Root border cells in plant-soil interactions

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Background. Root border cells are cells that detach from the root cap and remain in the (rhizosphere) soil adjacent to the elongating root. Border cells often live for a period of days after detaching and they may play a number of physical, chemical and biological roles in the interactions between the root and its rhizosphere environment. Recently it has been proposed that border cells may behave as decoys for pathogenic organisms in the rhizosphere, decreasing the likelihood of pathogen attack on the root tip. Previous work at SCRI has suggested that border cells may decrease friction between soil particles and the root cap surface, decreasing mechanical impedance to root growth. Experiments were therefore performed to investigate both biological and physical interactions in the rhizosphere. The work involved extensive collaboration with the Universities of Abertay, Nagoya, Aberdeen, and Bristol.

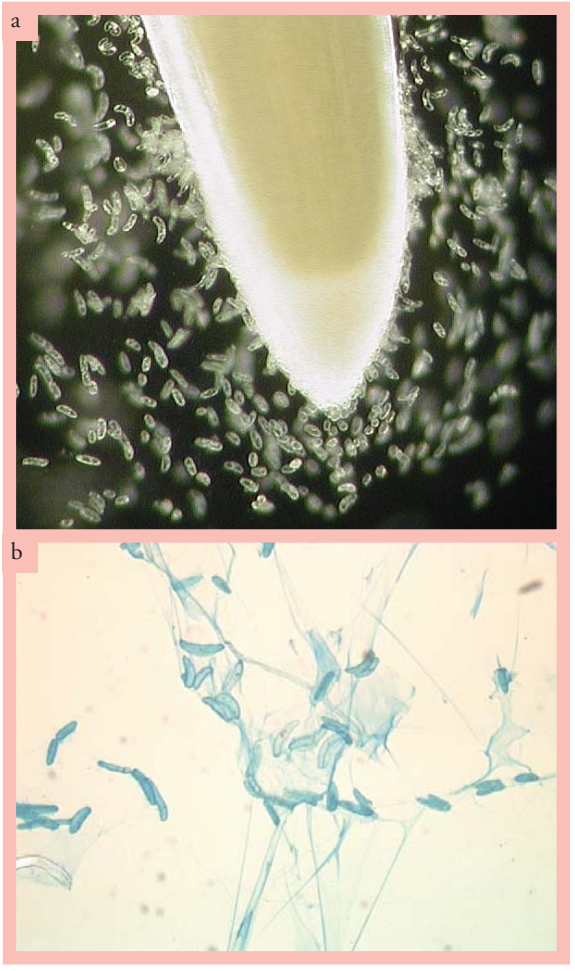

Figure 1 Root border cells (a) in water around root tip, (b) form a network with strands of mucilage from root tip.

Biological interactions. Sets of experiments were performed to study the interactions between maize root border cells and a biocontrol bacteria (*Pseudomonas fluorescens*), a pathogenic fungus (*Pythium aphanidermatum*), a parasitic nematode (*Meloidogyne chitwoodi*) and a bacterial-feeding nematode (*Caenorhabditis elegans*). Experiments were performed on agar, sand, and soil, and involved interdisciplinary collaboration in root biology, soil physics, soil microbiology, nematology and plant pathology.

We performed the first measurements of the uptake and release of carbon compounds from isolated cohorts of border cells using radioactive labelling of glucose. This showed that border cells actively take up and release small quantities of glucose-C [1]. We then assessed the availability of carbon compounds to biocontrol bacteria *P. fluorescens* and *Bacillus subtilis* using reporter gene technology, by measuring the fluorescence of lux-marked bacteria. This confirmed that carbon compounds released from border cells represented only a small source of carbon compounds for the biocontrol bacteria. Of potentially much greater importance is the possibility of these cells releasing specific signalling compounds that influence soil organism behaviour.

For border cells to act as decoys in the rhizosphere they need to affect the direction and speed of movement of their target organisms. Assays of nematode attraction to border cells [2] showed that nematodes were attracted significantly but relatively weakly to border cells. The speed of nematode movement was increased significantly in the presence of border cells and their associated mucilage as compared with control treatments.

Physical interactions - border cells form a disposable sleeve around the root cap. We manipulated border cell and mucilage production by removing the root cap (de-capping) of maize. Several series of experiments were performed to study the effect of de-capping on root penetration into soil, and colonisation by

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Figure 2 The use of microscopes to study roots and soil being illustrated at one of the Plant-Soil Interface Programme exhibits at the Institute Open Day.

beneficial bacteria (*Pseudomonas fluorescens*). De-capping decreased border cell numbers by an order of magnitude for a period of 2-3 days, until the root cap regenerated, but did not affect root elongation rates of roots grown on filter paper or agar.

Root growth in loose soil was unaffected by de-capping. In compacted soil, however, root elongation was slowed by about 47% [3], and was associated with an increase of about 67% in the root penetration resistance (pressure exerted by the root to penetrate the soil). The root diameter increased significantly for de-capped roots in compacted soil – also suggesting that roots were experiencing greater mechanical impedance. The most likely explanation is that border cells were acting as a low-friction sleeve around the root cap, decreasing the root penetration resistance.

We next investigated how this sleeve of border cells might influence colonisation of the root tip by relatively immobile soil-bacteria. We studied the distribution along maize primary roots of *Pseudomonas fluorescens,* labelled with Green Fluorescent Protein so the marked bacteria could be tracked and visualised easily. The numbers of colony forming units that were measured in regions along the maize root were affected by de-capping. Presence of the sleeve of border cells in the intact roots largely prevented colonisation of the root tip by bacteria [4]. This was confirmed by direct visualisation of the root tip using confocal microscopy. This suggests that bacteria, being relatively immobile, find it difficult to colonise the root tip, because bacteria located on border cells and their associated mucilage will remain in the rhizosphere as the root tip extends forward into new regions of soil. The presence of this sleeve of cells may therefore prevent the spread of beneficial biocontrol bacteria throughout a root system, in addition to protecting the root tip from pathogens. Colonisation by bacteria was qualitatively similar in compact and loose soil.

Genotypic variation in border cell complement. The potential to select plant genotypes with altered border cell production rates is potentially of interest for both breeding and experimental purposes. We measured the number of border cells present on the root tips of 15 maize cultivars. There was approximately an eight-fold variation (700 to 5600 cells) in this border cell complement per root tip between cultivars, suggesting that very significant variation exists. Such intra-species variation has not previously been observed and is of interest for further study into the mechanisms underlying it.

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