Geophysical Research Abstracts, Vol. 7, 09538, 2005
SRef-ID: 1607-7962/gra/EGU05-A-09538

Quantifying root exudate impacts on soil structure genesis using fracture mechanics

P.D. Hallett (1) and B. Zhang (2)

(1) Plant-Soil Interface Programme, Scottish Crop Research Institute, Invergowrie, Dundee, DD2 5DA, Scotland, (2) Institute of Soil Science, Chinese Academy of Sciences, P.O. Box 821, Nanjing 210008, People's Republic of China (p.hallett@scri.sari.ac.uk / FAX: +44 1382 562426)

Exudates produced by roots may act as biological glues in soil, leading to the highly aggregated physical structure that is often observed in the rhizosphere. Soil near roots has been shown to have a higher mechanical strength and physical stability than bulk soil. The aim of this study was to determine how root exudates impact on the fracture mechanics of soil, thereby quantifying particle surface energy, elasticity and resistance to crack growth. These parameters quantify the thermodynamic processes involved in fracture. Pure clay specimens were formed from kaolinite and mixed with 0, 1.2, 2.4, 4.9 or 12.2 mg kg^{-1} polygalacturonic acid (PGA) at a water content 90% of the liquid limit. Previous researchers have identified PGA as a major component of root exudates and it has been used as an analogue in several studies. The influence of weathering was simulated on half of the samples by washing them several times to remove PGA that was not bound to soil particles. Deep-notch bend specimens were formed, with fracture tests conducted using a mechanical test frame. Samples were tested wet and after drying at 40^{o}C.

In dry samples there was an exponential relationship between fracture toughness, K_{IC}, and added PGA, ranging from 54.33 $\pm$ 2.45 kPa m$^{-1/2}$ for 0 mg kg^{-1} to 86.87 $\pm$ 4.71 kPa m$^{-1/2}$ for 12.2 mg kg^{-1}. Washing increased K_{IC} to 61.31 $\pm$ 1.21 kPa m$^{-1/2}$ for 0 mg kg^{-1} and 132.09 $\pm$ 4.89 for 12.2 mg kg^{-1}. By accounting for elasticity (Youngs Modulus) the surface energy of the particles was evaluated. The highest added PGA was equivalent to 0.5 % carbon and doubled the surface energy in unwashed samples. Washing reduced this effect to 1.7 times. In wet soil, 12.2 mg kg^{-1} PGA increased K_{IC} by 1.5 and 2.1 times from the initial value of about 60 kPa m$^{-1/2}$

for unwashed and washed pure kaolinite, respectively. However, K_{IC} may not be an appropriate parameter for wet soil because it fails to account for energy loss through plastic processes. When plastic processes have a large effect on mechanical behaviour, it is more appropriate to evaluate fracture energy, J_{IC} which PGA increased by over 4 times for the unwashed samples. This was mainly due to the observed increase in strain that was required for fracture to occur.

By evaluating fracture mechanics parameters we have collected thermodynamic information to describe soil mechanical behaviour in the rhizosphere. It suggests that root exudates form recalcitrant bonds with soil particles that increase the resistance to fracture in both dry and wet states. Both the change in particle surface energy and elasticity influenced the fracture mechanics. The significance of this research to soil structure development in the rhizosphere will be discussed. In particular, we will highlight models from materials science that could use these parameters to predict aggregation and mechanical breakdown.