Belowground effects of transgenic maize

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The global commercial area of genetically modified (GM) plants reached 67.7M ha in 2003 and that of GM maize expressing the *Bacillus thuringiensis* toxin (Bt) was 9.1M ha. The potential for effects of Bt crops on non-target soil organisms is considerable, as the toxin is expressed constitutively in all parts of the plant so both plant residues remaining after harvest and root exudates released during plant growth could contain Bt toxin and be incorporated into the soil. Despite the large area of Bt maize, and other crops, and the potential for effects on non-target soil organisms, the number of studies is still relatively small. It was to address this lack of study on the effects of GM Bt-expressing crops on soil populations and processes that the EU-funded ECOGEN project (www.ecogen.dk) was initiated. This interdisciplinary study has followed the advice of previous expert panels in adopting a tiered approach (i.e. laboratory, glasshouse and field experiments) with an emphasis on soil communities and ecosystem functioning. SCRI is one of the partners within the project, with responsibility for mesocosm (glasshouse) experiments which fit into the overall workplan (Fig. 1). Within the ECOGEN project there are four field sites in different European climatic zones (Fig. 2) where Bt maize and a non-Bt isogenic control are grown. While it is clearly essential to compare the Bt crop with its genetically closest available variety to determine whether there are any effects attributable to the Bt variety, it is also essential to be able to put the magnitude of these changes into context. To be able to compare any differences that might be measured between these varieties we also took samples from another, conventional, maize variety. Although a comparison of only three maize varieties is insufficient to cover the range of potential varietal effects it would at least allow some assessment of the Bt variety against non-GM varieties. Finally we also took samples from the surrounding plots of grass, which would allow comparison of the differences due to maize variety, including Bt, with the magnitude of the changes due to growing another common crop. The question then arises whether observed changes due to the Bt trait are ecologically important. In the context of the current land use, and the time-scale of the study, then we would argue that they are not. Yield of the Bt and non-Bt maize was equivalent and, as they had both received the same management regime, the effects of the Bt maize on the soil microbial and microfaunal populations had clearly not affected crop growth. Longer term changes such as the accumulation or depletion of soil carbon, the establishment of a diverse flora should the land be taken out of agricultural production, or the growth of a different crop are beyond the scope of this study. We have demonstrated that our methodology was precise enough to detect differences between treatments and that the differences caused by growing GM maize expressing Bt toxin were not as large as those resulting

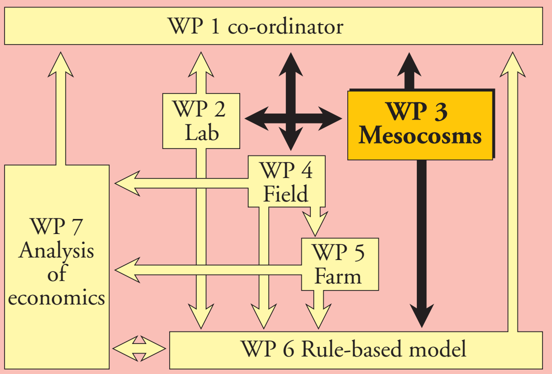

Figure 1 Flow chart to show how the individual components of the ECOGEN project combine. Arrows show the main routes of information and data transfer between workpackages (WP). SCRI has responsibility for WP3.

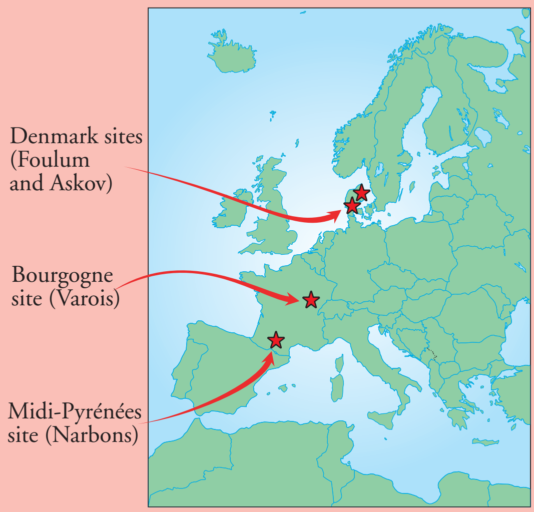

Figure 2 Location of field sites of the ECOGEN project. Two in France and two in Denmark.

Figure 3 Growth of maize in the experimental glasshouse at SCRI. The pots are randomised and include both Bt and non-Bt varieties.

from growing contrasting but conventional maize cultivars, from growing a different crop plant (in this case grass), or as large as natural differences between sites or sampling occasions. We would argue that the Bt effects, therefore, fall within the normal variation expected in these agricultural systems. The mesocosm experiments that we have undertaken include a factorial experiment to determine effects of: soil type (using soil from two of the field plots); Bt or non-Bt maize; and the effects of insecticide (used to control European corn borer in conventional maize crops) on a suite of soil parameters that are also monitored at the field sites. These include: plant growth and Bt content; microbial community structure by both phospholipid fatty acid and community level physiological profiles; microbial biomass; densities and population structure of protozoa, nematodes and microarthropods. Crop growth in the experimental glasshouse was good (Fig. 3), with plants reaching maturity and setting seed as they do in the field. There were no differences in plant performance between the Bt and non-Bt varieties. Results of the soil parameters are still being analysed but indicate large differences due to soil type, consistent with the field data, and some effects due to both insecticide and Bt treatments. Future experiments will be examining a wider range of Bt and non-Bt varieties to determine the likely extent of variation. The single-species tests are designed to quantify the concentrations of Bt toxin that are lethal to a range of representative non-target soil organisms, including protozoa, nematodes, collembola, enchytraeid worms, earthworms and molluscs. Preliminary results suggest a level of toxicity lower than for many commonly applied agrochemicals. The later stages of this 4 year (2002-2006) project will develop decision support tools and economic analyses related to belowground interactions of GM cropping systems.