Grasses bite back: silicon-based defences in crops and other grasses

Grasses, both native species and crops such as rice, wheat and barley, use silicon as a defence against herbivores. Grasses take up silicon from the soil in unusually high amounts and deposit it in their leaves, on the surface, in spines and in the form of sharp granules called phytoliths. Phytoliths make leaves more abrasive to herbivore mouthparts, so herbivores generally avoid feeding on plants containing high levels of silicon. Our studies have provided the first experimental evidence of the dramatic effects these silica bodies can have on herbivore performance, reducing their ability to extract essential nutrients from their food, slowing down their growth and reproduction and hence potentially even influencing their abundance. For example, female field voles fed on grass leaves high in silicon displayed growth rates almost half those of voles feeding on grass leaves low in silicon (Fig 1a), due to a reduced ability to absorb nitrogen from silicon-rich grass (Massey and Hartley 2006). We were also the first to demonstrate experimentally that silicon is an inducible defence (Massey et al. 2007): silicon levels in grasses grazed by voles quadrupled compared with levels in undamaged plants, but grasses clipped with scissors did not respond in to the same extent the same way (Fig 1b).

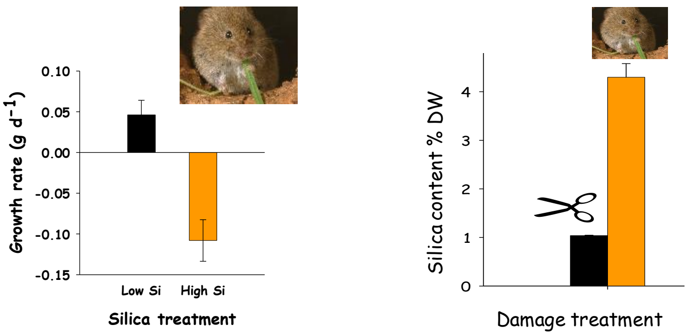

Figure 1 a) The effect of feeding on grasses low (black bars) and high (orange bars) in silicon on vole growth rate – negative values show voles lose weight when consuming high levels of silicon; b) The increase in silicon content compared with undamaged control plants following clipping by scissors (black bars) and grazing by voles (orange bars).

We have found that elevated levels of silicon also have profound impacts on agricultural pests, wearing down their mandibles (Figure 2) and reducing their growth and feeding efficiency irreversibly (Massey and Hartley 2009).

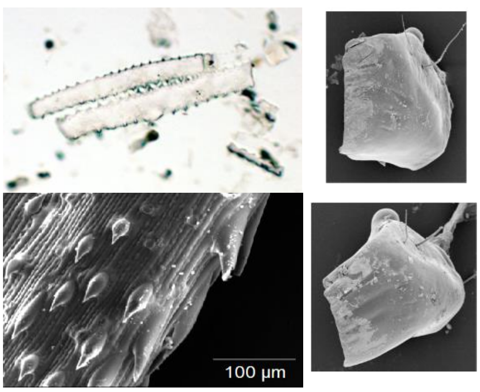

Figure 2 Phytoliths (top left) from *Deschampsia cespitosa*, a grass species high in silicon with silicon-rich spines covering its leaf surface (bottom left), and the impact of feeding on this grass on the mandibles (top right) of *Spodoptera exempta*, a pest of cereal crops compared with mandibles from the same insect species feeding on grasses low in silicon (bottom right).

We have also demonstrated that grasses respond to damage, and to the addition of silicon to the soil, by radically changing their leaf surface – they increase the size, shape, number and density of spines and phytoliths to make their leaves even more abrasive and more difficult for herbivores to eat (Fig 3).

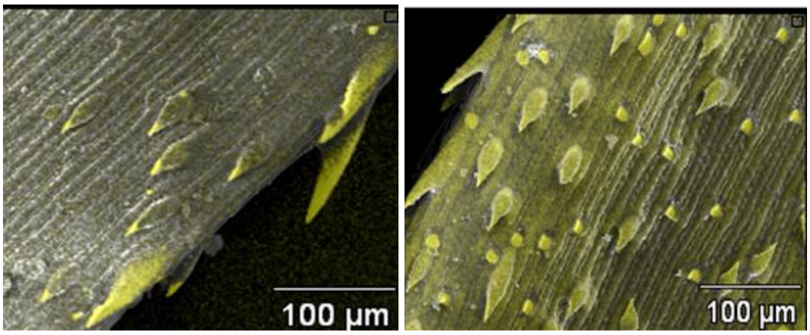

Figure 3 The silicon deposition (yellow colour) on the leaf surface of *D. cespitosa* leaves when undamaged and grown at low silicon levels (left), compared with when damaged and grown at high levels (right). In the former silicon is restricted to the tips of spines, in the latter there are many more spines and they are completely silicified, silicon covers the whole leaf surface and there are additional deposits of silicon rich bodies over the leaf surface.

Seven of the ten most important food crops are silicon accumulators and there is increasing interest in harnessing the many potential benefits of silicon to make agriculture more sustainable and less reliant on chemical inputs. As well as providing resistance to pests, silicon also protects crops from pathogens and alleviates abiotic stresses, such as drought and metal toxicity, but we still don't know enough about the mechanisms grasses employ to take up Si, the form in which they deposit it in their leaves, or the genes which are responsible for Si uptake and deposition. Improving our understanding of the biochemical and genetic mechanisms underpinning silicon accumulation in plants will not only provide insights into an important area of plant biology, but will also enable the development of strategies for improving the resilience of our crops to both environmental change and to the pests and diseases which threaten our food supply.

Massey, F.P and **Hartley, S.E.** (2006). Experimental demonstration of the anti-herbivore effects of silica in grasses: impacts on foliage digestibility and vole growth rates.

Massey, F.P. Ennos, R. and **Hartley S.E.** (2007). Herbivore specific induction of silica-based plant defences. Oecologia 152: 677-683

Massey, F.P and **Hartley, S.E.** (2009). Physical defences wear you down: progressive and irreversible impacts of silica on insect herbivores. Journal of Animal Ecology 78: 281-291