Lupins – Nitrogen Fixation and Carbon Footprint

The Australian Sweet Lupin belongs to a family of plants termed legumes, many of which have the distinct ability to thrive in the absence of fertilizer nitrogen. Legumes do this by forming a "symbiosis" with soil bacteria called "rhizobia" which they allow to infect their roots, forming structures called "nodules".

The nodule provides a safe home for rhizobia, into which the legume translocates sugars from photosynthesis to provide an energy source for the rhizobia to convert atmospheric nitrogen (N_2) into NH_3 – the basic form of nitrogen fertilizer. Hence legumes, with the right rhizobia, can form all their fertilizer nitrogen requirements from this symbiosis.

The Australian Sweet Lupin is exceptionally competent at forming a strong symbiosis with their specific rhizobia in the acidic sands common to Western Australia.

A section through nodules on the tap root of the Australian Sweet Lupin

The photo illustrates the dramatic red colouring of the lupin-produced "leghaemoglobin". This molecule has a very similar structure to human haemaglobin and performs a similar function: - it traps and removes oxygen from the nodule. This is important as oxygen can denature the critical enzyme (nitrogenase) that enables rhizobia to turn N_2 into NH_3. This overall process is called "nitrogen fixation", and is analogous to photosynthesis (which is termed by some scientists as "carbon fixation").

Aussie Lupin Beans

Nitrogen fixation by legumes, such as the Australian Lupin Bean, is very beneficial to man's attempts to reduce our carbon footprint. Greenhouse gas (GHG) emissions accounting in 2022 indicated that replacing fertilizer nitrogen inputs into Australian cropping systems with nitrogen fixation N from annual legumes could reduce nitrous oxide (N_2O) emissions by about 60% and halve total GHG emissions (using the methodology of Camargo et al. 2013).

This is possible because the energy from fossil fuels consumed to create synthetic nitrogen fertilizer is enormous.

Jensen et al., (2012) explain that the CO_2 respired from nodulated legume roots originates from photosynthesis and therefore does not represent a net contribution to atmospheric concentrations of CO_2, whereas the CO_2 generated during the synthesis of N fertilizer is derived from fossil fuels.

Not only are legumes grown without any applied fertilizer nitrogen, but the nitrogen rich residues breakdown to release organic N (and carbon) into the soil, largely replacing the need to apply fertilizer nitrogen to a following crop of cereal or canola. Some farmers in Western Australia use no fertilizer N on cereal crops grown after a good season of legumes, without seeing a reduction in yield or protein content in the grain.

References

Camargo GGT, Ryan MR, Richard TL. (2013). Energy Use and Greenhouse Gas Emissions from Crop Production Using the Farm Energy Analysis Tool. Bioscience 63: 263-273.

Jensen ES, Peoples MB, Boddey RM, Gresshoff PM, Hauggaard-Nielsen H, Alves BJR and Morrison MJ. (2012). Legumes for mitigation of climate change and provision of feedstock for biofuels and biorefineries. A review. Agron. Sustain. Dev. 32: 329-364.

Content provided by Professor John Howieson, Murdoch University, Western Australia