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A Natural Collaboration for Sustainable Agriculture: Pulses and Soil Health

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Pulses are an important source of protein and minerals for people everyplace in the world. But their production is generally limited by insufficient soil nitrogen and lower yields (Plant Archives, 2024). Pulses are more than nutrients. They link to a number of Sustainable Development Goals as they could help to end hunger, improve human health and reduce soil degradation. At the same time, excessive use of chemical nitrogen fertilizers pollutes the atmosphere and groundwater and contributes to soil acidification (Virk *et al*., 2024). In this respect, systems based on legumes are widely considered as a means to attain sustainable intensification (Stagnari *et al*., 2017). Here, we review the pulses-soil nexus, from the provision of nitrogen by the legume-rhizobia symbiosis, to the effects of pulses on the physical, chemical, and biological properties of soil in rotations and intercrops, to the potential for biofertilizers to improve the symbiosis, to the limits of the partnership.

Biological Nitrogen Fixation

Dinitrogen forms about 79 % of the atmosphere, but is not directly used by most plants. Legumes associate with nitrogen-fixing bacteria, especially rhizobia, and convert atmospheric N2 into ammonia that the host plant can readily utilize (Plant Archives, 2024). This enzyme is nitrogenase which is active in the rhizobia bacteroid within the root nodules (Hayat *et al*., 2010, as cited in Virk *et al*., 2024). Worldwide, pulses fix an estimated 2.95 Tg of nitrogen annually (Herridge *et al*., 2008, as referenced in Virk *et al*., 2024).

Rotational Benefits: Nitrogen and Beyond

Some of the most precise measurements have been made in a long-term study on the Canadian Prairies by Gan and co-workers at Swift Current. Maximal residual soil water and nitrogen were observed in a depth of 30–90 cm in fourteen four-year rotation systems with zero to three pulses, pea and lentil preceding wheat, or present more than once in the rotation. Compared to continuously grown wheat, pea and lentil increased the yield of the following wheat crop by 26 % and 18 %, respectively. Relative to a cereal-summer fallow system, a cereal-pulse system also increased protein yield by nearly 60%, fertilizer-nitrogen-use efficiency by 33% and total grain production by over 35%.

Soil Microbial Communities and Soil Carbon

Rotation changes the biology of soil. Gan and colleagues say crop rotation has a significant effect on soil microbial populations. For example, durum wheat does better after pea than after chickpea due to differences in root-microbe interactions. In wheat rhizosphere soil, Mortierella, Cryptococcus and Paraglomus were positively correlated with the yield of

subsequent wheat, while Fusarium and many other taxa were negatively correlated. The effects of pulses on the microbial communities in the roots were influenced by the host crop species, rotation pattern, climate and soil conditions. In dry land areas, rotations with two pulses every four years had significantly greater soil dehydrogenase activity, a measure of total microbial activity, than continuous wheat or rotations with one pulse. Carbon reactions are more involved. After 8 years, cumulative nitrogen from residues was highest under pea-wheat, while cumulative carbon addition from crop residue was similar for wheat-wheat and pea-wheat and lower for lentil-wheat and chickpea-wheat.

Legume Intercropping

Interplanted legumes took up less nitrogen from the soil, leaving more for the cereal. A global meta-analysis of 74 studies demonstrated that legume/non-legume intercropping increased non-legume production by 33.13 % and biomass by 21.14 %, along with soil nitrogen availability and arbuscular mycorrhizal fungi colonization (Chen *et al*., 2026). The quantity of nitrogen transferred from the legume ranged from around 0.5% to 53%, showing the influence of the environment and species on the strength of this process. A review from Indian institutions showed that the inclusion of legumes in cropping systems decreases bulk density, breaks hardpans, reduces erosion and increases soil organic matter (Parasuraman *et al*., 2025).

Biofertilizers: Strengthening the Symbiosis

Biofertilizers are inexpensive inputs that increase production through biological nitrogen fixation, nutrient solubilization, and plant growth stimulation. Rhizobium seed inoculation increased nitrogen fixation in mungbean (Hussain *et al*., 2012). Inoculation with Bradyrhizobium strains and Streptomyces griseoflavus P_4 encouraged nodulation in soybean and mungbean Virk *et al*., (2024).



Constraints and Trade-Offs

The collaboration has its limits. The use of high pulse frequencies in rotations can have negative consequences for the diversification of crops and the quality of the soil based on organic matter, leading to disease outbreaks and a decrease in the production of the system. With increasing pulse intensification, fungal richness and diversity decreased significantly, with rotations of three consecutive pulses showing the lowest levels. In one long term study, pea yields were reduced 52% from the first to the fifth year, and chickpea yields were reduced 66% from the first to the seventh year.

Conclusion

In many overlapping ways, pulses can make soil better: they supply nitrogen, add water and nutrients, stimulate the growth of beneficial microorganisms, need less fertilizer, and have a smaller carbon footprint. The data are consistent with the description of the interaction between pulses and soil as a natural cooperation that must be controlled.