

# SOIL HEALTH: a soil ecology perspective

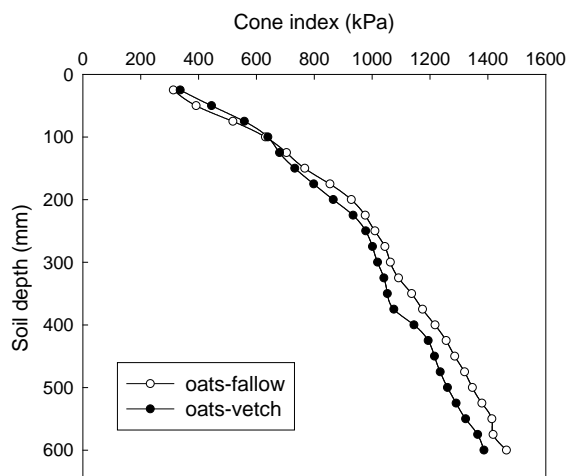
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Soil health has become more topical as some growers perceive a decline in their soil's fertility and as soil-borne diseases impact on cotton cropping systems. Soil health relates not just to the presence or absence of the pathogens, but to soil characteristics that promote vigorous and healthy crop growth. Soil structure, the availability of nutrients and abundance of microbial communities can give some measure of the soils' physical, chemical and biological properties.

Soil quality issues have been researched within a crop rotation experiment that started in 1994 at Narrabri. It compares three crop rotations that have included or excluded legume phases throughout this period. The data presented here relate to the most recent 2-year cycle of this experiment. Following cotton harvest in all three rotation systems in May 2004, oats was sown in two systems. Following oat harvest, the soil was either left fallow (oat-fallow treatment) or vetch was sown in the April 2005 and green-manured in August 2005 (oat-vetch treatment). In the third treatment, vetch was planted in May 2004, green-manured in August 2004 and cotton sown in October 2004, vetch was sown in May 2005 and green-manured in August 2005 (vetch-cotton-vetch treatment). Cotton (cv Sicot 71BR) was sown in October 2005 across all systems.

## Soil Structure

Soil structural differences were measured using a cone penetrometer which determines the force needed to push a metal probe into the soil to 600 mm depth. The results (Figure 1) indicate that the



instrument penetrated the soil more easily in the oat-vetch system compared with the oat-fallow system. This effect increased with soil depth.

**Figure 1.** Resistance to inserting the cone penetrometer in to soil was lower following a legume (vetch) crop, compared with fallow.

This phenomenon has been observed in each year of the experiment. Soils that offer less resistance to root growth allow plants to explore a larger volume of soil, thus enabling the plant to take up more nutrients and to access more soil water.

## Nutrient availability

### Leaf nutrient concentrations

Nutrient content of the youngest mature leaf (5<sup>th</sup> uppermost leaf from terminal) was determined at first flower (Table 1). Leaves collected from cotton plants growing in the oats-vetch system contained slightly higher or similar concentrations of most nutrients than those in the oat-fallow system. Iron, manganese and sodium concentrations were slightly lower in the oat-vetch system where better soil aeration and good physical soil structure maintains these nutrients at levels conducive to healthy plant growth. High levels of these nutrients can occur in poorly-aerated soils.

**Table 1.** Leaf nutrient concentrations were generally higher where legumes were included in the crop rotation sequence.

| Nutrient          | Oat-fallow | Oat-Vetch |
|-------------------|------------|-----------|
| Nitrogen (%)      | 4.60       | 4.62      |
| Phosphorus (%)    | 2.99       | 3.16      |
| Potassium (%)     | 1.60       | 1.66      |
| Sulfur (%)        | 0.88       | 1.00      |
| Calcium (%)       | 4.4        | 4.5       |
| Magnesium (%)     | 0.73       | 0.77      |
| Sodium (mg/kg)    | 839        | 798       |
| Zinc (mg/kg)      | 23         | 25        |
| Iron (mg/kg)      | 370        | 252       |
| Manganese (mg/kg) | 101        | 97        |
| Boron (mg/kg)     | 49         | 49        |
| Copper (mg/kg)    | 5.2        | 5.9       |

### Nutrient uptake by the crop

At cut-out, crop dry matter (DM) was determined by cutting 1 m sections of crop row and this material was dried, weighed, milled and analysed for nutrient content (Table 2). Cotton produced 10% more DM in the oats-vetch treatment than the oat-fallow treatment and took up greater quantities of most nutrients, including 33% more N, 7% more P, 12% more K and 23% more Zn. Sodium uptake was slightly higher in the oat-vetch system, but the amounts were low, compared with level of sodium taken up in sodic soils: cotton growing in more highly sodic soils may take up ten times the amounts reported here.

**Table 2.** Cotton DM production and nutrient uptake in two crop rotation systems.

| <b>Nutrient</b>    | <b>Oats</b> | <b>Oats-Vetch</b> |
|--------------------|-------------|-------------------|
| Crop DM (t/ha)     | 10.5        | 11.6              |
| Nitrogen (kg/ha)   | 180         | 239               |
| Phosphorus (kg/ha) | 32.9        | 35.3              |
| Potassium (kg/ha)  | 217         | 244               |
| Sulfur (kg/ha)     | 54          | 57                |
| Calcium (kg/ha)    | 211         | 228               |
| Magnesium (kg/ha)  | 43          | 51                |
| Sodium (kg/ha)     | 6.8         | 8.6               |
| Zinc (g/ha)        | 145         | 178               |
| Iron (g/ha)        | 1600        | 1400              |
| Manganese (g/ha)   | 458         | 523               |
| Boron (g/ha)       | 399         | 428               |
| Copper             | 71          | 59                |

## Soil micro-biology

Land management practices (such as crop rotation and tillage) can influence the abundance and composition of soil microbial communities. Microbial biomass is defined as the living component of soil organic matter. It has a much faster rate of turnover than total organic matter (OM) and thus can provide a more sensitive measure of changes due to land management practices.

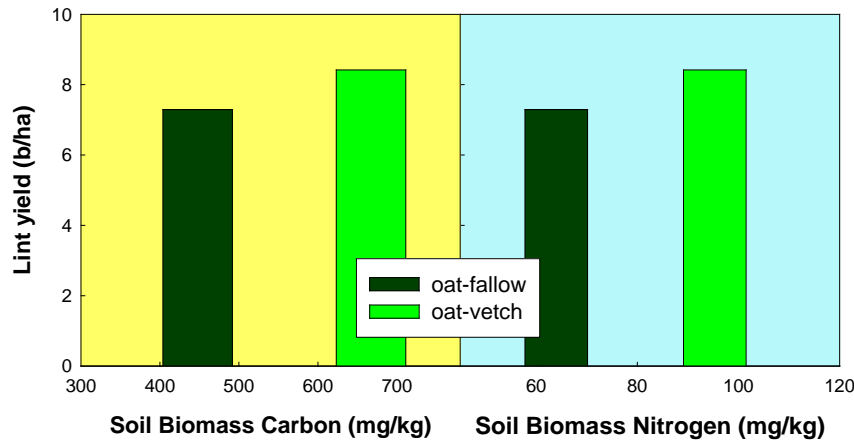
Most nutrient transformations are mediated by soil microorganisms. The microbial biomass is responsible for decomposing crop stubble which is incorporated into soil OM. From there, it is further mineralized and nutrients released for crop nutrition. The soil microbial biomass itself can become a substantial store of nutrients which are recycled as these microorganism populations grow and decline. The rate at which soil organic N is mineralized can provide a useful integrator of chemical, physical and biological aspects of microbial community; it reflects both the decomposer activity of general microbial population and the activity of specific communities such as nitrifying microorganisms.

Microbial activity (soil respiration), microbial biomass carbon (C) and N, and N mineralization potential are some of the measures suggested as potential indicators of biological status of soil (Sparling, 1997; Gupta and Roberts, 2001).

We measured these microbial properties using surface soil samples (0-10 cm) from the three treatments in the crop rotation experiment collected at sowing the 2005 cotton crop. Soils from the oats-fallow rotation contained the lowest levels of all the microbial properties measured, whereas the oats-vetch rotation supported the highest level of microbial biomass and activity (Figure 2, Table 3).

Soil from the oats-vetch rotation not only contained more N in the microbial biomass (34 kg/ha than the oats-fallow rotation) but also exhibited highest level of N mineralization potential (71% more than the oats-fallow rotation – Table 3). The soil from the continuous vetch-cotton-vetch rotation exhibited intermediary levels of microbial activity and N mineralization potential.

**Figure 2.** The amounts of soil microbial biomass carbon and nitrogen associated were substantially higher in the oat-vetch system compared with the oat-fallow system.



Microbial quotient (MQ) is considered a more useful measure to indicate changing soil microbial processes across management practices as it normalizes the microbial biomass values across different organic matter contents. Results in Table 3 indicate higher MQ value for the soil from oats-vetch rotation. In the majority of Australian agricultural soils, the biota is constrained by the lack of biologically-available organic matter. Hence, the cropping systems that provide more carbon inputs (above-ground and below-ground) generally support higher levels of microbial biomass and microbial activity.

**Table 3.** Rates of soil N mineralisation, microbial respiration and the proportion of soil carbon contained in the soil biomass (Microbial Quotient).

| Treatments                | Potential N mineralisation<br>( $\mu\text{g N / g soil / day}$ ) | Microbial respiration<br>( $\mu\text{g CO}_2/\text{g /day}$ ) | Microbial quotient<br>(MB-C/Organic C)<br>(%) |
|---------------------------|--|---|---|
| Oats-fallow-cotton        | 0.42 ( $\pm 0.07$ )  | 8.65 ( $\pm 1.27$ )   | 3.31  |
| Oats-vetch-cotton         | 0.72 ( $\pm 0.12$ )  | 13.20 ( $\pm 0.77$ )  | 4.63  |
| Vetch-cotton-vetch-cotton | 0.56 ( $\pm 0.07$ )  | 10.26 ( $\pm 0.62$ )  | 4.11  |

Nitrogen from fertilizer sources is prone to losses such as leaching, volatilization and denitrification whereas the N from microbial biomass is less prone to such losses. Since N availability is one of the major regulating factors of crop yield, even for the high input cotton crop, it is not surprising to see a significant relationship between microbial biomass-N value and lint yield. This relationship may not hold true in situations where crop growth is constrained by disease.

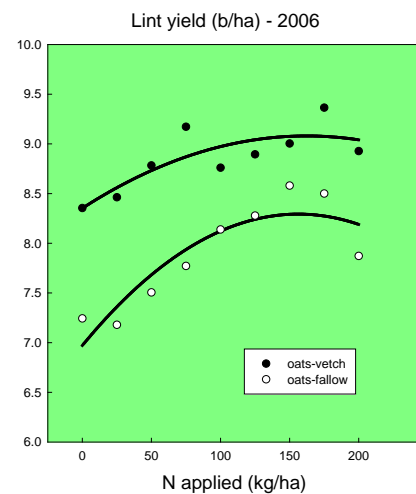
Oats-vetch rotation not only supplied a larger total amount of C but also crop residues of different quality (i.e. C:N ratio) and therefore potentially a more active and diverse microbial community. The three different crops (cotton, oats, vetch) harbor different types of microbial communities, due largely to the different compounds exuded from their root systems that produce distinct rhizosphere effects. In dryland grain and pasture systems, it has been shown that diverse plant types generally support a greater functional diversity in soil biota communities. Such information for cotton-based cropping systems is limited.

Pathogens can be seen as indicators of a lack of diversity in the cropping system, where diseases of the commonly-grown crops become more prevalent. Plant pathogens are more able to persist in situations where their host crop is under stress from soil constraints (poor structure, nutrient deficiencies or toxicities etc), hence remediating these constraints will reduce the impact of those pathogens. Pathogens are less able to infect healthy crops that are growing in healthy soils. Growing cotton on soils that have fewer constraints to crop growth provides some protection against our current suite of pathogens and those that may appear in the future.

### Crop yield and N fertiliser response

The response to applied N can be seen in Figure 3. Less N fertiliser was required by the oats-vetch system because of the N input from the vetch, but importantly, the oat-vetch treatment had a significantly higher yield. The elevated lint yields in the oat-vetch system were consistent at all N fertiliser levels. This effect is due not just to the N input from the legume, but also to the improved soil environment created by growing the vetch.

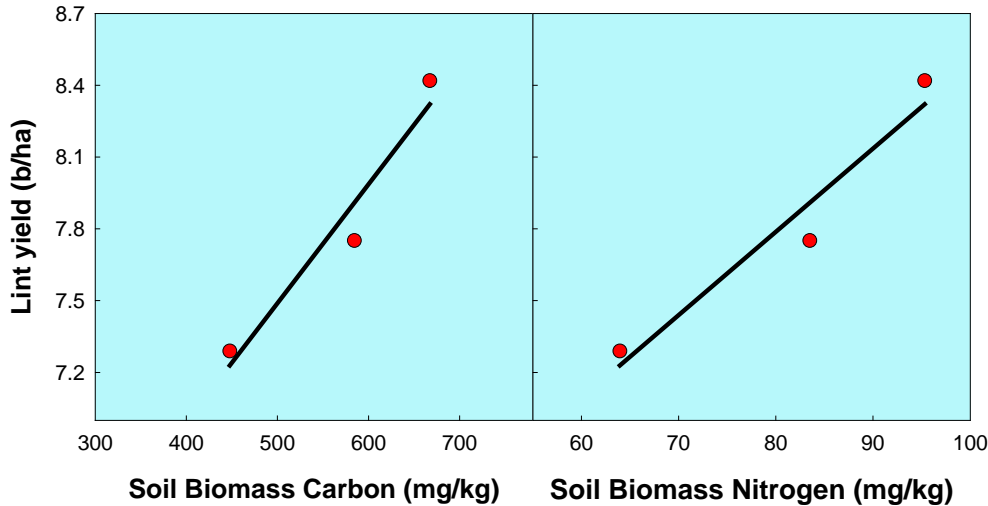
**Figure 3.** Lint yield of the two rotation systems and the response to applied N fertiliser.



## Conclusion

The combined effects of improved soil structure, nutrient availability and uptake, a more active and larger soil microbial biomass all contributed to a healthier soil enabling the cotton crop to flourish and produce greater lint yields (Figure 4).

**Figure 4.** The amounts of carbon and nitrogen associated with the soil microbial biomass in three rotation systems were highly correlated with the cotton lint yield determined in those systems.



## References

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