IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 5, Issue 5 Ver. II (Sep. – Oct. 2017), PP 21-29
www.iosrjournals.org

The Menace of *Tuta Absoluta*: A Review on the World Spread

I. I Ajibade[1], L. Sa'adu[1], N. C. Maduka[1] K. A. Murana[2]
[1]*Department of Physics*
[2] *Department Of Geology*
Federal University Gusau
P.M.B 1001, Gusau, Zamfara State, Nigeria
Corresponding Author: I.I Ajibade

ABSTRACT: *In this paper, we started by providing a fundamental information regarding tuta absoluta– a devastating pest of tomato or a harmful leaf mining moth with a strong preference for tomato plant – in the Mediterranean Basin countries and South America. We further review history of its invasion in Europe and Africa with the potential future spread of the pest in West Africa. The natural enemies in tomato crops in the aforementioned continents were documented with control method within IPM scheme.*
Key Points: *Tomato, Tuta Absoluta, Pest*

Date of Submission: 12-10-2017 Date of acceptance: 07-11-2017

In this paper, we started by providing a fundamental information regarding *tuta absoluta*– a devastating pest of tomato or a harmful leaf mining moth with a strong preference for tomato plant – in the Mediterranean Basin countries and South America. We further review history of its invasion in Europe and Africa with the potential future spread of the pest in West Africa. The natural enemies in tomato crops in the aforementioned continents were documented with control method within IPM scheme.

I. Introduction

Tomato is considered one of the vital vegetable crops of the world and also one of the most researched of all horticultural crops and so far a considerable and progressive success has been made in this aspect. This is so as a result of its nutritional values which could either be consumed fresh or raw material for food processing industries (Gebremariam, 2015). Tomato is the world's largest vegetable crop after sweet potato but it tops the list of canned vegetables (Olaniyi, *et al., 2010*). It is an important ingredient in most diets and a very cheap and very good source of vitamins A, C and E and minerals that are very good for body and protect the body against diseases (Taylor, 1987). It also contains a large quantity of water (75 %), calcium (20 %) and Niacin all of which are of great importance in the metabolic activities of man. Lycopene is a carotenoid that is present in tomatoes, processed tomato products and other fruits. It is one of the most potent antioxidants among dietary carotenoids. Dietary intake of tomatoes and tomato products containing lycopene has been shown to be associated with a decreased risk of chronic diseases, such as cancer and cardiovascular disease (Agarwal and Rao, 2000).

The tomato leaf miner also known as South American Tomato pinworm, *Tuta Absoluta* (Mey-rick) (Lepidoptera Gelechiidae) hails from South America, where it was first recorded as serious pest of tomato. It was experimented that a female *Tuta Absoluta* lays up to 260 eggs individually on the tender leaves during its life time (Desneux *et' al.,* 2010). *Tuta Absoluta* (Meyrick) was then later accidentally introduced to space in 2006 where it spread North to the Netherlands and East to Iran (Desneux, *et' al.,* 2010, 2011). It travels and breeds in swarms and has a reputation for swiftly ravaging tomato cultivation in a little above 48 hours prompting famers to nickname it tomato ebola. The moth and its larva feed on the leaves of the tomato plant depriving it of the nutrient to flower and to develop fruit (Larraín *et al.,* 2014).

This review is therefore aimed at giving an overview of the origin of this devastating pest across different region in the world. More importantly, the article highlights its bio-ecology, world spread, different methods of anti-pest applications employed by farmers in those regions for the purpose of prevention and control.

II. The Bio-Ecology Of *Tuta Absoluta*

Tuta absoluta is a holometabolous insect with a high rate of reproduction (Gebremariam, 2015). It is considered a devastating pest of tomato (Barrientos *et al.,* 1998; Estay 2000). According to Barrientos *et'al,* (1998) and NAPPO (2012), *Tuta Absoluta* life cycle comprises four development stages: egg, larva, pupa and adult and is completed with 24 days at 27^0C. The eggs are elliptical and their color varies from oyster – white to bright yellow, darkening in the embryonic phase and becoming dark near eclusion. The Larvae are whitish after eclosion, becoming greenish or light pink in the second to fourth instars according to food (leaflet or ripe fruit). The pupae are obtecta with greenish coloration at first, turning chestnut brown and dark brown near adult emergence. Adult moths are about 10 *mm* long, with silverfish – grey scales, filiform antennae, alternating light or dark segments and recurved labial pulps which are well developed (Imenes *et al.*, 1990). Adult usually laid eggs on the underside of leaves, buds, stems and calyx of unripe fruits on which they feed and develop. The pre-oviposition period of this insect which was found possible on unripe tomatoes only is short and ranged from 2.3 to 4.6 days depending on temperature (Monserrat, 2009*)*. The egg production showed to be affected by temperature variation and highest production occurred at 20^0C being 162 $\pm$ 30.94 eggs/female, with slight decrease when temperature decreased to 15 ^0C (Salama *et al.*, 2014). They are four larva stages-fully-fed larva usually drop to the ground on a silk thread and pupate in the soil, although pupation may also occur on the leaves pupae (length 5-6 *mm*) are cylindrical in shape and greenish when just finned becoming darker in colour as they are near adult emergence. Adult are 6-7 *mm* in length and present fili form antennae and silver to grey scales. Black sports are present on anterior wings and the female are wider and more voluminous than the males. The pest mainly present, nocturnal habit and adults usually remains hidden during the day, showing greater morning crepuscular activity with adults dispersing among crops by flying. Among a range of species within the solamanaceae, tomatoes (lycopersicon esculutuma Miller) appear to be primarily host of *Tuta Absoluta*. Pereyra and Sanchez (2006) suggested that *Tuta Absoluta* is multivioline and population parameters suggest that it is an r-selected species. The duration of the developmental cycle greatly depends on environmental conditions, with average development time of 76.3 days at 14 ^0C, 39.8 days at 19.7 ^0C and 23.8 days at 21.1 ^0C (Barrientos *et al.*, 1998; Arno and Gabarra, 2010; Desneux *et al.*, 2010).The most prolific ovipositing period is 7 days after mating, and females lay 76 % of their eggs at that time (Uchoa Fernandes *et al.*, 1995), with a maximum lifetime fecundity of 260 eggs per female (Harizanova *et al.*, 2009). It clearly appeared that *Tuta Absoluta* mated females exhibited a preference to lay eggs on leaves of the plant apex, compared to laying eggs on leaves of the two other parts of tomato host plant (Cherif *et al.*, 2013). In the same way, (Muniappan 2013; Estay 2000) indicated that this insect lays 73 %, 21 %, 5 %, and 1 % on leaves, veins and stems, sepals and fruits, respectively. Egg hatching takes place 4-6 days after egg lying. After hatching, the larvae wandered around the leaf surface for an average of 12 minutes and approximately 15 mm from its egg shell before starting to graze on the leave surface (Cuthbertson *et al.,* 2013). The young larvae penetrate into tomato fruits, leaves or stems on which they feed and develop, thus creating conspicuous mines and galleries (USDA – APHIS, 2011). The insect develops through four larval instars before transforming into the pupal stage (NAPPO, 2012).

Fully – grown larvae usually drop to the ground on a silk thread and pupate in the soil. Pupae are cylindrical in shape and greenish when just formed, becoming darker in color as they near adult emergence (NAPPO, 2012). Adults are about 1 *cm* long, with a wingspan of about 1 *cm* with mottled gray in color (USDA – APHIS, 2011).

Table 1: Temperature adaptation for egg, larva-adult of *Tuta absoluta*

Temperature^{0}C	6.9 -± 0.5	7.6 ± 0.1	9.2 ± 1.0
Development stages	Egg	Larva	Adult
Thermal constant	103.8 ± 1.4	238.5 ± 0.5	117.3 ± 5.3

The threshold for the three stages was 8.1± 0.2 ^0C whereas the total thermal constant from egg to adult was estimated at 453.6 ± 3.9 DD larvae appear to refrain from entry dispense as long as food is available and there can be 10-12 generation, per year in South Africa. Vercher *et al.*, (2010) was able to maintain *Tuta Absoluta* larvae alive during several weeks at 4 ^0C. When Tuta Absoluta does not pupate in the soil, a cocoon is usually built. Under Mediterranean conditions, adult of *Tuta Absoluta* can be detected around the year (Vercher *et al.*, 2010). Adult lifespan ranges, from 10 and 15 days for female and 6-7 *days* for males (Estay, 2000). Females mate only once a day and are able to mate up to six times during their lifespan, with a single mating about lasting 4-5 hrs. The most prolific on position period is 7 days after first mating and females lay 76 % of their eggs at that timing with a maximum lifetime fecundity of 260 eggs performance (Uchoa-fernandes *et al.*, 1995).

2.1 Mechanistic Model

A mechanistic model for tomato growth and development that includes dry matter assimilation and partitioning is reported in the literature (Heuvelink, 1999) and may serve as basis for developing a PBDM for the tomato plant to provide the bottom-up dynamics on *Tuta absoluta*. *Tuta Absoluta* is a multivoltine species with high reproductive potential (Tropea Garzia *et al.*, 2012). Studies on the moth's development (Barrientos *et al.*, 1998) estimated the lower thermal threshold and the duration of the life stages in degree-days (*dd*): eggs (103,8 *dd* above 6.9 °*C*), larvae (238.5 *dd* above 7.6 °*C*), and pupae (117.3 *dd* above 9.2 °*C*). Other data provided by (Barrientos *et al.* 1998) could provide information for estimating sub-models for temperature-dependent rate of development and for mortality. Sannino *et al*., (2010) monitored field populations year-round and estimated the duration of life stages in physiological time units (*dd*). These observations may be used as field estimates for inclusion in the developmental rate sub-model. Data from (Pereyra and Sánchez, 2006) on age-specific survivorship and fecundity profiles, net reproductive rate, and intrinsic rate of increase at 25 *°C* (on both tomato and potato), and data from (Medeiros *et al.*, 2009) on age-specific survivorship at 25 *°C* on tomato plants grown in conventional vs. organic systems could be used to develop sub-models for mortality and fecundity. (Sannino et *al*., 2010) found that adults can live up to six weeks at 15 *°C* but only a few days (4-5) at 35 *°C*, information that could help model the effect of temperature on adult longevity. The pre-oviposition period is about two days with eggs being laid singly or in batches of 2 -5. Total fecundity varies considerably (40-262 eggs per female) in the literature reviewed (Sannino *et al.,* 2010). *Tuta* continues development as food and weather allow (up to 12 generations in the warmer reaches of its native range). It appears not to have a diapause stage, and yet Sannino *et al.,* (2010) at Scafati found that overwintering pupae take 65.1 days on average to complete development with one third of the pupae formed in the first half of November developing to adults by the first half of December (17.9 days on average). The remaining pupae are quiescent during cold months and emerge the following year between January and February. This could indicate that insufficient thermal units accrue or some other factors delay development. For example, termination of diapause in *Anarsia linea tella* (Lepidoptera, Gelechiidae) requires chilling and its larvae complete diapause development in late January-early February (Damos and Savopoulou-Soultani, 2010) as occur red for some *Tuta* pupae. This aspect of the biology requires further examination. In Mediterranean climes, adults are found throughout the year (Vercher *et al.*, 2010). Other biological and behavioral traits include: adults are nocturnal and usually hide during the day in the canopy; females lay eggs on aerial parts of their host plants, and four larval instars develop; pupation may take place in the soil, on the leaf surface, or within mines (EPPO, 2005; Sannino and Espinosa, 2010).

A more recent study (Cardozo *et al.,* 1994) reported that *Tuta absoluta* is able to complete development on *Nicotiana tabacum*, and can use *Solanumelaeagnifolium* as an alternate host plant.

Fernandez and Montagne, (1990) conducted host preference studies in a laboratory in Venezuela. They found that the tomato cultivar "Rome Gigante" was the preferred oviposition host and the best host for larval development, when compared to tomato variety Cerasiforme, eggplant, tobacco, *Solanumhirtum*, *Physalis angulata*, *S. americanum,* and potato.

The lower developmental (or baseline) temperature for *Tuta absoluta* is 8.14 *°C*. For egg development this temperature is 6.9 *°C*; for larvae it is 7.6 °C; and for pupae it is 9.2 *°C*. Using the mean baseline temperature of 8.14*°C*, *Tutaabsoluta* requires 459.6 degree days to complete its development. A degree day is a measurement of heat units over time, calculated from daily maximum and minimum temperatures. Degree days are based on the rate of an insect's development at temperatures between upper and lower limits for development. The minimum temperature at which insects first start to develop is called the lower developmental threshold, or baseline temperature (Murray, 2008). Degree day requirements to complete egg, larval and pupal development are 103.8, 238.5 and 117.3, respectively (Barrientos *et al.,* 1998). Laboratory studies in Chile showed that the development of *Tuta absoluta* from egg to adult requires 76.3 days at 14 °C (57 *°F*), 39.8 days at 19.7 °C (67 *°F*), and 23.8 days at 27.1*°C* (81*°F*). The authors also recorded egg-to-adult survival at these temperatures. At 14 *°C*, 61.9 percent of the cohort survived to adulthood; at 19.7 *°C*, 60.7 percent of the cohort emerged as adults and at 27.1*°C*, 44.3 percent of the cohort completed development. At 27.1*°C*, eggs enclosed in 4 to 6 days, larvae completed their development in 11 to 13 days, and pupae emerged as adults in 5 to 8 days. At 19.7*°C*, eggs enclosed in 7 to 9 days, larvae completed their development in 18 to 22 days and pupae emerged as adults in 9 to 14 days. At 14.0 *°C*, eggs enclosed in 12 to 16 days, larvae completed their development in 33 to 42 days, and pupae emerged as adults in 20 to 28 days (Barrientos *et al.*, 1998). In laboratory studies in Venezuela, (Fernandez and Montagne 1990a) reported that the egg stage of *Tuta absoluta* lasted 4.4 to 5.8 days at a temperature of 24.6°C and a relative humidity of 76.17 percent; larval development was completed in 11 to 15 days at 24.09°C and 70.64 percent R.H.; adult males emerged in 7 to 8 days and females in 6 to 8 days at 26.3°C and 72.3 percent R.H. The sex ratio was 3 males to 4 females, or 1:1.33 male: female.

Adult *Tuta absoluta* are most active at dusk and dawn, and rest among leaves of the host plant during the day (Fernandez and Montagne, 1990; Viggiani *et al.,* 2009). Mating usually occurs the day after adults emerge, usually at dawn. Studies in Chile revealed that the greatest number of males was captured in pheromone traps during the period 7 to 11 am, suggesting that this is the time when males are searching for calling females (Miranda-Ibarra, 1999).

Hickel et al. (1991) studied the mating behavior of *Tuta absoluta* in the laboratory and determined the sequence of male mating behaviors can be divided into two phases: long-range female location and short-range courtship.

The tomato leaf miner prefers to lay eggs on the leaves (both sides); however, they will oviposit on other aerial parts of the plant such as shoots, stems, flowers and green fruit underneath the sepals that form the calyx. (Riquelme *et al.*, 2006) observed no significant differences in the vertical distribution of *Tutaabsoluta* eggs on tomato plants, however, females tended to concentrate their egg laying activity on the upper third of the tomato plants after the third week of planting (Riquelme *et al.*, 2006).

Larvae normally hatch from the eggs in the morning. In laboratory studies conducted in Venezuela, 96.8 percent of a cohort of 94 eggs enclosed between 6 and 9 a.m. (Fernandez and Montagne, 1990). After hatching, larvae penetrate plant tissue (leaves, shoots or flowers) and begin to feed, forming irregular mines that get longer and wider as the larvae continue to feed. The larvae consume the mesophyll leaving the epidermis intact. Later instars can attack maturing fruit (Vargas, 1970).

III. World Spread Of *Tuta Absoluta*

Tomatoes are planted by an estimated 85 % of the gardens each year. However, the production of this important vegetable crop is facing unprecedented challenge from South American originated pest. Thus, if no control measures are implemented as a devastating pest, yields of tomato may be reduced by 80-100 % (Lo´pez 1991; Desneux *et'al.* 2010). The spread of this pest has hit almost all the continents. Below is the highlight of the major areas where this pest has been discovered and appeared prevalent.

3.1 South America

Although it was first detected in Eastern Spain in late 2006 (Urbaneja et al. 2007), Tuta Absoluta has been recorded in all countries in South America, panama (Central America) and has been a long-time pest of open field and greenhouse tomato in South America (Vargas, 1970; Fernandez and Montagne 1990; Colomo *et al*., 2002). Other South American countries affected by the menace of this pest include Argentina, Bolivia, Chile, Colombia, Paraguay, Peru, Uruguay Venezuela and Brazil. In fact, its eventual introduction into Brazil, the leading neotropical tomato producer (FAO, 2014), led to drastic changes in tomato production in the country with a dramatic increase in insecticide use in the early 1980's (Guedes and Picanco, 2012; Guedes and Squeira, 2012).

3.2 Europe

In Europe it was initially detected in the Iberian Peninsula in 2006 and ever since then it has rapidly moved across the Mediterranean area (Potting, 2009) and has been detected in Italy, France, and even United Kingdom (UK) (Cuthbertson *et al.*, 2013). The reflection of the devastating potency of the pest is responsible for the large-scale destruction of tomato farms and if not controlled can produce 50% to 100% loss of fruit production (Larraín *et al.*, 2014),besides facilitating the contamination by pathogens. In Central Brazil, for example, this pest is present throughout the year due to favorable weather conditions, especially from July to September, during dry and hot period when the temperature is favourable for the crop to develop. Moth "a grey-brown" of about 7mm long can wipe out farms in days. It attacks fruits in the open farm and greenhouses; it is lethal, and a female pest can produce up to 200 eggs in 21 days.

3.3 Africa

One year after it was detected in Spain, *Tuta absoluta* was reported to have appeared in Tunisia in 2008 (Abbes *et al.*, 2012), then Morocco in 2008 (Desneux *et al.*, 2010), equally Western Africa in 2010 (USDA-APHIS, 2011) and some Eastern African countries such as Sudan and Ethiopia in 2011. Arnon and Gabara, (2010) opined four larva instars and the first 2 instars mine the leaves by feeding on the mesophy II and leaving the epidermis intact also appeared in Morocco and Algeria. The photosynthesis at the surface of the leaves is thereby reduced by the mines which result in early drying. Furthermore, Integrated Pest Management Collaborative Research Support Project (IPM CRSP) visit to Senegal found that tomato cultivated in the Niayes regions near Dakar and the centre puole. Development del' Horticulture research station had mines in leaves and bore holes in the fruits. Incubating the affected leaves and soil collected affected plants resulted to emergence of several adult moths, tentatively identified as *Tuta Absoluta*.

Tomatoes constitute 18 percent of all vegetables consumed by Nigeria's 180 million populace; this was in accordance with a research carried out by the Agricultural Economics Department of the University of Ibadan, Oyo State Nigeria (Businessdayonline 2015). The pest came into Nigeria from Niger Republic and manifests a powerful infestation that could make it impossible for the country to grow tomato if not dealt with, (Animasahun, 2016). It then spread across tomato farmlands in the northern part of the country, including areas in and around Makarfi, Hunkuyi, Soba and Zuntu villages in Kaduna State; in Danja, Katsina State, and in

Kadawa, Dakasoye and Kura villages in Kano State, according to Agro Nigeria. The disease was responsible for massive destruction of tomatoes in farmlands in Nigeria in 2016 which made the price of tomatoes to skyrocket.

IV. Prevention And Control

Cultural control- ploughing, manuring, irrigation, crop rotation, solarisation, and elimination of symptomatic leaves and destruction of infested tomato plants have all been used to control this pest. The removal of alternative reservoir hosts such as night shades is strongly recommended before and during cropping cycle. Alternating host crops, mainly tomato and potato, with non – host cultures can ensure a long-term reduction in the pest pressure.

4.1 Chemical Control

Chemical pesticides are common in pest control. Common chemicals are pyrethroids (Guedes and Picanço, 2012), organophosphates, spinosad, emamectin benzoate and abamectin (Campos *et al.*, 2014), chloride channel activators, benzoylureas (Haddi, 2012) and diamide (Roditakis *et al.,* 2015). Application of these chemicals against *Tuta Absoluta* has been reported with little success, mainly because of pest resistance and to some point could be utilized by plant as well (Siqueira e*t al.,* 2000). Tomato borer resistance has been reported widely used chemicals such as spinosad Cartap and Abamectin, creating further threat to farmers (Siqueira et al., 2000; Haddi, 2012; Guedes and Siqueira, 2012; Campos *et al.,* 2015).

Pest resistance has been reported to cause increased use of chemical pesticides applications against *Tuta Absoluta* in many parts of the world (Consoli *et al.,* 1998; Siqueira et al., 2000; Lietti et al., 2005). In Spain, about 15 applications have been reported (Guedes and Picanço, 2012). The pest resistance against spinosad chemical reached up to 180,000 resistances within seven further generations in Brazil (Campos *et al.,* 2014). In countries such as Tunisia, more than 18 chemicals were introduced during 2009-2011 for the control of tomato borer but none of them seemed efficient in solving the pest problem (Abbes *et al.,* 2012). Failure of these chemicals in controlling *Tuta Absoluta* opened a new window for development of other methods including biopesticides, pheromone traps, and parasitoids (Regnault-Roger, 2012; Cherif *et al.*, 2013; Zappala *et al.*, 2013). Though chemical pesticides are economically and environmentally unaffordable, farmers still seek them for their agricultural uses because is the only easily accessible option.

The most common method of controlling *Tuta Absoluta* in most South American countries is the application of insecticdes. (Lietti *et al.,*2005). Organophosphates were initially used for *Tuta Absoluta* control, which were gradually replaced by pyrethroids during the 1970s. During the early 1980s, cartap, which alternated with pyrethroids and thiocyclam, proved highly efficient in controlling pest outbreaks (Lietti et al. 2005). During the 1990s, novel insecticides were introduced, such as abamectin, acylurea IGR, spinosad, tebufonozide and chlorfenapyr.

Recently in Brazil, 10 new molecules of pyrethroids proved to be effective in controlling *Tuta Absoluta*, with different toxical effects, and in some cases, up to 100% larval mortality was recorded. Also, some vegetal products were assessed for potential use in the leafminer control, including extracts of Trichilia pallens (da Cunha *et al.*, 2006), species belonging to the same family of neem tree, whose extracts are largely used for insect pest control. However, the use of insecticide, drawing upon a limited set of products, has proven not to be a sustainable management option for this pest in South America. Since the 1980s, efficacy of organophosphates for *Tuta Absoluta* control has gradually decreased in countries like Bolivia, Brazil and Chile (Siqueira *et al*., 2000, 2001). In addition, resistance development has been reported against organophosphates and pyrethroids in Chile (Salazar and Araya 1997) and against abamectin, cartap, methamidophos and permethrin in Brazil (Siqueira *et al*., 2001).

Resistance to deltamethrin and abamectin has recently been demonstrated for open field and greenhouse populations of *Tuta Absoluta* in Argentina (Lietti *et al.*, 2005).

The decision scheme of using insecticides for management of *Tuta Absoluta* is largely based on adult captures in sexual pheromone traps (Benvenga et al. 2007), as adult catches are correlated with larval damages and yield losses (Faccioli 1993; Benvenga *et al*., 2007). In Brazil, Benvenga *et al.* (2007) reported an action level of 45 ± 19.50 *Tuta Absoluta* catched daily using pheromone traps, while in Chile extension specialists report an economic threshold of 100 males per pheromone trap per day. Action threshold could also be based on occurrence of the pest in the tomato crop with 2 females/plant or 26 larvae per plant (Bajonero et al. 2008) or 8% defoliation. Mass trapping may also effectively remove sufficient males to lower overall *Tuta Absoluta* population levels and reduce pest pressure (Witzgall *et al.,* 2010). However, mass trapping would likely be most effective when used in conjunction with recommended insecticides.

4.2 Botanicals

Botanicals have been reported to play a great role in controlling pests (Isman, 2006; Zekeya *et al.,* 2014). Many laboratory studies revealed the efficacy of plant compounds against insect pests including *Tuta Absoluta* (Castillo *et al.,* 2010). For instance, extracts from neem plants were reported to be efficient against *Tuta Absoluta* under laboratory condition (Durmusoglu *et al.,* 2011). Yankokova *et al.,* (2014) reported that Neem plant contains a number of active metabolites such as alkaloids which can control insect pests. These compounds have been reported to have control efficacy against tomato borer (Yankova *et al.,* 2014). Other plants which are promising in management of *Tuta Absoluta* include Piper (Brito *et al.,* 2015) whereas compounds from *Acmella oleracea* were revealed to be active against *Tuta absoluta* (Moreno *et al.,* 2012). Plant based pesticides have been recorded to be better than synthetic chemical pesticides as they are naturally accessible and environmentally friendly to none targeted organisms.

4.3 Bio Pesticides

Use of microorganism as bio pesticides for management of pests has increasingly gained popularity in recent years (Mollá *et al.,* 2014). Bacteria and fungi have been used for a long time in management of tomato borer in America and Europe (Trottin-Caudal *et al.,* 2012). The microbes have been reported to attack pests by their pathogenic effects and currently there are many commercially available bacterial and fungal formulations for controlling pests including *Tuta Absoluta* in America and Europe (Sabbour, 2014). The formulations are either by foliar spray or by drenching the roots (Amizadeh *et al.,* 2015). One of the best and successful formulations was that of *Metarhizium anisopliae* (fungus) and *Bacillus subtilis* (bacteria) which have been reported to reduce the population of *Tuta Absoluta* on tomato at all developmental stages in America and Europe. Other formulations reported to be tested against include that of *Metarhizium anisopliae* and *Beauveria bassiana* (Kaoud, 2014). Most of these reports however were all based on screen house studies (González-Cabrera *et al.,* 2011). Nematodes have been reported as biocontrols of *Tuta Absoluta* in some countries and depicted high insect mortality (Batalla-Carrera et al., 2010). The nematodes were reported to be effective against larvae, pupae and adult *Tuta Absoluta* (Garcia-del-Pino *et al.,* 2013). Unfortunately, none of these strategies have been reported to be effective in Nigeria.

4.4 Biological Control

Several biocontrol agents are used to control the tomato leaf miner in open field and greenhouse tomato cultivation. The most common predators against *Tuta Absoluta* are the mirid bugs, Nesidicoris tennis and Macrolophus pygamas. Other pest control approaches have been studied and documented, notably the potential use of biological control agents (predators, parasitoids and entomopathogens (Campos *et al.,* 2009) and botanical insecticides (da Cunha *et al*., 2006).

4.5 Host – Plant Resistance

Host – plant resistance was explored by developing tomato accessions with high Zingiberence and/or acylsugar contents resulting on how oviposition rates and larva feeding of *Tuta Absoluta* (Attygalle *et al.*, 1996).

V. Conclusion

The geometric importance of tomato (*lycopersicon esculentum*) as a vegetable accounts for the large volume of research on it. This review therefore mirrors on the advent of the tomato pest (*tuta absoluta)* right from South America to Europe and to Africans countries. The major intent was to pave way for this research team to come up with a proposed mathematical model of multilayer skinned approximations for tomatoes that are grown in Nigeria with a view to proposing a lasting solution to the aforementioned menace of *Tuta Absoluta*. Therefore subsequent publications by this team will give detail on the model.

Acknowledgement

This research team wishes to express their gratitude to the Tertiary Institution Fund (tetfund), Nigeria for the sponsorship of this ongoing work under the subhead of ……………..

References

[1] Abbes. K., Harbi, A. Chermiti, B. (2012).The tomato leafminer Tuta absoluta (Meyrick) in Tunisia: current status and management strategies. EPPO Bull. 42:226-233.

[2] Agarwal,S. and Rao , A.V (2000)Tomato lycopene and its role in human health and chronic diseases. *CMAJ* 2000;163 (6):739-44.

[3] Amizadeh, M., Hejazi M. J., Niknam, N., Arzanlou, M. (2015). Compatibility and interaction between Bacillus thuringiensis and certain insecticides: perspective in management of Tuta absoluta (Lepidoptera: Gelechiidae). Biocon. Sci. Technol. 25:671-684.

[4] Animashaun, M. (2016) On combating 'Tomato Ebola' without unleashing cancer on Nigerians by the Vanguard Newspaper June 19,2016.

[5] Arno, J., Gabara, R. (2010). Controlling Tuta absoluta, a new invasive pest in Europe,Training in integrated Pest management – No 5IRTA cabrils, spain.

[6] Attygalle, A. B., Jham, G. .N., Svatos, A., Frighetto, R. S. T., Ferrara, F. A. Vilela, E.F., Uchoa, F.M A. and Meinwald, J (1996). Tetradecatrienyl acetate, major sex pheromone Component of the tomato pest Scrobipalpuloides absoluta (Lepidoptera: Gelechiidae). Bioorganic and Medicinal Chemistry, **4**(3): 305 – 315.

[7] Bajonero, J., Cordoba N, Cantor, F., Rodriguez, D., Cure, J. R. (2008). Biology and life cicle of Apanteles gelechiidivoris (Hymenoptera: Braconidae) parasitoid of Tuta absoluta (Lepidoptera: Gelechiidae). Biologı´a y ciclo reproductivo de Apanteles gelechiidivoris (Hymenoptera: Braconidae), parasitoide de Tuta absoluta (Lepidoptera: Gelechiidae). Agron Colomb 26:417–426.

[8] Benvenga, S. R., Fernandes, O. A., Gravena, S. (2007). Decision making for integrated pest management of the South American tomato pinworm based on sexual pheromone traps. Hortic Bras 25: 164–169

[9] Barrientos, Z. R., Apablaza, H. J., Norero, S. A., Estay, P. P., (1998) – *Temperatura base y constante* termica *dedesarrollo de la polilla del tomate, Tuta absoluta(Lepidoptera: Gelechiidae)*. - Cienc. Investig. Agrar., 25: 133-137.

[10] Batalla-Carrera, L., Morton, A., García-del-Pino, F. (2010). Efficacy of entomopathogenic nematodes against the tomato leafminer *Tuta absoluta* in laboratory and greenhouse conditions. Biol. Cont. 55:523-530.

[11] Brito, F., Baldin, L., Silva, M., Ribeiro, P., Vendramim, D. (2015). Bioactivity of piper extracts on *Tuta* absoluta(Lepidoptera: Gelechiidae) in tomato. Pesqui. Agropecu. Bras. 50:196-202.

[12] Cardozo, M. R., M. B. Lopez, M. T. Evert, C. Palacio, S. Yasuda, H. Sugiyama, K. Mori, M. Kajita, and T. Sato. (1994). Control integrado de la palomilla del tomate, *Scrobipalpula absoluta* (Meyrick, 1917). Ins. Agr. Nac. CAACUPE, Paraguay.

[13] Cherif, A. Mansour, R.Grissa-Lebdi, K. (2013). Biological aspects of tomato leafminerTuta absoluta (Lepidoptera: gelechiidae) in conditions of Northeastern Tunisia: possible implications for the management. Environmental and Experimental Biology (2013) 11: 179-184.

[14] Colomo, M.V., Berta, D.C. Chocobar, M. J. (2002). El complejo de himeno´pteros parasitoides que atacan a la ‘‘polilla del tomate’’ Tuta absoluta (Lepidoptera: Gelechiidae) en la Argentina. Acta Zool Lilloana 46:81–92.

[15] Campos, R., Rodrigues, S., Silva, M., Silva, M., Silva, F., Guedes, C., Siqueira, A. (2014). Spinosad and the tomato borer *Tuta absoluta*: a bioinsecticide, an invasive pest threat, and high insecticide resistance. PloS one 9:e103235.

[16] Campos, M. L, de Almeida, M., Rossi, M. L, Martinelli, A. P, Litholdo, C. G, Figueira A., Rampelotti-Ferreira, F. T, Vendramim, J. D., Benedito, V. A., Peres, L. E. P. (2009). Brassinosteroids interact negatively with jasmonates in the formation of anti-herbivory traits in tomato. J Exp Bot 60:4346–4360.

[17] Consoli, L., Parra, P., Hassan, A. (1998). Side-effects of insecticides used in tomato fields on the egg parasitoid *Trichogramma pretiosum* Riley (Hym. Trichogrammatidae), a natural enemy of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). J. Appl. Entomol. 122:43-47.

[18] Castillo E, Jiménez J and Delgado, A. (2010). Secondary metabolites of the Annonaceae, *Solanaceae* and Meliaceae families used as biological control of insects. Trop. Subtrop. Agroecosys. 12:445-462.

[19] Cuthbertson, A.S., Mathers, J.J. Blackburn, L.F., Korycinska, A., Luo, W, Jacobson, R.J and Northing, P (2013). Population Development of Tuta absoluta (Lepidoptera: gelechiidae) under Simulated Uk Glasshouse Conditions. Insects 2013, 4, 185-197: doi:10.3390/insect4020185

[20] da Cunha, U. S., Vendramim, J. D., Rocha, W. C., Vieira, P. C. (2006). Fractions of Trichilia pallens with insecticidal activity against Tuta absoluta. Pesqui Agropecu Bras 41:1579–1585.

[21] Damos, P. T., Savopoulou-Soultani, M. (2010) – Synchronized diapause termination of the peach twig borer Anarsia lineatella (Lepidoptera: Gelechiidae): Brownian motion with drift?- Physiol. Entomol., 35: 64-75.

[22] Desneux, N., Luna, M. G., Guillemaud, T., Urbaneja, A. (2011). The invasive South American tomato pinworm, *Tuta absoluta*, continues to spread in Afro-Eurasia and beyond: the new threat to tomato world production.- *Journal of Pest Science*, 84: 403-408.

[23] Desneux, N., Wajnberg. E., Wyckhuys, K. A. G., Burgio, G., Arpaia, S., Narvaez-Vasquez, C. A., Gonzalez-Cabrera, J., Catalan, R. D., Tabone, E., Frandon, J., Pizzol, J., Poncet C., Cabello, T., Urbaneja, A. (2010). Biological invasion of European tomato crops by *Tuta absoluta*: ecology, geographic expansion and prospects for biological control. *Journal of Pest Science*, 83: 197-215.

[24] Durmusoglu, E., Hatipoglu, A, Balci, H. (2011). Efficiency of some plant extracts against *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae) under laboratory conditions. Turk. Entomol. Dergisi-Turkish J. Entomol. 35:651-663.

[25] EPPO [European and Mediterranean Plant Protection Organization]. (2005). Data sheets on quarantine pests: Tuta absoluta. - EPPO Bull., 35: 434-435.

[26] Estay, P. (2000). Polilla del Tomate Tuta absoluta (Meyrick) [WWW document]. URL http://alerce.inia.cl/docs/Informativos/ Informativo09. Accesed 2 Feb 2010.

[27] FAO [Food and Agriculture Organization of the United Nations]. (2014). FAOSTAT. Available: http://faostat3.fao.org/faostat-gateway/go/to/download/Q/QC/E. Accessed 2014 Feb 5.

[28] Faccioli, G. (1993). Relationship between males caught with low pheromone doses and larval infestation of Argyrotaenia pulchellana. Entomol Exp Appl 68:165–170.

[29] Fernandez, S., and A. Montagne. (1990). Preferencia de oviposicion de las hembrasy duracion, crecimiento y sobrevivencia de las larvas de *Scrobipalpula absoluta* (Meyrick) en diferentes Solanaceas. *Bol. Entomol.Venez. N.S.* 5(13):100-106.

[30] Gebremariam, G. (2015). Tuta Absoluta: A global Looming Challenge in TomatoProduction, Review Paper. *Journal of Biology, Agriculture and Healthcare*, Vol. 5, No 14.

[31] Garcia-del-Pino, F., Alabern, X., Morton, A. (2013). Efficacy of soil treatments of entomopathogenic nematodes against the larvae, pupae and adults of *Tuta absoluta* and their interaction with the insecticides used against this insect. BioCon 58:723-731.

[32] Guedes RNC, Picanço M. C. (2012). The tomato borer *Tuta absoluta* in South America: pest status, management and insecticide resistance. Bull OEPP/EPPO Bull 42: 211–216.

[33] Guedes RNC, Siqueira, H.A.A. (2012). The tomato borer *Tuta absoluta*: insecticide resistance and control failure. CAB Rev 7, no. 055. doi:10.1079/PAVSNNR20127055.

[34] González-Cabrera, J., Mollá O, Montón H, Urbaneja, A. (2011). Efficacy of *Bacillus thuringiensis* (Berliner) in controlling the tomato borer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). BioCont 56:71-80.

[35] Haddi, K. (2012). Studies on insecticide resistance in *Tuta absoluta* (Meyrick), with special emphasis on characterisation of two target site mechanisms. http://archivia.unict.it/handle/10761/1226.

[36] Harizanova, V., Stoeva, A., Mohamedova, M. (2009). Tomato Leaf miner, Tuta absoluta (Povolny) (Lepidoptera: gelechiidae)m-first record in Bulgaria. Agricultral Scienceand technology, Vol. 1. No 3, pp 95 -98.

[37] Heuvelinke. (1999) Evaluation of a dynamic simulation model for tomato crop growth and development. - Ann.Bot., 83: 413.

[38] Hickel, E. R., Viela, E. F., Gomes de Lima, J. O., Castro della Lucia T. M. (1991). Comportamento de acasalmento de *Scrobipalpula absoluta* (Lepidoptera:Gelechiidae). *Pesq.* agropec. *bras. Brasilia* 26(6):827-835.

[39] Imenes, S. D. L., Uchoa-Fernandes, M. A., Campos, T. B., Takematsu, A. P. (1990). Aspectos Biologicos compartmentais da trata do tomateiro Scrobipalpula absoluta (Meyrick) (Lepidoptera: gelechiidae) Arquivos do instituto Biologico, Sao Paulo57(112): 63-68.

[40] Isman, M. B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Ann. Rev. Entomol. 51:45-66.

[41] Kaoud, A. (2014). Alternative methods for the control of *Tuta absoluta*.GJMAS. J. 2:41-46.

[42] Larraín, P., Escudero, C., Morre, J. Rodríguez, J. (2014). "Insecticide effect of cyantraniliprole on tomato moth Tuta *absoluta* Meyrick (Lepidoptera: Gelechiidae) larvae in field trials". *Chilean journal of agricultural research*. Vol.74 no.2.

[43] Lietti, M. M., Botto, E., Alzogaray, R. A. (2005). Insecticide resistance in argentine populations of Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae).- Neotropical Entomology, 34: 113-119.

[44] Lo´pez, E. (1991). Polilla del tomate: Problema crı´tico para la rentabilidad del cultivo de verano. Empresa y Avance Agrı´cola 1:6–7.

[45] Medeiros, M. A. D., Sujii, e.R., Rasi, G. C., Liz, R. S., Morais, H. C. D. (2009). *Padrão de oviposição tabela de vida datraça-do-tomateiro Tuta absoluta (Meyrick) (Lepidoptera,Gelechiidae)*. - Rev. Bras. Entomol., 53: 452-456.

[46] Miranda-Ibarra, E. (1999). Fluctuacion poblacional, ritmo diario de vuelo de machos y eficacia de biopesticidas en polilla del tomate *Tuta absoluta* (Meyrick) en cultivo del tomate de otoño, bajo invernadero en la zona de Quillota Universidad Iberoamericana de Ciencias y Tecnologia.

[47] Muniappan, R. (2013). Tuta absoluta: the tomato leafminer. http:/wwww/coraf.org./documents/ateliers/2013-05/tuta-absoluta/Tuta-absoluta- Presentation.pdf, Accessed April, 2015.

[48] Mollá, O., Biondi, A., Alonso-Valiente, M., Urbaneja, A. (2014). A comparative life history study of two mirid bugs preying on *Tuta absoluta* and Ephestia kuehniella eggs on tomato crops: implications for biological control. BioCont 59:175-183.

[49] Monserrat, A. (2009). La polilla del tomate Tuta absoluta en la Regio´n de Murcia: bases para su control. Serie Te´cnica y de Estudios No. 34. Conserjerı´a de Agricultura y Agua

[50] Moreno, Shaiene C, Carvalho, Geraldo A, Picanço, Marcelo C, Morais, Elisangela G. F., Pereira, R. M. (2012). Bioactivity of compounds from *Acmella oleracea* against *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) and selectivity to two non-target species. Pest Manage. Sci. 68:386-393.

[51] Murray, M. S. (2008). Using Degree Days to Time Treatments for Insect Pests. Utah Pests Factsheet, Utah State University Extension and Utah Plant Pest Diagnostic Laboratory. Accessed January 28, 2011. http:// climate.usurf.usu.edu/includes/pestFactSheets/degree-days08.

[52] n. a. April (2017). Tuta Absoluta in Nigeria <http://www.businessdayonline.com/?s=tuta+absoluta>.

[53] NAPPO. (2012). Surveillance Protocol for Tomato leaf Miner, Tuta absoluta, for NAPPO Members Countries.

[54] Olaniyi, J. O. , Akanbi, W. B., Adejumo, T. A., Akande, O. G. (2010). Growth, fruit yield and nutritional quality of tomato Varieties. African Journal of Food Science Vol. 4(6), pp. 398 – 402.

[55] Pereyra P.C., Sánchez, N. E., (2006). Effect of two solanaceous plants on developmental and population parameters of the tomato leaf miner, Tuta absoluta *(Meyrick) (Lepidoptera:* Gelechiidae*)*. - Neotrop.Entomol., 35: 671-676.

[56] Potting, R. (2009). Pest risk analysis, Tuta absoluta, tomato leaf miner moth. Plant protection service of the Netherlands, 24 pp. www.minlnv.nl.

[57] Riquelme, M. B., Botto, E. N., Lafalce, C. (2006). Evaluación de algunos insecticidas para el control de la «polilla del tomate», *Tuta absoluta* (Lepidoptera: Gelechiidae) y su efecto residual sobre el parasitoid *Trichogrammatoidea bactrae* (Hymenoptera: Trichogrammatidae). *Rev. Soc.Entomol. Argent.* [online] vol.65, n.3-4, pp. 57-65.

[58] Regnault-Roger, C. (2012). Trends for commercialization of biocontrol agent (biopesticide) products. In Plant Defence*:* Biol. Cont. Spri Netherlands pp. 139-160.

[59] Roditakis E, Vasakis E, Grispou M, Stavrakaki M, Nauen R, Gravouil M, Bassi A (2015). First report of *Tuta absoluta* resistance to diamide insecticides. J. Pest Sci. 88:9-16.

[60] Sabbour, M. (2014). Biocontrol of the tomato pinworm *Tuta absoluta* (Meyrick)(Lepidoptera: Gelechiidae) in Egypt. *M*id East JAgric Res 3: 499-503.

[61] Salama, H., Fouda, M., Ismail, I. A. Ebada, I.,Shehata, I. (2014). Life Taable Parameters and Fluctuations in the Population Density of the Moth Tuta absoluta (Meyrick) – (Lepidoptera; gelechiidae). Current Science International 3(3): 252 -259, 2014, Issn: 2077 – 4435.

[62] Sannino, L., Espinosa, B. (eds.), (2010). *Tuta absoluta: guida alla conoscenza e recenti* acquisizioni *per una corretta difesa*. - Edizioni L'Informatore Agrario, Verona, Italy, 113

[63] Siqueira H. A. A., Guedes R. N. C. and Picanço M. C., 2000.- Insecticide resistance in populations of Tuta absoluta (Lepidoptera: Gelechiidae).- Agricultural and Forest Entomology, 2: 147-153.

[64] Siqueira, H. A. A., Guedes, R. N. C., Fragoso, D. B., Magalhaes, L.C. (2001). Abamectin resistance and Synergism in Brazilian population of Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae). International Journal of Pest Management, 47, 247 -251.

[65] Sulazar, E.R and Araya, J.E (1997). Detection de resistancia a insecticideas en la polilla del tomate (Detection of insecticide resistance in the tomato leaf miner). Simi ente, 67, 8 – 22.

[66] Taylor, J. H (1987). Text of lectures delivered at the national workshop on fruit and vegetable seedlings production held at NIHORT 9-13.

[67] Tropea garzia, G., Siscaro, G., Biondi, A., Zappalà L., (2012). Tuta absoluta, a South American pest of tomato now in the EPPO region: biology, distribution and damage. -– EPPO Bull., 42: 205-210.

[68] Trottin-Caudal, Y., Baffert, V., Leyre, M., Hulas, N. (2012). Experimental studies on *Tuta absoluta* (Meyrick) in protected tomato crops in France: biological control and integrated crop protection. EPPO. Bull. 42:234-240.

[69] Uchoa Fernandes, M. A., Della Lucia, T. M. C. Vilela, E. F. (1995). Mating, Oviposition and pupation of Sacrobipalpula absoluta (Meyrick) (Lepidoptera: Gelechiidae). Anais da Sociedade Entomologicado Brasil24:159 -164.

[70] Urbaneja , A., Vercher, R., Navarro, V., Porcuna, J. L. Garcia- Marí, F. (2007). La polilla del tomate, *Tuta absoluta*.- *Phytoma España*, 194: 16-24.

[71] USDA-APHIS. (2011). New Pest Response Guidelines: Tomato Leafminer (Tuta absoluta).

[72] Vargas, H. 1970. Observaciones sobre la biologia enemigos naturales de las polilla del tomate, Gnorimoschema *absoluta* (Meyrick). *Depto. Agricultura,Universidad del Norte-Arica* 1:75-110.

[73] Vercher, R., Calabuig, A., Felipe, C. (2010). *Ecología, muestreos y umbrales de Tuta absoluta (*Meyrick*)*. -Phytoma España, 217: 23-26.

[74] Viggiani, G., F. Filella, W., Ramassini, C. Foxi. (2009). *Tuta absoluta*, nuovo lepidottero segnalato anche in Italia. *Informatore Agrario* 65(2):66-68.

[75] Witzgall, P., Kirsch, P., Cork, A. (2010). Sex pheromones and their impact on pest Management. J Chem Ecol 36:80–100.
[76] Yankova, V., Valchev, N., Markova, D. (2014). Effectiveness of phytopesticide Ne m Azal T/S® against tomato leaf miner *Tuta absoluta* Meyrick in greenhouse tomato. Bul. J. Agric. Sci. 20 (5):1116-1118.
[77] Zappala, L., Biondi, A., Alma, A., Al-Jboory, J., Arno, J., Bayram, A., Guenaoui, Y. (2013). Natural enemies of the South American moth, *Tuta absoluta*, in Europe, North Africa and Middle East, and their potential use in pest control strategies. J. Pest Sci. 86:635-647.
[78] Zekeya, N. M, Shahada, F., Chacha, M. (2014). Bioefficacy of Bersama abyssinica extracts against cowpea beetle;Callosobruchus maculatus in Storage. Int. J. Innov. Res. Dev. 3:8.

I. I Ajibade The Menace of Tuta Absoluta: A Review on the World Spread." IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) , vol. 5, no. 5, 2017, pp. 21-29.