Co-funded by the European Union Grant #101181582

Co-funded by the European Union Grant #101060634

Online monitoring of biogenic volatile organic compounds emitted from Fall Armyworm-infested maize plants with transportable gas chromatography

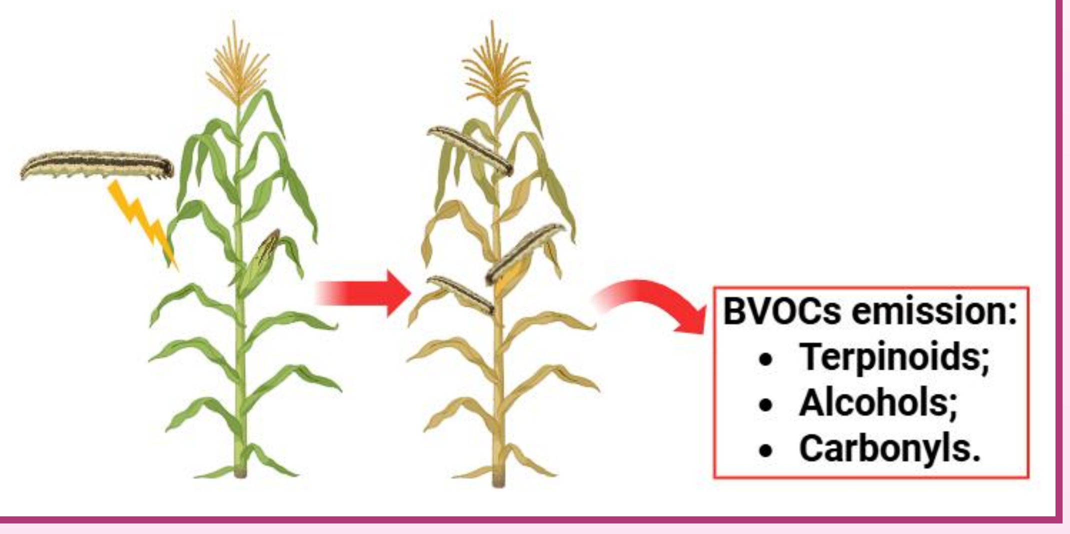
Axelle FILLINGER[1]; Amandine ANDRÉ[2]; Carla C. M. ARCE[2]; Marine MAMIN[2]; Christèle BORGEAUD[2]; Ted TURLINGS[2]; Ali GHADDAR[1,3]; Damien BAZIN[3]; Stéphane LE CALVÉ[1]

[1]Institut de Chimie et Procédés pour l'Energie, l'Environnement et la Santé (ICPEES), UMR-7515 CNRS-Université de Strasbourg, 67 000 Strasbourg, France.
[2]Laboratory for Fundamental and Applied Research in Chemical Ecology (FARCE), Institute of Biology, University of Neuchâtel, 2000 Neuchâtel, Switzerland.
[3]Chromatotec, Nouvelle-Aquitaine, 33240 Saint-André-de-Cubzac, France.

INTRODUCTION

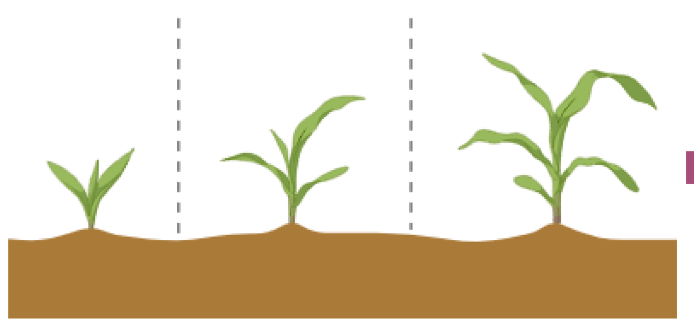
Originating from the tropical regions of America, the **fall armyworm** (FAW, *Spodoptera frugiperda*) is considered an **invasive pest** that could pose a major threat to over **80 plant crops**, particularly **maize plants** (*Zea mays*)[1]. In the **European Union** (EU), FAW infestation is expected to expand after its recent recorded occurrence in **Greece, Portugal, Romania, and Bulgaria**[2,3]. Some studies reported that infested plants emit **biogenic volatile organic compounds** (BVOCs) that can serve as **tracers of FAW presence**[4].

Reducing the risk of **further spread** involves the development of powerful **analytical tools** that can detect BVOCs at **trace levels** and thus sense pest infestation. Among various methods, **gas chromatography** (GC) stands as a selective and sensitive tool. Coupled with thermal desorption (TD) and lamp photoionization detection (L-PID), it can provide a **continuous, real-time** analysis of **BVOC signature emissions.**



METHODOLOGY

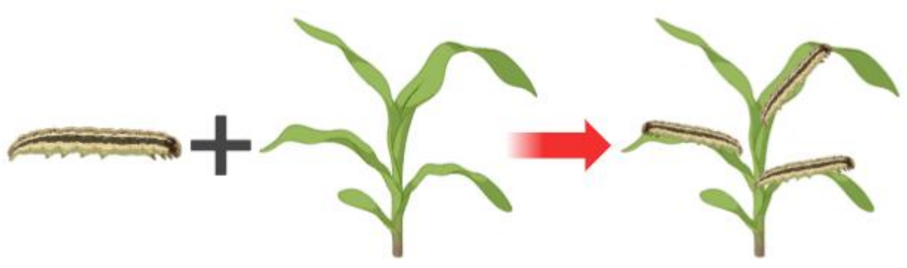
Maize (*Zea mays*) plant culture



Maize was grown in a greenhouse with control of:
- temperature;
- humidity;
- and light.

The **plant age** for the experiment was chosen to be between 14 and 21 days old.

Infestation with (*Spodoptera frugiperda*)



The **FAW larvae** were grown under strict quarantine conditions.
The larvae **development stage** was chosen to be from early third to late third. The infestation included **2 to 3 larvae** and started a few hours before the start of the **BVOCs measurement**.
The **damage** induced to the plant was quantified in terms of **leaf area**.

Collection of BVOCs

The **infested plant** was enclosed in a **glass bottle** (no ambient air contribution). The device was flushed with **1 L/min** of **pure air** for **24 h** of measurement[5].

AirToxic: continuous, online BVOCs' measurement

Working as **TD-GC-L-PID,** this analyzer **includes:**
- A **heated PTFE sampling line** (100°C);
- A **VOC-specific adsorbent** (Carbopack C/B) to trap and concentrate the VOCs;
- An **MXT-1 analytical column** (30 m × 0.28 mm × 1 µm) to separate VOCs;
- A **lamp photo ionization** detector (10.6 eV);
- A toluene **permeation tube** for calibration.

RESULTS AND DISCUSSION

I1 pest-infestation **tracer**:
retention time **818 seconds**

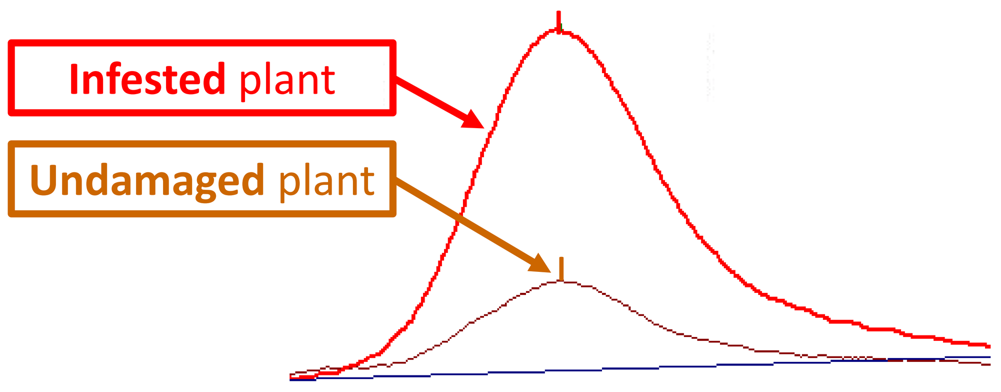


Figure 1: Chromatographic peak of the I1 pest-infestation tracer in the measurements of an infested (top) versus an undamaged (bottom) maize plant.

Recorded BVOCs signature in undamaged versus infested maize plants

- The emitted **BVOC tracers** are recorded to be released in **higher** quantities when the plant is **infested** by the FAW (**Figure 1**, in red) than when the plant is **undamaged** (**Figure 1**, in brown).
- The threshold for the choice of pest infestation tracers was based on the **ratio** value: when the ratio is calculated to be higher than or equal to 2, then the chemical compound is considered to be **specific** for infestation (**Figure 2**).
- The ratio of mean concentration between **infested** and **undamaged** plants is calculated as follows:

$$\textbf{Ratio} = \frac{\text{Tracer mean toluene} - \text{equivalent concentration in } \textbf{infested maize plant}}{\text{Tracer mean toluene} - \text{equivalent concentration in } \textbf{undamaged maize plant}}$$

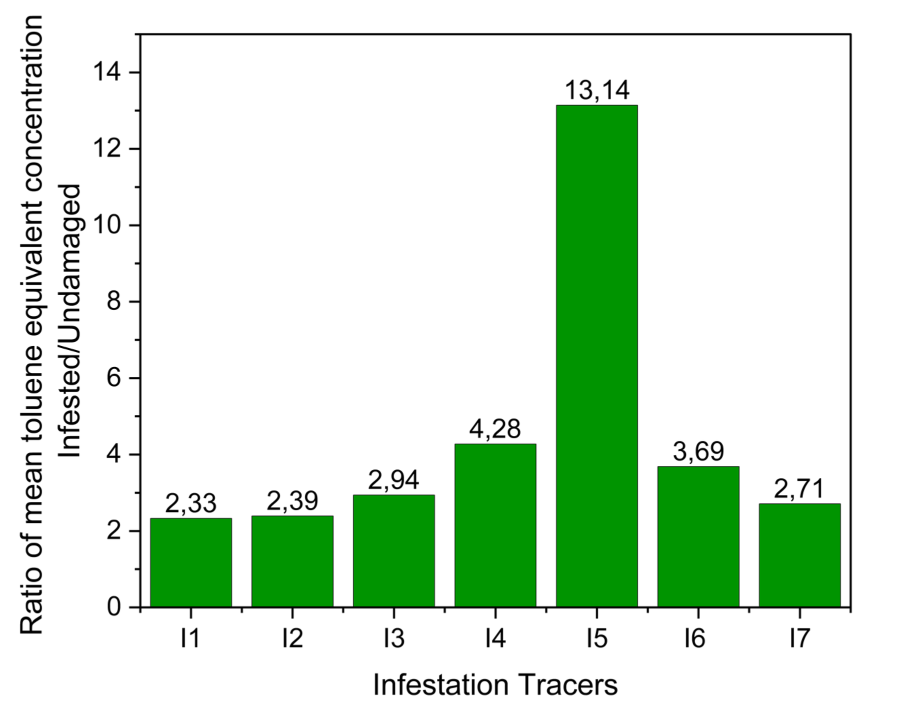


Figure 2: Bar graph of the ratio of mean toluene equivalent concentration between infested and undamaged maize plants.

Temporal evolution of BVOCs concentration

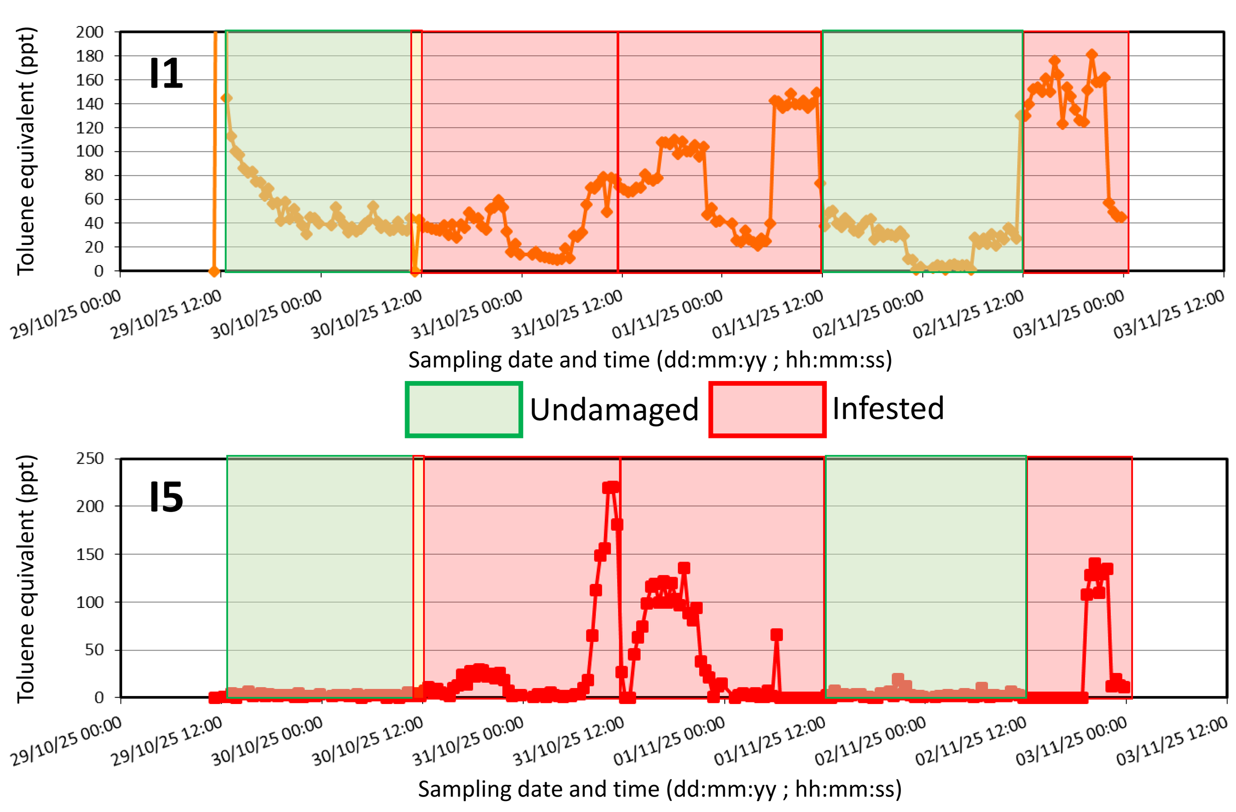


Figure 3: Temporal evolution of pest-infestation tracers I1 (top, orange) and I5 (bottom, red) concentrations over undamaged (green) and infested (red) time slots.

The **temporal trend** of BVOCs emissions was recorded by **24 h** time slot with real-time measurement of **undamaged** or **infested** plants. This evolution in time highlights the **day and night** difference in emitted tracer concentrations. The recorded BVOC concentrations were in the range **10–2200 ppt**. The tracers quantities emitted were dependent on **several parameters**, such as: the plant age; the number of pest individuals; the voracity of pests (damage).

Statistical analysis: correlation and regression studies

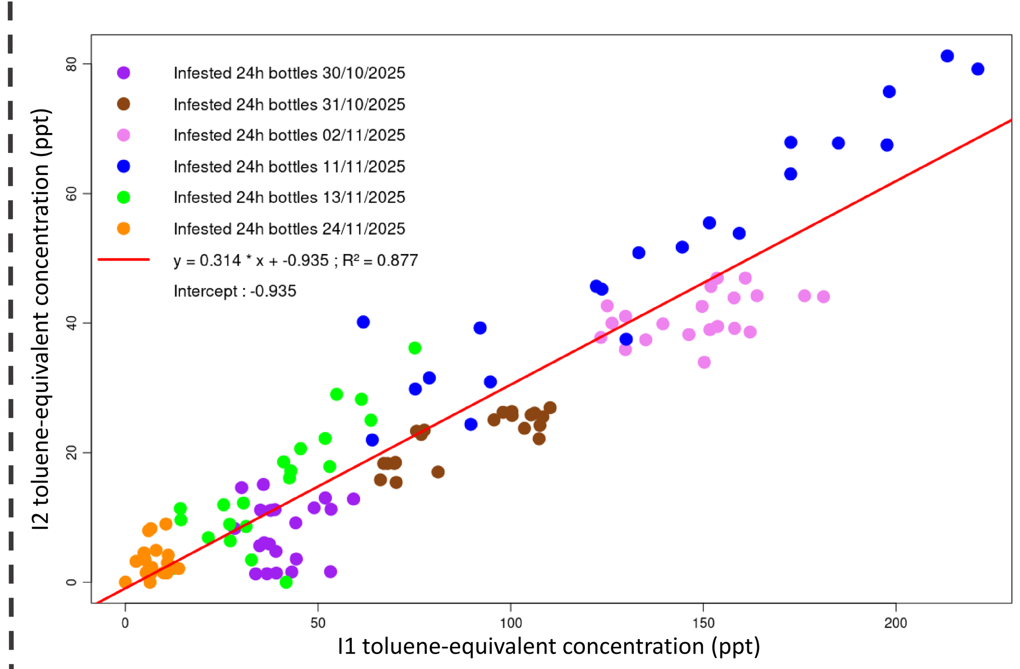


Figure 4: Linear regression for all 24h experiment replicates of infested maize plants for I1 and I2 infestation tracers.

The **regression study** showed a linear correlation between **I1** and **I2** tracers (R^2 = 0.877). The statistical analysis was performed taking into account only the infested plants' 24 h-measurements during the **daytime.** Whatever the species, no data recorded during the night were used since a strong decrease was observed when the light was off (**Figure 3**).

Spearman correlation test showed that the evolution between the **I1** and **I2** tracer concentrations was **non-random** (p-value < 0.05).

CONCLUSION AND PERSPECTIVES

The **temporal trend** of BVOC emissions highlighted the day and night evolution of **trace-level** concentrations of BVOCs in the range 10–2200 ppt. The results showed that 24h-continuous measurement **BVOC profiles differ** between **undamaged** and **FAW-infested plants** (n=12)**. Seven tracers** of the FAW infestation were assigned as **infestation-specific** based on the ratio of mean toluene-equivalent concentrations of BVOCs. **Statistical analysis** demonstrated the same behaviour of some tracers. This field campaign conducted under laboratory-controlled conditions has proven that the online TD-GC-L-PID analyser is **selective and sensitive** (able to detect BVOCs at **trace levels**) demonstrating its capability for **near real-time** analysis of **BVOC** signature emissions**.** Further miniaturization of the analyser will enable to obtain a **portable**, **non-invasive**, and **non-destructive analytical tool** (µ-TD-GC-L-PID).

ACKNOWLEDGMENTS: Funded by the European Union: Grant number **101181582** (senseApest) and Grant number **101060634** (PurPest). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

REFERENCES: [1]S. Kartakis, K. J. Horrocks, K. Cingiz, D. J. Kriticos, and J. Wesseler, "Migration extent and potential economic impact of the fall armyworm in Europe," Sci. Rep., vol. 15, no. 1, Dec. 2025, doi: 10.1038/s41598-025-02595-7. [2]Y. Geryak, V. Voronov, and M. Kaliuzhna, "First report of the invasive pest species Spodoptera frugiperda (Lepidoptera: Noctuidae) in Eastern Europe," Integr. Syst., vol. 8, no. 2, Jan. 2026, doi: 10.18476/2025.242735. [3]S. Szanyi et al., "First Report of a Migratory Pest, the Fall Armyworm, Spodoptera frugiperda (JE Smith, 1797) (Lepidoptera, Noctuidae) from Bulgaria," Insects , vol. 16, no. 2, Feb. 2025, doi: 10.3390/insects16020134. [4]C. C. M. Arce et al., "Odor-based real-time detection and identification of pests and diseases attacking crop plants," Jul. 29, 2024. doi: 10.1101/2024.07.29.605549. [5]T. C. J. Turlings and F. Wäckers, "Recruitment of predators and parasitoids by herbivore-injured plants," Insect Chemical Ecology 2, pp. 21–75, 2004.