Overlooked interactions between the leguminous plant and silicon: Concepts, contexts and consequences

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Plants associate with bacteria over the course of evolution. For example, leguminous plants (Leguminosae/Fabaceae) have evolved a distinct symbiosis with nitrogen-fixing bacteria (rhizobia) about 60 million years ago. Rhizobia are housed in specialised root structures, the nodules, and provide the host plants with available nitrogen. In exchange, the host plant rewards rhizobia with carbon-based compounds. The legume-rhizobia symbiosis differs from being mutualistic to somewhat parasitic. One of the driving factors of that is soil nutrients, e.g. silicon (Si). Yet, the functional role of Si in legumes is largely overlooked.

Previous studies suggest that Si has positive impacts on the legume-rhizobia symbiosis. For example, existing literature demonstrates that Si alleviates a broad range of environmental stresses. Crucially, there is a growing number of studies reporting that Si promotes symbiotic traits, such as increased root nodulation and nitrogen fixation across several leguminous species. To better understand this, a conceptual framework was recently proposed. It is hypothesised that Si uptake and accumulation (silicification) in plant tissues may compensate the high metabolic expenditure of carbon in cell wall formation, accelerate solute transport and gas exchange in the nodules, and protect the plants against stresses.

To investigate the impacts of Si enrichment on functional traits in legumes, a glasshouse experiment was conducted with a model legume, barrel medic (Medicago truncatula) associated with a rhizobial (Ensifer meliloti) strain SM1021. Three plant genotypes were either enriched with Si (+Si) or untreated (-Si). Furthermore, a suite of key functional traits broadly grouped as plant growth, physiology, elemental chemistry, nodule activity and nitrogen fixation were quantified using several analytical/chemical techniques. Si enrichment altered several traits depending on plant genotype and symbiosis with rhizobia. For example, nodule activity was generally promoted in +Si relative to -Si plants, but with a more profound impact in one specific genotype (Sephi). This promotion was correlated positively with silicification either in the foliar or nodule depending on plant genotype.

To examine a context dependency of Si impacts in legumes, a full-factorial experiment in a glasshouse was undertaken with the same model legume (two genotypes) and two rhizobial...
strains, i.e. SM1021 and SM1022, which the former strain is less effective than the latter. Each host-rhizobial association was supplemented with and without Si and challenged with the foliar-chewing cotton bollworm (*Helicoverpa armigera*) for a 5-day larval infestation (+herbivore and -herbivore). At 30-day post infestation, plants were harvested and further analysed for nodule traits and plant chemistry. Silicon enrichment strongly increased nodule numbers in both rhizobial strains but only in -herbivore plants and this impact was wiped out in +herbivore plants. However, foliar Si was induced only in +Si relative to -Si in +herbivore plants and the reverse was true for foliar C that might indicate a trade-off between Si and C following herbivory. In addition, Si enrichment generally promoted total soluble protein. Finally, when foliar amino acids (AAs) were clustered into essential, non-essential and total compounds, Si enrichment consistently promoted AAs only when herbivory was absent and shifted to a lesser extent when herbivory was present.