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The tomato leafminer (*Tuta absoluta*) (Lepidoptera: Gelechiidae) attack in Nigeria: effect of climate change on over-sighted pest or agro-bioterrorism?

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The tomato leaf miner (*Tuta absoluta*) destroyed tomato plants in seven of the Northern states in Nigeria, and has been found in two other states in the South in 2016. The study assessed the incident of the tomato leafminer attack using a questionnaire survey in one of the affected states, for a case study of the problem. A short literature review on bio-ecology of *T. absoluta* was also conducted, and responses to questionnaires were presented. It appeared that knowledge of farmers on pests and management procedures was poor. The results showed that farmers were not properly oriented on pest reporting, and many farmers were unaware of the existence of government pest support programs. Pest monitoring programs and post attack response systems were found inadequate. Many farmers perceived that the pest was new while some respondents reported that similar attacks occurred on their farms in the previous year. Most respondents declined to answer questions on the possibility of agro-bioterrorism being the cause of the attack. We found a lacuna in the government policy which could be potentially exploited by agro-terrorists to inflict attack on crops in a new dimension, but there is no evidence of agro-terrorism in relation to attack on tomato by *T. absoluta* in Nigeria. The findings could be useful in the development of pest mitigating strategies in agro-dependent developing countries.

Key words: *Tuta absoluta*, agro-terrorism, climate change, pest development, tomato.

INTRODUCTION

Nigeria is the largest producer of tomato in Africa, and also contributes significantly to the production of other major agricultural commodities (FAO, 2014). Agro-ecological regions within the country are diverse, and different regions possess environmental advantages in terms of climatic favourability and soil adaptability for the

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production of specific crops. The Northern regions are the main producers of tomatoes (Etebu and Enaregha, 2013).

However, Nigeria is not included in the list of countries exporting tomatoes, and huge amount of money is spent on tomato importation annually. Significant parts of annual production are lost to post-harvest spoilage due to poor handling, microbial deterioration, absence of storage facilities and processing industries (Bello et al., 2016; Etebu et al., 2013). The revived interest of the government to diversify the economy and the strong consideration for agricultural intensification probably inspired the emergence of the African largest tomato processing factory in Nigeria that is capable of adding values to the produce.

During the 2016 tomato season, a sporadic attack by invasive tomato leafminer, *Tuta absoluta*, nicknamed 'tomato ebola' occurred in the Northern parts of the country, where tomato production was most concentrated (Villareal, 1980). The pest caused over 80% loss of tomato production in the first cycle, and resulted in shortage of raw materials supply to the newly developed tomato processing industry, which subsequently closed-down.

Insect pests severely undermine agricultural productivity in Nigeria, and severity of attacks may be exacerbated by climate change related factors. However, the development of the tomato leaf miner was considered sudden and viewed by many stakeholders as an act of sabotage or agro-terrorism, targeted against agricultural production in Nigeria. Agro-bioterrorism is an intentional spread of pathogens or pests to livestock or crops in order to cause economic harm (Wilson et al., 2000). Agriculture can be a perfect target of bioterrorism, particularly in developing nations that lack adequate agro-biosecurity apparatus to notice and prevent attacks. Infective pathogens and developmental stages or adults of major insect pests of crops may be stealthily released by agro-bioterrorists to inflict speedy and colossal damage.

The incident occurred in the Northern part of Nigeria that has witnessed in the past six years various degrees of instability and terrorist attacks, adding to the suspicion of an attack. There were insinuations that the attack was a deliberate act, targeted at coercing growers and the government into adopting Genetically Modified (GMO) Seeds (Anon, 2016; Jibrin, 2016). Agro-bioterrorist agents were suspected to be responsible for the release of *T. absoluta* to undermine local production and technically, to enforce adoption of genetically modified (GMO) tomatoes which cannot replicate. The implications therefore could be a perpetual dependence of Nigerian tomato growers on GMO seeds of resistant hybrids (a form of horticultural colonialism). The use of Terminator Seed Technology (TST) to destroy indigenous tomato landraces in developing countries, and the implications on food security and biodiversity of plant species have been reported (Yusuf, 2010).

T. absoluta had not been officially reported as a potential threat to tomato production in Nigeria before 2016 (EPPO, 2016). Currently, it has emerged as a major threat to sustainable production of tomato in Nigeria. Thus, there is the need to conduct scientific investigations to establish whether the tomato producing agro-communities in Northern Nigeria have been living silently with *T. absoluta* (Brevault et al., 2014; Russell IPM, 2015) without noticing its presence until crops were devastated or Nigeria was agro-terrorized to sabotage sufficiency in tomato production in order to renew dependence on tomato importation.

The aim of this study was to conduct a short review of the ecology of *T. absoluta* in Africa, its biology on tomato and available control measures. The study sought for Information on the level of awareness of pest attacks, pest reporting, and crop biosecurity and protection systems in Nigeria as well as functionality of government quarantine policies.

METHODOLOGY

The study area

The survey was conducted in Plateau state Nigeria. Tomato production in the agro-ecological area comprise of irrigated and rain-fed farms. A major part of Plateau State is on high elevation, and has the lowest temperature records in Nigeria. In the dry season, the average daily temperature is often less than 24°C.

Sampling procedure

A purposive sampling technique (Guarte and Barios, 2006) was used to select tomato farms in one of the affected states for a case study. The selection was based on the records of *T. absoluta* attack in 2016 cropping season. The study sought for information on the level of awareness of pest attacks, pest reporting, and crop biosecurity and protection systems in Nigeria as well as functionality of government quarantine policies. Specifically, the farmers were interviewed to find out essentially their

1. knowledge of pest identification in general
2. Whether *T. absoluta* attack was witnessed in the time past.
3. Whether they are aware of any government institutions that conduct routing pest survey
4. Availability of extension services and pest reporting systems
5. Response of the government to the latest attack and prevention and control programs in place
6. Level of awareness on agro-bioterrorism as a likely cause of the invasive pest attack.

LITERATURE REVIEW

Ecology of *T. absoluta*

The tomato leaf miner, *T. absoluta* (Meyrick) (Lepidoptera: Gelechiidae) originated from South America (Desneux et al., 2011). It is a major pest of tomato capable of causing 80 to 100% damage in the absence of efficient control measures. After it was detected in Eastern Spain in 2006, it has invaded other parts of the world. *T.*

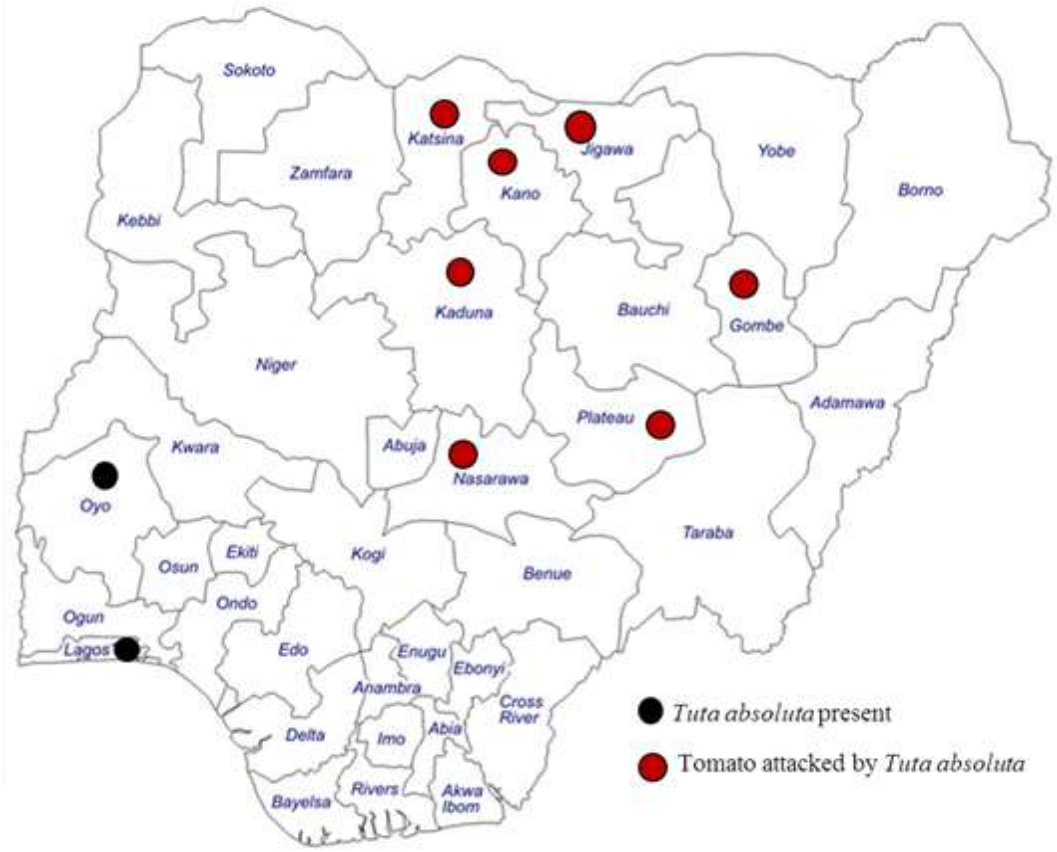

Figure 1. Map of Nigeria showing States where *T. absoluta* is present or caused economic damage to tomato plants.

absoluta outbreak was first reported in two West African countries: Niger and Senegal (EPPO, 2014; CABI, 2016) before its attack on tomato in Nigeria (EPPO, 2016). Currently, it has been found attacking tomato in the northern parts of Nigeria: Jigawa, Kano, Katsina, Kaduna, Plateau, Gombe and Nasarawa States. It has also been sighted in two other states in the South West; Lagos and Oyo (Figure 1)

Biology and description of *T. absoluta*

The pestiferous stage of tomato leaf miner moth is the larvae. Adult females release sex pheromones, comprising of two potent chemical compounds identified as tetradecatrienyl acetate and tetradecatrienyl acetate, to attract male insects to exhibit mating behaviours and copulation (Vacas et al., 2011).

Female insects begin mating at 1 to 2 days of emergence, and oviposition commence within 24 to 48 h after mating. About 96% of the eggs are laid within 7 days, and it is estimated that a female insect lay between 250 to 300 eggs in its life time. At temperatures between 25 to 30°C, the eggs hatch in 6 to 7 days into larvae (CABI, 2016).

Larvae pass through four instars, which is completed in approximately 20 days. *T. absoluta* has been reported to exhibit differentiated behaviour of pupating depending on the environment. The last instar larvae is capable of secreting cocoon and pupate in the soil, buried 1 to 2 cm deep or on leaf surface (CABI, 2016).

The pupation lasts 10 to 11 days for female insects while adults may take 11 to 13 days thus, enabling female insects to emerge first from the same batch of eggs. Under laboratory conditions, the longevity of adults was reported as 30 to 40 days. The duration of developmental cycle is modulated by environmental temperature, and developmental times of 76.3 and 39.8 days have been reported at 14°C and 19.7°C respectively.

At optimum temperature of 27°C, the developmental time was 23.8 days. For as long as food is available, larvae have been reported to refrain from entering diapause, and 10 to 12 over-lapping generations occurring all year round have been reported in South America. *T. absoluta* eggs are elliptical in shape, and laid in clusters. The colour of the eggs may vary but they are often oyster-white or bright yellow, turning dark in the embryonic stage, and almost black towards eclosion.

The newly emerged larvae are whitish, and subsequent instars could turn greenish or pink depending on the host plant and the available food; leaflet or ripe fruit. Pre-pupae are often lighter than the actively feeding first to fourth instars, with a distinguishing pinkish colour on the dorsal part. The pupae are obtecta with initial green colouration which over time become brown near adult emergence. Adult moth is about one centimeter in size, and has silvery or greyish scales with alternating light and dark segments (CABI, 2016).

Host range of *T. absoluta*

T. absoluta is a major pest of tomato (*Solanum lycopersicum*) in all agro-ecological regions of the world where it occurred, it is capable of attacking and subsisting on other wild members of the

Solanaceae including *Solanum nigrum, Solanum elaeagnifolium, Lycopersicon puberulum, Datura stramonium, Datura ferox* and *Nicotiana glauca* (Garcia and Espul, 1982). Other non-solanaceae host plants include the slender amaranth (*Amaranthus viridis*) (Amaranthaceae), common sowthistle, (*Sonchus oleuraceus*) and common cocklebur (*Xanthium strumarium*) both of which belong to the family Asteracea, Wild mustard (*Sinapis arvensis*) (Brassicaceae) and the bind weed (*Convolvulus arvensis*, which is a member of the family Convolvulaceae. There are also a few reports of *T. absoluta* attack on potato (Garlaza, 1984; Pereyra and Sánchez, 2006). *T. absoluta* shows preference for new buds, flowers and new fruits thereby making it easy to detect on affected plants. The characteristic mines on plant leaves are also an indicator of attack in addition to appearance of black frass on fruits where infestation is severe (Tropea et al., 2012).

Methods of control

Many control options including cultural, chemical, pheromone based strategies and biological control, which is basically the use of natural enemies of the pest have been found effective. Farm sanitation practices, pruning of leaves that show symptoms, removal and destruction of infested plants as well as ploughing, and soil solarization have been shown to significantly reduce attack by the pest. The elimination of wild and other alternative hosts on which the pest subsists in off-season periods are capable of breaking the life cycle, and have been found effective when the cropping cycle of the major hosts, especially tomato and potato are alternated with other crops that are non-host plants (Cabello et al., 2009; González-Cabrera et al., 2011; Guedes and Picanco, 2012; Cocco et al., 2013).

In severe incidents of *T. absoluta* attack, chemical control using cabaryl, pyrethrin and deltamethrin, have been reported. Extensive use of chemical insecticides in many parts of Africa where there were severe *T. absoluta* attack led to registration of several varieties of chemical insecticides. Where chemicals were used extensively for a prolonged period of time, their effectiveness were reported as low or moderate due to the cryptic nature of the larvae and high reproductive rates (Silva et al., 2011). Other control methods being developed for the management of *T. absoluta* include the use of semiochemicals, especially sex pheromones, to lure adults into traps (Chermiti and Abbes, 2012; Mafra-Neto et al., 2013; Comparros_Megido et al., 2013).

Releases of irradiated and sterile males (Cagnotti et al., 2016) are also being developed as an eco-friendly management option. Biological control using entomopathogenic fungal species, particularly the anamorphs of Hypocreales, *Metarhizium anisopliae* has been reported (Contreras et al., 2014). The use of fungal biocontrol agents (BCAs) will be especially effective where abiotic interactions, temperature and relative humidity fall within the range that is required for infectivity (Borisade and Magan, 2015) and sporulation or secondary spread (Borisade and Magan, 2014).

Many natural enemies of *T. absoluta*, particularly parasitoids and nematodes have been identified, and many are being evaluated for their biocontrol potentials. Development of resistant tomato varieties which are high in zingiberin or acyl sugar contents are being explored to reduce oviposition and feeding by the larvae. Integrated Pest Management (IPM) systems are also being developed for different crops in agro-ecological regions with long experience of *T. absoluta* attacks.

RESULTS

Demographic profile of respondents

Seventy questionnaires were randomly distributed for the survey and sixty of the completed questionnaires representing the areas where the pest attack occurred were returned, amounting to a response rate of 75% (Table 1). In addition to this, some farmers who declined to complete the questionnaires gave their opinions verbally. All the participants in the survey were above 18 years in age and there was no imposition of upper age boundary. Female participants represented 30% of the sample size. Five percent of the participants had secondary education while the remaining 95% consisted of people with post-secondary education or trainings. Majority of the participants (90%) in the post-secondary education category studied agriculture or trained in agriculture-related disciplines while the remaining 10% was an equal split between other specializations and unspecified disciplines, but practicing tomato farming.

Experience on general insect pests of tomato and leaf miner

Table 2 appraised the level of knowledge of the tomato farmers on entomological pest incidents, correctly identifying the damage symptoms, and the pests. The majority of the farmers (65%) operate small scale farms or backyard-cultivated tomato stands, while 15% have commercial farms. Others have a few stands of tomato plants growing around their homes. Eighty percent of the respondents had at a time experienced insect pests attack on their crops.

20% were unsure whether their plants were at any time attacked by insect pests, and 15% were either unable to describe the pest or the damage it caused. When asked for description of the pests and assessment of damage, fifty percent of the farmers (n=30) described tomato symptoms which are often associated with *Fusarium oxysporum* f. sp *lycopersici* wilt disease rather than foliar pest attacks. Fifteen percent of the respondents observed disappearance of the green or chlorophylous layer of their tomato leaves.

10% of the farmers reported that fruits were bored, and there were signs of gnawing on leaves. Twenty five percent of the farmers were unable to make specific description of the nature of damage. Majority of the farmers (65%) had no prior experience of *T. absoluta*, 35% are informed about the invasive pest and 10% reported that the pest caused a significant damage within a limited area before the severe outbreak which occurred in 2016 (Table 3).

80% of the respondents considered the tomato leaf miner a new pest in Nigeria, and chemical control only were employed in the management of tomato pests.

Existence and efficiency of pest control system

Majority of the respondents (80%) indicated that there were no pest control experts, and 90% have not reported

Table 1. Demographic profile of respondents

Variable		Frequency	Percentage (%)
Age	<18	0	0
	≥18	60	100
Gender	Male	42	70
	Female	18	30
Education level	Secondary	3	5
	Post-secondary	57	95
Field of specialization	Agriculture/Agriculture related	54	90
	Non-Agriculture	3	5
	Unspecified	3	5

Table 2. Scale of farm and experience of the respondents with entomological pests in general.

Variable	Frequency	Percentage (%)
What is the scale of your farm?		
Few stands in my backyard/Small scale	39	65
Found some tomato stands growing around my house	12	20
Commercial farm	9	15
Has your tomato been attacked by insect pests before?		
Yes	48	80
No	12	20
Were you able to identify the pest?		
Yes	21	35
No	39	65
Can you describe the nature of damage observed?		
Chlorosis, spot and rottening	27	45
Wilting and eventual death	3	5
Green surface eaten up and leaves became transparent	9	15
Fruits bored and the inside was eaten up	6	10
I cannot describe	15	25
On which of the following parts of the tomato was the damage or insect presence?		
Leaf	39	65
Stem	3	5
Fruit	18	30
When were the times you experienced the pest attacked?		
Earlier than 2013	12	20
Between 2014-2015	33	55
Year 2016	15	25

pest problems on their farms (Table 4). When asked about quarantine services offered by Government Departments, 40% were unsure whether they exist while 20% who answered 'yes' were against the 40% of the respondents that certainly indicated that quarantine personnel were non-existent. Significant number of the respondents (80%) agreed that government quarantine departments were not functional. On questions of

Table 3. Response to questions on level of awareness of tomato leafminer.

Variable	Response	Frequency	Percentage (%)
Have you heard of the tomato leaf miner?	Yes	21	35
	No	39	65
Do you consider tomato leaf miner a new pest in Nigeria?	Yes	48	80
	No	12	20
Has it ever infested your crops?	Yes	6	10
	No	54	90
If yes, did you initiate a control?	Yes	6	100
	No	0	0

Table 4. Response to questions on presence and efficiency of public pest control experts.

Variable	Response	Frequency	Percentage (%)
Is there any pest control expert in your area?	Yes	12	20
	No	48	80
Did you ever report any pest attack to pest experts?	Yes	6	10
	No	54	90
Are there government quarantine personnel in your area?	Yes	12	20
	No	24	40
	Not sure	24	40
Are the qarantine officers and pest control experts functional?	Yes	12	20
	No	48	80
Are there functional government quarntine policies in Nigeria?	Yes	24	40
	No	36	60

functionality of government quarantine policies, majority (60%) of the respondents indicated failed policies while the remaining 40% considered the policies working.

Agricultural bioterrorism

Table 5 shows the response of the farmers to questions that are related to the possibility of agro-bioterrorism being the cause of the loss of more than 80% of annual production of tomato in the first cycle to *T. absoluta* within the Northern agro-ecological area. Relatively fewer respondents were willing to answer questions on different aspects of the topic and spoke their opinions only verbally. Agro-bioterrorism as a term or as a concept was strange the respondents. Forty two percent of those attended to questions on the topic were aware that bio-terrorism can be potentially used to undermine agricultural production, through the internet, books and multimedia. However, 37.5% believed that the Nigerian incident was an act of bioterrorism while many considered it a natural occurrence.

DISCUSSIONS

This study reviewed the general biology and distribution of the invasive tomato pest, *T .absoluta* in Nigeria and its probable pathway into the country. The survey assessed the incident of attack on tomato in the Northern agro-ecological areas in order to understand the cause of the sudden epizootics, knowledge of farmers on agricultural insect pests, functionality and efficiency of pest control systems in Nigeria, operationality of pest prevention mechanisms, pest attack response systems, quarantine policies and post-attack capabilities. Drawing on the results of the survey and the peculiarity of the scenario, the nature of threats to agriculture in developing nations-Nigeria being a case study, would be discussed.

The majority of tomato growers in the region are peasants and practice agriculture as their secondary profession. This reflected in the scale of farms, where only 15% could be rated as commercial. Pest and disease attacks had occurred at various times in the past and it appeared that supports to farmers in form of provision of extension services, pest identification and

Table 5. Response to questions on agro-bioterrorism.

Variable	Frequency	Percentage (%)
Have you heard of agricultural bioterrorism before?		
Yes	8	42
No	11	58
If yes, where did you learn about it?		
Internet	6	75
Books	1	12.5
Multimedia	1	12.5
Do you think the tomato pinworm incident was somehow a delibrate attack?		
Yes	3	37.5
No	5	62.5

management were seriously lacking. However, the symptoms of pest damage which occurred earlier than 2016 as described by some respondents: loss of chlorophyll layer of tomato leaves due to insect feeding (leaf mining) and presence of worms in the fruits, are characteristic of tomato pinworm infestation. While the majority of the farmers regarded *T. absoluta* a new pest, a few confirmed earlier attacks which were controlled using insecticides. It appeared that pest attacks were not being reported and many of the growers were unaware of existence of pest control experts or quarantine services.

The sudden scarcity of tomato which was associated with the pest attack in 2016 may not only be a reflection of the magnitude of attack but also a sudden positive change in the economic value of the crop, when value addition industry capable of utilizing significant parts of annual produce sprang-up. Before the evolution of tomato processing industries, more than 60% of annually produced tomato was lost to post-harvest spoilage. The excess production used to buffer the effect of field pest attack on local supplies. The new tomato industry probably mopped up the annual excess, such that the effect of pests on productivity became apparent and probably affected the local demand and supply patterns that resulted in the hike in price of fresh tomatoes. Increase in crop value is capable of changing the status of attacking pests from 'potential pest status' to the status of a 'serious pest', when little damage become economically injurious. However, *T. absoluta* is a serious pest of tomato in all agro-ecological regions of the world where it occurred.

Currently, *T. absoluta* is much restricted to the Northern agro-ecological areas that serve as the major hub of tomatoes that are consumed in the south and other parts of Nigeria. Movement and spread of invasive entomological pest species are directly associated with transportation of products infested with the eggs, developmental stages and adult insects. The optimum temperature for the development of *T. absoluta* is 27°C, which is within the ambient temperature range in all agro-ecological regions of Nigeria- a guarantee for a potential spread to all parts of Nigeria over time, particularly in the absence of an effective quarantine system.

Based on the spatial pattern and the scales of tomato cultivation, challenges are expected in the management of *T. absoluta,* which has relatively high fecundity rate and short reproductive cycle. Sixty five percent of the growers produce at the level of 'backyard farming' while 15% have a few uncultivated stands around homes. Few-stands-around-home scale of farm is likely to present problems that are very similar to the effect crop left-overs in pest management. The few tomato stands around homes and backyard farms could serve as pest-reservoirs that are capable of relaying pests into another production cycle, thereby potentially posing dangers to commercial farms which might have earlier succeeded in suppressing pests.

The entrance corridor of *T. absoluta* into Nigeria have not been studied, but tomatoes were imported into Nigeria from some West African countries, including Niger that has records of the presence of *T. absoluta.* Problems of invasive insect species are expected to get worse in developing countries with relatively poor quarantine systems. The results of the survey in part, suggested that *T. absoluta* was present in Nigeria earlier than 2016. The environments in which crops would be grown within the next decade are expected to change significantly in relation to climate. The effect of climate change, especially increased temperature, erratic rainfall and wide relative humidity fluctuations could adversely affect ecological barriers and lead to emergence of new pests that are likely to get adapted to new crops. Pest dynamics are also expected to be modulated under a climate change scenario (LaštůVka, 2009; Dhaliwal et al., 2010).

All aspects of pest development-oviposition rates, time to eclosion, duration of life cycle and longevity of adults are affected by temperature (Cuthbertson et al., 2013).

Year 2016 showed peculiar long periods of relatively high temperature (Salau et al., 2016) and draught, capable of affecting insect development. Regional evidence of climate change in Nigeria had previously been reported (Odjugo, 2010). The effects could either be positive or negative depending on the insect and its optimum temperature requirements. CABI (2016) reported significant variabilities in the time taken by *T. absoluta* to complete its life cycle under different temperature and relative humidity regimes. The rate of development of pests also varies with the invaded plants. There are possibilities that the species of tomato being cultivated in the affected areas were especially favourable to *T. absoluta* development. Megido et al. (2013) studied the propensity of tomato leaf miner to develop and different tomato varieties, and found significant variabilities in developmental rates and magnitude of attack.

Despite the possibility that *T. absoluta* may have invaded Nigeria earlier than 2016, the magnitude of attack, population dynamics and the timing were a serious concern. Although there is lack of pest documentation and monitoring in Nigeria, the pattern of attack was considered a terrorist act by some respondents. Unfortunately, many of the respondents declined to respond to questions on agro-bioterrorism for unknown reasons. A few of the respondents confirmed that their crops were overwhelmingly invaded by pests from growers who deliberately left their farms to pests without initiating control measures. However, there is no evidence of agro-terrorism in Nigeria. The farmers who abandoned their farms were probably frustrated, and could not afford the extra cost of fumigation, since the crops were already economically injured.

Within the context of the findings in the current study, a typicality of Nigerian government policies on crop production, the freedom of individuals to embark on crop production without license and the absence of enforcement of growers to comply with standard pest management guidelines, a farm that is abandoned because of severe attack by invasive pests species may pose a significant threat to neighbouring farms. This Nigerian scenario may exemplify the vulnerabilities of other agro-dependent developing nations in West Africa, where crop production licenses are not compulsory.

Agro-bioterrorists employ a variety of approaches to achieve their desired goals after conducting a comprehensive study of the premises that can be exploited covertly. Agro-bioterrorism as earlier defined in the Introduction Section: ‘deliberate introduction of exotic biological agents to undermine agri-business’ and several of the views expressed in the work of Hassler (2003) on agro-bioterrorism share a common intersection: ‘introduction of exotic biological agents’, here considered as ‘classical agro-bioterrorism’.

The descriptions of some of the respondents resembled a scenario where growers were contracted to cultivate large expanse of tomato in *T. absoluta* endemic areas and deliberate abandonment of the farms for the pests to breed and evade other areas. This can be classified as bio-augmentation and bio-conservation of existing invasive pest numbers to wreak havoc- may be a potentially new form of agro-bioterrorism, which does not involve the introduction of new pest species.

However, the reasons for the abandonment of some tomato farms in the survey area could not be substantiated as intentional, ruling out the possibilities of a terrorist act. The lack of license and appropriate documentation of farm locations could create a hurdle for pest management departments to effectively monitor pest development, which may result into serious and widespread invasions.

CONCLUSION

Development of new tools for rapid detection of pests, effective monitoring systems, pest identification and reporting are very crucial. The time between introductions, whether by intent, accident or natural causes and detection are very important in controlling spread. Issuance of licenses to growers could help in the development of data base of existing farms and their locations, which are necessary in pest surveillance and enforcement of standard operating procedures capable of minimizing pest attacks. Investments in infrastructures capable of increasing pest prevention and preparedness are very important. Training of pest attack respondents and increase in budget on basic research are capable of strengthening post-attack responses and capabilities. Industries with huge investments on tomato processing and value addition in Nigeria may also need to invest significantly in pest management to complement public efforts to militate pest problems.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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