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MOLECULAR AND BIOLOGICAL STUDY OF *TUTA ABSOLUTA* (MEYRICK) (LEPIDOPTERA: GELECHIIDAE): IMPLICATIONS TO FOOD SECURITY AND EFFECTIVE NUTRITION IN NIGERIA

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ABSTRACT

Effectively managing the devastating tomato leafminer, Tuta absoluta, especially through biological control, requires identifying its most vulnerable lifecycle stages. Consequently, the current study aims to molecularly analyse T. absoluta and elucidate its biological traits to enhance management strategies effectively and sustainably. Tuta absoluta were reared under controlled conditions (average 27.5 ± 3 °C and 75.5 ± 3%, relative humidity). Key traits like Developmental Period-DP (days), morphometrics (mm), lifetable, parthenogenesis, Days to Adult Emergence (DAE), Adult Longevity (AL, days), sex ratio, and pre-oviposition and oviposition. were assessed alongside molecular characterisation. Molecular analysis showed this Nigerian isolate clustered within a biphyletic clade containing sequences from South Africa, the USA, Kenya, Egypt, Togo, and Nigeria. The complete life cycle averaged 20.9 days: DP for eggs, larva and pupa was 3-4, 10-13, and 6-8, respectively. Egg was oval (0.22±0.01); larva comprised four-instars. Net reproductive rate was 46.01. Deuterotokous parthenogenesis was observed. The DAE was 21 and AL varied with sex (virgin males:7.28±2.13, virgin females:12.87±3.55). Sex ratio was 1:1.5 (male:female). Poor food does not affect fecundity. The egg and first instar stages were identified as the most susceptible stages for effective control measures. Consequently, management strategies must be customised to suit the specific characteristics of the Nigerian local strain. Furthermore, meticulous monitoring of weather conditions on tomato farms is crucial before implementing any pest control actions.

Keywords: Farm, Pest management, Pesticide, Resistance development

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INTRODUCTION

Tuta absoluta (Meyrick) is recognised globally as an invasive insect pests with significant implications for ecological balance, agricultural output, and biodiversity preservation (Campos et al., 2014; Tarusikirwa *et al*., 2020). Tomato leaf miner (*T. absoluta*) is particularly destructive to tomato and other members of the solanaceous family, causing 80%-100% yield losses when poorly managed (Borisade *et al*., 2017). The tomato leaf-miner is a danger to food production and, by extension, national food security in Nigeria and throughout Africa (Awodoyin *et al*., 2024). This is due to its quick spread and detrimental effects on tomatoes and other related crops (Mutamiswa *et al*., 2017; Loyani *et al*., 2021). It was first discovered in Nigeria at Daura, Katsina State, in 2015 (Oke *et al*., 2016). It is a major problem of tomato farming in Africa, Europe and Asia (Acharya *et al*., 2023). The bulk of African nations rely on agriculture for their livelihoods (FAO, 2002). As a result, pests that spread like that of *Tuta absoluta* pose a danger to both food and nutrition security as well as biosecurity (Tarusikirwa *et al*., 2020; FAO, 2020).

In regions of the world where pests are endemic, food and nutrition security thus depend on the control and management of *T. absoluta*. It is widely acknowledged that pesticides are crucial to the growth of agriculture since they can lower agricultural product losses from insect and rodent infestation, increasing the quantity and quality of food produced at a reasonable cost (Strassemeyer *et al.*, 2017; Tudi *et al.,* 2021). Pesticides are employed in agriculture to control weeds, various pests, and vectors, such as insects and rodents (Fenik *et al.,* 2011; Strassemeyer *et al.,* 2017; Tudi *et al.,* 2021). According to reports, farmers who use pesticides to restrict the growth of pests on their crops and reduce their attack can greatly boost agricultural yield and mitigate the negative effects of pests on crops (Dhanker *et al.,* 2020; Mojo & Zemedu, 2022). Farmers have therefore generally benefited from and been satisfied with the use of pesticides.

Nevertheless, the efficacy of these agrochemicals has been hampered by insect pests' development of pesticide resistance. Studies in Nigeria have demonstrated Lambda-cyhalothrin resistance in Tuta absoluta (Oke *et al.,* 2020). Furthermore, because pesticides have a negative correlation with environmental poisoning, their use has been linked to detrimental effects on biodiversity (Pathak *et al.,* 2022; Ong'onge *et al.*,,2023). Numerous studies have attributed the development of resistance in insect pests to the indiscriminate and continuous application of chemical insecticides (Oke *et al.,* 2020; Pandey *et al.,* 2023; Olagundoye & Adesoye, 2023; Adelaja *et al.,* 2025; Adesoye *et al.,* 2025). In addition, a variety of further detrimental impacts have been recorded in the use of chemicals to control Tuta absoluta. These include pest resurgence and public health risks arising from residual insecticide contamination (Abdollahi *et al.,* 2004; Roditakis *et al.,* 2018). Hence, it is necessary to seek effective, environmentally friendly, and safer biologically derived alternatives for the sustainable management of *T. absoluta*, to be utilised within an integrated approach.

Molecular diversity plays a crucial role in informing pest management strategies by providing insights into the genetic variability and adaptability of pest populations. These may influence pest behaviour, resistance, and adaptability (Saxena 2025). Understanding these molecular differences allows for targeted approaches in pest control, ensuring that management practices are tailored to specific populations and their ecological contexts. This knowledge enhances the effectiveness of sustainable pest management by promoting strategies that consider local adaptations

and genetic diversity within agricultural ecosystems (Meagher *et al.,* 2024).

Despite extensive reports on *T. absoluta*'s invasion in Africa, significant knowledge gaps remain regarding the genetic diversity of African populations (Ndiaye *et al.,* 2021; Ong'onge *et al.,* 2023). Studies report conflicting evidence on the number of introductions and genetic differentiation within African populations, with some indicating multiple maternal lineages and others suggesting high genetic homogeneity (Ndiaye *et al.,* 2021, Javal *et al.,* 2024, Magalhães *et al.,* 2025).

To manage *Tuta absoluta* effectively using biological interventions, we must first pinpoint which of its lifecycle stages are most susceptible to control measures. Most of the reports on *Tuta absoluta* in Africa have focused on the incidence of its invasion, with limited information on its biology. Furthermore, the biology of *Tuta absoluta* varies based on temperature, change understudy to study or investigate. Through a detailed investigation of *T. absoluta* biology, we stand to gain pivotal insights that inform management strategies, promoting sustainable and preferable pest control methods. This methodology is in line with Integrated Pest Management (IPM) principles, advocating for a multifaceted approach to pest mitigation that minimises reliance on chemical pesticides Pandey (2023) . The objective of this study is to enhance our understanding of *T. absoluta's* biology and evolutionary patterns through molecular analysis, leading to more effective and sustainable management strategies.

MATERIALS AND METHODS

Study Locations

Tuta absoluta rearing took place in Entomological laboratories within the Department of Crop Protection and Environmental Biology, University of Ibadan, Oyo State, Nigeria, under ambient conditions of approximately 27.5 ± 3 °C temperature and 75.5 ± 3% relative humidity. The genetic characterisation of the insect pest was conducted at the Molecular Laboratory of the National Horticultural Research Institute (NIHORT) in Ibadan, Oyo State, Nigeria.

Source and Stock culture *T. absoluta*

To establish the stock culture, a two-phase method, based on Omoloye (2006), was implemented with minor adjustments. In the initial phase, larval samples of *T. absoluta* were sourced from a tomato field and placed into a rearing cage, which was a plastic net-made enclosure measuring 60 × 60 × 80 cm, with a light-dark cycle of 16 hours light and 8 hours dark. These larvae were reared on sweet tomato plants, acquired from an organically managed farm within the Teaching and Research Farm, University of Ibadan.

In the second phase, mated F1 females were introduced onto tomato plants in a screen-house. Emerging F2 larvae were carefully transferred to rearing cages and fed with fresh tomato leaves. This process was repeated to maintain a continuous culture for subsequent experiments, providing age-synchronised cohorts for biological and other studies.

Molecular Identification of *T. absoluta*

Tuta absoluta samples (n=10), obtained from a tomato field in Lagos State, were analysed at the molecular level to properly identify the *T. absoluta* obtained for this study. This examination was conducted at the Molecular Laboratory of NIHORT, Ibadan, as described by El-Sitiny *et al.,* (2022).

Genomic DNA Isolation

Single-insect DNA extraction of *Tuta absoluta* was carried out using a modified SDS extraction protocol. 100µL of extraction buffer, containing 5M Sodium Chloride (NaCl), 0.5M ethylenediamine tetraacetic acid (EDTA), 1M Tri-hydroxymethyl aminomethane hydrochloride (Tris-HCl, pH 8.0) and 4% β-mercaptoethanol was used in grinding a single *Tuta absoluta* in a 1.5ml extraction tube with a sterilised plastic pestle. Thereafter, 10µL of 20% Sodium dodecyl sulphate (SDS) and 5µL of proteinase K were added to the individual tubes. Samples were incubated at 65ºC for 30 minutes. Ten microlitres (10µL) of potassium acetate was added to each sample. Genomic DNA was precipitated with cold isopropanol, while purification was done with 200µL of 70% ethanol to remove residual salts. 50µL of sterile distilled water was added to resuspend the DNA pellet. The quality of DNA was checked, following DNA separation by electrophoresis in a 1.2% agarose gel.

Amplification of the cytochrome oxidase subunit I (COI) gene

Following Hajibabaei *et al.,* (2006)'s protocol, the extracted DNA was subjected to polymerase chain reaction (PCR) to amplify an approximately 700 bp fragment of the cytochrome c oxidase subunit I (COI) gene, using the degenerate primer set LepF1/ LepF2 [Table 1]. Amplification was performed in a 20µl reaction volume containing 2µl of template DNA, 0.5 µl of dNTPs, PCR buffer with 25 mM MgCl2, 0.5µl of each 5µM of primer and 0.5unit of Taq DNA polymerase. An Eppendorf Mastercycler Nexus gradient Thermal Cycler (USA Scientific, Inc.) was used for amplification under the following conditions: initial denaturation at 94ºC for 5mins, followed by 35 cycles of denaturation at 94ºC for 30 s, annealing at 55ºC for 1 min and extension at 72ºC for 1.5 mins, with a final extension at 72ºC for 7 mins (Hajibabaei *et al.,* 2006). Five amplicons of the *T. absoluta* COI gene were purified and sequenced by a commercial company (Inqaba Biotec West Africa) using the Sanger technology (Mukwa *et al.,* 2021).

Table 1. Primers used for the molecular characterisation of *Tuta absoluta*

Lep F1:	**5'ATTCAACCAATCATAAAGATATTGG3'**
LepR1	**5'TAAACTTCTGGATGTCCAAAAATCA3'**

Breeding and Life Cycle of *T. absoluta*

Twenty freshly emerged *T. absoluta* adults were placed in oviposition cages in the laboratory to investigate the life cycle parameters and developmental stages on the sweet tomato variety. The study evaluated oviposition, fecundity, and longevity of mated males and females. Pairs were monitored for mating activity in the early morning (05:00 – 08:00 h) and evening (18:00 – 20:00 h). Subsequently, mated males were paired with both virgin and mated females, while virgin males were paired with mated females. In a parallel experiment, the pre-oviposition period, post-oviposition period, and oviposition behaviour of adult females were examined.

Supplementary parameters recorded included the incubation period of eggs laid, percentage of eggs that hatched, and the longevity of mated and virgin adults using different treatments regime (water, 5% sugar, and 10% sugar). Furthermore, a life table was constructed. All experiments were replicated five times in a Completely Randomised Design (CRD) following the protocol of Oyedokun (2012) and Bajonero & Parra (2017).

Growth and Life Stages Assessments of *T. absoluta*

The growth progression of *T. absoluta* was assessed by measuring the mean head capsule width and recording developmental duration from first instar to adult emergence.

Upon emergence, adults were sexed, and pairs were maintained in separate cages. The total number of eggs, incubation period, larval morphometrics (including body length, abdominal width, and head capsule width), developmental period of instars, and number of instars were documented, along with the number of days until adult emergence and total adult emergence from the eggs.

Eggs were gathered from rearing cages and cultured separately under ambient conditions of approximately 27 ± 3 ºC temperature and 75 ± 3% relative humidity. Morphometric studies were conducted using ten eggs from each cage with the aid of an Olympus Microscope fitted with an ocular micrometre screw eyepiece.

Actual fecundity was determined as the total number of eggs laid by a gravid female.

The eggs laid by various groups of *T. absoluta* on the tomato leaves were counted and recorded daily.

The percentage eclosion of eggs was calculated:

% eclosion = x100

Upon emergence, twenty larvae were transferred into individual plastic cages and provided with leaves of the sweet tomato variety for feeding. Larvae were monitored in plastic dishes, fed with tomato leaves, to study their feeding habits, the time interval between larval stages, the developmental process, and behavioural patterns.

Pupation (20 pupae) was observed for duration and morphometric description to assess the pupal stage of *T. absoluta.*

For the assessment of the adult stage, thirty newly emerged adults (both male and female) were collected, sexed, and preserved in 70% alcohol for body length, body width, wingspan, and other morphometric measurements.

Data analysis

Statistical analysis was conducted using the Statistical Package for Social Sciences (SPSS version 20.0, Inc., Chicago, IL, USA). Data obtained for larval, pupal, and adult morphometrics were analysed utilising descriptive statistics. Subsequently, they were subjected to ANOVA, with means differentiated using Tukey's Honestly Significant Difference comparison test at 5% significance level ($P = 0.05$). The resultant nucleotide sequences were analysed using ClustalW included in the software MEGAX (Kumar *et al.,* 2016), and a maximum likelihood tree was built with MEGAX, with 1,000 bootstrap replicates.

RESULTS

Characterisation of *T. absoluta*

To characterise the *T. absoluta* isolates obtained from the study area, five amplicons from different insects were sequenced; the 684-bp nucleotide sequences of all isolates from this study were identical.

A consensus sequence was submitted to the NCBI GenBank under accession no. PQ187916, and the BLASTN searches in NCBI GenBank revealed that isolates from this study showed 99 -100% nucleotide similarity with MK189155 - 62 (Nigeria), Democratic Republic of Congo (MG693217) and other COI gene of *T. absoluta* deposits in the Genbank.A maximum likelihood tree for *T. absoluta* isolates was constructed using the partial nucleotide sequences COI segment.

There are two major clades on the tree, the isolate from this study grouped along with other isolates from Nigeria, USA, South Africa, India, China, Egypt, Pakistan, Kenya, Togo, Algeria, Ghana and the Democratic Republic of Congo. Based on the phylogenetic analysis, all isolates from Nigeria clustered within the same group. The tree illustrates that the variant of *Tuta absoluta* from Brazil stands distinct (Fig. 1).

The sequences from Nigeria originated from Kadawa, Kano State, and the sequence from this research marks the initial submission from Southwest Nigeria. The phylogenetic tree further showed that there is no diversity in the sequences derived from *T. absoluta* from Nigeria.

The average complete life cycle (from egg to adult) of *T. absoluta* was 20.9 days. *T. absoluta* progresses through four larval instars and a pupal stage before emerging as an adult. Newly laid eggs exhibit an oval shape, creamy white colour, and a translucent, smooth, and shiny texture when viewed under a microscope. These eggs were typically laid individually on the underside of leaves, positioned at an angle to expose their respiratory horns. Each egg measures approximately 0.44 ± 0.001 mm in length and 0.22 ± 0.002 mm in width at its widest point. The average developmental period spans 4.12 ± 0.016 days at a temperature of 27.3 ± 3 ºC and a relative humidity of 75.3 ± 1.6%. Just before hatching, typically after 3 to 5 days of incubation at 27–29 ºC, the eggs darken to black. Egg laying occurs daily for over 7 days, starting 24 hours after adult emergence, in both mated and virgin females (Table 2).

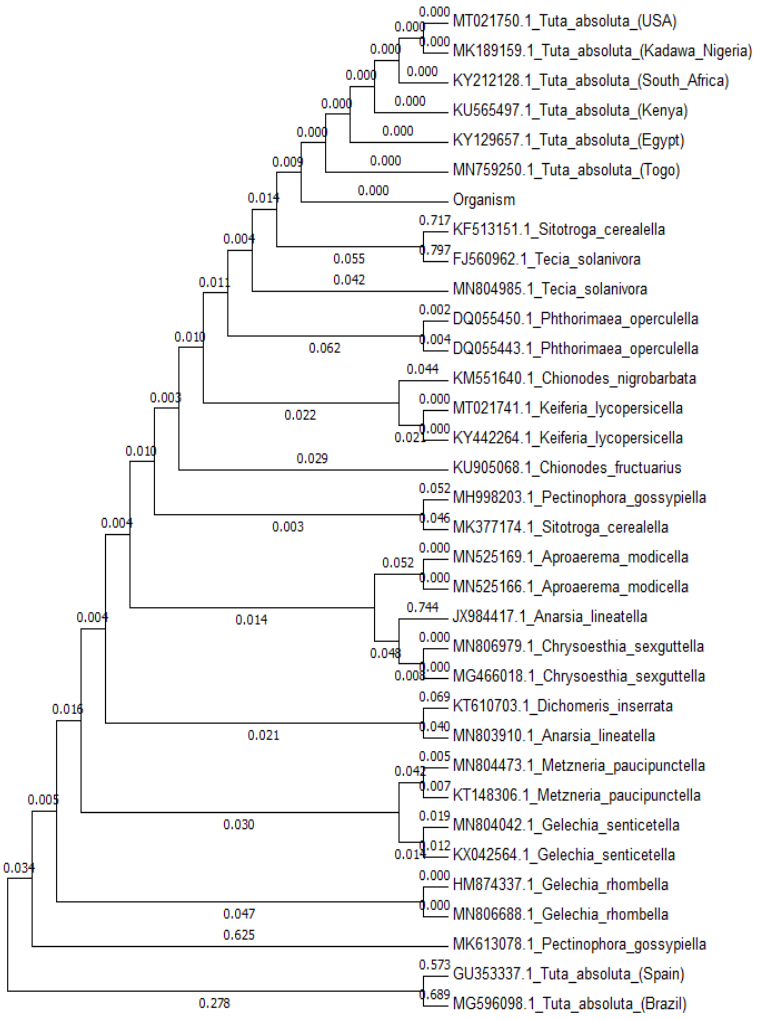


Figure 1: Maximum likelihood tree of partial COI gene of Tuta absoluta from this study with deposited isolates in the GenBank. Accession numbers and locations of each isolate used are indicated in the tree. The tree (1000 bootstrap replications) was generated using MEGAX software.

Table 2: Developmental Biology of *T. absoluta* eggs in Nigeria

Parameters	Mean ±SE	Range
Incubation period (days)	4.12 ± 0.02	3.9 – 4.30
Egg diameter (mm)	0.22 ± 0.01	0.1 – 0.26
Eggs laid	125.5 ± 3.58	115 – 132
Eclosion (%)	74.80 ± 2.30	63 – 105

SE= Standard error of the mean; N=20

Freshly hatched larvae (20), emerging (eclosed) from eggs after a period of four (4) days, display a soft, creamy-coloured body with a light brown head capsule. The initial larval instar stage persists for an average of 2.9 ± 0.08 days, featuring a mean head capsule size of 0.15 ± 0.001 mm and average body dimensions of 1.49 ± 0.015 mm in length and 0.28 ± 0.001 mm in width, respectively. Upon emergence, the newly hatched larva typically spends a few minutes (15 ± 4.5 minutes) circling on the leaf surface before settling on a spot to begin leaf penetration, a process taking approximately 25 ± 7.5 minutes, totalling 40 minutes to fully tunnel into the leaf. Subsequently, the second instar stage spans 2.5 ± 0.00 days, with a head capsule measuring 0.23 ± 0.002 mm and body dimensions of 2.82 ± 0.022 mm in length and 0.36 ± 0.11 mm in width, respectively (Table 3).

Table 3: Daily measurement of *Tuta absoluta* larvae, reared on sweet tomato in Nigeria.

Days after larval eclosion	Larval stage	Mean (mm) + SE (range) Body length	Body width	Head capsule
0	1st	0.41 ± 0.03 (0.20 -0.60)	0.10 ± 0.01 (0.07-0.13)	0.05 ±0.02
1		0.90 ± 0.01 (0.60 -1.30)	0.15 ± 0.03 (0.10-0.18)	0.09 ±0.02
2		1.21 ± 0.05(1.00– 1.27)	0.22 ± 0.05 (0.18-0.27)	0.12 ±0.01
3		1.49 ± 0.05(1.32-1.54)	0.28 ± 0.04 (0.25-0.33)	0.15 ±0.01
4	2nd	1.78 ± 0.09(1.66-2.20)	0.31 ± 0.05(0.28-0.33)	0.17 ±0.05
5		2.34 ± 0.15(2.27-2.59)	0.33 ± 0.02(0.31-0.40)	0.19 ±0.02
6		2.82 ± 0.22(2.56-2.90)	0.36 ± 0.01 (0.31-0.47)	0.23 ±0.03
7	3rd	3.43 ± 0.19(3.16-3.76)	0.40 ± 0.12 (0.35-0.43)	0.28 ±0.05
8		4.18 ± 0.15(3.95-4.21)	0.43 ± 0.16 (0.38-0.49)	0.34 ±0.06
9		5.69 ± 0.45(5.28-6.55)	0.48 ± 0.14(0.46-0.52)	0.39 ±0.09
10	4th	6.80 ± 0.22(6.62-7.36)	0.53 ± 0.22(0.49-0.57)	0.45 ±0.14
11		7.44 ± 0.36(7.22-7.70)	0.60 ± 0.38(0.55-0.65)	0.50 ±0.20
12		8.00 ± 0.50(7.90-8.24)	0.67 ±0.014(0.63-0.76)	0.56 ±0.12

n=20

The larvae enter the pupal stage following the fourth instar, initially displaying a green colouration that transitions to brown as maturity progresses. The pupa is cylindrical, and the outlines of the head and wings become discernible. Development takes approximately 7.4 ± 0.03 days for males, which is significantly higher (P=0.045) than in females, who undergo an average developmental period of 6.5 ± 0.04 days, resulting in the emergence of females preceding that of males. Sexual dimorphism is evident in body morphometrics; males have a significantly smaller (P =0.032) body weight, averaging 3.18 ± 0.02 mg, and non-significantly shorter body length (P =0.061), measuring 3.57 ± 0.03 mm, with a body width of 0.51 ± 0.04 mm, whereas females weigh 4.20 mg, with a body length of 4.00 ± 0.08 mm (Table 4). The wings and legs casings end at the 5th abdominal segment in the females but extend to the 6th abdominal segment in the male pupae (Figure 3).

Table 4: Morphometrics of male and female pupae of *Tuta absoluta* in Southwest, Nigeria

Mean ± SE (Range)

Sex/Parameter	Body length (mm)	Body width (mm)	Body weight (mg)	Duration (days)
Male	$3.37 \pm 0.03_a$ (2.43 – 4.54)	$0.51 \pm 0.04_a$ (0.38 – 0.76)	$3.18 \pm 0.02_b$ (2.88 – 4.22)	$7.4 \pm 0.03_a$ (5.65 – 8.00)
Female	$4.00 \pm 0.08_a$ (3.00 – 4.85)	$0.64 \pm 0.06_a$ (0.49 – 0.70)	$4.20 \pm 0.06_a$ (3.32 – 5.00)	$6.5 \pm 0.04_b$ (5.80 – 7.50)

Mean values with the same subscript along a column show that range values are not significantly different at 5% (*P* > 0.05) Tukey's Honestly Significant Difference test; n =20: male=10, female=1



Figure 3: Pupae of *Tuta absoluta:* (A) female (B) male (image edited)

Table 5 presents morphometrics, lifespan and sex ratio of male and female *Tuta absoluta*. The findings indicate that the male life span of 7.3 ± 0.20 is significantly lower (*P*=0.041) than that of females, which is approximately 12.9 ± 0.50. Offspring of both sexes were generated at a sex ratio of 1:1.5.

Table 5: Morphometrics, lifespan and sex ratio of males and females of *Tuta absoluta*

Sex	Body length (mm)	Mean ± SE (Range)		Lifespan (days)	Sex ratio
		Body width (mm)	Wingspan (mm)		
Male	$5.30 \pm 0.04_a$ (4.58 – 5.55)	$0.49 \pm 0.05_a$ (0.40 – 0.56)	$9.05 \pm 0.45_a$ (8.80 – 9.10)	$7.3 \pm 0.20_b$ (6.50 – 7.85)	1
Female	$5.57 \pm 0.04_a$ (5.00 – 6.40)	$0.55 \pm 0.07_a$ (0.48 – 0.65)	$9.55 \pm 0.06_a$ (9.00 – 10.50)	$12.9 \pm 0.55_a$ (10.30- 13.50)	1.5

Mean values with the same subscript along a column are not significantly different at 5% (*P* > 0.05) Tukey's Honestly Significant Difference test; n =20

Upon altering the diet to a 10% sugar solution, the mean fecundity of virgin males paired with virgin females reached 123.0 ± 4.22, with a mean hatchability of 96.7 ± 1.86%, resulting in a percentage hatchability of 78.34%. Conversely, under a 5% sugar solution, virgins exhibited a mean fecundity of 115.4 ± 1.58, significantly higher (*P*=0.041) than those fed with 10% sugar (123.4 ± 4.22). This is accompanied by a mean eclosion rate of 97.0 ± 2.77%; the percentage of eclosed individuals was 83.94%. When provided with water alone, females laid an average of 117.6 ± 7.41 eggs, with 84.2 ± 2.78 successfully hatched, equating to a hatchability percentage of 71.74%. (Table 6). Regarding the parthenogenicity of *T. absoluta*, unmated females deposited 94.4 ± 7.21 eggs, with 31.3 ± 2.60 successfully hatching, resulting in an eclosion percentage of 33.16%.

Table 6: Mean Fecundity and eclosion rate (%) of *Tuta absoluta* at different mating and treatment regimes

Treatment/Parameter	Fecundity Mean ± SE	Eclosion Mean ± SE	Percentage (%)	
			Eclosion	Mortality
Virgin female	94.4 ± 1.21c	31.3 ± 2.60a	33.16	66.84
Virgin male X virgin female	125.5 ± 3.58b	94.7 ± 3.53c	74.80	25.20
Virgin male X mated female	50.1 ± 6.84d	33.2 ± 1.49a	66.82	33.18
Mated male X virgin female	101.7 ± 2.49c	77.1 ± 3.07b	75.77	24.23
Mated male X mated female	49.4 ± 9.95d	29.4 ± 7.33a	59.53	40.47
Virgin males X virgin female (2:1)	127.9 ±15.29b	92.4 ± 3.01b	73.36	26.64
Multiple mating X virgin female (2nd mating 5th day of oviposition)	174.5 ±12.8a	134.7 ± 2.63b	76.13	23.87

Female fed on 5% sugar solution	115.4 ±1.58ac	97.0 ± 8.77a	83.94	16.06
Female fed on a 10% sugar solution	123.4 ± 4.22b	96.7 ± 1.86a	78.34	21.66
Females fed on water alone	117.6 ± 7.41c	84.2 ± 2.78a	71.74	28.26

Mean values with the same subscript along a column are not significantly different at 5% (*P* > 0.05) Tukey's Honestly Significant Difference test; n = 10 females for each bioassay

DISCUSSION

Molecular characterisation is pivotal in enhancing the managerial comprehension of the biology, ecology, and control measures, thereby bolstering endeavours to alleviate the impact of *Tuta absoluta*, a significant agricultural pest (D'Esposito *et al.,* 2021; Wang *et al.,* 2021). The molecular analysis in the present study reveals that the cytochrome oxidase subunit I (COI) gene sequences from the Tuta absoluta sample are genetically related to those from the United States, Egypt, Kenya, Togo, Nigeria, and South Africa. The pest we worked with in this study has a common ancestry with others documented from America, Asia and Africa, and thus confirms the migratory nature of the pest as reported by Mansour *et al.,* (2018). However, the biological characteristics of the current strain of *T. absoluta* differ from those observed in sequences from Spain and Brazil, which means the pest has a great adaptation to different climatic conditions, which has helped in its invasion of new territories.

Understanding the life cycle stages, reproductive behaviour, and developmental requirements of *T. absoluta* enables precise interventions at vulnerable points. This knowledge facilitates the strategic timing of control measures such as pesticide application, biological control, or cultural practices like crop rotation (Cuthbertson *et al.,* 2013; Mohamed *et al.,* 2022). The current investigation has contributed to enhancing the comprehension of the pest's reproductive and developmental biology, underscoring the inevitability of effective control. The investigation unveiled that the life cycle of *Tuta absoluta* on sweet tomato varieties lasts around 20.23 days from egg laying to adult emergence, occurring within an average temperature range of 27.3 ± 2.17 ºC and relative humidity of 75.3 ± 1.6%. A certain number of authors have reported variability in the life cycle of *T. absoluta* in relation to temperature. Mohamed *et al.,* (2022) reported an optimum temperature range of 21 -23 ºC for the immature stages and female fecundity, while reporting a significantly higher intrinsic rate of increase (rm), gross reproductive (GRR), and net reproductive (Ro) rates at temperatures between 20–25 °C. This is lower compared to what was observed in this present study and shows one of the reasons for *Tuta absoluta's* successful invasion across different ecological zones globally.

Understanding the behaviour of *T. absoluta*, particularly its mating patterns, can inform the development of effective control strategies (Rizvi *et al.,* 2021). In this study, the developmental period of *T. absoluta* on the sweet tomato variety, from oviposition to adult emergence, was 20.23 days at 27.3 ± 2.17 ºC and 75.3 ± 1.6% RH. This is shorter than the 23.8 days at 27 °C reported by Borisade *et al.,* (2017),a difference that can be attributed to temperature variation, which moduclates the development period of the pest. Cuthbertson *et al.,* (2013) reported 37 days at 19 °C and 23 days at 25 °C, from egg

to adult emergence, while Munniapan (2013) reported 83 days at 14 °C.

Duarte *et al.,* (2015) demonstrated that temperature influences developmental period, pupal viability and sex ratio in *T. absoluta*, highlighting its critical role in the pest's development. However, varietal differences may also contribute, as secondary metabolites profiles vary among tomato varieties and can influence development. Duarte *et al.,* (2015) further reported that there were differences in pre-oviposition, oviposition, and post-oviposition of adult moths reared on cultivars Vyta and Bravo. Thus, environmental factors and variety have direct effects on the duration of *Tuta absoluta* development. Also, the morphological traits and sex ratio of the emerging adults could be affected.

The resistance evaluations in this study further showed that developmental biology was influenced by the accessions, although all accessions evaluated were susceptible to *T. absoluta* infestation. Hence, further screening of varieties that could suppress or disrupt the development of *T. absoluta* is recommended.

For egg morphometric, the results obtained were largely consistent with those reported by Munniapan (2013), Cuthbertson *et al.,* (2013) and Mutamiswa *et al.,* (2017). The larval stage lasted 12 days, and the optimal window for insecticide application is when first instar larvae attempt to penetrate the leaf surface. In this study, tunnelling by the first instar larvae was completed in 25 minutes. This is considerably shorter than the 82 minutes reported by Cuthbertson *et al.,* (2013).

The females provided with water alone exhibited lower fecundity that those fed 10% sugar solution, whereas no significant difference was observed between females fed 5% sugar solution and those provided with water only.

This shows that poor food quality would not deter *T. absoluta* from reproducing and thus causing untold damage to a farm once it is infested. Hence, there is a need for Integrated Pest Management, which encompasses biological, chemical and physical methods to mitigate and manage the effects of the *T. absoluta* invasion. Although interplanting tomatoes with some plants like coriander (Mahmoud *et al.,* 2020) and black nightshade (Campos *et al.,* 2021) could help in reducing infestation, however, this might still not help due to the ability of the pest to subsist on suboptimal food.

Multiple mating events resulted in the highest fecundity among females, implying that they would lay more eggs in a secluded area screen, potentially leading to higher damage compared to a wider open field. In addition, previously oviposited females continued to mate and oviposit, albeit at a reduced rate and with lower hatchability. Furthermore, deuterotokous parthenogenesis was observed among the female moths. This reproductive mode is relatively uncommon in Lepidoptera, with only about 20 soecies across various families, including Gelechiidae, known to reproduce asexually (Munniapan, 2013; Duarte *et al.,* 2015). Hence, its occurrence in *T. absoluta* is not unexpected.

CONCLUSION

Since control and management of *T. absoluta* are imperative, they must be customised to suit the specific characteristics of the Nigerian local strain. This is essential because the strain of the pest varies geographically, as influenced by its phylogenetic origins. Strategies for controlling *Tuta absoluta* should focus on promoting the establishment of segmented tomato farms rather than large, continuous fields. This fragmentation disrupts the pest's oviposition patterns, offering a disadvantage. Considering the variability of the pest's life cycle, particularly in response to temperature changes, it is crucial to carefully monitor the weather conditions of tomato farms

before implementing any pest management measures. Furthermore, awareness and extension programmes are needed to educate farmers on the appropriate use of chemical pesticides, which can adversely affect the environment when misused. In conclusion, control methods such as sex-pheromone trapping and sterile male release should be discouraged given the parthenogenesis observed in this pests. Instead, targeting the eggs and/or the first instar larval stages prior to leaf mining would provide a more effective control strategy.

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CONFLICT OF INTEREST

Authors declare no conflict of interest.

AVAILABILITY OF DATA AND MATERIALS

The datasets analysed during the current study are available from the https://www.ncbi.nlm.nih.gov/nuccore/PQ187916.

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