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Effect of Insecticide on the Agronomic Impact Due to Insect Pests Associated with *Solanum Aethiopicum* L. (Solanaceae) in the Locality of Nkongoa (Centre Cameroon)

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Abstract
The search for a crop protection strategy against pests led us to research the effect of certain insecticides for peasant use on the African eggplant *Solanum aethiopicum* (Solanaceae). To this end, we carried out observations in Nkongoa (towards Mfou) on leaves, fruits and stems of *S. aethiopicum* in two fields previously set up by a farmer and differing by a treatment based on insecticides. The results showed that the damage caused on the leaves is caused by the whiteflies *Bemisia tabaci* (Aleyrodidae), the aphids *Aphis gossypii* (Aphididae) and the flea beetles *Epithrix* sp. (Chrysomelidae) while those caused on fruits and stems are mainly due to the eggplant shoot and fruit borer *Leucinodes orbonalis* (Pyralidae). The average leaf attack rates of *S. aethiopicum* due to aphids, whiteflies and flea beetles were higher in the untreated site (11.47±2.88% for *A. gossypii*; 14.45±2.69 % for *Bemisia tabaci* and 34.46±4.80% for *Epithrix*. sp) compared to the site treated with insecticides (4.30±1.33% for *A. gossypii*; 10.66±2.69% for *Bemisia tabaci* and 10.84±2.34% for *Epithrix* sp). This attack rate kept the same dynamic for *L. orbonalis* on the stems and fruits: high in the untreated site (11.25 ± 3.78% on the fruits and 5.41 ± 2.94% on the stems), compared to the treated site (5.51±1.83% on the fruits and 1.25±0.87% on the stems). The average number of individuals of *A. gossypii* and *B. tabaci* per leaf of *S. aethiopicum* was lower in the treated site (0.32±0.12 individuals/leaf for *A. gossypii* and 1.72±0 .66 individuals/leaf for *B. tabaci*) than in the untreated site (3.97±0.75 individuals/leaf for *A. gossypii* and 7.77±1.29 individuals/leaf for *B. tabaci*). These results are an asset in the search for possibilities of biorational use of insecticides in the chemical control of eggplant pests.

Keywords: *Solanum Aethiopicum*, Chemical Control, Attack Rate, Abundance, Pests

1. Introduction

The food insecurity that follows the increase in the population growth rate over the years has pushed the Cameroonian populations to engage in income-generating activities such as market gardening (Nguegang *et al*. 2005; FAO, 2017) [28, 16]. For these populations, mainly those in urban and peri-urban areas, market gardening has become not only the main activity (Kegne, 2002) [22], but also a very profitable activity (Kahane and Temple, 2004; Dongmo *et al*. 2005) [19, 12]. In northern Cameroon, the African eggplant, *Solanum aethiopicum* (Solanaceae) is the 5th most sold and most consumed vegetable species after tomatoes, carrots, cucumbers and lettuces (PSID, 2004) [30]. Cultivated species of eggplant have rapid growth and high nutritional value (Westphal *et al*. 1985; Kegne, 2002) [37, 22]. Its bitter fruits are used to treat various pathologies such as arterial hypertension, colic, uterine affections, cholera, diabetes, asthma, bronchitis (Grubben and Denton, 2004; Adeniji and Aloyce, 2012) [17, 2]. Despite this strong economic and food potential, African eggplant encounters many problems and undergoes many constraints: the emergence and diversification of pests due to the intensification of eggplant production systems, soil depletion, the high cost of agricultural inputs and their misuse, the almost non-existent marketing policies (Kumar, 1991) [24]. Some practices, such as the excessive and uncontrolled use of pesticides, insecticides and fertilizers, prove to be very dangerous for the environment, which is degraded by it, for farmers and consumers, whose health is threatened, but they can also lead to pest resistance problems (Djieto-Lordon and Aléné, 2006) [11]. Considering all these limitations, Kekeunou *et al*. (2006) [23] believe that it is necessary to undertake all the operations necessary to set up a control system that is both economical and has no harmful effect on the environment. For this, they strongly recommend integrated pest management. It combines physico-ecological, chemical and biological methods. Its implementation is essential in the protection of *Solanum aethiopicum* against these various pests in order to increase its yield; however, the associated chemical control must be conventional and biorational.

This study is a contribution to the knowledge of the effects of certain insecticides used by farmers in the fields of *Solanum aethiopicum* with a view to researching integrated pest management strategies. To carry out this work, we propose to: (i) describe the damage observed and caused by pests of economic importance on the different parts of *Solanum aethiopicum*; (ii) assess the attack rates due to pests of economic importance on the leaves, fruits and stems of *Solanum aethiopicum* according to the insecticide treatment; (iii) evaluate the average abundances of whiteflies and aphids on the leaves of *Solanum aethiopicum* according to the insecticide treatment.

2. Materials and Methods

2.1 Study Site

The study was conducted from March 10 to June 17, 2021, in the rainforest zone of southern Cameroon. We worked in Nkongoa (3°47’46.8’’N and 11°36’22.1’’E), a place located around Mfou 10 km away, department of Mefou and Afamba (Fig 1). This site with very degraded vegetation, belongs to the semi-deciduous forest domain and is under the influence of an equatorial climate of the Guinean type with four seasons (Suchel, 1987) [33]: a long dry season (mid-November to March); a short rainy season (mid-March to June); a short dry season (July to August); a long rainy season (September to mid-November). Temperatures are between 22 and 29°C. Our observations were carried out in the fields of vegetable crops of *Solanum aethiopicum* surrounded by *Chromolaena odorata*, *Eremomasta speciosa* (Acanthaceae), *Momordica charantia* (Cucurbitaceae), *Aquilinium* sp. (Polypodiaceae), *Canna indica* (Cannaceae), *Landolphia owarensis* (Apocynaceae) and *Pennisetum purpeurium* (Poaceae).

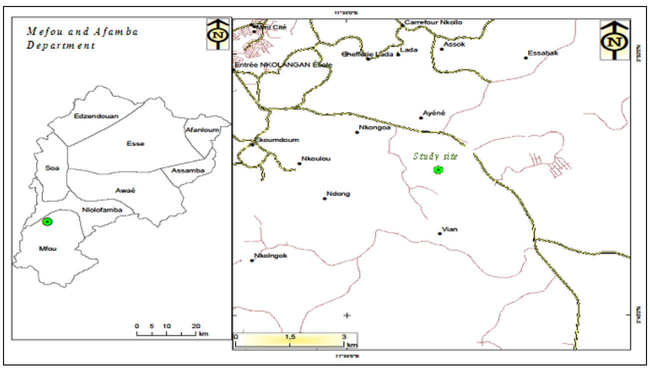


Fig 1: Location of the study site (Nkongoa)

2.2 Geology and Soil

According to Bachelier (1959) [5], the soil is lateritic and classic forest, with a more or less superficially leached red horizon which can reach a depth of 4 to 10 m under favorable conditions, then a gravelly horizon, a mottled horizon and a horizon of weathering of the substratum. In addition to swamps, this soil is poor in chemical elements but can support rich crops in semi-rural areas, if it is enriched or as long as a significant forest cover protects it from erosion.

2.3 Material

The plant material used during our study consisted of eggplant plants of the species *Solanum aethiopicum*, variety “jakatu”. The biological material consisted of insects observed on the different organs of eggplant plants. As for the technical equipment, it was field sheets, a pencil and an eraser to record the various data on the plots treated and not treated with insecticides.

2.4 Methodology

2.4.1 Characteristics of the experimental field

We worked in two sites, separated by a swamp, each constituting fields of *Solanum aethiopicum* of the "jakatu" variety of about one hectare, set up by a farmer. Site “A”, made up of relatively young plants, was untreated, while the plants on site “B” had regularly received applications of contact insecticides: Gaïman, a granule that repels leaf caterpillars; Cigoïne 360, against flies and wasps on fruit; Fixe, against white grubs, termites, ants, locusts and crickets and K-Optimal, against white flies (information received from the owner of the field). Each field was made of ridges 10 m long at the rate of 20 plants per ridge with spacing of 0.5 m between plants on the same line and 0.8 m between plants in two neighboring lines.

2.4.2 Data Collection

After having randomly chosen two ridges of 20 plants in each site, the work consisted of: (i) counting all the stems, leaves and fruits present on each plant, (ii) counting all the stems, fruits and leaves attacked by pests, (iii) recognize then count the pests of economic importance (aphids, whiteflies and flea beetles) observed on each organ of the plant, (iv) evaluate the attack rates due to each pest; this according to the two sites (treated and untreated).

2.4.3 Damage Evaluation

The attack rate on fruits (AR_F) / stems (AR_S) / and on leaves (AR_L) was calculated from the ratio of the number of fruits (ni_F) / stems (ni_S) and leaves (ni_L) attacked by it to the total number of fruits (N_F) / stems (N_S) and leaves (N_L) on the plant multiplied by 100, according to the formula:

$$\boldsymbol{AR_{F/S/L}\ (\%) = (ni_{F/S/L} / N_{F/S/L}) \times 100}$$

Where:

$AR_{F/S/L}$ (%) = Attack Rate on Fruits/Stems/Leaves

2.5 Data Analysis

Excel 2013 software was used to enter the data and build the graphs. The “Statistica” software version 8.0 (2007) allowed us to calculate the averages and compare them using the Analysis of Variance test (ANOVA) and Post hoc Tukey test. All these results were assessed with a degree of significance of 0.05.

3. Results

3.1 Average number of *A. gossypii* and *B. tabaci* per leaf of *S. aethiopicum* per treatment

The average number of individuals of *A. gossypii* per leaf of *S. aethiopicum* according to the treatments showed a highly significant variation (ddl=1, F=26.29, P=0.00000) with average values 12 times lower (0.32±0.12 individuals/leaf; Min=0.08; Max=0.56; N=40) in the treated site than in the untreated site (3.97±0.75 individuals/leaf; Min=2.45; Max=5.49; N=40). This variation was the same for *B. tabaci* (ddl=1; F=14.18; P=0.00006) with ever higher averages in the untreated site (7.77±1.29 individuals/leaf; Min=5.16; Max=10.38; N=40) than in the treated one (1.72±0.66 individuals/leaf; Min=0.38; Max=3.06; N=40). Considering the two suckers individually, *B. tabaci* is more abundant on eggplant leaves compared to *A. gossypii* (Table 1).

Table 1: Mean number of *A. gossypii* and *B. tabaci* per leaf of *S. aethiopicum* per treatment

Pest suckers	Sites		Probability values			N
	Treated	Untreated	ddl	F	P	
Aphis gossypii	0.32±0.12a	3.97±0.75b	1	26.29	0.00000	40
	(0.08-0.56)	(2.45-5.49)				
Bemisia tabaci	1.72±0.66a	7.77±1.29b	1	14.18	0.00006	40
	(0.38-3.06)	(5.16-10.38)				
Mean±SD	**1.02±0.81**	**5.87±2.19**				

Note: Data in parentheses represent confidence intervals of the mean at +/- 95.00% (Tukey test).

3.2 Mean number of leaves per plant of eggplant per treatment

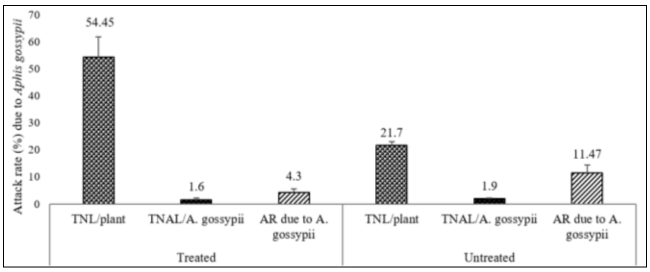
The average total number of leaves per eggplant plant during the study showed significant variations depending on the treatments (ddl=1; F=18.24; P=0.000054). This number was 2.5 times higher in the treated eggplant site (with a value of 54.45±7.52 leaves; Min=39.23; Max=69.66; N=40) than in the untreated eggplant site (21.70±1.49 leaves; Min=18.68; Max=24.71; N=40) (Fig 2).

3.3 Index damage (%) on leaves

3.3.1 Index damage (%) due to *Aphis gossypii* on leaves per treatment

The average number of leaves of *S. aethiopicum* attacked by *Aphis gossypii* showed non-significant variations depending on the treatments (ddl=1; F=0.23; P=0.63) with values of 1.60±0, 52 leaves; Min=0.54; Max=2.65 in the treated site and 1.90±0.34 leaves; Min=1.20; Max=2.59; N=40 in the untreated site (Fig 2).

The attack rate on leaves of *S. aethiopicum* due to *Aphis gossypii* showed significant variations depending on the treatments (ddl=1; F=5.08; P=0.02). It is higher in the untreated site (11.47±2.88%; Min=5.62; Max=17.31, N=40) compared to the treated site (4.30±1.33%; Min=1.60; Max=6.99; N=40) (Fig 2).



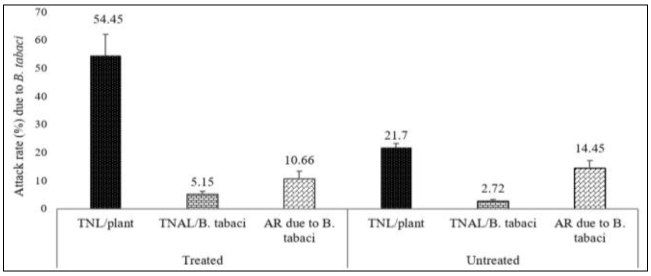
Note: TNL=Total number of leaves; TNAL=Total number of attacked leaves; AR=Attack rate (%).

Fig 2: Index damage (%) due to *Aphis gossypii* on leaves of *S. aethiopicum*

3.3.2 Index damage due to *Bemisia tabaci* on leaves per treatment

The average number of leaves of *S. aethiopicum* attacked by *Bemisia tabaci* presented non-significant variations depending on the treatments (ddl=1; F=3.78; P=0.05) with values of 5.15±1.11 leaves; Min=2.90; Max=7.40 in the treated site and 2.72±0.56 leaves; Min=1.58; Max=3.87; N=40 in the untreated site (Fig 3).

The attack rate on leaves of *S. aethiopicum* due to *Bemisia tabaci* presented non-significant variations depending on the treatments (ddl=1; F=0.98; P=0.32) with values of 10.66± 2.69%; Min=5.30; Max=16.02 in the treated site and 14.45±2.69%; Min=9.09; Max=19.81; N=40 in the untreated site (Fig 3).



Note: TNL=Total number of leaves; TNAL=Total number of attacked leaves; AR=Attack rate (%).

Fig 3: Index damage (%) due to *Bemisia tabaci* on leaves of *S. aethiopicum*

3.3.3 Index damage (%) due to *Epitrix* sp. on leaves per treatment

The average number of leaves of *S. aethiopicum* attacked by *Epitrix* sp. presented non-significant variations depending on the treatments (ddl=1; F=2.55; P=0.11) with values of 4.77±0.94 leaves; Min=2.55; Max=6.39 in the treated site and 6.52±0.86 leaves; Min=4.77; Max=8.27; N=40 in the untreated site (Table 2). The attack rate on leaves of *S. aethiopicum* due to *Epitrix* sp. presented significant variations according to the treatments (ddl=1; F=19.49; P=0.000032) with values of 10.84±2.34%; Min=6.09; Max=15.59 in the treated site, lower than those of the untreated site (34.46±4.80%; Min=24.74; Max=44.18; N=40) (Table 2).

Table 2: Attack rate (%) due to *Epitrix* sp. on leaves per treatment

Variables	Study sites		Probability values			N
	Treated	Untreated	ddl	F	P	
MNAL/ *Epitrix* sp.	4,47±0,94	6,52±0,86	1	2.55	0.11	40
	(2.55-6.39)	(4.77-8.27				
AR% due to *Epithrix* sp.	10,84±2,34	34,46±4,80	1	19.49	0.003	40
	(6.09-15.59)	(24.74-44.18)				

Note: MNAL=Mean number of attacked leaves; AR=Attack rate (%); Std. Err. =Erreur Standard. Data in parentheses represent confidence intervals of the mean at +/- 95.00% (Tukey test).

3.4 Index damage (%) on fruits due to *Leucinodes orbonalis* per treatment

We noted a highly significant variation in the average total number of eggplant fruits depending on the treatments (ddl=1; F=93.20; P=0.0000) because the averages show more fruits on the treated plants (14.70±1.37 fruits/plant; Min 11.92; Max=17.47; N=40) than on those not treated with insecticide (1.25±0.24 fruits/plant; Min 0, 76; Max=1.73; N=40) (Table 3).

We did not note any significant variation to the number of fruits attacked by *L. orbonalis* according to the insecticide treatment (ddl=1; F=3.39; P=0.06). However, by generating the averages, we note slightly more attacked fruits in the treated site (1.30±0.42 attacked fruits; Min=0.43; Max=2.16; N=40) compared to the untreated site (0.45±0.17 attacked fruits; Min=0.10; Max=0.79; N=40) (Table 3).

The attack rate on fruits due to *L. orbonalis* did not vary significantly according to the insecticide treatment (ddl=1; F=1.86; P=0.17) with an average attack rate of 5.51±1.83%; Min=1.80; Max=9.21; N=40 for the treated site and 11.25±3.78%; Min= 3.60; Max=18.89; N=40 for untreated site (Table 3).

Table 3: Mean number of fruits of eggplant and attack rate (%) due to *Leucinodes orbonalis* per treatment

Variables	Study sites		Probability values			N
	Treated	Untreated	ddl	F	P	
Mean Number of fruits	14.70±1.37 (11.92-17.47)	1.25±0.24 (0.76-1.73)	1	93.20	0.00001	40
Mean Number of attacked fruits	1.30±0.42 (0.43-2.16)	0.45±0.17 (0.10-0.79)	1	3.39	0.06	40
Attack rate (%) on fruits due to *L. orbonalis*	**5.51±1.83% (1.80-9.21)**	**11.25±3.78% (3.60-18.89)**	**1**	**1.86**	**0.17**	**40**

Note: Data in parentheses represent confidence intervals of the mean at +/- 95.00% (Tukey test).

3.5 Index damage (%) on stems due to *Leucinodes orbonalis* per treatment

With regard to the stems, we note an always significant variation in the total number of stems according to the treatments (ddl=1; F=38.83, P=0.00000). The ratio of the means of the total number of stems in the treated site (5.65±0.48 stems/plant; Min=4.66; Max=6.33; N=40) to this same number in the untreated site (2.55±0.14 stems/plant; Min=2.25; Max=2.84; N=40) is 2.21 (Table 4).

Similarly, there were no significant differences to the number of stems attacked by *L. orbonalis* depending on the insecticide application (ddl=1; F=1.06; P=0.30); the averages being 0.05±0.03 attacked stems/plant; Min=-0.020; Max=0.12; N=40 for the treated site and 0.12±0.006 attacked stems/plant; Min=-0.004; Max=0.25; N=40 for the untreated site.

Considering fruits and stems individually, we find that *L. orbonalis* is more interested in fruits than stems regardless of treatment (Tables 3 and 4).

The same is true for the stems where there was no significant variation to the rate of attack on the stems depending on the treatment (ddl=1; F=1.83; P=0.17); with an average attack rate of 1.25±0.87%; Min=-0.51; Max=3.01 on treated site and 5.41±2.94%; Min=-0.54; Max=11.37 on those not treated with insecticide; N=40 (Table 4).

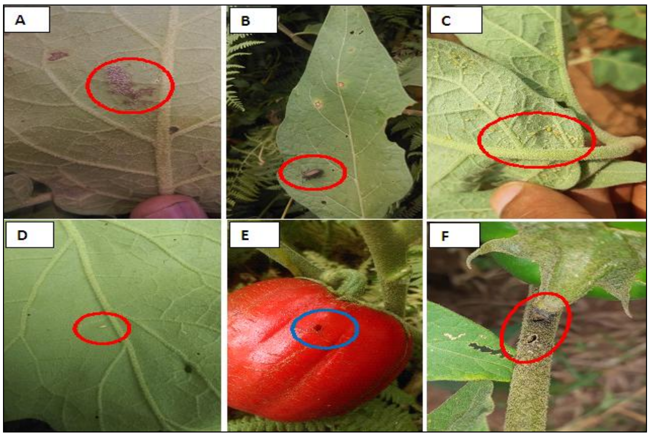
Table 4: Mean number of stems of eggplant and attack rate (%) due to *Leucinodes orbonalis* per treatment

Variables	Study sites		Probability values			N
	Treated	Untreated	ddl	F	P	
Mean Number of stems	5.65±0.48 (4.66-6.33)	2.55±0.14 (2.25-2.84)	1	38.83	0.00001	40
Mean Number of attacked stems	0.05±0.03 (-0.02-0.12)	0.12±0.06 (-0.004-0.25)	1	1.06	0.30	40
Attack rate (%) on stems due to *L. orbonalis*	**1.25±0.87% (-0.51-3.01)**	**5.41±2.94% (-0.54-11.37)**	**1**	**1.83**	**0.17**	**40**

Note: Data in parentheses represent confidence intervals of the mean at +/- 95.00% (Tukey test).

3.6 Observed damage on field due to pests on leaves, stems and fruits

During our observations, we identified several types of damage, some of which are illustrated in Fig 4: perforations of leaves, fruits and stems; silvering of the foliage; discoloration of the fruits, presence of rust on the foliage, presence of completely gnawed leaves, lack of growth of the stems and leaves. This damage was much more marked in the field not treated with insecticide.



Note: A: damage due to *B. tabaci*; B: leaf perforation by *Epithrix* sp.; C: *A. gossypii* on leaf; D: *B. tabaci* on leaf; E) fruit perforated by *L. orbonalis* larvae; F) Stem punctured by *L. orbonalis* larvae.

Fig 4: Field damage caused by agronomic importance pests

4. Discussion

We noted that the damage observed on the different parts of *Solanum aethiopicum* is due to *Aphis gossypii*, *Bemisia tabaci* and *Epithrix* sp. (on leaves), and *Leucinodes orbonalis* (on fruits and stems). These insects are an integral part of the 12 orders and 62 families of arthropods inventoried by Elono Azang (2017) [14] in his study of the arthropodofauna associated with some market gardening Solanaceae in the locality of Okola (peri-urban area of Yaoundé). According to Bordat and Arvanitakis (2004) [7], *Epithrix* sp. holes in eggplant leaves and causes serious damage to young eggplant plants in the event of heavy outbreaks; *Leucinodes orbonalis* bores eggplant fruits, devouring the interior and can also act as a stem borer; the saliva of *Bemisia tabaci* causes silvering of the foliage while *Aphis gossypii* is a vector of viruses and leads to the discoloration of the leaves.

Attack rates on *S. aethiopicum* leaves due to aphids and whiteflies are higher in the untreated site compared to the treated site. The contact insecticides (Gaïman, Cigoïne 360, Fixe and K-Optimal) applied by farmers would have the effect of keeping these pests away from the leaves of the plant. The similar results observed with the attack rate due to *Epithrix* sp. reinforce the hypothesis raised above on the repellent effect due to insecticides.

In terms of mean abundance of the two sap-sucking pests, *B. tabaci* was more abundant on eggplant leaves compared to *A. gossypii* at both sites. This result could be explained by the gregarious behavior of *B. tabaci* whose life in a colony causes leaf curling in Solanaceae (Bordat and Arvanitakis, 2004) [7]. If *B. tabaci* populations are so difficult to manage in the field, it is in particular because of their high population growth rate and their great capacity to rapidly develop resistance (Horowitz *et al*. 2011) [20].

By considering the attacks on the fruits and stems of eggplant, in addition to the repellent effect of the insecticides mentioned above, we found that the larvae of *Leucinodes orbonalis* prefer the fruits more than the stems. This typical behavior of fruit pest is in agreement with the work of Elono Azang (2017) [14] and Owoundi (2020) [29] working on the incidence of *Leucinodes orbonalis* on fruits in the field. This fruit and shoot borer is considered the most important pest of *Solanum aethiopicum*. It can cause 100% damage if no control measures are put in place (Lester and Seck, 2004) [25]. In South Asia, *L. orbonalis* causes significant damage to *Solanum* sp. especially during the fruiting stage and during fruit harvests (FAO, 2003) [15]. The non-significant difference observed on the attacked fruits and stems as well as on the attack rates due to *Leucinodes orbonalis* on eggplant fruits and stems according to the insecticide treatment (treated site and untreated site), should be explained by the endophytic character of its larvae which remain protected from contact insecticides (Djiéto-Lordon and Aléné, 2006) [11]. *Leucinodes orbonalis* can infest other plants of the same family as eggplant (Solanaceae); indeed, Schippers (2004) [31] found this species in attacked fruits of *Capsicum annuum* and their results showed an attack rate of 1.06% with a relative abundance of 9%.

S. aethiopicum pests did not disappear in the field that received insecticide applications. This could be explained by the empirical use of these insecticides by farmers, but also by the resistance developed by pests. Indeed, resistance to insecticides in *B. tabaci* is now widespread and applies to most of the chemical classes used, including those that have recently arrived on the market (Basit, 2019, Horowitz *et al.* 2020) [6, 20]. According to the Arthropods Pesticide Resistance Database (Whalon *et al*. 2019) [36], there are now around 650 reported cases of insecticide resistance in the genus *Bemisia*, which involve more than 60 different active substances.

5. Conclusion

The study carried out in the eggplant fields of Nkongoa (Mfou) enabled us to obtain some preliminary data on the effect of the insecticides used by the farmers in the fields. Gaïman, Cigoïne 360, Fixe and K-Optimal have a repelling effect on pests associated with eggplant; the attack rates due to the various pests and their average abundance being low in the treated site. Despite the low values of the epidemiological characteristics and the fact that the pests do not completely disappear in the treated field, this result is encouraging for the possibilities of biorational use of these insecticides as a chemical control agent against pests of *S. aethiopicum*.

6. Acknowlegments

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