Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(4): 657-664

Received: 10-05-2019
Accepted: 12-06-2019

Adja Nahoulé Armand
National Polytecthnic Institut of Yamoussoukro; Institut National Polytechnique Félix Houphouët-Boigny (INP-HB); Departement of Agriculture and Animal Resouces; BP 1313 Yamoussoukro (Côte d'Ivoire)

Ouédraogo Yacou
Regional Agriculture and Rural Development: (MINADER); Direction Régionale de l'Agriculture de Bouaké (Côte d'Ivoire)

Kouakou Malanno
National Agriculture Research Centre; Centre National de Recherche Agronomique (CNRA); Station de Bouaké, 01 BP 633 Bouaké 01 (Côte d'Ivoire)

Fondio Lassina
National Agriculture Research Centre; Centre National de Recherche Agronomique (CNRA): Station de Bouaké, 01 BP 633 Bouaké 01 (Côte d'Ivoire)

Akamou Fataye
Ministry of Agriculture and Rural Development: Ministère de l'Agriculture et du Développement Rural (MINADER): Direction de la Protection des Végétaux, du Contrôle et de la Qualité, Abidjan (Côte d'Ivoire)

Danho Mathias
National Polytecthnic Institut of Yamoussoukro; Institut National Polytechnique Félix Houphouët-Boigny (INP-HB); Departement of Agriculture and Animal Resouces; BP 1313 Yamoussoukro (Côte d'Ivoire)

Correspondence
Adja Nahoulé Armand
National Polytecthnic Institut of Yamoussoukro; Institut National Polytechnique Félix Houphouët-Boigny (INP-HB); Departement of Agriculture and Animal Resouces; BP 1313 Yamoussoukro (Côte d'Ivoire)

Topic: Control of the invasive tomato leaf miner, *Tuta absoluta* (Meyrick, 1917) (Lepidoptera, Gelechiidae) in the centre of Ivory coast

Adja Nahoulé Armand, Ouédraogo Yacou, Kouakou Malanno, Fondio Lassina, Akamou Fataye and Danho Mathias

Abstract
Tomato (*Solanum lycopersicum* L.) is an important vegetable crop for income and nutrition of smallholder farmers in sub-Saharan Africa. Its infestation by the leaf miner *Tuta absoluta* (Meyrik) results in a considerable economic loss. This pest was recorded for the first time in the centre of Ivory Coast during 2016. Therefore, the current study aims to monitor the population of *Tuta absoluta* adults and determine the impact of the larvae on tomato plants. Treated and untreated plots arranged in complete random blocks with 5 treatments (4 insecticides and one control) and 3 replicates were installed at Djébonoua (7°30'N: 5°5'W), in the centre of Ivory Coast. Delta trap with pheromone, efficiency for monitoring the male insect was tested during one tomato season in 2017. Direct examination of tomato revealed a fluctuation of the insect larvae and their impact on tomato plants and yield. Data collected were analyzed with Statistica 7.1 at 5%. Monitoring of males catches revealed that the locality has a high risk of infestation (more than 30 males per week). The insecticides Tihan175-O-Teq (Spirotetramate 75g/l and Flubendiamide 100g/l), Viper 46 EC (Acetamiprid 16g/l and Indoxacarb 30g/l), Vertimec 18 EC (Abamectin 18g/l) and K-Optimal (Lambdacyhalothrin 15g/l and Acetamiprid 20g/l) significantly reduced larval populations and their damage on plants and fruits compared to the control. The results showed high efficiency of Tihan (0.4 l/ha) and Viper (1 l/ha), average efficiency of Vertimec (1 l/ha) and low efficiency of K-optimal (1 l/ha). Insecticides control *Tuta absoluta* larval populations, reduce its damage and improve the yield from 54.85 to 144.65% compared to the control. Tihan and Viper can be recommended at fourteen days and Vertimec at seven days of intervals.

Keywords: Tomato, control, pest, *Tuta absoluta*

1. Introduction

Vegetables contributes to food security and the reduction of poverty of the smallholder farmers in sub-Saharan Africa. In Ivory Coast, several vegetable crops are grown, but the most important are eggplant, pepper, okra and tomato [30]. Tomato (*Solanum lycopersicum* L.) is an important vegetable crop for income and nutrition of smallholder farmers in sub-Saharan Africa [22]. Its infestation by the leaf miner *Tuta absoluta* (Meyrik) results in a considerable yield and economic loss [13]. The invasive South American moth, *T. absoluta* has been key pest of tomato in the South American region since 1960 [11]. This pest is widely spread in South America [15-16], Europe [10], Asia [20], North Africa [25-27], South Africa [33], East Africa [34] and West Africa [6-26]. In Ivory Coast, this pest was recorded for the first time at Bouaké in the centre of the country in 2016 [9].

The insect passes through four developmental stages; egg, larva, pupa and adult. The adult of *T. absoluta* is a micro Lepidopteran moth which is nocturnal and may be found between the leaves of host plants during the day [30]. The larvae of this oligophagous attack the tomato plants in all developmental stages causing losses of up 80 to 100% by attacking leaves, flowers, stems and especially fruits besides mining their leaves [10-25].

In order to manage this pest, chemical control remains the most effective means of control in the short term. In fact, Ivorian farmers' used several insecticides to control vegetable pest. But, actives ingrediants not approved on vegetables are used [22]. This increasing and unreasoned use of crop protection products induces the emergence of resistant pest populations, major health risks such as pesticide residues in food products and environmental pollution [22]. So, the present study aims to evaluate the efficiency of four insecticides with different actives ingredients for the controlling of *T. absoluta* larvae and its damages.

It's also aims to evaluate the risk of infestation of the farm by following the dynamics of the adult male populations of *T. absoluta* on tomato crop by the capture of adults with delta trap.

2. Materials and Methods

2.1. Field study

The study was carried out at Djébonoua (07°30'N: 05°04'W), new Bouaké in the center of Ivory Coast. This locality belongs to the dry tropical climatic with four seasons (two raining seasons and two drying seasons). Annual rainfall varies between 1000 and 1500 mm and the relative humidity varies from 65 to 85%. Temperatures belong 21 °C to 34 °C. Vegetation is a preforestery savannah with tropical ferruginous soils [3]

2.2. Materials

Plant material consisted to tomato hybrid variety seed, F1Cobra 26. It has a very good tolerance to bacterial wilt and has a very good early maturity. This seed is used by the majority of the producers of this locality. Animal material consisted of collecting of *T. absoluta* adults and larvae, present in the tomato plots. Four insecticides of various chemical families already approved in Ivory Coast on vegetable crops, were used in this study (Table 1). Then, Furadan 5G (50 g/kg carbofuran) and Banko plus (550 g/l Chlorothalonil and 100 g/l Carbendazime) were used to control nematodes and fungi [17].

Table 1: Characteristics of the insecticides used during the test

Trade Names	Active Ingredients	Chemical Families	Insecticide doses (l/ha)
Tihan175-O-Tec	Spirotetramat (75g/l) and Flubendiamid (100g/l)	Ketoenols and Phthalic Diamid Acids	0.4
Viper 46 EC	Acetamiprid (16g/l) Indoxacarb (30g/l)	Neonicotinoids and Oxadiazins	1
Vertimec 18 EC	Abamectin (18g/l)	Avermectins	1
K-Optimal 35 EC	Lambdacyhalothrin (15g/l) Acetamiprid (20g/l)	Pyrethrinoids and Neonicotinoids	1

2.3. Methods

2.3.1. Experimental Design

The experimental design consisted in treated and untreated plots arranged in complete random blocks with 5 treatments (4 insecticides and one control) and 3 replicates (Figure 1). The experimental area covers 475 m^2 (25m x 19m). It is subdivided into 15 elementary plots (Figure 1). Each plot covers an area of 10 m^2 (5m x 2m) and contain 24 plants (4 rows of 6 plants). The plants were cultivated with spacing of 0.50 m x 0.50 m. The plots were separated by 1m and the blocks by 2m.

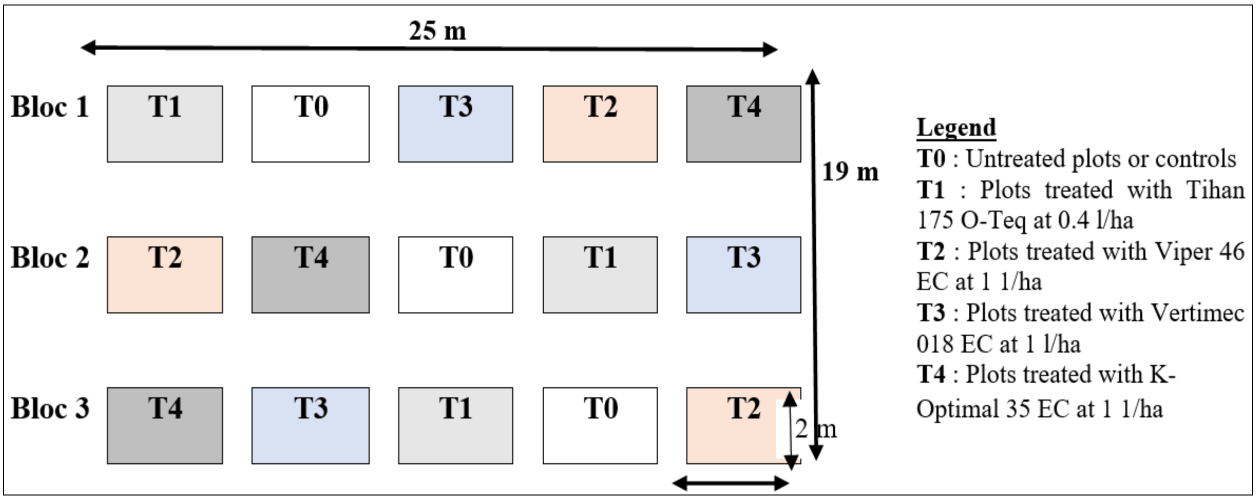

Fig 1: Experimental Design

2.3.2. Planting and fiel monitoring

The study was conducted on open-field tomato crops. A nursery was carried out on land newer the experimental area on a plot of $2m^2$ (2 m x 1 m). The plants were cultivated using local standard agronomic practices, such as fertilization and the use of pesticides [9]. Hilling, hoeing and weeding were realized regularly during tomato plants development whenever necessary. Pesticides were applied using a compressed air sprayer (15 l). One sprayer was assigned to each of the treatments and applications are performed at intervals of 14 days, three times. A first survey (the number of larvae per plot and the number of plants attacked) was carried out, three day before application of the insecticides. Subsequently, three surveys are carried out at 3: 7 and 13 after each application. The applications and survey of the infestation were carried out from 6 to 9 o'clock [2]. In addition, a delta pheromon trap was installed the transplanting day of tomato seedlings for detecting the adult of *T. absoluta* [35]. This trap is equipped on the basal side with a wedged plate on which there was Tuta-lure 0.5mg/capsule sex pheromone (Figure 2a) for the trapping of the adults of the pest [8]. A single trap has been installed, in the center of the experimental area and hanged on a post at 1m 20 from the soil (Figure 2b). One trap must be installed through an area less than or equal to 3500 m² [18]. The plate was changed when saturated by *T. absoluta* male captured (Figure 2c).

Fig 2(A): *Tuta absoluta* sexual pheromone | **Fig 2(B):** Delta trap hanged on tree in the field | **Fig 2(C):** Adult males of *Tuta absoluta* captured on plat

2.3.3. Sampling

Evaluation of *Tuta absoluta adults* population and larval population

The adult of *T. absoluta* catches were counted weekly, using the delta trap installed within the field. These catches allowed to follow the dynamic of the male populations and to determine the level of potential risk of infestation of the field (Table 2) [18]. The larvae of *T. absoluta* were counted on eight plants, randomly selected per plot.

Evaluation of the damage on tomato plants

The evaluation of the damage was done by visually estimating the plant status (healthy and attacked plants) and the degree of damage caused by the insect on differents organs (stem, leaves, apex, flowers and fruits) [2]. A scale of six levels of infestation were established (Table 3) [18]. A tomato plant is attacked when it has at least one active mine. Subsequently, the percentages of healthy and attacked plants were determined.

Table 2: Standards for assessing the level of risk of infestation of *Tuta absoluta* on tomato plot according to males catches [18]

Number of adults catches	Level of attack
Zero (0) individual catches per week	No risk of attack
Less than 3 individuals catches per week	Weak risk of attack
Three (3) to 30 individuals catches per week	Moderate risk of attack
More than 30 individuals catches per week	High risk of attack

Table 3: Standards for assessing infestation levels of *Tuta absoluta* larvae on tomato plants [18]

Levels of infestation	Percentage of affeted plants
0: No damage	No symptoms, no larvae detected
1: Very low damage	Less than 5% of plants with an active mine
2: Low damage	5% to 25% of affected plants, with an active mine
3: Average damage	25% to 50% of affected plants, with an active mine
4: High damage	50% to 75% of affected plants with an active mine
5: Very high damage	More than 75% of affected plants, with an active mine

Evaluation of the yield

The evaluation of the health of the fruits was carried out by a visual assessment of the fruits on each plot. Green fruits on eight plants per plot were observed and counted to determine the rate of infested green fruits. A fruit is considered attacked if it has at least one hole caused by the entry or exit of larvae of *T. absoluta* [18]. At maturity, the fruits (healthy and attacked) of all plants per plot were harvested, counted and weighed to assess yield. Subsequently, the yield of healthy fruit and the healthy yield profit rate of the treated plots relative to the control were calculated [2].

$$Healthy\ Yield\ Profit\ Rate = (HYTP - HYCP) * 100/HYCP$$

Legend: HYTP: Healthy Yield on Treated Plot; HYCP: Healthy Yield on Control Plot

2.3.4. Data analysis

Data collected was processed using Microsoft Excel 2007 release for curves and histograms and STATISTICA 7.1 for statistical analysis. One-way analysis of variance was performed on larvae populations, number of fruits (healthy and attacked). Duncan test was used to perform the multiple comparison of the averages when their were significant difference at 5%. With regard to the damage, the percentage of healthy and attacked plants was calculated for each treatment [2].

3. Results and Discussion

3.1. Results

3.1.1. Effect of trapping on *Tuta absoluta* males and risk of infestation of the field

Males adults populations of *T. absoluta* fluctuated during the study (Figure 3). They varied between 51 individuals (49 days after transplanting) to 390 individuals (42 days after transplanting). The lowest catches were observed at 28: 35 and 49 days after transplantation (respectively with 84: 94 and 51 individuals) while the highest catches were observed at 7 and 42 days after the installation of the delta trap with 295 and 390 individuals. These observations showed that the risk of infestation of the field by *T. absoluta* is high because the number of weekly catches is greater than 30 individuals (Figure 3) when refered to Table 2.

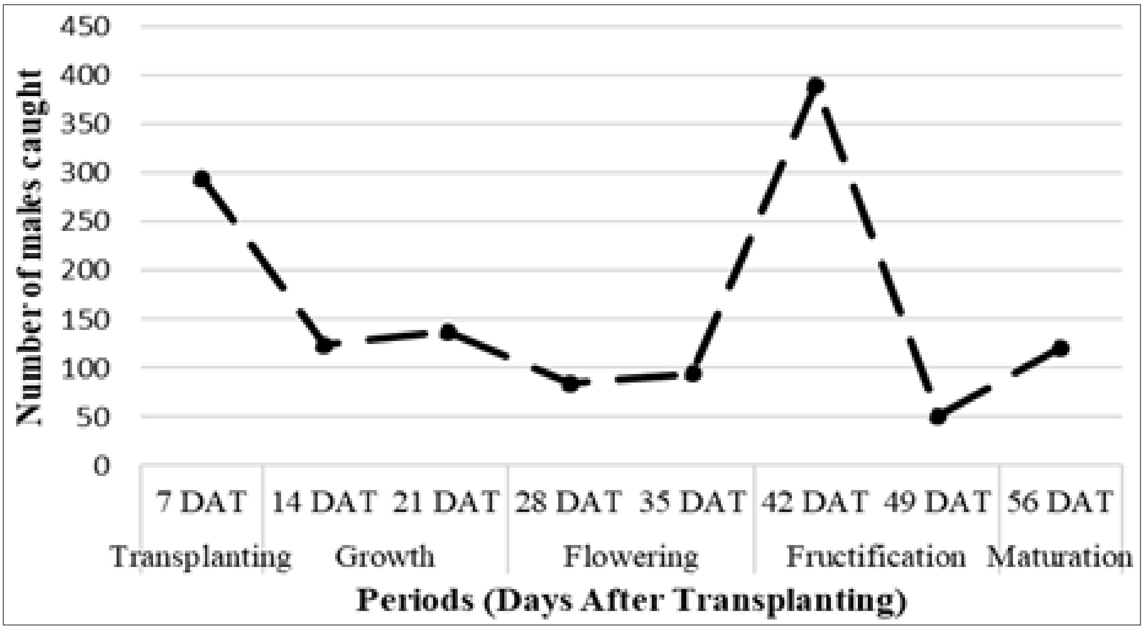

Fig 3: Evolution of *Tuta absoluta* males caught during tomato plants developpements

3.1.2. Effect of the treatment on *Tuta absoluta* larval populations

Three days after transplanting and before applied of insecticide, *T. absoluta* larvae were present on all the plots. Mean larval populations range from 1.33±1.15 to 2±2 individuals per plot. There is no significant difference between the treatments ($p>0.05$) (Annex 1). Throught the plant developement, larval populations on control plots, fluctuated from 1.33±1.15 to 133.33±22.03 individuals per plot with two peaks of 133.33±22.03 and 113±12,49 larvae respectively at flowering and maturation of the tomato (Figure 4). *Tuta absoluta* larval populations were were significantly ($p<0.05$) important on control plot than those on treated plots. In addition, larval populations on treated plots varieted up 0 to 46±5 (Figure 4). It was significantly lower ($p<0.05$) on Tihan and Viper than Vertimec and K-optimal at the differents stages of tomato plants (growth, flowering, fructification and maturation). Likewise, larval populations were significantly lower at three and seven days after application compared to thirteen days after application, mostly on Vertimec and K-optimal.

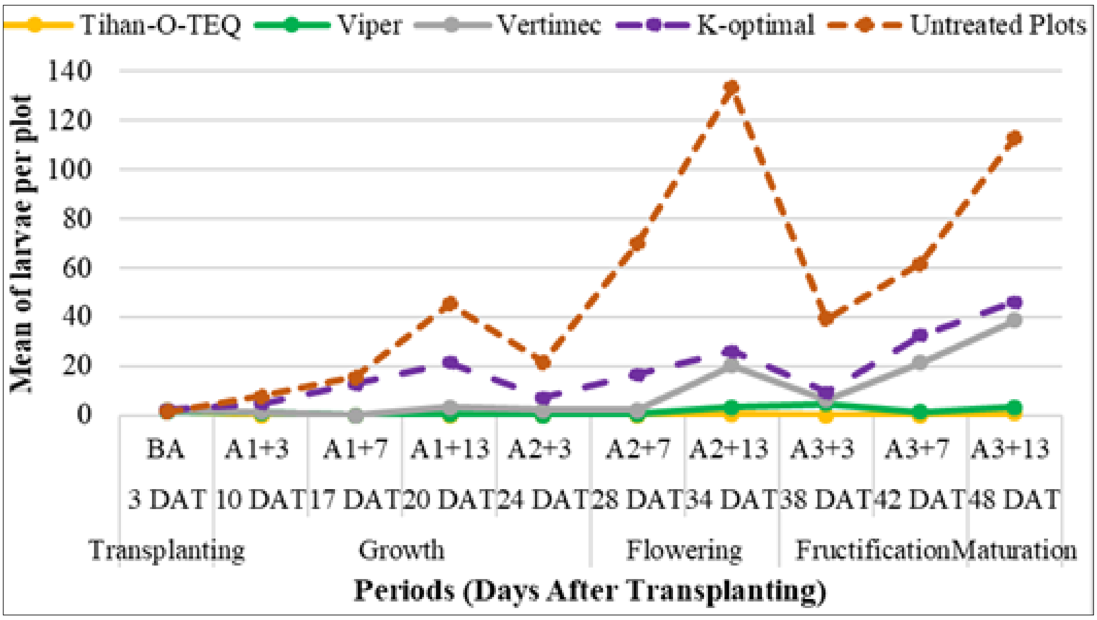

Fig 4: Evolution of the population of *Tuta absoluta* larvae according to the treatments

Legend: BA: Before Application; **DAT:** Days After Transplanting

3.1.3. Effect of treatments on damage caused by larvae of *Tuta absoluta* on tomato plants

Before insecticide application, 16.67 to 25% of the plants had actives mines (mines with *Tuta absoluta* larvae) on all the plots (Figure 5). The infestation level were low (level 2). During the differents stages of tomato plants developpement, infestation were high on control plot up to 50 to 100% of plants attacked. In contrast, on treated plots, infestations level were average to high on K-optimal plots: low to average on Vertimec plots and null to low on Tihan and Viper plots (Figure 5).

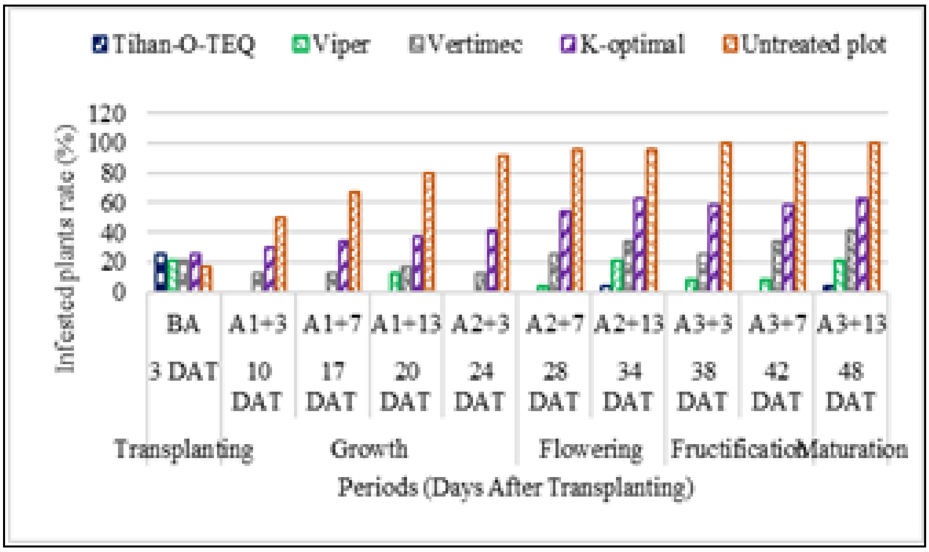

Fig 5: Tomatoes plants Infested rate according to treatments

Legend: BA: Before Application; **DAT**: Days After Transplanting

3.1.4. Effect of the treatments on tomato yield

The number of immature fruits varied between 48,33±1,53 and 76,33±8,02 (34 days after transplanting) to 84±7,93 and 151,33±4,16 (48 days after transplanting) (Annex 3). The immature fruits on control plots (48,33±1,53 to 84±7,93) were significantly lower (p<0.05) than those on treated plots (54±3,6 to 151,33±4,16) (Annex 3). At the fructification and the maturation, the immature fruits on plots treated with Tihan and Viper were similar, but higher (p<0.05) (Annex 3) than those on plots treated with Vertimec and K-optimal, which remain higher than those of control plots (Annex 3). Likewise, the infested fruits rate on control plots (39.84±2.13 to 43,71±7,39%) was higher (p<0.05) than those of plots treated with K-optimal (12,83±2,89 to 14,93±0,64%) and Vertimec (8,46±1,55 11,5±0,66 %). Infestation were null or low on Tihan and Viper plots (Annex 3).

The total number of mature fruits harvested were 281±9.85 to 471.33±27.15 (Annex 4). There were significant differences between treatments (p<0.05) (Annex 4). In fact, the numbers of fruits on Tihan (471.33±27.15) and Viper plots (449±32.6) were similar, but significantly higher than those on Vertimec (352±21.28) and K-optimal plots (328.33 ± 21.01) which remained higher than these of untreated plots (281±9.85). In addition, the rate of infested haevested fruits on Tihan plots (3.02±0.35%) was lower (p<0.05) than these on Viper plots (6±0.25%), which remained inferior to those of Vertimec (11.56±0.7%) and K-optimal plots (16.71±0.96%). The infested fruits rate on treated plots remained lower than the rate of untreated plots (45.81±1.93) (Annex 4). Healthy fruits yield profits due to insecticide applications on plots treated with Tihan, Viper, Vertimec and K-optimal were respectively 144.65: 124.26: 68.92 and 54.85%, compared to untreated plots (Annex 4).

3.2. Discussion

The monitoring of the male populations of *Tuta absoluta* showed that the pest was pesent at all the stages of the tomato plants. The first generation of butterflies that appear during the transplanting and the growth of tomato plants, could arise from neighboring tomato crops and potential hosts plants of this pest [13]. In fact, *T. absoluta* have many host plants as Solanaceae [11], Amaranthaceae, Brassicaceae and Convolvulaceae [23]. The adult of *T. absoluta* is a micro Lepidopteran moth which is nocturnal and may be found between the leaves of host plants during the day. The second generation emerges at the fructification of tomato plants and emanated from the first generation. Fluctuations of the pest populations and the peak observed may be related to climatic conditions including rainfall and temperature [5]. The average daily temperatures observed during the study varied between 23 and 25 °C. This makes it possible to have at least two generations during the tomato growing cycle because this pest can achieve 10 to 12 generations per year when weather conditions are favorable and the food is abundant [10]. The risk of infestation of the experimental area by *T. absoluta* is high because the number of weekly captures is greater than 30 individuals [18]. In addition, control of *T. absoluta* adults using pheromone Delta traps allowed for the capture of male specimens and thus reduces the populations of insects witch are able to reproduce [13].

The pestiferous stage of tomato leaf miner is the larvae [32 -6]. The insecticides Tihan and Viper reduced significantly the larval populations of the pest on tomato plants compared to K-Optimal and Vertimec. Those insecticides control significantly the pest compared to the untreated plot. The efficiency of these insecticides on the pest larvae could be attributed to the action of the chemical, the formulation or to the in the diet of the pest. For Tihan, Spirotetramate is a systemic chemical that acts as a moulting disturbance and regulates growth [29] while Flubendiamide causes ion release resulting in paralysis and death of the insect [24]. For Viper, Acetamiprid is a systemic chemical that acts by contact and ingestion on caterpillars [34] while Indoxacarb is very active on larvae of Lepidoptera. Affected insects stop feeding, are paralyzed and die. Vertimec contains Abamectin witch acts by ingestion and by contact on the pest [21]. This efficiency could be due to the frequency of application (14 days apart). Indeed, it was found a re-infestation of the plots treated with this chemical seven days after the spray. This observation could be related to the persistence of the chemical which would be of short duration. Since Avermectins like abamectin have often been reported to be quickly photo-degradated in the environment [31]. It may be advisable to apply this chemical every week. In addition, Abamectin tolerance and resistance problems have been reported in southern america

[28]. K-Optimal contains Lambda-cyhalothrin and Acetamiprid showed low efficacy on *T. absoluta* larvae. Lambda-cyhalothrin acts by contact and by ingestion with rapid action. It is a synthetic pyrethroid that has a wide range of pests [19]. Its low efficiency on *T. absoluta* larvae is due to the resistance of this pest to pyrethroids.

Otherwise, the effectiveness of various chemicals in controlling of tomato leafminer were reported. But, *T. absoluta* developed resistance to a number of pesticides [34]. Additionally, most chemical pesticides have adverse impacts to both humans, non targeted organisms and the environment as well. However, for sustainable management of this pest, it is necessary to combine all available control, including correct use and alternating of approved chemicals pesticides, physical control, cultural control (resistant varieties, irrigation, crop rotation) and biological control (parasitoids and predators) and destruction of infested plant material [1-13]. Although these methods are applied, they are not guaranteed to reduce this pest and may be costly and not readily available, especially for smallholder tomato farmers in Sub-Saharan Africa.

Before insecticide applications, infestations were low on all the plots. But, through the developmental stages of tomato plants, infestation by the pest became important. The damage is done by the larvae which tunnel into the stems, apical buds as well as the green and ripe fruits reducing their quality and subsequently the yields [25-26]. On the plots treated with Tihan and Viper, the damage were null to low whereas on the plots treated with Vertimec and K-Optimal, the damage varies from average to high. However, untreated plots have high to very high damage. Infestation rate increases through the development of tomato plants. Indeed, there is a synchronism between the plant and its pest, so that the stage of outbreak of the pest occurs when the plant is in the stage favorable to its development [14]. The larva is the harmful stage [10: 6] and shows prefrence for new buds, flowers and new fruits thereby making it easy to detect on affected plants [6]. The characteristics mines on plant leaves are also an indicator of attack in addition to the appearance of black frass on fruits where an infestation is severe [32].

Applications of the insecticides made it possible to control *T. absoluta* larvae, reduce damage and improve yield. The immature fruit infested rate on treated plots were lower than those on untreated plots. In addition, the number of mature fruits harvested are more important on treated plots than on untreated plots. Damage results in the stems fragility, a reduction in the plant's production capacity, a decline in flower buds, the fall of larval-attacked fruit, injury-induced decay, and loss of production. Then, applications improved yield from 54.85 to 144.65% compared to control. Attacks by *T. absoluta* larvae affect the photosynthetic capacity of the plant and decrease the yield quantity and quality [12]. Tomato fruit loss were reported resoectively in Tunisia (between 11.08 and 43.33%) [8], Colombia (between 45 and 100%) [7] and Nigeria (about 80 to 100%) [26].

Annex 1: Mean of larvae populations according to the treatments

	Transplanting	**Growth**				**Flowering**		**Fructification**		**Maturation**
	3 DAT	**10 DAT**	**17 DAT**	**20 DAT**	**24 DAT**	**28 DAT**	**34 DAT**	**38 DAT**	**42 DAT**	**48 DAT**
	BA	A1+3	A1+7	A1+13	A2+3	A2+7	A2+13	A3+3	A3+7	A3+13
Tihan-O-Teq	2±1 a	0±0 a	0±0 a	0±0 a	0±0 a	0±0 a	0,33±0,57 a	0±0 a	0±0 a	0,67±0,57 a
Viper	1,67±0,57 a	1±1 a	0±0 a	0,33±0,57 a	0±0 a	0,33±0,57 a	3,33±0,57 a	4,67±1,15 ab	1,33±1,15a	3,33±0,57 a
Vertimec	2±1 a	1,33±1,15 a	0±0 a	3,33±0,57 a	2±1 a	2±1,73 a	20,33±4,51 b	6,33±1,52 ab	21,33±4 c	38,67±3,21 c
K-optimal	2±2 a	4,67±0,57 b	12,67±1,53 b	21,33±1,52 b	7±2,64 b	16,67±3,21 b	26±3,6 b	9,33±1,15 b	32,33±10,78 b	46±5 b
Control plot	1,33±1,15 a	7,67±0,57 c	15,33±1,52 c	45,33±4,16 c	21,67±4,04 c	70±12,16 c	133,33±5,03 c	39±8,89 c	61,67±7,76 d	113±12,49 d
P	0,946	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001	0,0001

Legend: In the same column, averages followed by the same letter do not differ significantly, **BA :** Before Application ; **DAT :** Days After Transplanting; **Am + n** : n Days after m Application (so A1+3 means three days after the first application)

Annex 2: Rate of infested plants according to the traetments

	Transplanting	**Growth**				**Flowering**		**Fructification**		**Maturation**
	3 DAT	**10 DAT**	**17 DAT**	**20 DAT**	**24 DAT**	**28 DAT**	**34 DAT**	**38 DAT**	**42 DAT**	**48 DAT**
	BA	**A1+3**	**A1+7**	**A1+13**	**A2+3**	**A2+7**	**A2+13**	**A3+3**	**A3+7**	**A3+13**
Tihan-O-Teq	25	0	0	0	0	0	4,17	0	0	4,17
Viper	20,83	12,5	0	0	0	4,17	20,83	8,33	8,33	20,83
Vertimec	20,83	12,5	12,5	16,67	12,5	25	33,33	25	33,33	41,67
K-optimal	25	29,17	33,33	37,5	41,67	54,17	62,5	58,33	58,33	62,5
Control plot	16,67	50	66,67	79,7	91,67	95,83	95,83	100	100	100

Legend: In the same column, averages followed by the same letter do not differ significantly, **BA :** Before Application ; **DAT :** Days After Transplanting; **Am + n** : n Days after m Application (so A1+3 means three days after the first application)

Annex 3: Number of immatures fruits and rate of infested green fruits according to the treatments

Période	**A2+13**		**A3+3**		**A3+7**		**A3+13**	
	Total grenn fruits	**Infested fruits rate (%)**	**Total grenn fruits**	**Infested fruits rate (%)**	**Total grenn fruits**	**Infested fruits rate (%)**	**Total grenn fruits**	**Infested fruits rate (%)**
Tihan-O-Teq	71,67±10,06 b	0±0 a	92,33±4,72 c	0±0 a	142,67±8,38 c	0±0 a	151,33±4,16 d	0,88±0,39 a
Viper	76,33±8,02 b	0±0 a	94±2,64 c	0±0 a	131,67±6,65 c	0±0 a	142,67±3,21 d	1,88±0,86 a
Vertimec	59±2 a	8,46±1,55 b	71,33±4,72 b	8,38±1,06 b	105,33±8,62 b	10,8±2,13 b	121,67±4,04 c	11,5±0,66 b
K-optimal	54±3,6 a	12,83±2,89 b	67±10,58 ab	13,98±2,61 c	94±8,71 b	13,79±0,56 b	107±10,58 b	14,93±0,64 b
Control plot	48,33±1,53 a	35,09±4,47 c	57,67±3,51 a	37,57±4,68 d	74,33±4,04 a	39,84±2,13 c	84±7,93 a	43,71±7,39 c
P	0,0009	0,0001	0,0001	0,0001	0,0001	0,0001	0,0009	0,0001

Legend: In the same column, averages followed by the same letter do not differ significantly, **Am + n** : n Days after m Application (so A2+13 means Thirteen days after the second application)

Annex 4: Fruits harvested according to treatments

	Total harvested fruits	Infested fruits rate (%)	Healthy fruits rate (%)	Number of healthy fruits	Healthy fruits weight (kg)	Healthy Yield Profit Rate (%)
Tihan-O-Teq	471,33±27,15 c	3,02±0,35 a	96,97±0,35 e	457±24,63 c	168±12 c	144,65
Viper	449±32,6 c	6±0,25 b	93,99±0,25 d	422±30,19 c	154±11,13 c	124,26
Vertimec	352±21,28 b	11,56±0,7 c	88,43±0,7 c	311,33±20,03 b	116±8,54 b	68,92
K-optimal	328,33±21,01 b	16,71±0,96 d	83,28±0,96 b	273,33±14,5 b	106,33±4,04 b	54,85
Control plot	281±9,85 a	45,81±1,93 e	54,18±1,93 a	184,67±15,17 a	68,67±6,51 a	-
P	0,0001	0,0001	0,0001	0,0001	0,0001	

Legend: In the same column, averages followed by the same letter do not differ significantly

4. Conclusion and Prospect

Currently, *Tuta absoluta* is present everywhere in Africa where the tomato is grown; the pest is a potential impending threat to tomato production that spreads across Africa. At the end of this study, it appears that the different stages of the *T. absoluta* pest (adults and larvae) are present throughout tomato development stages. Tracking the male catches could be used as a predictive and warning system for reducing pest populations to an economically acceptable level for the producers. Application of insecticides allowed to control the populations of this pest, reduce its damage, and then, improve yield from 54.85 to 144.65% compared to untreated control plots. Therefore, in the context of the management of the *Tuta absoluta* pest, it is necessary to use catches of adults with traps and combine several chemical insecticides in order to reduce resistance problems and improve producer income.

5. Acknowledgments

The authors would like to thank the Service of Plant Protection, Control and Quality (DPVCQ) and the Regional Agriculture and Rural Development of Gbèkè (Bouaké) which gave tous insecticides, delta traps and sex pheromones. We express our gratitude to the tomato smallholders of Djébonoua who facilitated the set up and follow-up of the study.

6. References

1. Abbes K, Harbi A, Chermiti B. The tomato leafminer *Tuta absoluta* (Meyrick) in Tunisia: current status and management strategies, EPPO Bulletin. 2012; 42:226-233.
2. Adja NA, Danho M, Alabi TAF, Gnago AJ, Zimmer JY, Francis F *et al.* Entomofaune associée à la culture de cucurbites oléagineuses africaines (*Lagenaria siceraria* Molina (Standl. 1930) et *Citrullus lanatus* Thumb (Matsum & Nakai 1916)) et impact des ravageurs sur la production. Annales de la Société Entomologique de France (N.S.): International Journal of Entomology, 50. 2014; 3-4:301-310.
3. ANADER. Rapport d'activité de la zone ANADER de Bouaké, 2017, 107.
4. Bajracharya ASR, Mainali RP, Bhat B, Bista S, Shashank PR, Meshram NM *et al.* The first record of South American tomato leaf miner, *Tuta absoluta* (Meyrick 1917) (Lepidoptera: Gelechiidae) in Nepal. Jour. of Ent.y and Zool. Studies. 2016; 4(4):1359-1363.
5. Barrientos ZR, Apablaza H, Norero J, Estay SA. Threshold temperature and thermal constant for development of the tomato moth, *Tuta absoluta* (Lepidoptera, Gelechiidae). Ciencia e Investigacion Agraria. 1998; 25:133-137.
6. Borisade OA, Kolawole AO, Adebo GM, Uwaidem YL. The tomato leafminer (*Tuta absoluta*) (Lepidoptera: Gelechiidae) attack in Nigeraia. Effect of climate change on over-sight pest or agro-bioterrorism? Journal of Agriculture Extension and Rural development. 2017; 9(8):163-171.
7. Cely L, Cantor F, Rodríguez D. Determination of levels of damage caused by different densities of *Tuta absoluta* populations (Lepidoptera: Gelechiidae) under greenhouse conditions. Agronomía Colombiana. 2010; 28(3):401-411.
8. Chermiti B, Abbes K, Aoun M, Ben Othmane S, Ouhibi M, Gamoon W. Firt Estimate of the Damage of *Tuta absoluta* (Lepidoptera: Gelichidae) and Evaluation of the Efficiency of Sex Pheromone Trap in Grennhouses of Tomato Crops in the Bekalta Region, Tunisia. The African Journal of Plant science and Biotechnology. Global Science Books. 2009; 3(1):49-52.
9. CNRA. Rapport de la visite du périmètre de production de tomate de Kpato (Sakassou) suite à un problème entomologique signalé par les producteurs, 2017, 10.
10. Desneux N, Wajnberg E, Wyckhuys KAG, Burgio G, Arpaia S, Narvaez-Vasquez CA. *et al.* Biological invasion of European tomato crops by *Tuta absoluta*: Ecology, geographic expansion and prospects for biological control. Journal of Pest Science. 2010; 83(3):197-215.
11. Garcia MF, Espul JC. Bioecology of the tomato moth (*Scrobipalpula absoluta*) in Mendoza, Argentina Republic. Revista de investigaciones Agropecuarias. 1982; 17:135-146.
12. Guenaoui Y, Ghelamellah A. *Tuta absoluta* Meyrick, (Lepidoptera: Gelechiidae), nouveau ravageur de la tomate en Algérie premiers données sur sa biologie en fonction de la température. AFPP-8éme Conférence Internationale sur les ravageurs en Agriculture, Montpelier Sup Agro, France, 22-23 octobre 2008. ISBN 2-905550. 2008;17(1):PP 645-651.
13. Illakwahhi DT, Srivastava BBL. Control and Management of Tomato Leafminer, *Tuta absoluta* (Meyrick) (Lepidotera, Gelechiidae). A Review. Journal of Applied Chemistry, e-ISSN: 2278-5736www. iosrjournals.org. 2017; 10(6):14-22.
14. Lietti MM, Botto E, Alzogaray RA. Insecticide resistance in argentine populations of Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae). Neotrop. Entomol. 2005; 34:113-119.
15. Luna MAG, Sanchez NE, Pereyra PC. Parasitism of *Tuta absoluta* (Lepidoptera, Gelechiidae) by *Pseudapanteles dignus (*Hymenoptera, Braconidae) Under Laboratory Conditions. Environmental Entomology. 2007; 36(4):887-893.
16. Martins JC, Picanço MC, Silva RS, Gonring AHR, Tarcísio VS, Galdino TVS. Assessing the spatial distribution of *Tuta absoluta* (Lepidoptera: Gelechiidae*)* eggs in open-field tomato cultivation through geostatistical analysis. Pest Management Science. Society

of Chemical Industry. 2018; 74:30-33.
17. MINAGRI, Index Phytosanitaire. Ministère de l'Agriculture (MINAGRI/DPVCQ), FIRCA, WAAPP/PPAAO. Côte d'Ivoire, 47ème édition, 2015, 536.
18. Monserrat-Delgado A. La pollila del tomate *Tuta absoluta* en la Région de Murcia: bases para su control. Técnica 34, Conséjeria de Agricultura y Agua, Region de Murcia, 2009, 112.
19. Mrosso FP. Biological efficacy of Perfecto 175 SC (Lambdacyhalothrin 5% plus Imidacloprid 12.5%) for the control of major insect pests of cotton in eastern cotton growing area, Tanzania. *Afr. J. Agric. Res.* 2013; 8(22):2744-2749.
20. Nayana BP, Shashank PR, Kalleshwaraswamy CM. Seasonal incidence of invasive tomato leafminer, Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae) on tomato in Karnataka, India. Journal of Entomology and Zoology Studies. 2018; 6(1):400-405.
21. Novelli A, Vieira BH, Vasconcelos AM, Peret AC, Espindola ELG. Field and laboratory studies to assess the effects of Vertimec® 18EC on *Daphnia similis.* Ecotoxicology and Environmental Safety. 2012: 75:87-93.
22. Ouali-N'goran SWM, Yao KP, Kra KD, Kouassi KP, Tano Y. Évaluation de l'efficacité de l'insecticide Tricel 480 EC comparée à la Deltamétrine et à la Cyperméthrine contre les ravageurs du chou (*Brassicacae* L. sp.) en milieu paysan dans la région de Yamoussoukro en Côte d'Ivoire, 2014, 14.
23. Pereyra PC, Sánchez NE. Effect of two Solanaceous plants on developmental and population parameters of the tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Neotrop. Entomol. 2006; 35(5):671-676.
24. Roditakis E, Skarmoutsou C, Staurakaki M. Toxicity of insecticides to populations of tomato borer *Tuta absoluta* (Meyrick) from Greece. Pest Manag Sci. 2013; 69:834-840.
25. Salama H, Fouda M, Ismail AI, Ebada I, Shehata I. Life Table Parameters and Fluctuations in the Population Density of the Moth Tuta absoluta (Meyrick)-(Lepidoptera: Gelechiidae). Current Science International. 2014; 3(3):252-259.
26. Sanda NB, Sunusi M, Hamisu HS, Wudil BS, Sule H, Abdullahi AM. Biological Invasion of Tomato Leaf Miner, *Tuta absoluta* (Meyrick) in Nigeria: Problems and Management Strategies Optimization: A Review. Asian Journal of Agricultural and Horticultural Research. 2018;1(4):2581-4478.
27. Shehata I, Ebada I, Ismail AI, Fouda M, Hussein S, Salama HS. *et al* On the Population Dynamics of the Tomato Leaf Miner *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in Egypt. Ecologia Balkanica. 2016; 8(2):65-75.
28. Silva GA, Picanço MC, Bacci L, Crespo ALB, Rosado JF, Guedes RNC *et al.* Control failure likelihood and spatial dependence of insecticide resistance in the tomato pinworm, *Tuta absoluta*. Pest Manage. Sci. 2011; 67(8):913-920.
29. Siegwart M. Mode d'action des insecticides; Journées d'échanges sur les résistances aux produits de protedtion des plantes, 2017, 34.
30. Soro S, Doumbia M, Dao D, Tschannen A, Girardin O, Performance de six cultivars de tomate *Lycopersicon esculentum* Mill contre la jaunisse en cuillère des feuilles, le flétrissement bactérien et les nématodes à galles. *Sciences & Nature.* 2007; 4(2):123-130.
31. Tisler T, Erzen NK. Abamectin in the aquatic environment. Ecotoxicology. 2006; 15:495-502.
32. Tropea-Garzia G, Siscaro G, Biondi A, Zappalà L. *Tuta absoluta*, a South American pest of tomato now in the EPPO region: biology, distribution and damage. *EPPO Bull.* 2012; 42(2):205-210.
33. Visser D, Nofemela R, Mailula T. The invasive tomato leaf miné (*Tuta absoluta*) in South Africa. Insect Ecology - Insect Pests: Fact Sheet N°, 2017, 3.2.
34. Zekeya N, Ndakidemi PA, Chacha M, Mbega E. Tomato Leafminer, *Tuta absoluta* (Meyrick 1917), an emerging agricultural pest in Sub-Saharan Africa: Current and prospective management strategies. *African* Journal of Agricultural Research. Acdemic Journals. 2017; 12(6):389-396.
35. Ziri S. Contribution à la lutte intégrée contre *Tuta absoluta* sur tomate en plein champ. Thèse en vue de l'obtention du grade de magister en sciences agronomiques; option: Entomologie appliquée à la protection des cultures. Ecole Nationale Supérieure Agronomique EL HARRACH, 2011, 92.