LIÈGE université
Gembloux
Agro-Bio Tech

Le Corps professoral de

Gembloux Agro-Bio Tech - Université de Liège vous prie

de lui faire l'honneur d'assister à la défense publique de la dissertation originale que

Mr Md Ahsan MOZAFFAR,

Titulaire d'un *master of science, major : physical geography and ecosystem analysis*,

présentera en vue de l'obtention du grade et du diplôme de

DOCTEUR EN SCIENCES AGRONOMIQUES ET INGENIERIE BIOLOGIQUE,

le 29 septembre 2017, à 14 heures précises (personne ne sera admis après cette heure),

en l'auditorium TOPO 1 (Topographie, bât. 3),

Passage des Déportés, 2 à 5030 GEMBLOUX.

Cette dissertation originale a pour titre :

« Exchanges of biogenic volatile organic compounds between the atmosphere and agricultural plants/ecosystems in controlled and field conditions »

Le jury est composé comme suit :

Président: Prof. P. LEJEUNE, Président du Département BIOSE,
Membres : Prof. B. HEINESCH (Promoteur), Dr C. AMELYNCK (Copromoteur – Belgian Institute for Space Aeronomy), Prof. M. AUBINET, Dr P. DELAPLACE, Dr T. HOLST (Lund University, Suède).

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Summary

Terrestrial vegetation is a huge source of volatile organic compounds (VOCs) in the Earth's atmosphere. Those biogenic VOCs (BVOCs) are very diverse in composition and many of them react rapidly with the major atmospheric oxidants, thus affecting the oxidation capacity of the atmosphere, air quality and climate. In order to quantify the impact of BVOC fluxes on the atmospheric composition, flux measurements from different plant species were already started a few decades ago. Most of those studies, however, focussed on fluxes from tree species and, despite the fact that 38% of the global land surface area is used for agricultural purposes, the number of BVOC exchange studies on agricultural species is still very limited. Furthermore, agricultural plants/ecosystems are expected to exchange mainly oxygenated VOCs (OVOCs) with the atmosphere and large uncertainties remain about the mechanisms which control the exchanges of those compounds.

This thesis aims at increasing the knowledge on BVOC exchanges between agricultural plants/ecosystems and the atmosphere by focussing on maize, a highly cultivated crop species (cultivated on 13% of the global cropland surface area), and on grassland, one of the most widely distributed ecosystems in the world (covers one fourth of the Earth's land surface).

For maize, the main objectives of these investigations were to characterize the type and quantity of BVOCs exchanged and how they vary among the different leaf developmental stages. BVOC fluxes from young up to senescent leaves were investigated in a temperature and light-controlled environmental chamber using dynamic flow-through enclosures and proton transfer reaction mass spectrometry (PTR-MS). BVOC flux intensities as well as their responses to variations in incoming radiation varied strongly among the different leaf developmental stages. Methanol was found to be the highest exchanged compound at all leaf developmental stages. Young leaves exchanged significantly more methanol than leaves at other developmental stages. They showed a complex emission pattern which might be related to the diurnal evolution in leaf growth rate or the diurnal variability in enzyme activity. Particularly, young maize leaves showed strong emission peaks following light/dark transitions, which were impossible to reproduce with state-of-the-art modelling and for which guttation was put forward as a hypothetical emission pathway. Mature leaves showed a less complex response to varying light conditions and emissions could be fairly well reproduced with a dynamic BVOC emission model, by assuming a methanol production function depending both on light and temperature. Finally, both yellow leaves during chlorosis and dry brown leaves after chlorosis were identified as important methanol sources, with emissions that were no longer correlated with light. Fluxes of other compounds than methanol were followed as well, important ones being acetone/propanal, acetic acid, methyl ethyl ketone/butanal, hexenals and hexenols/hexenyl acetates. Senescent leaves showed a larger diversity of emitted compounds than leaves at the other developmental stages, with strong differences among VOCs in temporal emission profiles. As the first maize leaf from the base of the plant starts senescing long before flowering and this process continues for all the leaves from the base to the top of the plant throughout the growing season, senescence can be an important leaf developmental stage in terms of BVOC emissions from a maize field. Whereas data for BVOC fluxes from senescent maize leaves are not yet available in the literature, fluxes from young up to mature maize leaves were found to be considerably lower than those observed in previous maize studies, except for an ecosystem scale study performed on the same variety.

For grassland ecosystems, the principal objectives of this work were to identify the constitutively exchanged BVOCs and their flux intensity and drivers, and to find out how grazing-induced VOC fluxes differ from the constitutive ones. To meet these objectives, BVOC fluxes were followed simultaneously from side-by-side situated undisturbed and grazed patches in a managed grassland at the Dorinne Terrestrial Observatory (DTO) in the Province of Namur, Belgium, using automated dynamic flow-through enclosures and PTR-MS. For the undisturbed grassland, methanol was the main exchanged compound (emission) among the measured compounds, followed by acetic acid (deposition) and acetaldehyde (deposition). A good positive correlation between fluxes of all the emitted compounds and light intensity, temperature, transpiration and net photosynthesis rates was observed, while deposited compounds showed a relatively good negative correlation with ambient concentration. Strong qualitative and quantitative differences between the BVOC fluxes from the grazed and undisturbed grassland patches were observed, with daytime emissions for all the measured compounds induced by grazing. These induced emissions generally lasted for 2-5 days after the grazing event. Nevertheless, grazing-induced fluxes observed in the current study are typically one to two orders of magnitude lower than those for harvested grassland, where grass is left drying on the field for hay production.

This is the very first investigation on BVOC fluxes from maize at all leaf developmental stages, providing insight on intensity and pattern of BVOC fluxes from this important crop species. Moreover, this is also the first study ever on BVOC fluxes from grassland induced by grazing, which is a common biotic stress on these ecosystems (60% of the world's agricultural land is grazing land). These findings can be useful to modellers to estimate the total annual BVOC fluxes from these widely distributed ecosystems more correctly. Incorporation of the information in regional and global chemistry and climate models may help to assess the effect of BVOC fluxes on present and future air quality and climate.