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Comparative Effect Of Abamectin, *Bacillus Thuringiensis, Metarhizium Anisopliae* And A Pheromone Trap On The Tomato Leaf Miner *Tuta Absoluta* Meyrick (Lepidoptera : Gelechiidae) Infestation In The Western Highland Of Cameroon.

Effet Comparé D'abamectine, Bacillus Thuringiensis, Metarhizium Anisopliae Et Du Piege A Pheromone Sur L'infestation De La Chenille Mineuse De La Tomate Tuta Absoluta Meyrick (Lepidoptera : Gelechiidae) Dans Les Hautes Terres De L'ouest Cameroun.

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ABSTRACT

Tuta absoluta has been the main pest of tomato crops in Cameroon since 2016. The main control method used against it is chemical control. However, *T. absoluta* is resistant to most chemical insecticides, which are also dangerous for human health and for the environment. This study was conducted with the aim of promoting integrated control strategies through the use of pheromone traps and biological insecticides as a control method. To do this, a device was set up in the villages of Lépé and Lépo in the Nkong-ni subdivision in west of Cameroon. The bioinsecticides used were Biotrine (abamectin), Antario (*Bacillus thuringiensis*) and Recharge (*Metarhizium anisopliae*) and the pheromone trap that was used was the synthetic pheromone of the female pest. The chemical insecticide used was Emacot (emamectin benzoate). In Lépé the treatments were Biotrine alternated with Antario + Recharge, Emacot (positive control) and in Lépo they were Biotrine alternated with Antario + pheromone trap and Emacot + pheromone trap. The parameters examined were caterpillar abundance, infestation rate, percentage of fruit damaged and yield losses. For all these parameters, the results reveal that the treatments applied to Lépé have similar performances as those applied to Lépo. However, the comparison of the two plots shows better results in Lépo. The number of caterpillars per plant is 6.35 against 14.54 in Lépé, the infestation rate of 33.74% against 45.65% in Lépé, the percentage of damage on the fruits and the losses in yield are respectively 3.6 times and 2.9 times less important.

Key words: Tomato, *Tuta absoluta*, bioinsecticides, pheromone trap, highland Cameroon

RESUME

Tuta absoluta est le principal ravageur des cultures de tomate au Cameroun depuis 2016. La principale méthode de lutte employée contre elle est la lutte chimique. Cependant *T. absoluta* s'avère résistant à la plupart insecticides chimiques. Cette étude a été menée dans le but de promouvoir des stratégies de lutte intégrée à travers l'utilisation des pièges à phéromones et des insecticides biologiques. Pour ce faire, un dispositif a été mis en place dans les villages Lépé et Lépo de l'arrondissement de Nkong-ni à l'Ouest Cameroun. Les bioinsecticides utilisés ont été Biotrine (abamectine), Antario (*Bacillus thuringiensis*) et Recharge (*Metarhizium anisopliae*) et la phéromone synthétique de la femelle. L'insecticide chimique employé a été Emacot (émamectine benzoate). A Lépé les traitements ont été Biotrine alterné avec Antario + Recharge, Emacot (témoin positif) et à Lépo Biotrine alterné avec Antario + piège à phéromone et Emacot + piège à phéromone. Les paramètres examinés ont été l'abondance des chenilles, le taux d'infestation, le pourcentage de fruits endommagés et les pertes en rendement. Pour tous ces paramètres, les résultats révèlent que les traitements appliqués à Lépé présentent des performances similaires tout comme ceux qui ont été appliqués à Lépo. Par contre, la comparaison des deux parcelles montre de meilleurs résultats à Lépo. Le nombre de chenille par plant y est de 6,35 contre 14,54 à Lépé, le taux d'infestation de 33,74% contre 45,65% à Lépé, le pourcentage de dégâts sur les fruits et les pertes en rendement sont respectivement 3,6 fois et 2,9 fois moins importantes qu'à Lépé.
Mots Clés : Tomate, *Tuta absoluta*, bioinsecticide, piège à phéromone, hautes terres de l'Ouest Cameroun

Introduction

Tomato culture (*Lycopersicon esculentum* Mill.) is an important economic activity in Cameroon, with a total production of 1,279,853 tonnes in 2017 (FAO, 2017). It is the most widely grown and most consumed vegetable in the country (FAO, 2017). Its fruits are appreciated for the taste quality they give to sauces, soups or salads. Processed products such as sweets, wine, juice, tomato puree and canned tomatoes are also of great economic importance (PROTA, 2008).

While tomato production in Cameroon has grown in the last twenty years (Guay, 2016), it is now seriously threatened by a major pest, especially the tomato leaf miner or *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae). The latter devours the parenchyma of the leaves causing their necrosis (Ramel and Oudard, 2008), destroys the apical and axillary buds, causes the fall of the flowers and destroys the bay after having perforated the fruits (Fraval, 2009). It can therefore be responsible for losses ranging from 80 to 100%, both in the field and under shelter (Olama, 2017). In Cameroon, the presence of the insect was reported in 2016 in several localities, including the district of Dschang, where it is currently considered to be the most important pest of the tomato (Olama, 2017). This is not only because of the intensity of attacks on leaves, flowers and fruits (Krid and Messati, 2013), but also because of its presence throughout the crop cycle (Oliveira *et al.*, 2008).

Since the introduction of this leaf miner in several countries, as in Cameroon, chemical control has been the main control method used to control it (Santos and Silva, 2008, Olama 2017). However, the efficacy of chemical insecticides is poor, due on the one hand to the endophytic behaviour of the caterpillar, protected in the mesophilic leaves or in fruits (Cocco *et al.*, 2013) and on the other hand to the development of resistances in the pest with respect to several groups of insecticides and active ingredients (Siqueira *et al.*, 2000a, Siqueira *et al*., 2000b, Siqueira *et al.*, 2001, Lietti *et al*., 2005, Santos and Silva, 2008, Reyes *et al.*, 2012), including pyrethroids (Guedes and Picanço, 2012), organophosphates, insecticides based on spinosad, emamectin benzoate (Campos *et al*., 2014), and diamide (Roditakis *et al.*, 2015). Furthermore, their use has many disadvantages including profit reductions due to the high cost of insecticides, the destruction of natural enemy populations (Kaouthar *et al*., 2011), the deposit of insecticide residues on fruits, and the environment (Onil, 2014). In an effort to reduce the excessive use of chemical insecticides in tomato crops, environmentally friendly control strategies have been developed including the use of bioinsecticides (Taadaouit *et al.*, 2011) and the use of sex pheromones insects (Megido *et al.*, 2013). However, these control methods are still little exploited in Cameroon, and even unknown in several production areas (Olama, 2017). It is in this impetus that this study proposes to evaluate the effectiveness of an integrated fight associating a trap of pheromone of female *T. absoluta*, biological insecticides and a chemical insecticide, in the district of Nkong-ni in the West Cameroon. The main objective of this work is to improve the national tomato productivity by the use of bioinsecticides and pheromone trap and specifically to evaluate the abundance of caterpillars on plants, to determine the rate of infestation of plants, to estimate the prevalence of damage on fruits, to determine the level of yield loss and to assess the attack risk levels and the effect of the pheromone trap on *Tuta absoluta*.

I- Materials and Methods

I-1 Period of study

The study ran from February to April 2019.

I-2 Study area

It has been on two sites, especially Lepé and Lépo, two villages in the subdivision of Nkong-Ni, in the Menoua division, Western Region Cameroon. The Lépé village site is located on a slope of about 5%, at an altitude of 1543 m and its geographical coordinates are as follows: latitude 5 ° 32'5.5"N and longitude 10 ° 5'21.8 " E. The village site Lépo is located on a slope of about 12%, at an altitude of 1291 m and has the following geographical coordinates: latitude 5 ° 30'59.4"N and longitude 10 ° 4'56.9 ' E The location map of the site is shown below (Figure 1):

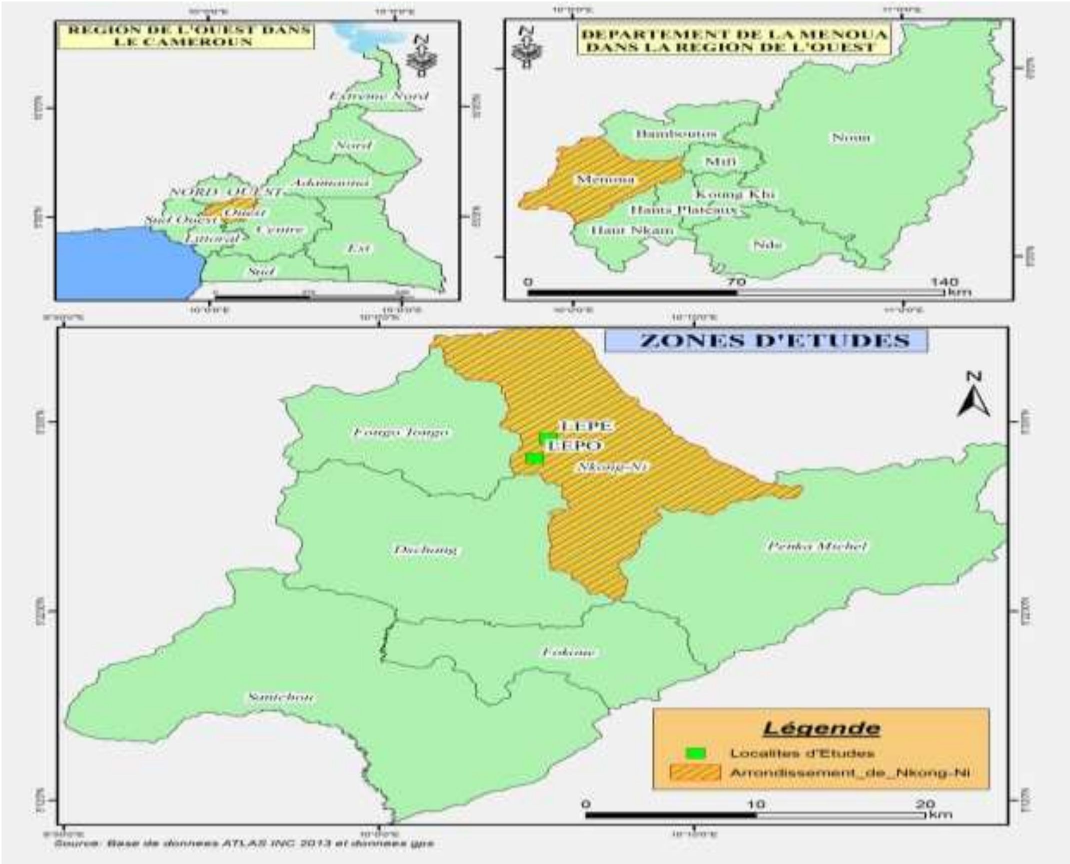


Figure 1: Location map of the study site

I-3-1 Plant material

Only one plant material was used to carry out this test. It is the F1 hybrid variety of tomato Cobra selected by Vilmorin. This is the most cultivated by producers because of the high market demand.

I-3-2 Insecticide material

Three bioinsecticides, a chemical insecticide and a pheromone trap were used in this test. The following table 1 shows the trade names, active ingredients, and dosages used for each product.

Table 1: Trade names, active ingredients and dosages used for each products

Trade names	Actives ingredients	Dosages
Biotrine	Abamectin (5%)	3 ml.15l^{-1}
Antario	*Bacillus thuringiensis*	1 g.l^{-1}
Recharge	*Metarhizium anisopliae*.	1 g.l^{-1}
Emacot	Emamectine benzoate	12 g.15l^{-1}
TUA-Optima	Female pheromone: (3E, 8Z, 11Z)-3, 8, 11-tetradecatrien-1-yl acetate or TDTA and (3E, 8Z)-3,8-tetradecadien-1yl acétate or TDDA	

I-4 Methods

I-4-1 Experimental design

The experimental setup used to carry out this study is the completely randomized blocks design with three replications. The total area in Lépé is 71.5 m^2 for a length of 14.30 m and a width of 5 m. The blocks consist of two experimental units (two treatments) each 7.2 m x 1.6 m, or 11.52 m^2. The plot of Lépo is 206.25 m^2, 37.5 m long and 5.5 m wide and experimental units 13 m x 2.6 m = 33.8 m^2. The spacings between plants are 40 cm on the line and 80 cm between the rows, a density of 32,000 plants per hectare. The treatments applied on these sites are presented in the table 2 below:

Table 2: Treatments Applied by Plots

Plot	Applied treatments
Lépé	T_1 = Biotrine alterned with Antario + Recharge
	T_2 = Emacot
Lépo	T_3 = Biotrine alterned with Antario + Pheromone trap
	T_4 = Emacot + Pheromone trap

I-4-2 Technical route

The nursery was set up on December 25, 2018 on honeycomb plates. The transplanting took place on January 15, 2019, thirty-one days after sowing. Insecticide treatments have been carried out every two weeks: February 4th, February 18th, March 4th, March 18th and April 1st. The mixtures (Biotrine + ordinary water, Antario + regular water, Recharge + ordinary water and Emacot + ordinary water) were made in 10 l buckets before being introduced into the sprayer. Biotrine, Antario and Emacot were applied as foliar sprays while Recharge was applied to the soil, all around the root zone and between plants. The pheromone trap was only installed in the plot of Lépo. The device consisted of a plastic basin for trap water, a roof cover and a pheromone basket. The basin was filled with a mixture of ordinary water and cooking oil. The trap was installed suspended on the basin and protected by the roof. The set was placed on the ground. Renewal of the water was done every 7 days and that of the pheromone every six weeks. Several other cultural operations have been practiced including irrigation, fertilization, weeding and staking. The plants have also been protected by a fungicide.

I-4-3 Sampling and data collection

In each experimental unit, 5 plants were randomly selected and tagged with a stake and a marker. The border plants were not taken into account to avoid the border effect. Data collections were made from the growth stage (two weeks after transplanting), to the fruit ripening stage. The plants were visually examined once a week and very early in the morning, and observations were recorded on a data collection sheet and/or photographed using a phone. Evaluation parameters were as follows:

- ❖ Determination of the abundance of caterpillars per plant:

The number of caterpillars present per plant allowed us to calculate the average abundance of caterpillars on the plants for each treatment and each collection.

- ❖ Determination of plant infestation rate:

In each experimental unit, the observation of 3 leaves (one of the base, one in the middle and one at the apex) was done for the 5 plants sampled. The number of leaflets mined makes it possible to determine the infestation rate of the plants according to the formula of Balajas *et al.* (2008):

$$Infestation\ rate = \frac{Number\ of\ mined\ leaflets}{Total\ number\ of\ leaflets} x100$$

- ❖ Determination of the prevalence of fruit damage and yield losses

The fruits present on the 5 plants chosen from the beginning, were classified in three classes: healthy fruits, recipe-bunched fruits and unrecoverable stung fruits. The fruit was considered healthy in the absence of any *T. absoluta* perforation on the surface of the fruit, stung but recoverable when the perforations were observed just below the calyx and/or on the surface of the fruit without that the fruit does not ooze or rot and sting unrecoverable otherwise. The number of fruits infested per plant allowed to determine the percentage of the damage according to the formula of Tóthné *et al*. (2015):

$$Percentage\ of\ damage\ on\ fruits = \frac{Number\ of\ stung\ fruits}{Total\ number\ of\ fruits}\ x\ 100$$

In addition, the number of irrecoverable stung fruits made it possible to estimate yield losses thanks to the formula of Tóthné *et al*. (2015):

$$Percentage\ of\ losses = \frac{Number\ unrecoverable\ fruits}{Total\ number\ of\ fruits}\ x\ 100$$

- ❖ Determination of the risk level of *T. absoluta* attacks:

The butterflies captured by the pheromone trap were counted at each collection with a twig, and the solution of the basin was renewed. The number of butterflies was used to assess the risk of attack of the leaf miner, from the Fredon scale (2009a).

I-4-4 Statistical Analysis

The data obtained were processed using Microsoft Excel software, 2010. In each plot the treatments were compared with each other. The average results of the two plots were also compared to determine the plot with the best performance. The normality testing of residues (Shapiro-Wilk test) and variance equality were performed using the R software (R Development Core Team, 2011). When these two parameters were accepted, the Student's test was performed. Otherwise the Wilcoxon's test was preferred. For correlations between the number of moths captured and the prevalence of damage and the number of moths caught and yield losses, they were performed using the Spearman test.

II- Results

II-1 Evolution of the number of caterpillars according to treatments and time

The caterpillars were enumerated in all experimental units and their mean abundance according to treatments and time is shown in Figure 2. At 3 Week After Transplanting (WAT) the number of caterpillars is low for Biotrine + Antario + Recharge (T1) and Emacot treatments (T2) and none for Biotrine + Antario + pheromone trap (T3) and Emacot + pheromone trap (T4). Peaks are observed for T1 and T2 at the fifth and sixth week after transplantation (WAT) respectively and at the sixth week after transplantation for T3 and T4. As of the seventh WAT however, the number of caterpillars drops in all treatments and no longer exceeds 15.93 (recorded for T1) until the end. It goes down again to 0 at weeks 7, 8 and 9 after transplantation in treatments T3 and T4 but goes back to the ninth week to no longer cancel until the end.

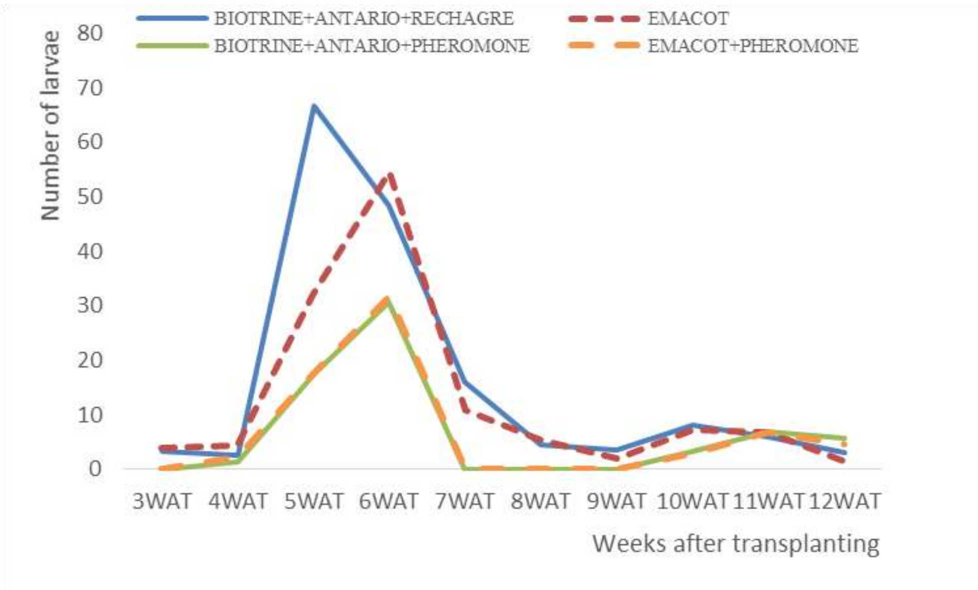


Figure 2: Evolution of the average number of caterpillars according to treatments and time

II-2 Evaluation of the infestation rate

Figure 3 shows the infestation rates of the plants per leaf stratum (inferior, medium, superior) and applied treatment. The lower strata are the most infested in all treatments, followed by middle strata and upper strata. Biotrine + Antario + Recharge (T1) has the highest infestation rate in the lower strata while the others are virtually similar. For the middle strata, the highest infestation rate is recorded for Biotrine + Antario + pheromone trap (T3) while Emacot (T2) has the lowest. In the upper strata, Biotrine + Antario + pheromone trap (T3) obtains a maximum rate while Biotrine + Antario + Recharge cause minimal infestation.

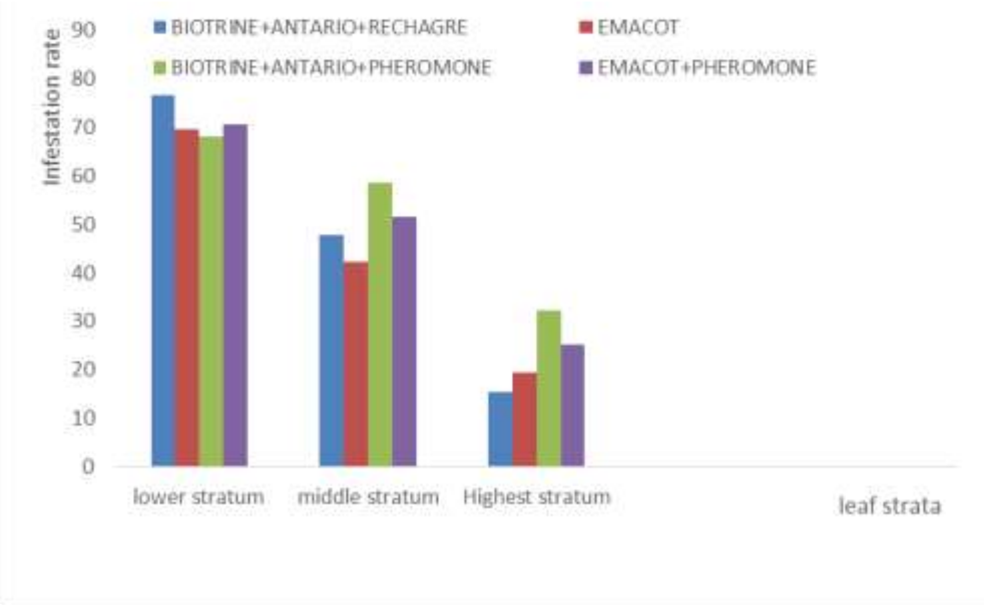


Figure 3: Average infestation rate per leaf stratum and treatment

Figure 4 shows the average infestation rate of plants based on treatments and time. It is observed that the infestations varied during the cycle and the treatments were different at each collection. As for the number of caterpillars, the peaks are obtained at 5 WAT with Biotrine + Antario + Recharge and Emacot. Biotrine + Antario + pheromone trap (T3) and Emacot + pheromone trap (T4) treatments also achieve high infestation rates at 6 WAT. These rates then decrease to minimum values at 8 WAT, then rise sharply and remain high until the end of the crop.

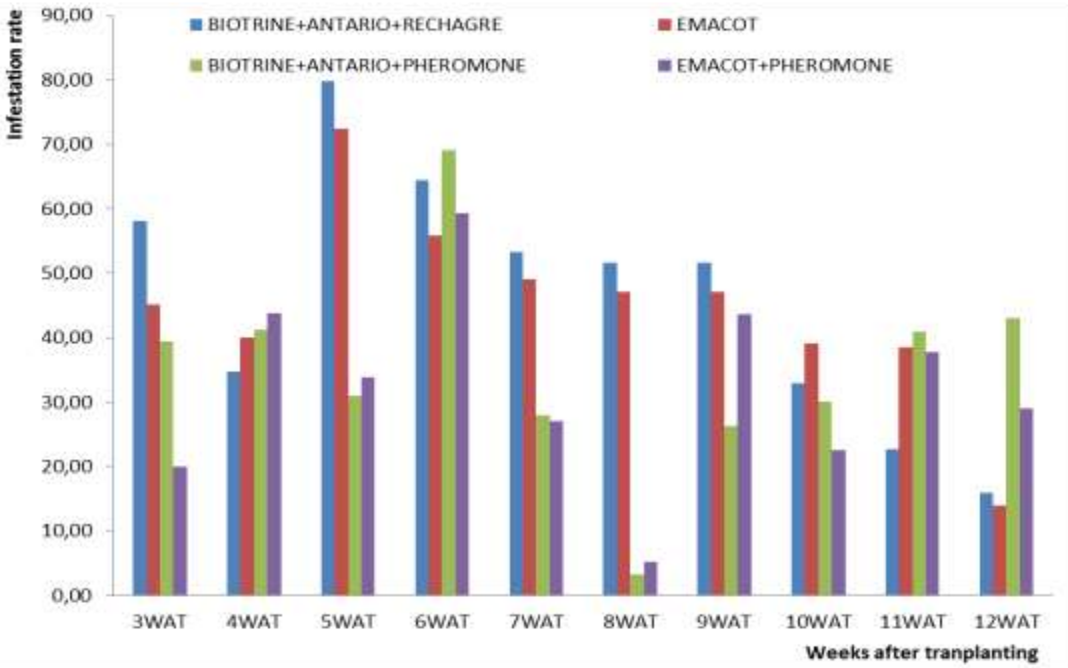
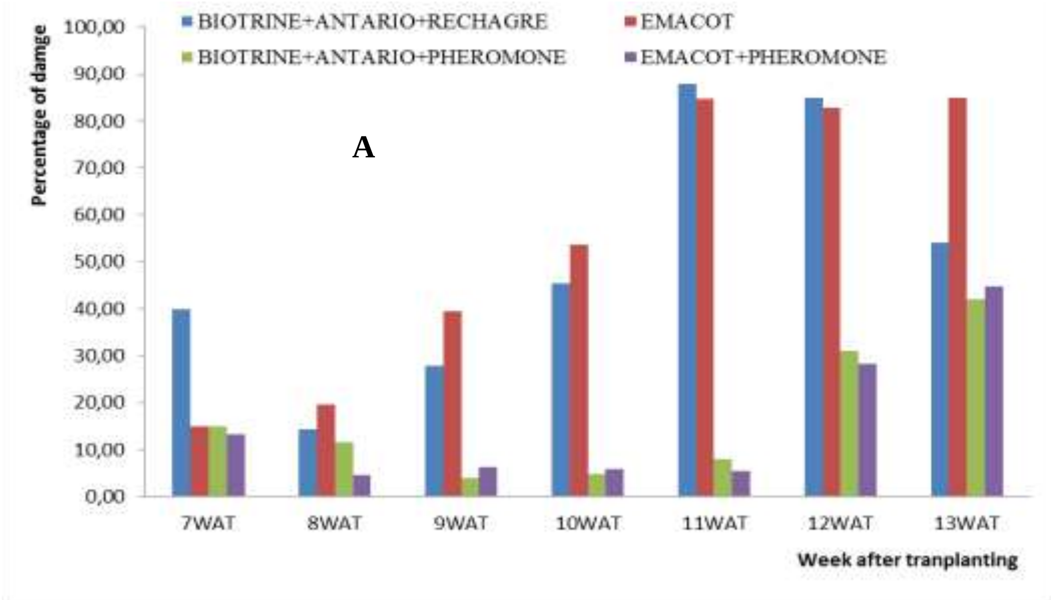


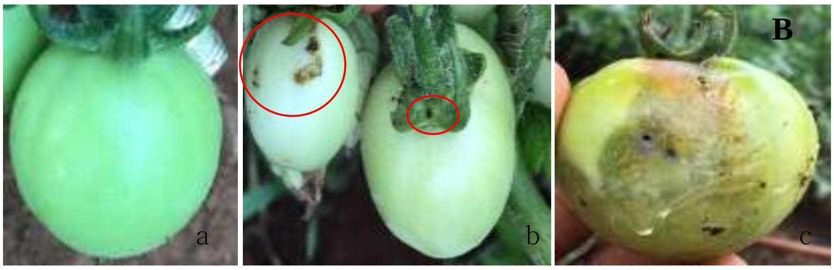
Figure 4: Plant infestation rates as a function of time and treatments

II-3 Evaluation of the damage on the fruits according to the treatments and the time

Figure 5A shows the evolution of the damage on the fruits in the different treatments and time. It turns out that the damage percentages in the Biotrine + Antario + Recharge (T1) and Emacot (T2) treatments gradually increase to 11 WAT. From this date, they oscillate around 85%. Both treatments have the highest levels of damage throughout the trial. Biotrine + Antario + pheromone trap (T3) and Emacot + pheromone trap (T4) allowed obtaining small percentages of damage up to 11 WAT, compared to the two previous ones for the same period of time. High percentages, however, are noted 12 and 13 WAT.

Figure 5B present pictures of healthy fruit and damaged fruits.





-Healthy fruit (a),

-recoverable pitted fruit (b),

-unrecoverable pitted fruit (c)

Figure 5: Percentage of fruit damage based on treatments and time (A) and damaged fruits (B)

II-4 Evaluation of yield losses according to treatments and harvest time

Figure 6 shows the percentages of leaf miner yield losses in the four treatments and four harvests. The yield losses increase with time and the largest losses were recorded for Biotrine + Antario + Recharge (T1) and Emacot (T2) at the first and second harvest. Biotrine + Antario + pheromone trap (T3) and Emacot + pheromone trap (T4) show very low losses during the first two harvests. At the third harvest, there is a loss of 57.68% for T1 and 54.49% for T2. Treatments T3 and T4 have respective rates of 14.29% and 22.17%. The fourth harvest corresponds to the highest levels of losses reported for all treatments. Among treatments, T3 (22.17%) had the smallest level of yield loss compared to T2(55.00%) and T4 (23.48%. In general, plots with pheromones showed the least yields losses. These results are in the same direction as those obtained for fruit damage.

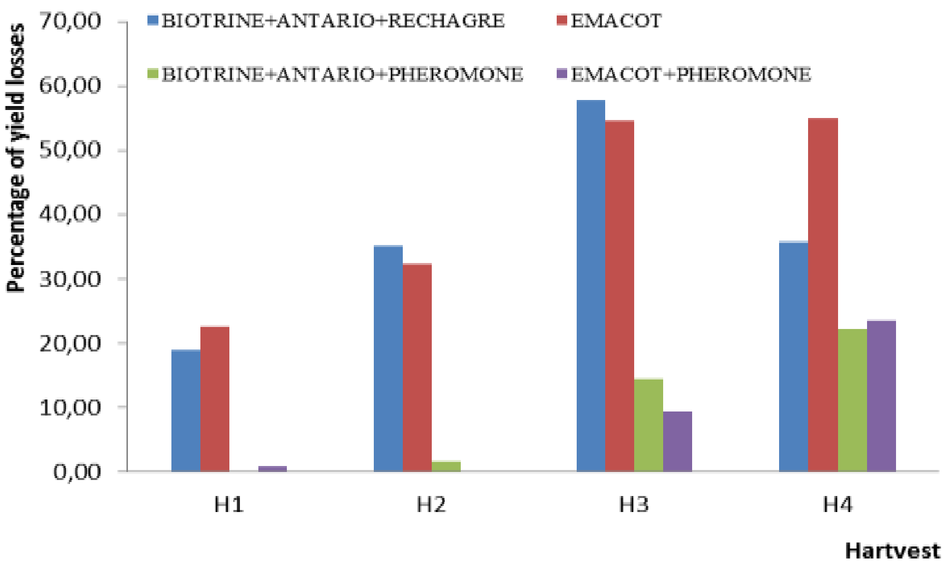


Figure 6: Percentage of Performance Losses by Treatments and harvest time

II-5 Performance by parameters and plots

For all parameters, the statistical tests showed that there is no significant difference (p> 0.05) between the Biotrine + Antario + Recharge and Emacot treatments on the one hand (Lepé plot) and Biotrine + Antario + pheromone trap and Emacot + Pheromone trap on the other hand (plot of Lepo). However, they revealed strong differences between the pheromone-free plot and the pheromone plot. Based on these tests, the pheromone-free plot had the highest number of caterpillars, averaging 14.54 per plant, compared with 6.35 caterpillars per pheromone plot. It obtains 45.65% as average plant infestation rate while that with pheromone obtains an average of 33.74%, a difference of 11.91%. The pheromone-free plot was the area with the highest fruit damage, averaging 59% of damaged fruit. The plot with pheromone on the other hand makes it possible to obtain an average of 16.26% of damaged fruits, that is 3.6 times less than the first parcel. The losses in yield are much greater in the first plot (40.44%) while they are smaller (14.08%) in that with pheromone (2.9 times less than the first). The following table 3 summarizes the performance of treatments in each plot.

Table 3: Performance of treatments by parameters and by plots

Treatments	**Average number of larvae per plant**		**Mean leaflet infestation rate**		**Mean percentage of damage**		**Mean percentage of yield losses**	
	Lépé	**Lépo**	**Lépo**	**Lépé**	**Lépo**	**Lépé**	**Lépo**	**Lépo**
Biotrine + Antario + Recharge	11,90	-	49,51	-	57,03	-	36,87	-
Emacot	15,02	-	45,73	-	60,85	-	44,00	-
Biotrine + Antario + pheromone trap	-	5,94	-	35,33	-	16,57	-	10,88
Emacot + pheromone trap	-	6,01	-	32,15	-	15,95	-	17,28
General average	**14,54a**	**6,35 b**	**45,65a**	**33,74b**	**59,00a**	**16,26b**	**40,44a**	**14,08b**
P-value	0,26	0,65	0,88	0,49	0,1452	0,7439	0,28	0,75
	4,811e-07		0,0007		1,921^{e}-09		0,0002	

II-6 Evaluation of the risk level of the attacks by pheromone trap

Figure 7 shows the evolution of the total number of moths captured by the pheromone trap throughout the test. At 3 WAT, 835 butterflies were counted in the trap. As of the following week, this number decreases and reaches 150 to 5 WAT. It then goes up to reach 350 to 6 WAT then goes down again. A second growth of this number records at 8 WAT then it drops again to 103 butterflies, number kept constant for the weeks 11 and 12 after the transplantation. After renewal of the pheromone at the eighth week, there is only a slight increase in the population in the trap.

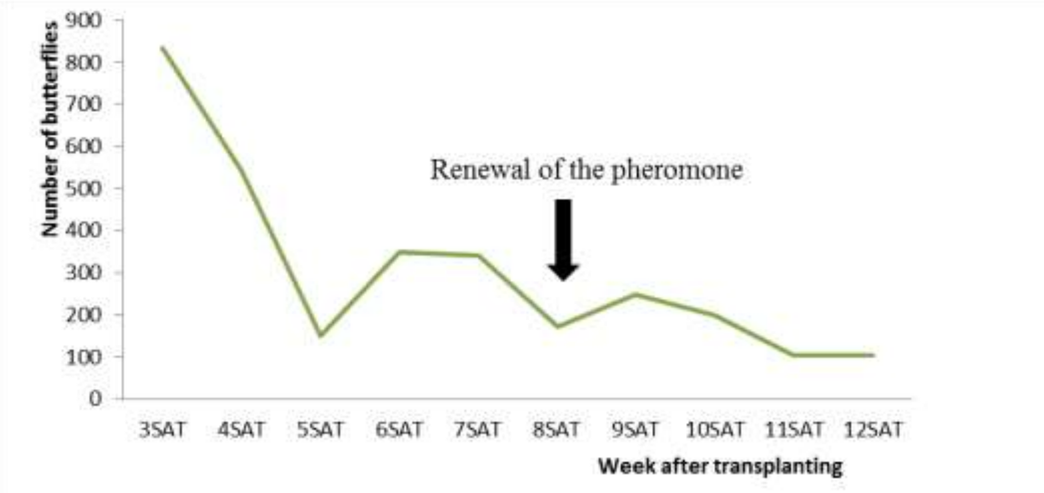


Figure 7: Evolution of the total number of butterflies captured by the pheromone trap

II-7 Correlation between pheromone trap catches, damage and yield losses

II-7-1 Correlation between pheromone trap catches and percentage of fruit damage

The analyzes show that there is a linear correlation and a very strong quadratic correlation between the number of butterflies captured by the trap and the damage on the fruits (Figure 8). These correlations are both negative. Figure 8 shows the quadratic link between the two variables. It appears from this figure that the greater the number of captured butterflies, the lower the damage reported.

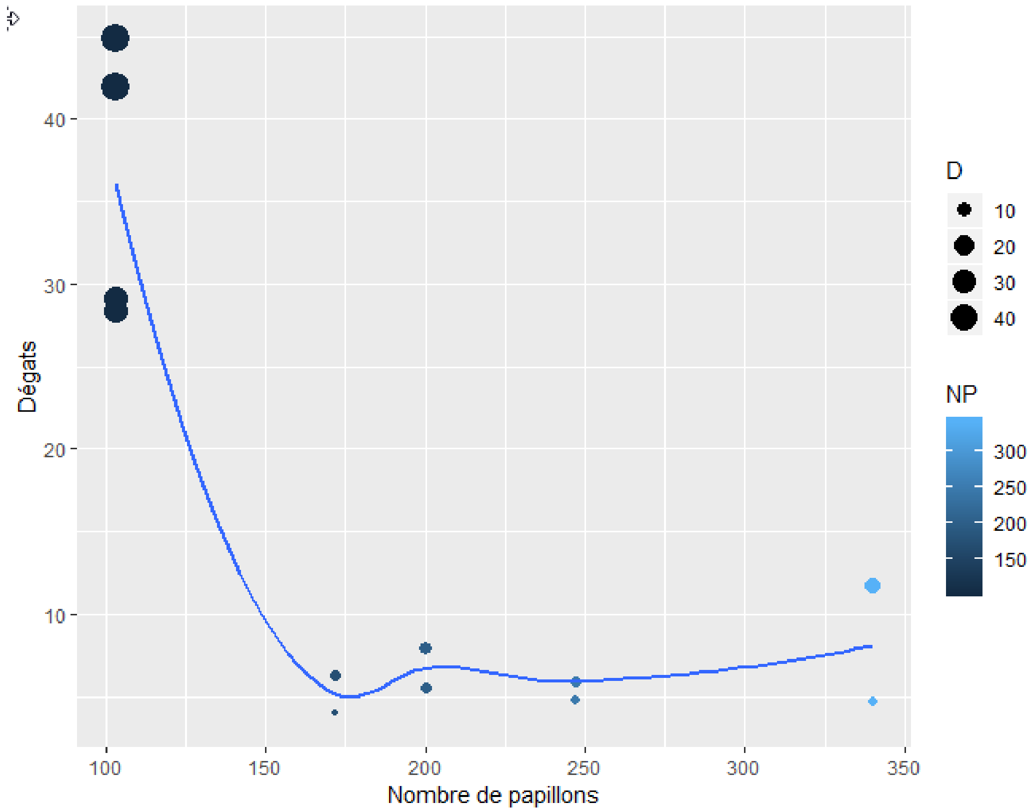


Figure 8: Correlation between the number of butterflies and the level of fruit damage

II-7-2 Correlation between pheromone trap catches and yield losses

According to correlation tests, there is a linear correlation, a strong quadratic correlation and a very strong cubic correlation between the catches made by the pheromone trap and yield losses. These correlations are all negative. Figure 8 shows the cubic link between the two variables. In general, the figure 9 shows that the greater the number of butterflies caught, the lower the yield losses.

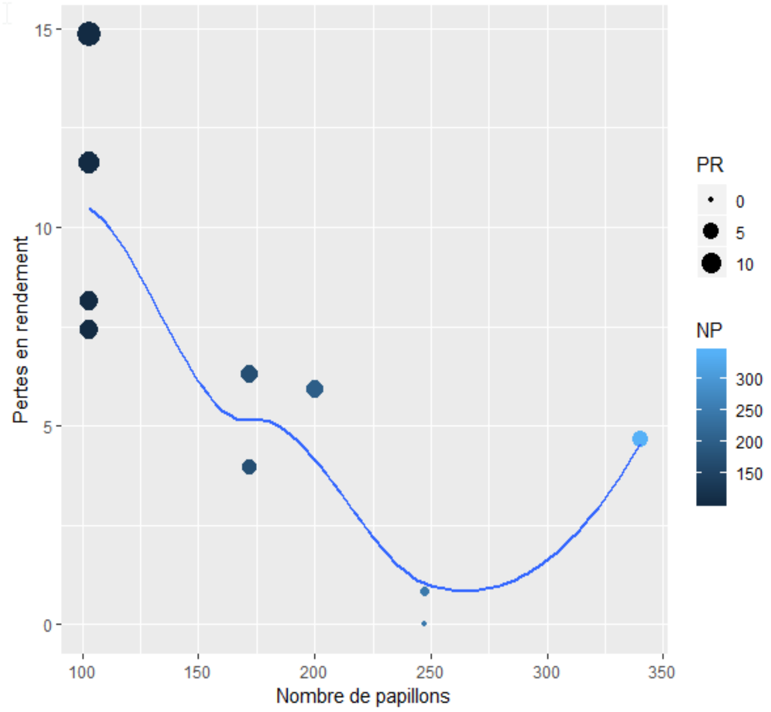


Figure 9: Correlation between the number of butterflies and the yield losses

III- Discussion

III-1 Abundance of caterpillars according to treatments and time

The very low numbers of caterpillars at 3 WAT and 4 WAT probably indicate that they are mostly present in the early larval stages (1 and 2), where they are not very visible. Indeed, according to Hanafy and El-sayed (2013), the first damage can be discrete. That said, the peaks obtained at weeks 5 and 6 after transplantation would be due to the fact that the nutrition of the caterpillars of remarkable advantage because of their growth facilitated their identification. The fact that in each plot the treatments were similar can come from the fact that abamectin (active ingredient of Biotrine) and *Bt* (active ingredient of Antario) act on the caterpillars causing their paralysis and later their death, as is emamectin benzoate (Fanigliulo and Sachetti, 2008). The decline in the number of caterpillars in Lépé also results from insecticide functions (Sanchis, 2016).

In the plot with pheromone, the effect of the latter combined with that of insecticides would have achieved the best results. Because of its peculiar attraction to male moths, the pheromone has certainly affected reproduction and consequently the number of caterpillars (Witzgall *et al.*, 2010). According to Hassan (2018), mass trapping is a technique that eliminates a sufficiently large proportion of males from the insect population. On the other hand, *M. anisopliae* (the active ingredient in Recharge) reportedly destroyed chrysalis and eggs in the soil (Russell IPM, 2016), thus contributing to a decrease in the number of caterpillars. This is in agreement with the results found by Alam *et al.*(2018), which achieved a significant decrease in the caterpillar population (84.8%) after using Biotrine. Similarly, according to Alsaedi *et al.* (2017) suspensions of concentration 106; 105; 104 cell.ml^{-1} of *Bacillus thuringiensis* var. Kurstaki have mortality rates of 20.00%, 22.66%, 18.66% and 23.33% respectively on first, second, third and fourth stage *T. absoluta* larvae. Kaouthar *et al.* (2011) similarly show that the larval population of the tomato leaf miner was reduced by 40 and 57% respectively after 3 and 6 days after treatment with Bt. In terms of the intake of the entomopathogenic fungus *M. anisopliae*, studies have shown that it causes up to 54% mortality in *T. absoluta* adults (Pires *et al.*, 2009, Pires et al., 2009). It can also induce a mortality of

37.14% in females (Gervásio and Vendramim, 2007).

III-2 Infestation rate of plants according to treatments and time

The fact that the lower strata have always been the most infested is due to the fact that *T. absoluta* prefers to remain in the bushy parts of plants (Viggiani *et al*., 2009), which are characteristic of this stratum. It could also be that it is more obvious for caterpillars to leave this stratum on the ground to perform pupation.

Peaks recorded for Biotrine alternating with Antario and Recharge 5 and 6 WAT could be due to the stage of the caterpillars at the time of spraying, probably inadequate for their active ingredients. According to Hassan (2018) these products act preferentially on 1st and 2nd stage caterpillars. This can also be valid for Emacot because it has the same mode of action as the previous ones. In addition, these high rates correspond to the peaks recorded for caterpillar abundance. Thus, the large number of caterpillars has certainly involved the attack of a larger number of leaves to ensure their nutrition. Koudjil *et al.* (2014) show that the evolution of larval stages requires an increase in the weight of the leaves consumed, which is divided between L1, L2 and L3. Bajracharya1 (2017) still achieved a leaf infestation rate of 57.60% after use of abamectin against *T. absoluta* and Youssef and Hassan (2015) recommends the use of *Bt* in the context of integrated control of the insect after obtaining 28.81% as a reduction of the male population. Alam *et al.* (2018) did not obtain any significant difference with the control after using the Recharge product.

With regard to pheromone trap treatments, its particularity in decreasing the adult population would have decreased the rate of reproduction while the applied insecticides would have killed the caterpillars found on the plants, hence the best results obtained for the pheromone trap. Likewise, Salem (2015) recommends its use with insecticides, having achieved an infestation rate of 11.1% by combining it with Biotrine. However, in general, the trap only kept the infestation rate at an average level (33.74%). This can be explained by the results of Silva (2008) and Megido *et al.* (2012) who demonstrated that females are able to lay eggs without male fertilization. Thus, it makes it more difficult to control the population of *T. absoluta* by the trap.

III-3 Evaluation of the damage on the fruits according to the treatments and the time

The increase in damage over time is probably due to the endophytic character of the caterpillar, which becomes difficult for insecticides to reach (Cocco *et al.*, 2013). The fact that the Biotrine + Antario + Recharge and Emacot treatments on the one hand and Biotrine + Antario + pheromone trap and Emacot + pheromone trap on the other hand are statistically identical reinforces the idea that the chemical active substance emamectin benzoate can be substituted by biorational active substances abamectin, *Bt* var. *Kurstaki,* and *M. anisopliae*. This is supported by the results obtained by Bajracharya1 (2017), which records an average rate of 19.97% for fruit damage after use of abamectin. Similarly, Hassan (2018) obtains the combination of *M. anisopliae* + abamectin to maintain damage between 4% and 8%.

As with other parameters, the pheromone trap combined with insecticides is certainly the factor that makes the difference, as Ziri (2011), which achieves 13.41% losses after using a pheromone trap in combination with emamectin benzoate.

III-4 Evaluation of yield loss according to treatments and time

The best results for the pheromone plot may be due to the fact that sex pheromones play a large role in the detection and control of the population, as Witzgall *et al.* (2010). According to the same researchers, they allow the reduction of the population and the disruption of the mating of the species through mass trapping. Similarly, Oke and Oladigbolu (2018c), obtained with a combination of mass trapping, foliar applications of *Bt* and abamectin and application of *M. anisopliae* on the soil, better control than with several other chemical insecticides. Cocco *et al.* (2013) also advocate that pheromone traps be used in combination with other control measures to achieve an acceptable level of damage otherwise they remain ineffective.

T. absoluta can cause 80 to 100% loss in the absence of effective control measures (CFIA, 2010). The effect of the Biotrine + Antario + Recharge and Emacot treatments is such that the damage reaches almost 60% at the last harvest. This is probably due to the voracious appetite of the caterpillar inside the fruit, which once in the fruit is difficult to reach by insecticides. This hypothesis is approved by Cocco *et al.* (2013) who report that the effectiveness of chemical insecticides is poor in combating the leaf miner, due to the inner position of the caterpillar on the leaves and fruits. This can also be attributed to the development of resistance to active ingredients as proposed by Desneux *et al.*, (2010). Similarly, the decline in efficacy of Biotrine + Antario + pheromone trap and Emacot + pheromone trap notified in harvest 3 and 4 can be attributed to the same cause or the fact that *T. absoluta* females were able to lay eggs without male fertilization (Silva, 2008, Megido *et al.*, 2012).

III-5 Assessment of the risk level of attacks and the effect of the pheromone trap

The Fredon scale (2009a) allows us to conclude that throughout the duration of the trial, the risk of attack was very high (number of catches always greater than 30). This is due to the fact that the villages Lépé and Lépo are now much infested sites since the arrival of the miner in West region of Cameroon. Olama (2017) has indeed obtained infestation rates of 80 to 100% during its investigation to recognize the pest in several villages of Menoua division. The strong negative correlations found testify to the fact that the pheromone trap had a great impact on the reduction of damage and losses in the units that received this treatment.

Conclusion

The main objective of this work was to improve the tomato productivity by the use of bioinsecticides and pheromone trap and specifically to evaluate the abundance of caterpillars on plants, to determine the rate of infestation of plants, to estimate the prevalence of damage on fruits, to determine the level of yield loss and to assess the attack risk levels and the effect of the pheromone trap on *Tuta absoluta*. At the end, the results revealed that caterpillars were present in the field during the tomato production cycle and peak numbers was noted at weeks 5 and 6 after transplantation. The Biotrine + Antario + Recharge and Emacot treatments manage to maintain the average number of caterpillars present in the Lépé plot at 14.54 per plant. The treatments Biotrine + Antario + pheromone trap and Emacot + pheromone trap maintain it at 6.35 caterpillars per plant in Lepo. For the rate of infestation of plants, the basal leaves were more infested follow by the median leaves than those of the extremities in all the treatments. In addition, treatments with a pheromone trap resulted in an average of 11.91% less leaves infested in the pheromone plot than in the pheromone-free plot. For fruit damage, in the plot of Lépo (trap plots), the damage was 16.26% on average while they amounted to 59.00% in Lépé, 3.6 times more than in Lepo. Yield losses increased over time and the largest losses were recorded in Lépé with an average loss of 40.44%. In Lépo, however, the losses are 14.08% or 2.9 times less than in Lépé. The risk of attacking the leaf miner remained very high throughout the trial period despite the mass destruction of butterflies by the trap. For all the parameters evaluated, Biotrine alternated with Antario + Recharge and Emacot on the one hand and Biotrine + Antario + pheromone trap and Emacot + pheromone trap on the other hand showed similar performances. In conclusion, traps are to be recommended in a tomato production in combination with alternating bioinsecticides with emamectin benzoate (Emacot).

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