**Essential oils in plant protection: recent developments, opportunities and challenges**

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Essential oils (EOs) are a complex mixture of volatile hydrophobic compounds (monoterpenes, sesquiterpenes, phenylpropanoids, …) obtained by hydrodistillation or steam distillation of plants. Mainly produced in southern countries, EOs are largely used in the North where knowledge of their appropriate uses is frequently lacking. EOs are used in an increasingly number of sectors like health, cosmetics, food industry and more recently agronomy. In agronomy, EOs are employed as bio-pesticides for their insecticidal, antifungal or bactericidal effects but also as bio-herbicides. Several bio-pesticides based on EOs are already registered.

EOs present numerous advantages for a use as bio-pesticide. Firstly, they are 100 % bio-based. Moreover, as EOs contain a great number of structurally diverse compounds acting frequently in synergy, they are poorly subject to resistance. Finally, as highly volatile compounds are found in EOs, they typically cause no residue problems in food products.

Nevertheless, EOs are not a panacea that cures all existing plant diseases and fight all pests without any side effect. Indeed, EOs supply can be really challenging because they are frequently produced in restricted area of the world. Moreover, EOs can be available only seasonally, in varying amounts depending on climatic conditions and geopolitical events. Prices can also greatly vary from year to year for the same reasons. At a chemical composition point of view, they can greatly vary from months to months or place to place rending the formulation of a bio-pesticide even more difficult. Besides, while EOs high volatility is interesting for some specific applications, it can be a problem when developing a bio-pesticide with long lasting effect. Finally, EOs are frequently phytotoxic, which is perfect for an herbicide formulation, but not for other applications.

To overcome several of those problems, our laboratories are working on the development of new bio-based encapsulation methods that allow a controlled and slow release of the EOs. New administration modes are also investigated, like direct injection of EOs in the trees’ xylem sap.

Above all, the development of new bio-pesticides based on EOs requires an in-depth study of their action modes, which are largely lacking and often very descriptive. To fill this gap, we are applying an integrative approach combining *in silico* (molecular modelling approaches) and *in vitro* (Langmuir monolayers, isothermal calorimetry, fluorescence and infrared spectroscopies) biophysical tools, previously developed to study structure-activity relationships of molecules of biological interest (pharmacological drugs, proteins, peptides, surfactants). Combined to biological data, our study should shed light on how EOs exert their herbicide effects at a molecular point of view.