Monitoring plant odors in tomato culture for in-situ stress detection

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Abstract

Plants release a lot of volatile organic compounds (VOCs), which are produced either constitutively or after an induction by external stress factors. These factors could be identified by specific VOC or family of compounds activated and released in response to the stress. This preliminary study suggests that in-vivo monitoring of VOC signatures for crop management seems to be possible and would need to be tested with others genotypes, and portable devices for in-situ stress detection.

Introduction

In the future, crops will likely experience more repeated cycles of stress, which could negatively impact yield (Farooq *et al.*, 2009). These stress may result from abiotic or biotic factors or from combinations of both. The difficulty to manage stress lies in the lag time between stress perception by plant and symptoms appearance. Plants emit a wide range of volatiles, whose fingerprint might indicate the presence of stress before visible symptoms appear. Consequently, monitoring VOC emissions from crops could be interesting to assess the crop health status. Biotic and abiotic stresses do not activate the same stress metabolic pathways (Atkinson and Urwin, 2012), so we can assume it is the same with volatile output. To explore the potential use of in-vivo monitoring of VOC signatures in crop management, we have started a series of experiments, in which we exposed two tomato cultivars (*Solanum lycopersicum* Mill.) to a range of environmental stresses. In addition we compared the VOC contents of leaf extracts.

Materials & Methods

Plant Material:
- Momor (sensitive to abiotic stress)
- Monalbo (sensitive to biotic stress)

Plant Treatments:
See table 1

VOC stored in leaves:
VOC Extraction was realized with a solution of 10ml of dichloromethane (plus biphenyl as internal standard) in a ultrasonic bath during 10 min. Samples were concentrated with pure nitrogen gas to achieve a volume of 300 µl.

VOC emission capture: **Cartridges filled with Tenax TA**
- Enclosure device for abiotic stress encompassing one leaflet (fig. 1A)
- Enclosure device for biotic stress encompassing one leaf (fig. 1B)

VOC were analysed with a TD-GCMS Shimadzu QP2010
Splitless, injection in high pressure : 250 KPa for 1ml/min
Column DB-5 (60m 0.25µm 0.25mm)
Partie GC : 40°C 1 min, 4°C/min between 40 - 170°C, 10°C/min for 170 - 250°C and 250°C 6 min
Partie MS: Solvant cut time : 5 min, End time: 47 min, Threshold : 100, carrier gas: helium, 70 eV

Statistical analyses:
T-test of Student was used to compare each treatment to the control

Family of stress	Stress	Temperature of measurements	Luminosity in PAR	Stress time exposition
Abiotic	Heat	42°C	400	3h
	Drought (15 days)	30°C	400	15 days
	Heat oxidative stress	42°C	2200	3h
	After heat oxidative stress	30°C	400	1h
Biotic	Botrytis cinerea on leaves	30°C	400	3 days
	Botrytis on stem	30°C	400	15 days
	Oïdium	30°C	400	15 days

Table 1: Stress conditions applied to the two genotypes

Figure 1: Different enclosure devices used for abiotic stress (1A), (1B) and biotic stress experiments (1C).

Results

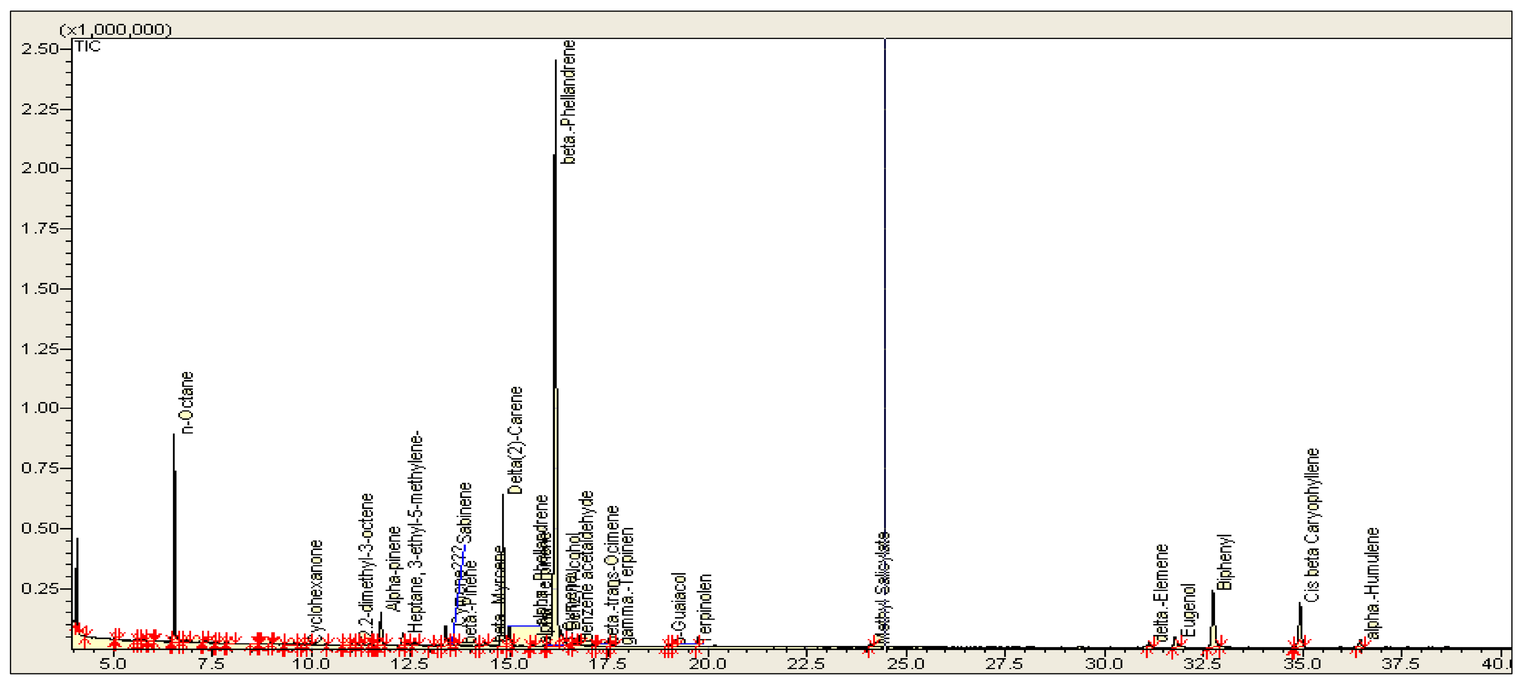

Figure 2: Spectrum of VOCs stored in leaf of a control plant (tomato, cv. Monalbo)

Stored VOCs:
- Major compounds stored in leaves of tomato (figure 2) are monoterpenes with β-phellandrene, δ-(2)-carene, α-pinene, cymene and α-phellandrene.
- Also sesquiterpenes (caryophyllene and α-humulene) and phenols (eugenol) were found.
- Plants exposed to deficit irrigation had a significantly increased contents of several VOCs, among which methyl-salicylate, a derivative of the stress hormone salicylate (figure 3).

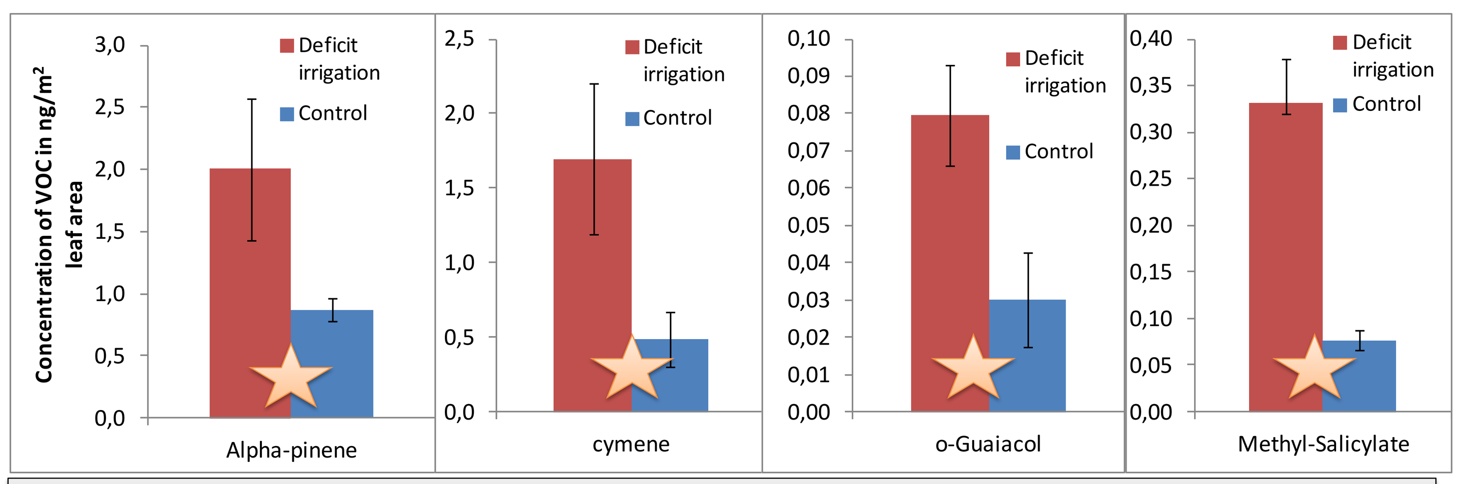

Figure 3: Concentrations of VOCs stored in leaf of tomato (cv. Monalbo) in control plants and plants kept under deficit irrigation (stars denote statistical differences between treatments).

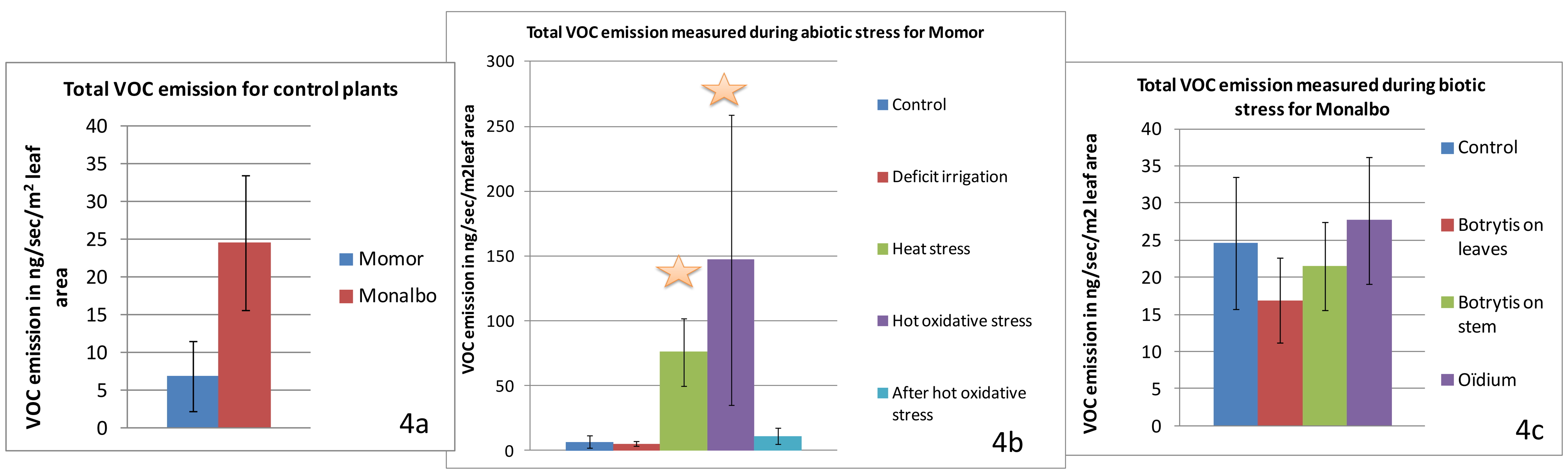

Figure 4:
4a: Comparison of the total foliar VOC emission rate (only monoterpenes, products of LOX pathway and apocarotenoids were considered) between control plants of Momor and Monalbo tomato cultivars.
4b et c: Total VOC emission rates from tomato leaves during various abiotic stress and biotic stresses (stars denote statistical differences between treatments).

Emitted VOC :
- The two genotypes presented different total emission rates; Momor emitted less VOC than Monalbo (6.88 and 24.61 ng m^{-2} leaf area sec^{-1}, respectively, for the total VOCs emitted by control plants)
- Some VOC were predominantly or exclusively emitted in specific cases. For example, the lipid peroxidation products (*E*)-2-heptenal and 3-methyl-2-hexanone were exclusively emitted during and after exposures to high radiation combined with high temperatures.
- On the other hand, the emission of (*E*)-geranyl-acetone, a product of carotenoid breakdown, was diminished under abiotic and biotic stress conditions.

Conclusion & Perspectives

We detected quantitative and qualitative differences between the VOC emissions of two tomato genotypes that differ in their sensitivity to environmental stresses (Momor had lower emissions than Monalbo). Some compounds such as (*E*)-2-heptenal might be used as a potential marker of specific stress while others such as α-terpinene might indicate the global plant health status.
In the case of plants adapted to moderate drought, the detection of stress would require quantitative VOC emission measurements.
Monitoring VOC emissions in tomato culture might be suitable for the *in-situ* detection of plant health status, but more repetitions with others genotypes are necessary to draw final conclusions.

References:
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Farooq M, Wahid A, Kobayashi N, Fujita D, Basra SMA. 2009. Plant drought stress: effects, mechanisms and management. *Agronomy for Sustainable Development 29, 185-212.*