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INDEPENDENT STRATEGIC ANALYSIS OF AUSTRALIA'S GLOBAL INTERESTS

FDI Feature Interview

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The Role of Mycorrhizal Fungi in Regenerating Healthy Soils and Agricultural Productivity: Walter Jehne and Phil Lee

Key Points

- A type of fungi known as 'mycorrhizal fungi' forms an integral link between 98 per cent of the world's flora and their soils, which assist plants in accessing limited essential nutrients.
- Over the past 60 years, however, industrial agricultural practices, such as the overuse of agricultural inputs, have significantly impaired these natural processes, contributing to widespread degradation of global cropping soils and a decline in the nutritional integrity of our food.
- These practices are unsustainable; high inputs, combined with the effects of climate change, threaten the financial viability of many farms.
- An innovative minority of farmers in Australia are applying mycorrhizal fungi into their soils with minimal inputs, and are witnessing encouraging results in improved crop yields, nutritional density and longevity of green growth.
- Mycorrhizal fungi will be fundamental in re-designing a viable agricultural outcome for the future of food production and our health and social stability.

Commentary

FDI: *Why do we need to investigate and discuss these relationships?*

WJ & PL: The productivity of Australia's natural vegetation, particularly on the old leached soils of Western Australia, is fundamentally dependant on a range of microbial symbioses[1] between mycorrhizal fungi and the roots of plants. This enables our flora to access limited

[1] Symbioses (*noun; plural*): A close, prolonged association between two or more living organisms of mutual benefit.

essential nutrients from soils to sustain their productivity, diversity and resilience. Through years of industrial farming and fertiliser overuse, we have impaired these symbioses and, with that, the ability of plants to sustain their nutrition and productivity.

Only by restoring these symbioses, specifically the mycorrhizal fungi that govern much of the availability of essential nutrients from soils, can we regenerate Australia's degraded agricultural soils and landscapes. Leading farmers are refining practical approaches to do this to improve yields, root growth, carbon and moisture retention and the nutritional integrity of their crops. These outcomes are being achieved without the need for expensive fertilizer inputs. The extension of such approaches through farmer groups will be critical to the regeneration of Australia's agricultural soils and landscapes and their capacity to produce food with nutritional integrity.

FDI: *What are mycorrhizal fungi?*

WJ & PL: Mycorrhizal fungi proliferate throughout most natural soils and colonise the roots of most plants to form an extensive microbial interface. These fungal-plant-soil interfaces are often critical for the solubilisation and uptake of essential, otherwise un-available, nutrients to aid the growth and health of that plant.

Although we cannot see them directly, we have identified two main types: ecto-mycorrhizae, common on some trees, and endo-mycorrhizae or arbuscular mycorrhizae (AM), common on 98% of all other plants.

FDI: *Do these fungi have a history of being used or applied by man to regenerate soils?*

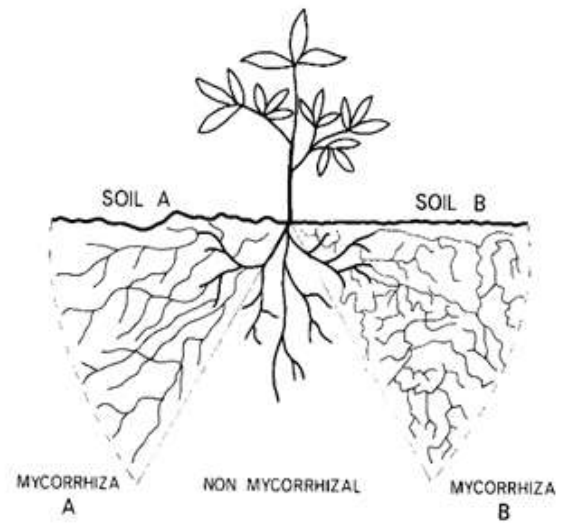


Figure 1: the plant-soil interface with and without mycorrhizas. Mycorrhiza strains A and B illustrate the genetic flexibility specific fungi can provide a plant in contrasting soil environments.

Source: Jehne, W 1984, 'Mycorrhizas and Stylosanthes', in The Biology and Agronomy of Stylosanthes, eds H.M Stace & L.A Edye, Academic Press Australia, Samford Valley, pp. 227-241.

WJ & PL: Until recently, we have not had to do this as they were naturally and nearly universally present. We took them and their critical role in supplying nutrients for our food and bio-systems for granted.

Their essential need and role, however, became apparent when, for example, we sought to introduce exotics such as pine trees into new lands and could not do so unless we also introduced their essential mycorrhizal symbionts. The same applies for most introduced fruit trees and crops.

Introduced grain crops mostly relied on forming mycorrhizas from the native grass AM fungi. While some crops do not rely on, and may suppress these, mycorrhizal fungi, the nutrition and growth of 98% of plants and bio-systems in nature depend on these fungal symbiotic associations.

The extension of industrial agriculture over the past 60 years, however, has significantly impaired the level and activity of these fungal symbioses. This was because of high inputs and soil disturbance through cultivation, soil carbon oxidation, excessive fertiliser use, biocides, fallows and irrigation.

This accentuated our dependence on high fertiliser inputs to sustain agricultural productivity. The degradation of our soil structures, their productivity and soil and plant health has, in turn, accelerated. We are now losing over 10 million hectares of critical crop soils globally per year to erosion and degradation.

We need to regenerate these soils urgently if we are to provide food for a growing world population and reverse the ongoing serious degradation of most of our 1.5 billion hectares of cropping soils. We can do this, but only as nature did, by restoring these natural processes that governed the formation, nutrition and productivity of these soils. Restoring these fungal symbioses is central to achieving this.

FDI: *Does the average Australian farmer accept that their soil and farm productivities are declining?*

WJ & PL: Absolutely. Most know this, and many are desperate as they often do not know what they can do. While the conventional response has been to add more inputs, this has accelerated degradation and threatens the viability of many farms.

An innovative minority, however, is quietly refining local solutions out of necessity and passion, which challenge this status quo. These solutions need to be documented so they can contribute, where relevant, to other local groups so they, too, can plan strategies to regenerate their soils and landscapes and revitalize our farming communities.

These innovative farmers are demonstrating that they can markedly enhance their resilience and thus, lower inputs and financial risks. These efforts secure their viability both on-farm and regionally. The outcomes speak for themselves and hopefully will catalyse a tipping point for regenerative change.

FDI: *What advantages and significance does it have for agriculture***?**

WJ & PL: The restoration of the natural mycorrizal symbioses can deliver major benefits to agricultural land and the societies that depend on them. They still underpin the health of most of the natural bio-systems.

Soils, agriculture or their dependent civilizations could not have evolved or have been sustained without these natural fungal symbioses; neither could soils have sequestered nor stored their vast quantities of stable carbon that they did up to the start of industrial agriculture.

This carbon 'sponge' was fundamental in the ability of soils to retain rainfall and sustain green plant growth over much of the land surface. Much of the planet's hydrological dynamics would be impaired without this sponge, compromising their critical natural function in cooling the planet.

While we take them for granted, our food and existence relies absolutely on these fungal symbioses. Hence, our recent impairment of them due to industrial agriculture has serious consequences including:

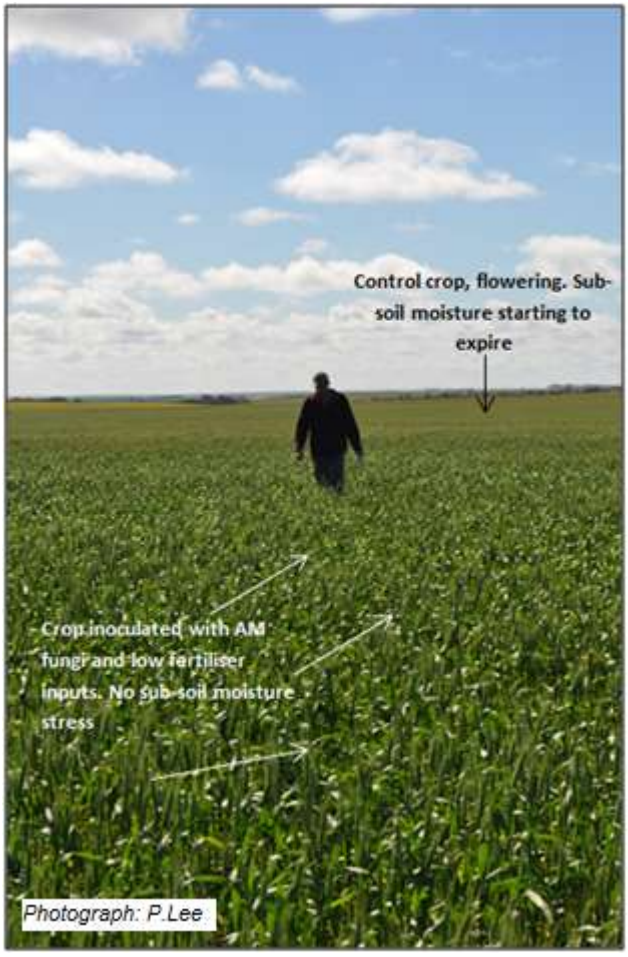
- The degradation of our soils and their productivity.
- The oxidation of vast quantities of soil organic matter as CO2 emissions.
- The impairment of local hydrological cycles and the desertification of over 30% of the former vegetated land surface.
- The marked decline in the nutritional integrity of our food and thus the health of the animals and humans that depend on that food.
- The impaired resilience of our agricultural systems to stress and diseases, requiring farmers to apply ever more expensive and degrading inputs to try to sustain yields.

As climate extremes and limits in oil and inputs intensify, these mycorrhizal symbioses will be fundamental in re-designing a viable agricultural outcome for food production, nutritional integrity and health, social stability and our future.

FDI: *How are these fungi introduced into field soils? Can these fungi be applied to all farms and products?*

WJ & PL: As indicated, most natural soils and plants rely on and thus have relevant natural mycorrhizas. In new or heavily degraded soils, however, they may need to be introduced. We can do this readily and safely by taking soil or plants from areas with healthy mycorrhizal fungi to inoculate degraded or virgin soils.

It is important to note that the success of introduced mycorrhizas becoming established and active in that soil or plant often depends on how conducive or suppressive that soil is to the establishment of



Photograph: P.Lee

the fungus. Removing the suppressive soil conditions may be essential to enable either the natural or introduced mycorrhizas to be active and effective in such soils.

While mycorrhizas are critical for the natural nutrition and growth of most plants on most soils, and thus their production of plant products, a small number of plants do not form mycorrhizal symbioses with such fungi, relying instead on other organisms or root chemistries for their competitive growth.

FDI: Why do fertilisers not work on some crops? How do mycorrhizas alter this?

WJ & PL: Fertilisers are applied to aid the nutrition and thus the growth of crops. Their effectiveness, however, relies on whether the required nutrients are available to the plant in the forms, concentrations and times when they are needed. Added nutrients may leach rapidly, vaporize or be fixed to the soil surface, making these nutrients unavailable to that plant. While some soils may contain adequate nutrients, the plants often cannot access them; their roots can only passively take up the soluble nutrients within and from the soil solution and not those on the soil surface.

Mycorrhizal plants operate through fundamentally different nutrient uptake processes. In these plants, mycorrhizal hyphae (microscopic fungi fibres) proliferate through large volumes of soil. Through this process, fungi actively dissolve and selectively absorb the nutrients that they and the plant need in exchange for sugars from the plant. The mycorrhizal hyphae can also take up water and soluble nutrients from the soil solution at levels that are well beyond those possible by non-mycorrhizal plants, even under arid conditions.

These selective uptake processes enable mycorrhizal plants to colonize and grow in soils that would be too toxic, saline or dry for the same plant without this selective nutrient uptake capacity.

FDI: *What results have you seen in the application of mycorrhizal fungi in farm trials so far?*

WJ & PL: Farmers have recorded many important benefits from the application of mycorrhizal fungi. Through improving plant growth, carbon sequestration and the proliferation of roots and hyphae, the soil surrounding mycorrhizal plants often contains far more moisture to depth than in non-mycorrhizal plants. This increase in the infiltration and retention of rainfall often aids the longevity of green growth in mycorrhizal plants and thus their productivity and resilience to stress.

These growth responses in mycorrhizal plants often result despite the plants receiving far lower or no nutrient additions i.e. fertiliser inputs. These enhanced natural nutrient uptake processes ensure that mycorrhizal plants mostly contain the full range of essential nutrients, at optimal levels, from the soils. Fertilised plants, by contrast, frequently have excess levels of the few added nutrients but very low levels of the over 30 macro and micronutrients essential for the health of that plant, our food and our health.

Individual farmers have saved up to 70% of their former nutrient input costs through these practices. Mycorrhizal plants can also grow on soils with levels of, for example, aluminium toxicity that would kill non-mycorrhizal plants.

Yield data also confirms that the mycorrhizal plants, due to their enhanced longevity of green growth, consistently filled more seeds in the heads of wheat than non-mycorrhizal plants. These seeds also showed improved levels of starch, protein and other nutrients.

FDI: *When can farmers expect to see benefits from mycorrhizal fungal applications?*

WJ & PL: Farmers can expect to see benefits from the mycorrhizal treatments within days through the improved emergence of healthier seedlings and subsequent enhancements in the growth of these plants.

Mycorrhizal plants without fertiliser may not grow as fast as heavily fertilised control crops as they are initially investing more of their sugars in their extensive root and soil interface. They are, however, far less prone to frost, drought, disease and stress, sustaining their longevity of green growth to produce higher quality grains with often greater yields.

Improvements in soil structure, carbon, moisture and stability can often be observed as a result.

Industry factors, such as marketing and financial pressures, currently sustain high input farming systems. As leader farmers use and observe the performance outcomes of natural regenerative systems, others will adopt these practices.

FDI: *Can we apply this on a broad scale to regenerate soil health across, for example, Western Australia? What and how long would it take?*

WJ & PL: The issue is not can we, but that we must urgently and extensively restore such natural soil ecologies. This is integral if we are to regenerate healthy soils and bio-systems and sustain agricultural outputs in the face of increasing land degradation, climate extremes, demand and input stresses. Just as lead farmers are doing, we need to extend the adoption of such profitable innovative approaches, with their lower inputs and risks to their peers, through local regeneration groups throughout Australian agriculture.

Making these changes, however, requires more than simple textbook prescriptions. Farmers and groups need to diagnose what are the key limiting factors in their soil-plant interface and viability and plan how to use relevant natural processes to help overcome them through practical, commercial strategies. They may need access to local mentors and relevant specialists to help refine and implement them.

Some 50 to 100 relevant skilled specialists could fundamentally and rapidly introduce such changes. The savings in input costs, reduced risks of crop failures, increased resilience and natural soil capital improvements would more than offset the cost of such specialist soil health and mentoring support.

FDI: *How can we spread this knowledge among local farmers?*

WJ & PL: We have an urgent challenge not just to re-inform farmers of these soil health issues but to help refine and implement practical regeneration strategies relevant to local conditions. Local regeneration groups, case studies, relevant specialist scientific and mentor support and supportive financial and market conditions are all important to effect the critical urgent changes.

By documenting these processes and their outcomes, it should be possible to encourage other farmer groups and innovative regeneration strategies Australia wide. We have the science, the skills, the successful processes and the imperative to regenerate our soils. While there will always be more to know, we can learn and advance this best through such local farmer groups who can identify, implement and document practical commercial solutions to their specific soil and land regeneration challenges.

Most of all, the wider community needs to understand what leading farmers know: nature is clearly telling us that our current industrial agricultural system is unsustainable and is degrading our soils. We need to change. Our unique natural landscape can show us highly effective, profitable and safe ways to make this change, including the use of mycorrhizal fungi as outlined above. We can and must face these realities and act through sustainable options. The question is: will we have time?

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About the Interviewees:

Walter Jehne is a retired scientist with a specialist background in soil microbiology and plant ecology who has worked in Australia and overseas, including for CSIRO. He is now part of two not-for-profit groups, Soils for Life and Future Directions International, which foster solutions for the regeneration of Australia's landscape and the development of the agricultural and pastoral sectors of Australia

Phil Lee has many years working experience on his family farm in Southern WA. He began developing an interest in soil microbiology in the early 1990s and is now helping farmers to improve the soil quality of their farms across the state.

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Any opinions or views expressed in this paper are those of the individual interviewee, unless stated to be those of Future Directions International.

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