Simulating dynamics of allelochemical production from living plants

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Abstract

Allelochemicals or allelopathins are considered to act as defence agents in the plant chemical defence system. The contents and production of allelochemicals in living plants affect plant defence capability or allelopathic potential. A preliminary analysis of a mechanistic model to simulate allelochemical dynamics in living plants and their fate in the environment is presented. A good agreement has been achieved between published experimental data and the model prediction.

Key Words

Allelopathin, mathematical modelling, plant defence.

Introduction

Contemporary researchers have broadened the context of allelopathy and consider it acting as a plant defence (4). Defence agents, allelochemicals or allelopathins, are largely secondary plant metabolites that play an important role in allelopathic interactions and plant defence. Research efforts have been made in identification of allelochemicals from living plants, detecting their dynamics in plants and the environment, characterising their modes of actions, and determining the effect of abiotic and biotic factors. It is now timely to develop a mathematical model to integrate scattered research information, to assemble a generalized picture of allelochemical production in living plants and their fate in the environment. . A preliminary result of such a model is presented in this paper.

Description of the model

The model for dynamics of allelochemical production from living plants is shown schematically in Figure1 and Eq. (i)

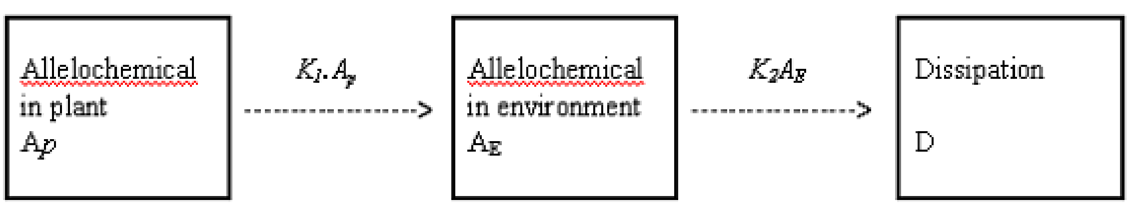

Figure 1 Schematic representation of the model.

$$A_E = \left(\frac{k_1 A_p^0}{k_2 - k_1}\right)\left(e^{-k_1 t} - e^{-k_2 t}\right) \quad \text{(i)}$$

where A_E amount of allelochemicals in the environment at time *t*

A_P amount of allelochemicals in the living plant at time 0

t time, day

*k*1 rate constant of allelochemical release, day -1

*k*2 rate constant of allelochemical degradation, day -1

Results and discussion

Once allelochemicals are produced in plants, they are released into the environment through volatilisation, root exudation, abscission and leaching by rain. Generally, allelochemical content in living plants declines with age, and there is a corresponding fate in the environment, which is illustrated in Figure 2.

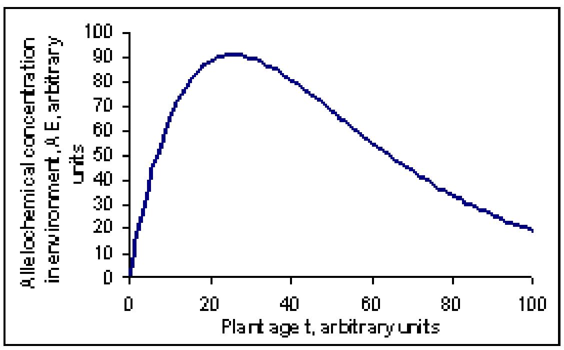

Figure 2. Dynamics of allelochemicals from living plant in environment. A_E is allelo-chemical released, *t* is plant age, both in arbitrary units.

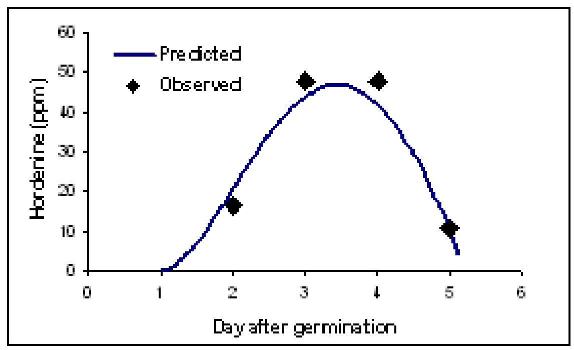

Figure 3.Comparison of the model prediction with observed data. A_E is hordenine released by germinating barley (Data from Lovett and Liu, 1987).

The model shows that the production of allelochemicals from living plants has two features: its persistence in the environment is definable, and its distribution is not balanced over time. Initially, allelochemical concentrations in the environment are low, but increase sharply. At time t^*, they reach a peak value, and then gradually decline due to the activity of microorganisms and other chemical activity. This is consistent with reports in the literature (1, 2).

An example from the literature is shown in Figure 3 together with the model prediction. In this example (3) the alkaloids gramine and hordenine, well known allelochemicals, were released by germinating seedlings of barley at least until day 6, with peak production occurring on days 4 and 5.

Understanding the cause-effect relationships in allelopathy requires knowledge of how chemicals are produced in living plants and their time-course and fate in the environment. The model simplifies the complexities and well simulates allelochemical production in living plants and their corresponding dynamics in environment. This shall help to further increase our understanding of allelopathy and to suggest directions for future research in quantifying the impact of allelochemicals produced in living plants on agricultural ecosystems.

References

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