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Comparative Efficacy of Two Sex Pheromone Trap Types (Deltasan and Tutasan) for Monitoring and Mass Trapping of *Tuta absoluta* (Lepidoptera: Gelechiidae) in Tomato Crops in Cote d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. Authors ADK, EOT and AS conceived and designed the study, developed the experimental protocol, and carried out the investigation. Authors EOT and NAA revised the study design, supervised the research activities, and performed the statistical analyses. All authors contributed to manuscript preparation, reviewed, and approved the final version of the paper.

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ABSTRACT

Aims: This study evaluated the comparative effectiveness of two pheromone trap designs, Deltasan and Tutasan, for capturing the tomato leaf miner *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae), a major pest of tomato crops in Côte d'Ivoire.
Study Design: The experiment was conducted in Yamoussoukro, central Côte d'Ivoire, on a tomato (*Solanum lycopersicum* L.) field where adult male captures were recorded from five randomly selected traps of each type during each sampling period.
Place and Duration of Study: The study took place from July to September 2024 during the rainy season in the village of Gogokro (6°49′ N, 5°26′ W).
Methodology: Count data were analyzed using a Generalized Linear Model (GLM) with a negative binomial distribution to account for data non-normality and overdispersion typical of insect populations.
Results: A significant interaction was observed between trap type and crop phenological stage. During the flowering stage, no significant difference was detected between Deltasan and Tutasan traps. However, during the fruiting and ripening stages, the Tutasan trap captured significantly more adults than the Deltasan trap. Overall, capture numbers increased with crop development, particularly for Tutasan traps.
Conclusion: These results highlight that the efficacy of pheromone traps varies with the phenological stage of the tomato crop. The Tutasan trap proved more efficient for both monitoring and mass trapping of *T. absoluta* during critical periods of infestation. This study provides insights for optimizing Integrated Pest Management (IPM) strategies against *T. absoluta* and related Gelechiidae pests in tropical tomato production systems.

Keywords: Pheromone trap; phenological stage; integrated pest management; trap performance evaluation; sustainable tomato production.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* Mill.) is one of the most widely cultivated and consumed vegetable crops worldwide. According to FAO data, in 2014, the global tomato cultivation area reached approximately 3.7 million hectares with a production exceeding 159 million tons (Yah N'guettia et al., 2022). Despite its economic importance, tomato productivity is severely constrained by several pests, among which the tomato leaf miner *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) stands out as the most destructive. This invasive species can cause yield losses approaching 100% in the absence of adequate control measures (Kaouthar et al., 2010).

Originally native to South America, *T. absoluta* has become one of the most invasive lepidopteran pests of solanaceous crops. Following its first detection in Spain in 2006, the pest spread rapidly across Europe, North Africa, and Asia. It was first reported in Africa in 2007, where it has since emerged as a major threat to tomato production systems (Rwomushana et al., 2019). In West Africa, *T. absoluta* was first recorded in Senegal in 2012 and likely the same year in Côte d'Ivoire, where subsequent surveys have confirmed its establishment in major tomato-producing regions, including Yamoussoukro (Konan et al., 2022).

In Côte d'Ivoire, tomato is the most consumed vegetable, with an estimated annual production of 52,000 tons against a national demand of nearly 100,000 tons (Yah N'guettia et al., 2022; Yao et al., 2022). This production deficit is further exacerbated by severe field infestations and post-harvest losses caused by *T. absoluta*.

Chemical insecticides remain the predominant control method employed by farmers (Adja et al., 2023; Adja et al., 2023; Kakou et al., 2021). However, their repeated and often unregulated use has led to the development of resistance, elimination of beneficial organisms (Tiénébo, 2016; Tiénébo et al., 2019; Yao et al., 2023) and increased environmental and human health risks (Bilé et al., 2025; Huang et al., 2024). Consequently, Integrated Pest Management (IPM) strategies have gained prominence as sustainable alternatives, combining cultural, biological, physical, and mechanical control methods to keep pest populations below economic thresholds (Gadji et al., 2025; Adhikari & Ayele, 2022; Awasthi et al., 2025).

Among IPM components, pheromone-based trapping plays a crucial role in both monitoring and suppressing *T. absoluta* populations (Biondi et al., 2018; Desneux et al., 2010). Pheromone traps utilize synthetic sex attractants that mimic the volatiles emitted by females (Svatoš et al., 1996) to lure males, thereby disrupting mating and reducing pest populations (Cherif et al., 2018; Ünlü et al., 2021). These traps also enable early detection, population monitoring, and mass trapping, contributing to environmentally sound management of the pest while minimizing pesticide inputs (Biondi et al., 2018; Sabbahi & Azzaoui, 2022).

Selecting the most efficient trap design is critical for optimizing capture rates and improving the reliability of monitoring programs. In this context, the present study was conducted to evaluate and compare the field performance of two commercial pheromone trap models, Deltasan and Tutasan, in capturing *Tuta absoluta* across different phenological stages of tomato crops in Côte d'Ivoire.

2. MATERIALS AND METHODS

2.1 Study Site

The study was conducted in central Côte d'Ivoire, within the Autonomous District of Yamoussoukro, specifically in the village of Gogokro (6°49′ N, 5°26′ W). The experimental site was located approximately 3 km from Sahabo and 11 km from downtown Yamoussoukro (Fig. 1).

The region has a humid tropical climate characterized by two rainy seasons (March–July and September–November) and two dry seasons. The study took place from July to September 2024. During the study period, the village of Gogokro (6°49′ N, 5°26′ W) experienced warm and humid weather characteristic of the southern forest–savanna transition zone of Côte d'Ivoire. Mean air temperatures ranged between 26 and 27 °C, with daily minima around 21–23 °C and maxima reaching 30–32 °C. Relative humidity remained high throughout the period, averaging 85–90 %, reflecting the persistence of moist conditions during the rainy season. Monthly rainfall totals varied between 70 and 100 mm in July, 40–70 mm in August, and 50–80 mm in September, indicating a gradual decline in precipitation after the main wet season peak.

The soil is ferrallitic and slightly acidic, providing favorable conditions for tomato (*Solanum lycopersicum* L.) cultivation.

2.2 Biological material

The plant material consisted of short-cycle hybrid tomato varieties (approximately 90 days), namely DARA F1, COBRA F1, UC82B, and CNRA.

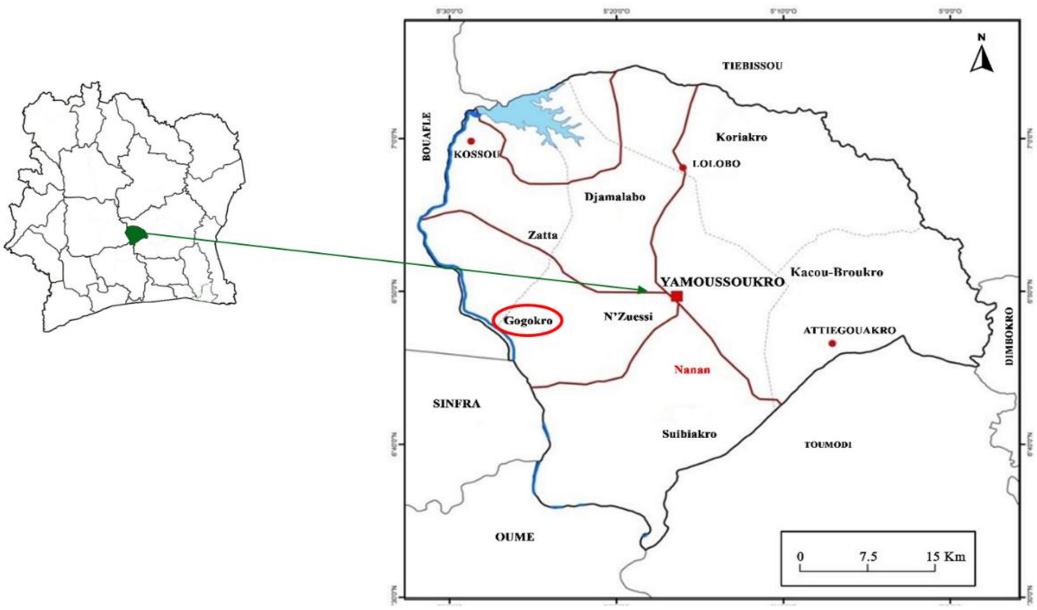

Fig. 1. Location of the experimental site in Yamoussoukro, central Cote d'Ivoire

The target insect species was the tomato leaf miner, *T. absoluta*, which naturally occurs in the experimental field.

2.3 Technical material

Two types of pheromone traps were used for capturing adult males of *T. absoluta* (Fig. 2):

- **Deltasan trap:** a white triangular delta trap (15 cm per side, 25 cm in length) equipped with an internal sticky surface designed to retain insects attracted by the pheromone.

- **Tutasan trap:** a red circular bucket trap (30 cm diameter, 5 cm depth) fitted with a small green container holding the pheromone capsule. A mixture of water and liquid soap (or vegetable oil) was added inside the bucket to immobilize captured insects. The liquid was renewed after each sampling event.

Each trap was baited with a synthetic sex pheromone capsule specific to *T. absoluta*. Additional equipment included standard agricultural tools (such as hoes and watering cans) and data collection sheets.

2.4 Chemical material

The pheromones used were commercial synthetic sex attractants specific to male *T. absoluta*. They were supplied in small green conical capsules. Each capsule remained effective for 4–6 weeks, depending on climatic conditions. In this study, pheromone lures were replaced weekly to maintain optimal attractiveness throughout the experiment.

2.5 Experimental Design

The experiment was carried out on a 0.5-ha tomato plot divided into two homogeneous subplots of 0.25 ha each.

One subplot was equipped with Deltasan traps and the other with Tutasan traps. Ten traps of each type were installed at 15 m intervals, corresponding to an average density of 40 traps per hectare. No insecticide treatments were applied during the study period to avoid external interference.

The experimental design employed a factorial scheme with two treatments (trap types) and repeated measures over time, according to tomato phenological stages (flowering, fruiting, and ripening).

Trap type was considered a fixed factor, and the phenological stage was a repeated temporal factor. The analysis considered the main effects of these factors and their interaction (Trap × Stage).

2.6 Data Collection

Data were collected from July 22 to August 17, 2024, covering the three tomato phenological stages. Sampling was conducted twice a week.

At each sampling date, ten traps were randomly selected (five Deltasan and five Tutasan). The number of *T. absoluta* adults captured per trap was recorded, along with the corresponding crop phenological stage.

Pheromone lures were renewed weekly to ensure consistent attractiveness throughout the experiment.

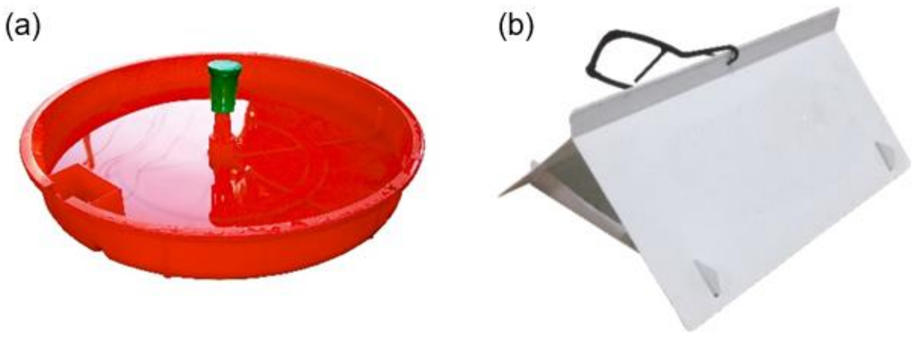

Fig. 2. Two types of pheromone traps used: (a) Tutasan; (b) Deltasan

2.7 Data Analysis

Preliminary data exploration revealed non-normality and overdispersion of count data. Therefore, a Generalized Linear Model (GLM) with a negative binomial distribution and a log-link function was applied to model the number of captured individuals.

The model included trap type, phenological stage, and their interaction as explanatory variables. To determine the significance of the model terms, a Type III Analysis of Deviance was conducted on the Negative Binomial model. The contributions of the main effects (trap type, phenological stage) and their two-way interaction were evaluated using both Wald and Likelihood Ratio tests. Post hoc comparisons of estimated marginal means were conducted using the Bonferroni correction to control the type I error rate. All statistical analyses were performed using RStudio 2025.09.1 Build 401 (Posit Software, PBC).

3. RESULTS AND DISCUSSION

3.1 Overall Model and Goodness-of-Fit

A Negative Binomial Generalized Linear Model (GLM) was fitted to account for overdispersion in the count data of *T. absoluta* captures. The model included trap type, phenological stage, and their interaction as explanatory variables. Overall, the model provided a satisfactory fit to the data (Table 1).

The fitted model exhibited a substantial reduction in deviance relative to the null model (from 207.32 to 120.92), indicating that the predictors explained a large portion of the variability in moth captures. The estimated dispersion parameter ($\theta = 4.988$) confirmed that the Negative Binomial model was more appropriate than a Poisson alternative. Examination of residual plots revealed no systematic patterns, supporting the adequacy of the model assumptions. Therefore, this model was retained for inference on factors affecting *T. absoluta* trap captures.

Parameter estimates for the Negative Binomial GLM are presented in Table 2. Coefficients are expressed on the log scale. The intercept (2.380) represents the log of the expected mean number of moths captured by the Deltasan trap during the Flowering stage. When exponentiated (exp[2.380] = 10.8), this corresponds to a mean capture of approximately 10.8 moths, consistent with the estimated marginal means.

The coefficient for Trap type (Tutasan) (0.231; $P = .171$) indicates that during the Flowering stage, Tutasan traps captured a slightly higher, but not significantly different, number of moths compared to Deltasan traps. For phenological stages, captures by Deltasan traps did not differ significantly between the Flowering and Fruiting stages (estimate = –0.150; $P = .388$), but were significantly higher during the Ripening stage (estimate = 0.665; $P < .001$), demonstrating a strong seasonal effect.

Table 1. Goodness-of-fit statistics for the negative binomial model

Statistic	Value	Interpretation
Model formula	Count ~ Trap_type × Phenological_stage	-
Data distribution	Negative Binomial	Accounted for over-dispersion in count data.
Link function	Log	Ensured predictions were non-negative.
Null deviance	207.32 (on 119 df)	Total variability in the data.
Residual deviance	120.92 (on 114 df)	Remaining variability after model fitting.
Dispersion parameter (Theta)	4.988 (SE = 0.821)	Confirms over-dispersion (Theta > 1); a Poisson model (Theta = ∞) would have been inappropriate.
Akaike Information Criterion (AIC)	847.07	Used for model comparison; lower values indicate a better balance of fit and parsimony.
Residual df	114	-
2 ×Log-likelihood	-833.070	Basis for Likelihood Ratio Tests.

Table 2. Coefficients of the Negative Binomial GLM for *Tuta absoluta* trap captures

Coefficient	Estimate	Std. Error	z-value	P-value
(Intercept)	2.380	0.121	19.657	< .001
Trap_type (Tutasan)	0.231	0.168	1.369	.171
Phenological_stage (Fruiting)	-0.150	0.173	-0.863	.388
Phenological_stage (Ripening)	0.665	0.165	4.042	< .001
Trap_type (Tutasan) × Stage (Fruiting)	0.594	0.237	2.505	.012
Trap_type (Tutasan) × Stage (Ripening)	0.200	0.229	0.874	.382

Note: The model uses Deltasan trap and Flowering stage as reference categories.

The interaction terms revealed that trap performance varied across phenological stages. A significant positive interaction was observed for Tutasan × Fruiting (estimate = 0.594; P = .012), indicating that the relative efficiency of Tutasan traps increased significantly during the Fruiting stage compared with the Flowering stage. Conversely, the Tutasan × Ripening interaction was not significant (estimate = 0.200; P = .382), suggesting that the difference in trap performance remained relatively stable between the Fruiting and Ripening stages.

3.2 Effects of Trap Type, Phenological Stage, and their Interaction on *Tuta absoluta* Captures

A significant interaction between trap type and crop phenological stage was detected (Wald χ^2 = 6.54, P = .038), indicating that the effectiveness of each trap type varied according to the tomato growth stage. Consequently, the main effects of trap type and phenological stage cannot be interpreted independently, and subsequent analyses focused on the simple effects of one factor at specific levels of the other.

Both the Wald and Likelihood Ratio (LR) tests yielded consistent results, confirming the robustness of the statistical model (Tables 3 and 4). The LR test similarly revealed a significant interaction between trap type and phenological stage (LR χ^2 = 6.54, P = .038). The effect of phenological stage alone was highly significant (LR χ^2 = 29.07, P < .001), showing that moth capture rates varied markedly with crop development. In contrast, the main effect of trap type, considered across all growth stages, was not significant (LR χ^2 = 1.87, P = .171).

These results demonstrate that trap performance in capturing *T. absoluta* depends strongly on the developmental stage of the crop, highlighting the importance of considering crop phenology when selecting monitoring tools for this pest.

3.3 Summary of Mean Captures

The estimated marginal means (on the response scale), together with Bonferroni groupings, highlight the interaction between trap type and tomato phenological stage (Fig. 3; Table 5). The Tutasan trap during the Ripening stage recorded the highest mean capture (32.3 moths), forming a statistically distinct group. Both trap types exhibited comparable performance during the Flowering stage; however, their capture rates diverged significantly in the Fruiting and Ripening stages, with Tutasan consistently outperforming Deltasan.

In summary, a significant interaction between trap type and crop phenological stage influenced *T. absoluta* capture rates. Although Tutasan generally yielded higher captures than Deltasan, this difference was most pronounced during the Fruiting and Ripening stages. Capture dynamics also varied seasonally between traps. These results emphasize the need to consider both trap selection and crop stage in the design of integrated pest management (IPM) programs for *T. absoluta*. For effective monitoring, particularly during mid- to late-season, the Tutasan trap is recommended.

Table 3. Analysis of deviance (Type III Wald tests) for the Negative Binomial model of *Tuta absoluta* captures

Source	Df	Wald χ^2	P-value
(Intercept)	1	386.39	< .001
Trap type	1	1.87	.171
Phenological stage	2	28.08	< .001
Trap type × Phenological stage	2	6.54	.038

Table 4. Analysis of deviance (Type III Likelihood Ratio tests) for the Negative Binomial model of *Tuta absoluta* captures

Source	LR χ^2	Df	P-value
Trap type	1.874	1	.171
Phenological stage	29.069	2	< .001
Trap type × Phenological stage	6.536	2	.038

Note: The model was a Negative Binomial GLM with a log link. The significant interaction term indicates that the effect of trap type on capture rates is dependent on the crop's phenological stage

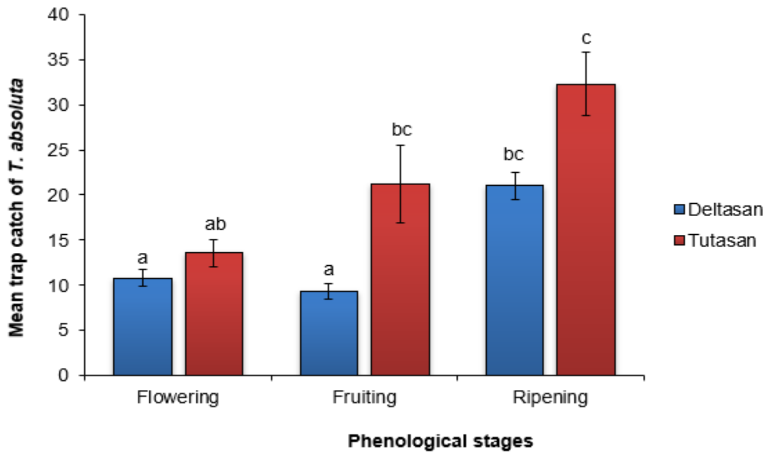

Fig. 3. Mean captures of *Tuta absoluta* in Deltasan and Tutasan traps across tomato phenological stages.

Error bars represent standard error of the mean. Bars sharing a common letter are not significantly different (Bonferroni test, α = 0.05)

Table 5. Estimated marginal means of *T. absoluta* captures (back-transformed from log scale) with Bonferroni grouping

Trap type	Phenological stage	Mean count	Lower 95% CI	Upper 95% CI	Group
Deltasan	Fruiting	9.3	6.7	12.9	a
Deltasan	Flowering	10.8	7.8	14.9	a
Tutasan	Flowering	13.6	10.0	18.5	ab
Deltasan	Ripening	21.0	15.7	28.2	bc
Tutasan	Fruiting	21.2	15.8	28.4	bc
Tutasan	Ripening	32.3	24.3	42.9	c

Note: Means sharing the same letter are not significantly different (p > 0.05).

3.4 Comparison of Trap Efficiency Across Phenological Stages

3.4.1 Between-trap comparison: effect of trap type within each phenological stage

Post hoc pairwise comparisons with Bonferroni adjustment were performed to evaluate the effect of trap type within each phenological stage (Table 6). The relative performance of Tutasan and Deltasan traps varied significantly across the crop phenological cycle.

During the Flowering stage, capture rates did not differ significantly between Tutasan and Deltasan traps (P = .171). In contrast, during the Fruiting stage, Tutasan traps captured significantly more moths than Deltasan traps (Rate Ratio = exp (0.824) = 2.28, P < .0001). This trend continued into the Ripening stage, though with a reduced magnitude (Rate Ratio = exp (0.431) = 1.54, P = .0054). These findings indicate that the Tutasan trap was consistently more effective than the Deltasan trap during the later developmental stages of the crop.

3.4.2 Within-trap comparison: effect of phenological stage on trap captures

The effect of the tomato phenological stage on *Tuta absoluta* captures was further analyzed separately for each trap type, with results expressed as incidence rate ratios (IRR) to facilitate interpretation (Table 7). The temporal patterns of adult captures varied considerably between Deltasan and Tutasan traps (Fig. 4).

In Deltasan traps, capture rates during the *Flowering* and *Fruiting* stages were statistically similar (IRR = 1.16, *P* = 1.000). However, captures increased significantly at the *Ripening* stage. Specifically, the number of moths caught during Ripening was approximately 1.95 times higher than during Flowering (IRR = 0.514, *P* = .0002) and 2.26 times higher than during Fruiting (IRR = 0.443, *P* < .0001).

In contrast, Tutasan traps exhibited a different capture pattern across crop stages. The highest capture rates were observed during the *Ripening* stage. Captures at *Flowering* were 1.56 times greater than at *Fruiting* (IRR = .642, *P* = .0179), whereas captures at *Ripening* were 2.38 times higher than at *Flowering* (IRR = .421, *P* < .0001). The difference between *Fruiting* and *Ripening* stages was also significant, with captures during Ripening being 1.52 times higher (IRR = .656, *P* = .0196).

These results indicate that both trap types captured significantly more moths as the crop approached maturity, but the magnitude and timing of these increases differed between traps.

Table 6. Pairwise contrasts of trap types within each phenological stage (Bonferroni-adjusted).

Phenological Stage	Contrast	Estimate (log)	SE	z-ratio	P-value
Flowering	Deltasan - Tutasan	-0.231	0.168	-1.369	.1710
Fruiting	Deltasan - Tutasan	-0.824	0.167	-4.943	< .0001
Ripening	Deltasan - Tutasan	-0.431	0.155	-2.780	.0054

Note: Negative estimates indicate lower log-counts for Deltasan relative to Tutasan.

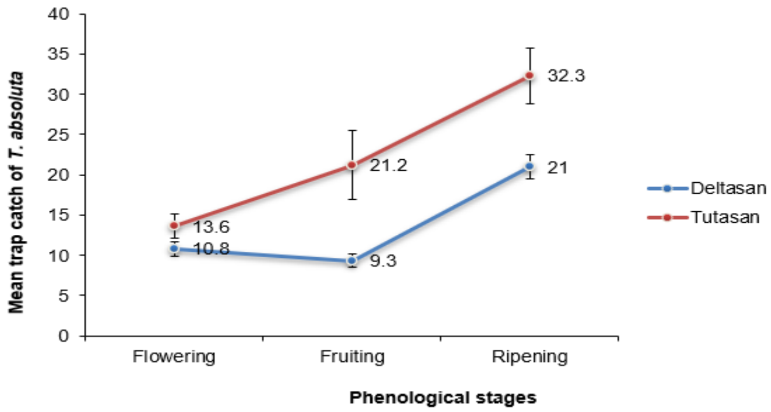

Fig. 4. Trap-specific seasonal progression of *Tuta absoluta* captures during tomato crop development

Error bars indicate the standard error of the mean

Table 7. Within-trap comparisons of *Tuta absoluta* captures across phenological stages, expressed as incidence rate ratios (Bonferroni-adjusted).

Trap Type	Contrast	Ratio	SE	z-ratio	P-value
Deltasan	Flowering / Fruiting	1.161	.201	.863	1.0000
	Flowering / Ripening	0.514	0.085	-4.042	.0002
	Fruiting / Ripening	0.443	0.074	-4.885	< .0001
Tutasan	Flowering / Fruiting	0.642	0.104	-2.749	.0179
	Flowering / Ripening	0.421	0.067	-5.441	< .0001
	Fruiting / Ripening	0.656	0.102	-2.720	.0196

Note: A ratio < 1 indicates a lower capture rate in the first stage of the contrast relative to the second.

3.5 Discussion

The analysis of *Tuta absoluta* capture data revealed strong overdispersion, a common feature in studies dealing with insect populations exhibiting aggregated spatial distributions. The use of a Generalized Linear Model (GLM) with a negative binomial distribution was therefore appropriate, providing reliable estimates and robust statistical inferences (Hilbe, 2011).

The findings highlight the critical influence of the tomato's phenological stage on the relative efficiency of pheromone traps. The significant interaction observed between trap type and crop stage confirms that trap performance is not constant throughout the growing season. During flowering, Deltasan and Tutasan traps showed comparable efficacy, suggesting their interchangeable use for early pest detection. However, during the fruiting and ripening stage periods coinciding with the peak reproductive activity of *T. absoluta*, the Tutasan trap proved significantly more effective than the Deltasan trap.

This superior performance of the Tutasan model corroborates the results of Sisay et al. (2023) in Kenya, where similarly designed traps captured higher numbers of lepidopteran pests than delta or bucket traps. The enhanced efficacy of the Tutasan trap may be attributed to its open and wider design, which increases the capture surface area and improves insect retention through the presence of a liquid trapping medium.

The progressive increase in captures observed as the crop developed, particularly with Tutasan traps, reflects the biology of *T. absoluta*. Females preferentially oviposit on mature plants that provide abundant foliage and fruits, creating favorable conditions for larval development and survival (Guenaoui & Ghelamallah, 2008; Awasthi et al., 2025). This positive correlation between plant maturity and pest density indicates that crop phenology should be considered a key factor in monitoring and management programs.

From an Integrated Pest Management (IPM) perspective, Tutasan traps appear to be versatile tools suitable for both spatial and temporal monitoring, as well as mass trapping during critical infestation periods. Their increased efficiency at high pest pressure could help reduce dependence on insecticides while improving the accuracy of decision-making for intervention. These findings are consistent with Desneux et al. (2022), who emphasized the importance of combining monitoring, biological control, and cultural practices in sustainable IPM frameworks.

Practically, tomato growers could adapt their trapping strategies based on crop phenology. During flowering, trap selection may be guided by economic or logistical considerations. In contrast, during fruiting and ripening, the preferential use of Tutasan traps would maximize trapping efficiency and reduce the buildup of infestations.

Nevertheless, some methodological limitations must be acknowledged. The experiment was conducted in a single field, which restricts the generalizability of the results. Replicated trials across different agroecological zones and growing seasons are needed to validate the observed trends. Additionally, the exclusive placement of each trap type in separate subplots may have introduced bias due to unaccounted environmental heterogeneity.

Finally, to enhance the sustainability of pest management strategies, future research should explore the integration of pheromone trapping with complementary biocontrol approaches, such as the use of botanical extracts with insecticidal or attractant properties (Ndereyimana et al., 2020). Such integration would support an ecologically sound and durable approach to managing *Tuta absoluta* in tomato production systems.

4. CONCLUSION

This study demonstrated that the efficiency of pheromone traps for capturing *T. absoluta* is strongly influenced by the phenological stage of the tomato crop. Deltasan and Tutasan traps showed comparable performance during the flowering stage, indicating similar effectiveness for early population detection. However, during fruiting and ripening stages, the Tutasan trap significantly outperformed the Deltasan trap, reflecting a higher ability to intercept males during peak reproductive activity.

These findings highlight the importance of integrating both crop development dynamics and pest behavior when assessing trapping systems. Within an Integrated Pest Management framework, the Tutasan trap appears particularly suitable for spatio-temporal monitoring and mass trapping of *T. absoluta* populations, thereby reducing pest pressure while minimizing dependence on chemical insecticides.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Adhikari, A., & Ayele, B. A. (2022). Empirical review of *Tuta absoluta* Meyrick effect on the tomato production and their protection attempts. *Advances in Agriculture, 2022*, 1–9. https://doi.org/10.1155/2022/2595470

Adja, A. N., Bley-Atse, A. B., Gnago, J. A., Tienebo, E.-O., & Danho, M. (2023). Damage caused by lepidopteran pests on maize fields in Yamoussoukro, Central Côte d'Ivoire. *International Journal of Plant & Soil Science, 35*(18), Article 18. https://doi.org/10.9734/ijpss/2023/v35i183348

Adja, A. N., Bley-Atse, A. B., Tienebo, E.-O., Gnago, J. A., & Danho, M. (2023). Use of selected chemical and biological insecticides to control lepidopteran pests of maize fields in Central Côte d'Ivoire. *International Journal of Environment and Climate Change, 13*(11), 812–825. https://doi.org/10.9734/ijecc/2023/v13i113229

Awasthi, S., Giri, A. T., Lohani, S., Chaulagain, B., et al. (2025). Monitoring of tomato leaf miner (*Tuta absoluta*) and assessment of management practices adopted in Tanahun, Nepal. *Tomato and Agriculture Sciences, 2025*, 1–12. https://doi.org/10.17311/tas.2025.01.12

Bilé, E. E. J., Gadji, A. A. G., Tienebo, E.-O., Kambiré, O., Kouadia, M.-J. A., Kouadio, T. K., Nganko, J. M., & Abo, K. (2025). Valorization of agricultural and industrial wastes to produce *Trichoderma virens*, an effective plant disease biocontrol agent. *Waste and Biomass Valorization.* https://doi.org/10.1007/s12649-025-02888-y

Biondi, A., Guedes, R. N. C., Wan, F.-H., & Desneux, N. (2018). Ecology, worldwide spread, and management of the invasive South American tomato pinworm, *Tuta absoluta*: Past, present, and future. *Annual Review of Entomology, 63*, 239–258. https://doi.org/10.1146/annurev-ento-031616-034933

Cherif, A., Harbaoui, K., Zappalà, L., & Grissa-Lebdi, K. (2018). Efficacy of mass trapping and insecticides to control *Tuta absoluta* in Tunisia. *Journal of Plant Diseases and Protection, 125*(1), 51–61. https://doi.org/10.1007/s41348-017-0140-6

Desneux, N., Han, P., Mansour, R., Arnó, J., et al. (2022). Integrated pest management of *Tuta absoluta*: Practical implementations across different world regions. *Journal of Pest Science, 95*(1), 1–19. https://doi.org/10.1007/s10340-021-01442-8

Desneux, N., Wajnberg, E., Wyckhuys, K. A. G., Burgio, G., Arpaia, S., Narváez-Vasquez, C. A., González-Cabrera, J., Catalán Ruescas, 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*(3), 197–215. https://doi.org/10.1007/s10340-010-0321-6

Gadji, A. A. G., Coulibaly, N. D., Tienebo, E.-O., Ossey, C.-L., N'gaza, A. F., N'gbesso, M., Fondio, L., & Abo, K. (2025). Antifungal activity of aqueous extract of garlic and oils of carapa and neem on the causal agent of tomato late blight disease. *International Journal of Biological and Chemical Sciences, 18*(6), 2388–2398. https://doi.org/10.4314/ijbcs.v18i6.24

Guenaoui, Y., & Ghelamallah, A. (2008). *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae), a new tomato pest in Algeria: First data on its biology as a function of temperature. [Conference presentation]. *8th International Conference on Pests in Agriculture*, Montpellier, France.

Hilbe, J. (2011). Negative binomial regression: Modeling. In *Negative Binomial Regression: Second Edition* (pp. 221–283). Cambridge University Press. https://doi.org/10.1017/CBO9780511973420.010

Huang, P.-C., Yuan, P., Grunseich, J. M., Taylor, J., Tiénébo, E.-O., Pierson, E. A., Bernal, J. S., Kenerley, C. M., & Kolomiets, M. V. (2024). *Trichoderma virens* and *Pseudomonas chlororaphis* differentially regulate maize resistance to anthracnose leaf blight and insect herbivores when grown in sterile versus non-sterile soils. *Plants, 13*(9), Article 9. https://doi.org/10.3390/plants13091240

Kakou, M. A., Adja, N. A., Johnson, F., Kouadia, A. M. J., Tienebo, E.-O., Kouadio, K. T., Danho, M., & Abo, K. (2021). Identification of maize insects and fungi affecting sanitary and physiological quality of stored maize grains in Central Côte d'Ivoire. *Asian Journal of Crop Science, 13*(1), 36–45. https://doi.org/10.3923/ajcs.2021.36.45

Kaouthar, L. G., Manel, S., Mouna, M., & Ridha, B. (2010). Integrated control of the tomato leafminer, *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) in Tunisia. *Entomologie Faunistique – Faunistic Entomology, 63*(1), 35–44.

Konan, K. A. J., Ouali, N. S.-W. M., Fondio, L., Ochou, O. G., Koné, D., Desneux, N., & Martin, T. (2022). Geographical distribution and host range status of *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) in Côte d'Ivoire. *International Journal of Tropical Insect Science, 42*, 365–377. https://doi.org/10.1007/s42690-021-00554-z

Ndereyimana, A., Nyalala, S., Murerwa, P., & Gaidashova, S. (2020). Field efficacy of entomopathogens and plant extracts on *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae) infesting tomato in Rwanda. *Crop Protection, 130*, 105040. https://doi.org/10.1016/j.cropro.2019.105040

Rwomushana, I., Beale, T., Chipabika, G., Day, R., Gonzalez-Moreno, P., Lamontagne-Godwin, J., Makale, F., Pratt, C., & Tambo, J. (2019). *Tomato leaf miner (Tuta absoluta): Impacts and coping strategies for Africa.* CABI. https://www.cabi.org/cabi-publications/tomato-leafminer-tuta-absoluta-impacts-and-coping-strategies-for-africa/

Sabbahi, R., & Azzaoui, K. (2022). The effectiveness of pheromone traps in controlling the tomato leaf miner, *Tuta absoluta*, in the United Arab Emirates. *Journal of Plant Diseases and Protection, 129*(2), 367–374. https://doi.org/10.1007/s41348-022-00572-0

Sisay, B., Subramanian, S., Weldon, C. W., Krüger, K., Khamis, F., Tefera, T., Torto, B., & Tamiru, A. (2023). Evaluation of pheromone lures, trap designs and placement heights for monitoring the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in maize fields of Kenya. *Crop Protection, 176*, 106523. https://doi.org/10.1016/j.cropro.2023.106523

Svatoš, A., Attygalle, A. B., Jham, G. N., Frighetto, R. T. S., Vilela, E. F., Šaman, D., & Meinwald, J. (1996). Sex pheromone of tomato pest *Scrobipalpuloides absoluta* (Lepidoptera: Gelechiidae). *Journal of Chemical Ecology, 22*(4), 787–800. https://doi.org/10.1007/BF02033586

Tiénébo, E.-O. (2016). *Effect of inoculation of* Pseudomonas chlororaphis *30-84 and/or* Rhizophagus irregularis *DAOM 197198 on maize anthracnose leaf blight and tomato zebra chip disease* [Thesis, Texas A & M University]. http://oaktrust.library.tamu.edu/handle/1969.1/158069

Tiénébo, E.-O., Harrison, K., Abo, K., Brou, Y. C., Pierson, L. S. I., Tamborindeguy, C., Pierson, E. A., & Levy, J. G. (2019). Mycorrhization mitigates disease caused by "Candidatus Liberibacter solanacearum" in tomato. *Plants, 8*(11), 507. https://doi.org/10.3390/plants8110507

Ünlü, L., Ögür, E., & Uulu, T. E. (2021). Control of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in open field tomato crops using the mating disruption technique. *Phytoparasitica, 49*(3), 385–396. https://doi.org/10.1007/s12600-021-00881-4

Yah N'guettia, M., N'douba, A. P., Koffi, A. M. H., Soro, S., Kanté, D., & Koffi N'dodo Boni, C. (2022). Control of tomato (*Solanum lycopersicum* L.) diseases in cultivation with three plant extracts in Daloa (Côte d'Ivoire). *European Scientific Journal, 18*(17), 111. https://doi.org/10.19044/esj.2022.v18n17p111

Yao, A. S., Yéo, G., Nandjui, J., Tiénébo, E.-O., Kassi, K. F. J.-M., Kouadio, E. Y. G., Konan, K. U. U., Kakou, D. J., Kouadio, K., & Abo, K. (2023). Plant parasitic nematodes associated with vegetable crops in the main agroecological zones of Côte d'Ivoire. *Asian Journal of*

Agriculture and Biology, 2024(2), 1–11. https://doi.org/10.35495/ajab.2023.128

Yao, J. J., Kouassi, J. N., Groga, N., & Yatty, J. K. (2022). Effect of organic fertilization on the production of two tomato varieties (*Lycopersicum esculentum* Mill.) cultivated under semi-controlled conditions in Daloa, Center-West, Côte d'Ivoire. *Afriques Science*. http://www.afriquescience.net

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