Exploiting the allelopathic properties of agricultural crops in low-input cropping systems

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***Abstract* - Benzoxazinoids, a group of secondary metabolites with allelopathic properties, are present in wheat, rye and maize. The FATEALLCHEM project (www.fateallchem.dk) (Fate and Toxicity of Allelochemicals in Relation to Environment and Consumer) showed that when cereals are used as catch crops and green manure, the allelopathic properties of the cereals could now be more extensively exploited by choosing varieties with optimal production of benzoxazinoids and other bioactive secondary metabolites and by optimising the time of sowing in relation to the formation of bioactive soil metabolites. It was also shown that future assessments of an extensive use of allelopathic crops must include the development of validated analytical methods, considerations of relevant concentrations, studies on soil transformation, toxicological studies on individual compounds and mixtures and joint effect studies on weeds, insects and pathogens.[1]**

INTRODUCTION

Allelopathy has received new attention in modern research. Targeted use of the allelopathic properties of plants could lead to a reduction of the use of synthetic pesticides. However, modern analytical techniques and a holistic approach are needed for a thorough evaluation of exploitation strategies. The aims of the FATEALCHEM project were to evaluate the possibilities of exploiting the allelopathic properties of wheat in modern farming through an assessment of target and non-target effects and to develop a framework for future assessments of allelopathic crops (Fomsgaard *et al.*, 2006a).

METHODS

The project comprised the following main tasks: 1) Isolation and synthesis of chemical compounds, 2) Development of sensitive, intercalibrated analytical methods in LC-MS and determination of levels of benzoxazinoids in wheat varieties grown in different conditions, 3) Fate studies, 4) Studies of non-target effects and 5) Target suppressive effects on weeds, fungi and pests

RESULTS AND DISCUSSION

Isolation and synthesis of compounds

Benzoxazinoids from wheat, either synthesised or isolated, and synthesized soil metabolites are listed with acronyms in Table 1. For chemical formulas and systematic names, please see Macias *et al.*, (2006a).

Table 1. Chemical compounds produced and used for studies in the project.

Benzoxazinoid standards isolated from wheat or synthesised
DIMBOA-glc, DIBOA-glc, DIMBOA, DIBOA, HBOA, HMBOA, MBOA, BOA
Synthesised soil metabolites
MBOA, BOA, AP, APO, AMPO; AAPO, AAMPO, HPMA, HMPMA, HPAA, HHPAA

For chemical formulas and systematic names, please see Macías *et al*., (2006a).

Analysis of benzoxazinoids in plants

Fast and reliable highly sensitive methods for benzoxazinone derivatives in the FATEALLCHEM project were developed. The application of the methods on wheat varieties grown under different conditions revealed a genetic difference between varieties in the inherent content of natural defence compounds as well as environmental effects on the production by the plants (Mogensen *et al.*, 2006; Stochmal *et al.*, 2006; Villagrasa *et al.*, 2006).

Transformation in soil

Benzoxazinoids from wheat were shown to degrade very rapidly in soil with DT50 values of 1–2 days. The formation of degradation products depended on the initial concentration of the benzoxazinoids in soil or test media, and a complex pattern of transformation products was formed (Macías *et al*., 2004; Gents *et al.*, 2005; Understrup *et al.*, 2005; Etzerodt *et al.*, 2006; Krogh *et al.*, 2006; Fomsgaard *et al.*, 2006) (Figure 1 and Figure 2). Future studies on the effects of allelochemicals should definitely consider the relevant concentration levels, if natural systems are to be simulated, and should include metabolic profiling of the soil environment when effects on weeds or soil borne diseases are investigated.

Non-target effects

An extensive exploitation of allelopathic properties of plants must include an evaluation of non-target effects. The ecotoxicological studies showed that the soil transformation products suppressing weeds and pathogenic fungi also were the most toxic to beneficial organisms [carabid beetle larvae (*Poecilus cupreus*), collembola (*Folsomia candida*) and selected aquatic organisms]. Comparisons were made with structure-related synthetic pesticides. The adverse effects of the most active metabolites did not exceed the negative effects of these substances (Coja *et al*., 2006a; Coja *et al*., 2006b; Fritz and Braun, 2006; Idinger *et al.*, 2006; Lo Piparo *et al*., 2006a; Lo Piparo *et al*., 2006b).

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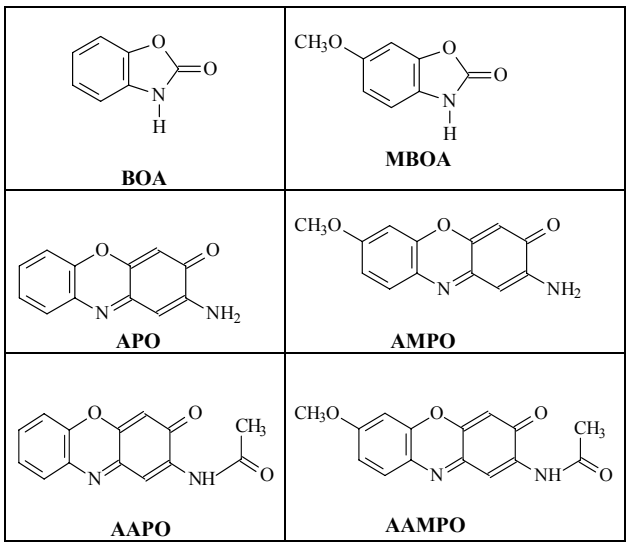

Figure 1. Molecular structure of rye and wheat benzoxazinoids, BOA and MBOA and of transformation products, APO, AAPO, AMPO and AAMPO. For systematic names, please see Macías et al., 2006a.

Target effects

A comparison of suppressive effects of benzoxazinoids and soil metabolites revealed that root length was most affected, followed by shoot length and finally germination. The most active compound was the soil metabolite APO, followed by synthetic derivates of the benzoxazinoids (under consideration as new lead molecules) and finally the plant compounds DIMBOA and DIBOA (Macías *et al*., 2006b). A general conclusion on target effects is that the transformation product 2-aminophenoxazin-3-one (APO) had significantly higher suppressive target effects on both weeds and fungi than the parent compound (Macías *et al*., 2006b; Chunhung *et al*., 2006; Martyniuk *et al*., 2006). Joint effect studies of combinations of benzoxazinoids or benzoxazinoids with phenolic acids revealed that no synergistic effects were seen, contrary to the hypothesis presented by other researchers (Chunhung *et al*., 2006).

Future prospects

The project results clearly showed the relevance of optimising the exploitation of cereal benzoxazinoids and other biologically active secondary metabolites. By growing cereals as a catch crop or for green manure, the allelopathic properties of the cereals could now be much more extensively exploited by choosing varieties with maximum production of the bioactive compounds and optimising the time of sowing in relation to the formation of bioactive metabolites in soil. A framework for future assessments of allelopathic crops must include the development of validated analytical methods, considerations of relevant concentrations, soil transformation studies, toxicological studies on individual compounds and mixtures, efficacy studies on weeds, insects, pathogens and other pests and studies on mode of action. Combining the results of such studies with knowledge on the biosynthetic pathways of allelochemicals and studies on gene expression could result in substantial gains for sustainable agriculture.

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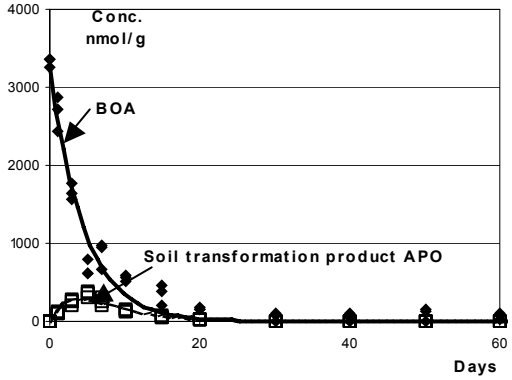

Figure 2.Transformation of the 2-benzoxazolinone (BOA) (dominating compound in rye) to 2-aminophenoxazin-3-one (APO). The figure shows concentration as a function of days.

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