving individual semi-structured questionnaire interviewees. The questionnaire was elaborated and adjusted after a pre-test. Interviewees were selected taking into account either cotton or vegetables (tomato, okra or leafy vegetables) production. In each village, farmers participating in the survey were randomly sampled among cotton or vegetables producers with the help of extension or research workers. However, the decision to belong to the final sample was based on farmer's willingness. Gender issue was taken into

account. A total number of 200 farmers (including 35 women) were interviewed in 17 villages selected throughout the five agro-ecological zones. Interviews were conducted generally at farmers' home or fields with the assistance of farmers' association leaders. The study objectives were briefly explained to the participants prior to the survey.

Information on farmers' ability to recognize the two major cotton pests *H. armigera* and *A. gossypii,* their host plants and management practices were collected. The identification of each insect was based on their pictures or specimens. Knowledge on the plant parts damaged by each insect pest was additional information to confirm farmers' ability to recognize them. Farmers also gave information on practices or strategies applied to efficiently manage the two insect pests. The questionnaire was individually administered to farmers with the help of an interpreter when required.

Data collected in the different agro-ecosystems (conventional or organic cotton areas) were analyzed using descriptive statistics (averages, frequencies, etc.).

Results

Knowledge of A. gossypii and H. armigera by farmers

The majority of farmers interviewed easily identified *H. armigera* and *A. gossypii.* All the producers sampled (100%) identified the bollworm in zones 2, 4, 5, 8 and the organic cotton areas while 96. 66% did in zone 6. For 99.5 % of interviewed farmers, *H. armigera* heavily damaged cotton and tomato crops. According to the farmers, *H. armigera* destroyed buds, inflorescences, fruits or capsules, regardless of agro-ecological zones.

On the other hand, the percentage of farmers who were able to identify the aphid *A. gossypii* varied between agro-ecological zones. In the zone 5, all the producers (100%) knew *A. gossypii.* The percentages of farmers who could identify the aphid in the agro ecological zones 2, 4, 6, 8 and the organic cotton areas were 92.6%, 88.9%, 83.3%, 88.6 and 91.7%, respectively. An overall percentage of 91% of the producers could recognize *A. gossypii.* Most of the sampled farmers reported *A. gossypii* as a phyllophagous insect. Capsules infestation by the aphid was less known to farmers. The aphid was also known as a major vegetables insect pest.

Both insects have been well known to farmers since many years. High percentage of the farmers knew aphid and bollworm for more than 5 years. In zone 2, 88.01% of respondents claimed to know *H. armigera* for over 10 years against 65.19% for *A. gossypii.*

Crops infested by A. gossypii and H. armigera as assessed by farmers

The two insect pests *H. armigera* and *A. gossypii* were recognized as major problem in many cultures in all agro ecological areas. Nine and fourteen plant species were reported by farmers as host plants for *H. armigera* and *A. gossypii*, respectively. But, six crops were considered as main host plants of these two insect pests (Tables 1a and 1b). The bollworm *H. armigera* regularly infests cotton (100% on average), tomato (73.49%), okra (42.86%) and cowpea (37.5%). The caterpillars were reported to also damage sorghum and maize. The aphid *A. gossypii* attacked cotton (90.91% on average), cowpea (39.29%), okra (30.16%), tomato (20.40%) and vegetables with variable incidence. The aphid seriously infests leafy vegetables in zone 6 (61.11%) and zone 8 (77.04%). Farmers of zone 8 reported the aphis as pest on cabbage (22.22%), cucumber (33.33%) and pepper (14.70%).

Others crops are also infested by these pests at low rate. Farmers recognized *H. armigera* on yam (zone 4) and leafy vegetables (zone 8). The aphid was observed in low proportion on yam (zone 4), cassava (zones 4 and 5) and soybean (zone 2 and 4). In organic cotton areas, producers found *H armigera* (14.29%) and *A. gossypii* (7.14%) on groundnut.

According to very few farmers, the aphid could also infest tomato, sorghum, pepper, cassava, soybean, maize, groundnut and yams.

The impact of these insects varied with host plant. These pests could infest plant with limited damage and for that reason crops are not treated except for Couffo and Oueme valley.

The bollworm *H. armigera* was reported to be a key pest in cotton, tomato, okra, and to a lesser extent in cowpea. This insect was found to be a minor pest in cotton (20% of farmers) and tomato (31% of farmers) at zones 4 and 8, respectively. Aphid was reported to seriously damage cotton, vegetables, cowpea and sorghum but fewer losses were observed in okra and tomato. The aphid damage varied within some agro-ecological zones. The aphid *A. gossypii* is a major pest according to cassava producers while damage in soybean is little to moderate. In zone 8, other vegetable species such as cucumber, cabbage and pepper have been reported to be attacked by aphid.

Although damage by *A. gossypii* or *H. armigera* varied with host plant, they cause severe losses in cotton, cowpea and okra (appendix 1), while only *H. armigera* was found to be dangerous in tomato. On the other hand these two insect pests were considered as minor pests in maize.

Crop protection against H. armigera and A. gossypii
Importance of treatment against H. armigera and A. gossypii in different crops and methods used
Cotton was a major crop protected against *H. armigera* in all agroecological zones with exception to zone 8 where tomato was the most protected crop (Figure 1a). The least treated crops were cowpea in zone 2, 4, and 6, maize in zone 5, leafy vegetables in zone 8 and sorghum in organic cotton area. Generally, men were responsible of pest monitoring (89.5% of respondents).

Likewise, cotton was the first crop treated against *A. gossypii* in all agroecological zones except for zone 8 where leafy vegetables were the most protected (Figure 1b). The least treated crop varied between zones.

Protection against these two insect pests was done using chemicals, botanical extracts and sometime in combination with mechanic control.

Control of H. armigera and A. gossypii
The most applied method was chemicals use (Appendix 2). While this method followed a defined common strategy in cotton, farmers developed their own strategies to protect the other crops. Beside chemical application, biological control means were implemented in some target cotton villages with the help of Non-Governmental Organizations (NGOs). On the other hand, farmers also applied plant extracts or ash to protect various crops such as sorghum, okra on limited sowing areas. Chemical protection of others crops except cotton was done with various compounds present in the market.

Control of cotton pests followed three windows with two treatments. Chemicals used varied between agro-ecological zones and the target pest. The most used products for the control of *H. armigera* was Nurelle D 236 EC (Cypermethrin (36 g / L) / Chlorpyrifos (200 g / L) in zone 4 and 6, Thunder145 O-Teq (Betacyfluthrin (45 g / L) / Imidacloprid (100 g / L) in zone 5 and Tihan 175 O-Teq (Flubendiamid (100 g / l) / Spirotetramat (75 g / L)) (13,03%) in zone 2.

Protection against *A. gossypii* was done using mostly Tiihan 175 O-Teq in zones 2, 4 and 5, and Fanga in zone 6. Mixtures of two or more insecticides were sometimes applied to improve the control effectiveness.

In organic cotton area, aqueous neem was the product used to control insect pests. The neem extract was made of grounded neem seeds, or pepper (pili-pili), papaya leaves, garlic and traditional soap as emulsifier. In addition to this treatment, OBEPAB (in French: Organisation Béninoise pour la Promotion de l'Agriculture Biologique) suggested the use of residues from sweet local drink for attracting beneficial insects.

Number treatments for the control of H. armigera and A. gossypii

The number of chemicals or plant extracts application varied between zones and ranged from 2 to 3 for synthetic insecticides and 4 to 6 for plant products in organic cotton area (Figures 2a and 2b). The number of treatments against *A. gossypii* was generally lower than that against *H. armigera* with exception for vegetables production zones (zones 6 and 8) where the number of treatments exceeded two applications.

In total, 36.03% of respondents perform two treatments for the control of *H. armigera* against 63% those of *A. gossypii*. But the number of treatment against each pest depends on the target crop.

Frequency of treatments

The time interval between two treatments for the control of *H. armigera* varied between the different agro-ecological zones. It ranged between 3 and 14 days (Figure 3a). Relatively higher percentage of producers treated their crops every 14 days in zone 4 while the majority applied control measures with a time interval of 7 days in zones 5 and 6. In organic cotton area, most of the producers did one treatment every 3 days. In total, about 38.8% of producers treated their crops once every 7 days against 22.4% and 22.3% every 14 and 3 days, respectively in an interval of 14 days and 22.3% in an interval of three days.

Treatment frequencies for the control of *A. gossypii* varied between the different agro-ecological zones. The time interval ranged between 3 and 14 days (Figure 3b). In zones 2, 4 and 5 the majority of producers applied treatment every 14 days. But in zone 8 and organic cotton areas, the time interval between two treatments was mostly 7 days. Relatively important percentage of producers (39.3%) applied control measures every three days. The overall percentage of farmers applied control every 14 days was 41% against 33.7% and 15% for 7 and 3 days, respectively.

Effectiveness of treatment according to the producers

The perception of the effectiveness of the different control products used depends on the target insect species (Table 3). The majority of producers claimed that the different products applied were effective against *H. armigera* in all agro-ecological zones with exception to zone 2 where the producers were not satisfied. Products used to control *A. gossypii* were found to be effective in all agro-ecological zones (Table 2).

Damage by *H. armigera* was reported by most of the producers to be more serious than that done by *A. gossypii* (Figure 4). The aphid was considered as a minor insect pest regardless of the agro-ecological zone. Very few producers (14.5%) considered *A. gossypii* as a major insect pest compared to *H. armigera* in vegetables production areas (Zones 6 and 8).

According to the farmers, the impact of *A. gossypii* increased from north to south of Benin while the incidence of bollworm *H. armigera* decreased. In general for most of the farmers, management of cotton insect pests was not satisfactory. Farmers suggested the improvement of the current strategy by including other factors such as rainfall, specific crops needs, availability of good quality pesticides. Many farmers claimed that they have defined their own control strategies in the absence of good supervision by extension or research services.

Table 1a. Proportion of farmers identifying *H. armigera* as a pest of crops

Crops	Producers (%)					
	Zone 2	Zone 4	Zone 5	Zone 6	Zone 8	Organic cotton area
Cotton	100±0	100±0	100±0	33.33±33.33	0±0	100±0
Tomato	23.80±23.80	0±0	16.67±16.67	92.59±7.41	90.30±5.78	0±0
Okra	16.67±8.82	86.67±13.33	0±0	16.67±16.67	27.27±27.27	42.22±2.22
Sorghum	0±0	4.17±4.17	0±0	0±0	0±0	21.59±3.41
Cowpea	12.86±8.37	40.91±21.48	49.40±12.81	3.33±3.33	20±20	60±20
Maize	16.43±2.71	5.56±5.56	9.59±1.58	5.56±2.77	12.12±12.12	27.78±5.56
Others vegetables	0±0	0±0	0±0	0±0	28.48±14.33	0±0
Groundnut	0±0	0±0	0±0	0±0	0±0	14.29±14.29
Yam	0±0	8.83±5.25	0±0	0±0	0±0	0±0

*Means are followed by standard errors

Table 1b. Proportion of farmers identifying *A. gossypii* as a pest of crops

Crops	Producers (%)					
	Zone 2	Zone 4	Zone 5	Zone 6	Zone 8	Organic cotton area
Cotton	90.37±6.58	88.89±5.56	96.67±3.33	33.33±33.33	0±0	79.17±20.83
Tomato	13.09±7.24	0±0	44.44±29.40	25.40±12.99	18.18±10.50	0±0
Okra	30±25.17	6.67±6.67	0±0	16. 67±16.67	39.39±30.75	45.56±34.44
Sorghum	18.65±12.22	3.33±3.33	0±0	0±0	0±0	48.86±23.86
Cowpea	32.22±19.28	36.06±16.98	39.88±9.35	10±10	16.67±16.67	50±10
Maize	2.22±2.22	8.33±4.81	0±0	0±0	0±0	12.5±12.5
Leafy vegetables	0±0	0±0	0±0	61.11±30.93	77.04±7.04	0±0
Groundnut	0±0	0±0	0±0	0±0	0±0	7.14±7.17
Yam	0±0	5.56±5.56	0±0	0±0	0±0	0±0
Soybean	0±0	21.22±16.87	4.76±4.76	0±0	0±0	0±0
Cassava	11.11±11.11	11.11±11.11	0±0	0±0	0±0	0±0

*Means are followed by standard errors

Table 2: Effectiveness of perception of treatments on control of *A. gossypii* and *H. armigera*

	Effectiveness of strategy	Zone 2 (%)	Zone 4 (%)	Zone 5 (%)	Zone 6 (%)	Zone 8 (%)	Organic cotton areas (%)
H. armigera	Yes	31.11±31.11	91,67±8.33	81.11±15.67	60.56±26.18	88.64±2.66	95.83±4.17
	No	68.89±31.11	8.33±8.33	18.89±15.67	5.56±5.56	8.33±4.81	4.17±4.17
	Don't know	00±00	00±00	00±00	33.89±29.03	3.03±3.03	00±00
A. gossypii	Yes	100±00	85.71±8.25	88.891±11.11	100±00	90.3±5.78	90.48±9.52
	No	00±00	14.29±8.25	11.11±11.11	00±00	9.70±5.78	9.52±9.52

*Means are means of three villages, in zones 2, 4, 5, 6, 8 and two villages in organic cotton area

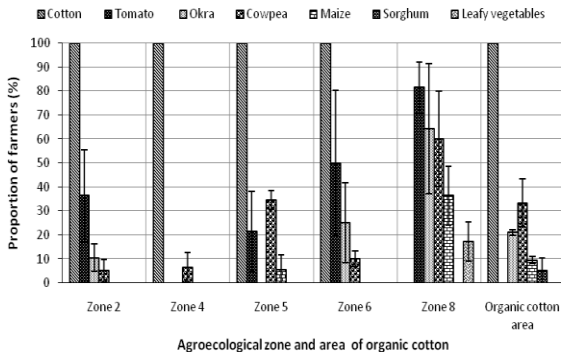

Figure 1a. Proportion of main crops undergoing treatment after infestation by *H. armigera*

*Lines in bars represent standard error of the means

**Means are means of tree villages, in zones 2, 4, 5, 6, 8 and two villages in cotton biological area

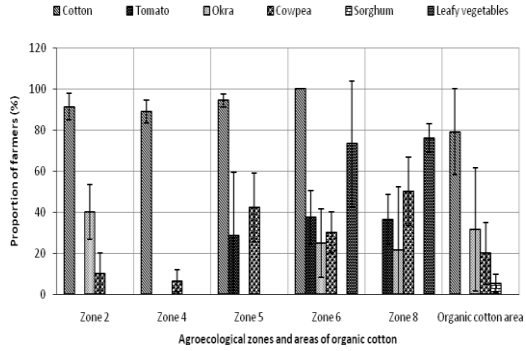

Figure 1b. Proportion of main crops undergoing treatment after infestation by *A. gossypii*

*Lines in bars represent standard error of the means

**Means are means of tree villages, in zones 2, 4, 5, 6, 8 and two villages in cotton biological area

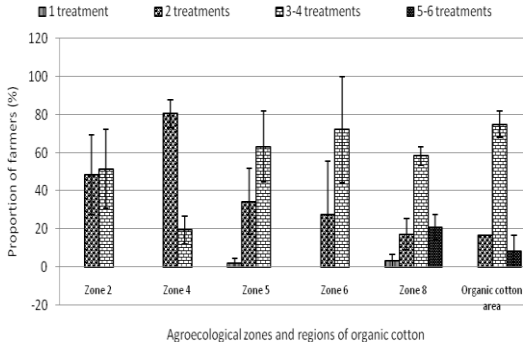

Figure 2a. Farmers performing a given number of treatments for the control of *H. armigera*

*Lines in bars represent standard error of the means

**Means are means of three villages, in zones 2, 4, 5, 6, 8 and two villages in organic cotton area

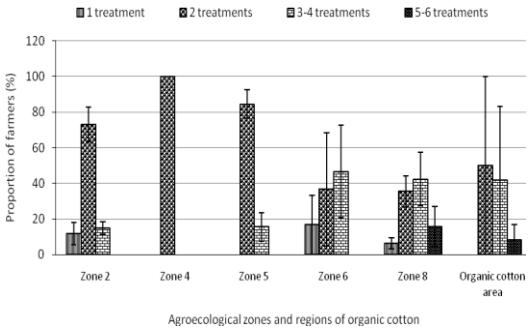

Figure 2b. Percentage of farmers performing a given number of treatments for the control of *A. gossypii*

*Lines in bars represent standard error of the means

**Means are means of three villages, in zones 2, 4, 5, 6, 8 and two villages in organic cotton area

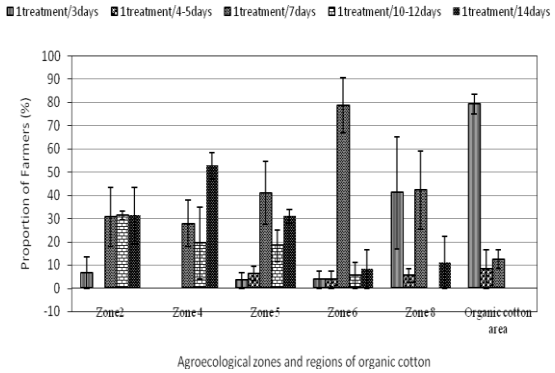

Figure 3a. Frequency of crop treatments against *H. armigera*

*Lines in bars represent standard error of the means

**Means are means of three villages, in zones 2, 4, 5, 6, 8 and two villages in organic cotton area.

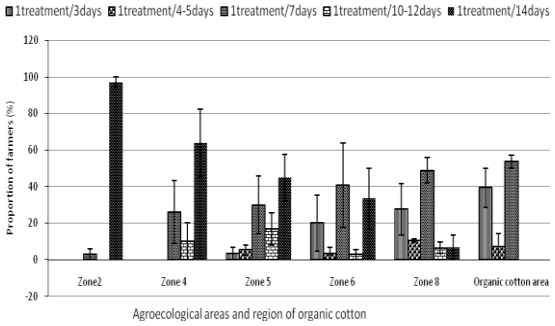

Figure 3b. Frequency of crop treatments against *A. gossypii*

*Lines in bars represent error standard of the means

**Means are means of three villages, in zones 2, 4, 5, 6, 8 and two villages in organic cotton area

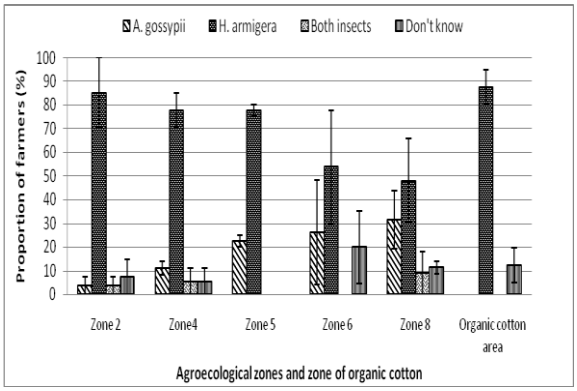

Figure 4. Perception of harmfulness ratio between *A. gossypii* and *H. armigera*

*Lines in bars represent error standard of the means

**Means are means of three villages, in zones 2, 4, 5, 6, 8 and two villages in organic cotton area

Discussion

Accurate identification and damage assessment remain key steps in defining effective control strategies of insect pests. The bollworm *H. armigera* and the aphid *A. gossypii* are major insect pests for several crops in Benin. The recognition of the pest status of these insects results in the importance of their damage. From the analysis of the results, farmers in the five agroecological zones have sound knowledge on *A. gossypii* and *H. armigera,* their damage and attacked organs even they were not able to give their scientific names. They are used to give local names to these insect species based on the attacked organs, the type of damage and the insect size or shape. The majority of farmers interviewed recognized *H. armigera* and *A. gossypii* as pests for many crops, confirming their polyphagy reported by Blackman and Eastop (2000). Farmers did recognized *H. armigera* (99.44% of interviewed farmers) better than *A. gossypii* (90.85% of interviewed farmers) because of the low visibility of aphid on plant leaves when their damage was not generalized to the whole plant. Indeed, at the beginning of their infestation, aphids live on leave tips, only observable when leaves were distorted. Thus, aphids that are small of size could be obvious at late development stage or when their population had increased in size (Velay *et al.*, 2001).

The different host plants reported by farmers for the two insect species have been already listed by several researchers. Indeed, *H. armigera* host plants include cotton, corn, potatoes, sorghum, tomato, *Phaseolus* spp. (EPPO, 2003), vegetables, pigeon pea, millet, groundnuts (Ali *et al.*, 2009.), Cowpea (Annecke and Moran, 1982) and okra (Yoshimatsu, 1995; Hamamura, 1998). Caterpillars of this moth seriously damaged host plants flowers or fruits (Mabbet *et al.*, 1980). The aphid *A. gossypii* considered early as minor cotton pest was ranked as major pest by interviewed farmers (Vaissayre *et al.*, 2006).

Knowledge and interest of farmers for these two insect pests were also related to the economic impact of their damage which depends on host plant species, the agro-ecological zone and the season (Cherry *et al.*, 2005). Caterpillars of *H. armigera* were found heavily damaging plants such as tomato and maize grown during the second season in fishing (Oueme valley) and Terre de barre (Allada) areas of Benin. The high level of *H. armigera* infestation was due to its high population building capacity (Ali *et al.*, 2009). Follin and Deat (2004) reported an increase in yield losses in the areas with two rainy seasons (90-100%) compared to the general yield losses (40-60%).

Farmers' perception on the economic impact of the two insect species varied between the agro-ecological zones and crops. The harmfulness of *H. armigera* as perceived by farmers decreased from north to south Benin, while that of *A. gossypii* increased. This observation may be related to cultivated plants in each area. Indeed, in addition to food crops grown throughout the country, cotton is the main cash crop in the north (zones 2, 4 and 5) while vegetable crops are more cultivated in the south (zones 6 and 8). When considering plant species, *H. armigera* was identified as major pest with the highest losses in cotton followed by tomato, okra and cowpea. Likewise, *A. gossypii* was found to induce high losses in cotton followed by vegetables (Leclant and Deguine, 1994).

Control of these two insect pests is done mainly by chemicals applications except for organic cotton areas

where farmers used biological control methods with the support of some Non-Governmental Organizations (NGOs). In Benin, only the conventional cotton system is well organized with elaborated calendar-based chemicals applications recommended by the national cotton research institute "Centre de Recherche Agricole Coton et Fibre". But farmers did not fully follow these recommendations especially for the number of applications (6), treatment frequency and pesticides doses. Choice of pesticides used to control insect pests in the other crops was associated to (1) pesticide availability, (2) cost of the pesticide and (3) advice of other farmers or sellers. In general, farmers lack in specific inputs for food crops. Thus, farmers in zones 2, 4 and 5 used cotton pesticides for food crops, increasing thereby food unsafety. In a survey study, Nebie *et al.* (2002) reported the presence of high concentrations of Cypermethrin (1 to 100 mg.kg-1 of MS) and Deltamethrin (12 to 146 mg.kg-1 of MS) in samples of fruits, vegetables and cereals treated with cotton pesticides. For producers, the choice of pesticides depends on the crop rather than the pest species explaining the reason why interviewed farmers used the same pesticides to control both *A. gossypii* and *H. armigera*. By doing so, farmer contribute to resistance development in *A. gossypii* for instance (Mallet and Luttrell, 1991; Delorme *et al*., 1997; Herron *et al*, 2001. Vergilino, 2004) and *H. armigera* (Alaux, 1994; Martin *et al*., 2000; Ochou and Martin, 2002; Brevault *et al*, 2008; Djihinto *et al*, 2009). In addition, Katary and Djihinto (2007) pointed out that increasing pesticide dose and application frequency could lead to a rapid resistance development. To solve this problem, research suggested the combination of different active matters. But, according to Sougnabe *et al*. (2010), 64.7% of the pesticides used were single formulation. On the other hand, in organic cotton areas where a new vision of sustainable development is being promoted, biological pests control was applied with the support of some NGOs such as Beninese Organization for the Promotion of Organic Agriculture (l'Organisation Béninoise pour la Promotion de l'Agriculture Biologique) known by French acronym OBEPAB at Kassakou (Kandi) (OBEPAB, 2002) and the "Cotton Project Alafia" at Wantéou (Materi). The use of botanical extracts including neem seeds extract, traditional soap, pepper and papaya leaves extract was proposed. Farmers appreciated this alternative method but complained about the extract preparation which was tedious and requires a high application frequency.

From the current survey study, farmers interviewed claimed to have a sound knowledge on *H. armigera* and *A. gossypii,* well recognized by specific damage, their economic impact. Different chemicals were applied to control them. However, farmers were aware of the so many side effects of this method and some of them appreciated alternative methods namely biological control. Such alternative method needs to be improved with supportive management system for large scale use.

Appendix 1. Perception of the impact of *H. armigera* and *A. gossypii* on some crops by farmers

Host Plants	Impact level	Producers (%)											
		Zone 2		Zone 4		Zone 5		Zone 6		Zone 8		Organic cotton area	
		H. armigera	*A. gossypii*	*H. armigera*	*A. gossypii*	*H. armigera*	*A. gossypii*	*H. armigera*	*A. gossypii*	*H. armigera*	*A. gossypii*	*H. armigera*	*A. gossypii*
Cotton	High	100±0	78±2.5	67±13	81±13	88±7.8	80±12	33±33	33±33	0±0	0±0	100±0	75±25
	Middle	0±0	4.4±4.4	11±5.6	5.6±5.6	6.7±6.7	6.7±6.7	0±0	0±0	0±0	0±0	0±0	0±0
	Low	0±0	8.3±5.3	22±18	2.8±2.8	5.6±2.9	10±10	0±0	0±0	0±0	0±0	0±0	4.2±4.2
Tomato	High	24±24	13±7.2	0±0	0±0	17±17	44±29	78±11	0±0	56±1.8	12±12	0±0	0±0
	Middle	0±0	0±0	0±0	0±0	0±0	0±0	8.3±8.3	0±0	3±3	0±0	0±0	0±0
	Low	0±0	0±0	0±0	0±0	0±0	0±0	6.5±3.3	25±13	31±7.6	6.1±6.1	0±0	0±0

Host Plants	Impact level	Producers (%)											
		Zone 2		Zone 4		Zone 5		Zone 6		Zone 8		Organic cotton area	
		H. armigera	*A. gossypii*	*H. armigera*	*A. gossypii*	*H. armigera*	*A. gossypii*	*H. armigera*	*A. gossypii*	*H. armigera*	*A. gossypii*	*H. armigera*	*A. gossypii*
Okra	High	6.7±6.7	17±12	73±27	6.7±6.7	0±0	0±0	0±0	17±17	21±21	33±33	42±2.2	40±40
	Middle	6.7±6.7	0±0	0±0	0±0	0±0	0±0	0±0	0±0	3±3	3±3--	0±0	0±0
	Low	3.3±3.3	13±13	13±13	0±0	0±0	0±0	17±17	0±0	3±3	3±3	0±0	5.6±5.6
Cowpea	High	4.8±4.8	26±21	18±14	36±17	36.9±7.2	37.5±7.2	0±0	2.8±2.8	6.7±6.7	10±10	40±0	50±10
	Middle	0±0	6.7±6.7	3±3	0±0	8.3±8.3	0±0	0±0	0±0	10±10	0±0	0±0	0±0
	Low	8.1±4.2	0±0	19±12	0±0	42±4.2	2.4±2.4	3.3±3.3	0±0	3.3±3.3	6.7±6.7	20±20	0±0
Maize	High	5.9±3.2	0±0	2.8±2.8	5.6±5.6	1±1	0±0	0±0	0±0	0±0	0±0	0±0	13±13
	Middle	0±0	0±0	0±0	0±0	0±0	0±0	0±0	0±0	3±3	0±0	8.3±8.3	0±0
	Low	11±5.4	2.2±2.2	2.8±2.8	2.8±2.8	8.6±1	0±0	5.6±2.8	0±0	9.1±9.1	0±0	19±2.8	0±0
Vegetables	High	0±0	0±0	0±0	0±0	0±0	0±0	0±0	61±31	6.4±3.2	59±2.3	0±0	0±0
	Middle	0±0	0±0	0±0	0±0	0±0	0±0	0±0	0±0	3.3±3.3	8.3±8.3	0±0	0±0
	Low	0±0	0±0	0±0	0±0	0±0	0±0	0±0	0±0	19±11	9.7±5.8	0±0	0±0

*Means are followed by error standard

Appendix 2: Products used for management of *H. armigera* and *A. gossypii* on other crops

Crops	Zone 2	Zone 4	Zone 5	Zone 6	Zone 8	Zone of organic cotton
			H. armigera			
Cowpea	Pacha, Sumitex Nurelle D, Thian	Thian	Nurelle D Thian, Thunder Lanbdacal	Thunder	Sumitex Pacha	Neem extract
Tomato	Nurelle D Thian (spécifique à Donwari)		Lambda super	Lambda super Fanga, Cypercal Lambdacal Pacha, Laser Tihan, Nurelle D	Super Omaye Tihan, Nurelle D Gazelle, Cystium Sumitex, Laser Attack, Cypercal Cypadem, Lambda Super	
Maize			Kotofan, Nurelle D		Sumitex, Pacha	Neem extract Local drink residue
Okra	Wood ash		Lambda super 2,5 EC	Wood ash, Sumitex		Wood ash
Vegetables					Attack, Pacha Cypercal, Laser Lambdacal	

Crops	Zone 2	Zone 4	Zone 5	Zone 6	Zone 8	Zone of organic cotton
Cowpea	Thian Neem extract	Tihan	Lambdacal Tihan, Thunder Nurelle D	Tihan	Cypercal Sumitex, Pacha	Neem extract
Tomato			Lambdacal Thunder	Lambdacal Pacha	Lambdacal Attakan, Laser Cypercal, Gazelle, Sumitex, Cypadem	
Okra	Wood ash			Wood ash	Laser, Cypercal Pacha, Sumitex	Wood ash
Leafy vegetables				Wood ash Lambdacal Cypercal, Laser Pacha, Sumitex	Attakan, Cypercal Cypadem, Pacha Sumitex, Laser Lambdacal Alphacal, Silpha 80	
			A. gossypii			
Cowpea	Pacha, Sumitex Nurelle D, Thian	Thian	Nurelle D Thian, Thunder Lanbdacal	Thunder	Sumitex Pacha	
Tomato	Nurelle D Thian (spécifique à Donwari)		Lambda super	Lambda super Fanga, Cypercal Lambdacal Pacha, Laser Tihan, Nurelle D	Super Omaye Tihan, Nurelle D Gazelle, Cystium, Sumitex Laser, Attack Cypercal, Cypadem Lambda Super	
Maize			Kotofan, Nurelle D		Sumitex, Pacha	
Okra	Wood ash		Lambda super 2,5 EC	Wood ash Sumitex		
Vegetables					Attack, Cypercal Laser, Pacha Lambdacal	
Cowpea	Thian Neem extract	Tihan	Lambdacal Tihan, Thunder Nurelle D	Tihan	Cypercal Sumitex, Pacha	
Tomato			Lambdacal Thunder	Lambdacal Pacha	Lambdacal Attakan, Sumitex Cypercal, Cypadem Gazelle, Laser	
Okra	Wood ash			Wood ash	Laser, Cypercal Pacha, Sumitex	
Leafy vegetables				Wood ash Lambdacal Cypercal, Laser Pacha, Sumitex	Attakan, Pacha Cypercal, Laser Cypadem, Sumitex, Silpha 80 Lambdacal, Alphacal	

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