Mycorrhizae and their influence on P nutrition

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Arbuscular mycorrhizae (AM) previously known as VAM, are symbiotic associations between specific soil fungi and plant roots and have been found to be very important in our cropping systems. Many of the summer crops grown in northern Australia have a high to very high AM dependency while our major winter crops such as wheat, barley and canola are lower down on the dependency scale (Table 1).

In cropping systems, most plants are mycorrhizal and depend, to varying degrees, on these fungi to supply them with nutrients such as phosphorus and zinc. In turn, the plant hosts the fungus and supplies it with carbohydrates.

Unlike saprobic soil fungi, which colonise and break down organic matter and do not require a host plant in the system to complete their lifecycle, arbuscular mycorrhizal fungi (AMF) – the type found in cropping systems – do require the presence of a host to reproduce and are therefore called obligate symbionts.

They produce spores as a means of survival in soil during the absence of a host (for example, a clean fallow) and then germinate and colonise host roots. The longer the fallow, the less chance of survival of these spores and this is the cause of the syndrome that is called 'Long Fallow Disorder' (LFD). Hyphae in soil or in roots in the soil may also grow to new roots but they survive for less time in the soil than the spores.

Primarily, LFD is a phosphorus or zinc deficiency of the plant and can be overcome by the application of P and/or Zn fertilisers. Having adequate populations of mycorrhizal fungi present in soils therefore can be beneficial and in some cases essential for crop growth.

Without mycorrhizae, much higher amounts of P and/or Zn fertiliser are required to attain the same level of productivity as when plants are mycorrhizal.

Management to optimise mycorrhizae

There are two important and distinct concepts to understand when considering the management of crops for optimising mycorrhizal levels:

- A crops' dependency on mycorrhizae (important for the growth of that particular crop); and,
- That crops' ability to produce mycorrhizal inoculum (important for the growth of the following crop).

A crop with a low dependency may still produce suitable levels of inoculum for the next crop.

AM dependency, the extent to which a crop relies on AM to achieve maximum growth, varies with the crop species and

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AT A GLANCE...

Maintaining high mycorrhizal populations promotes good crop growth and the efficient use of P and Zn fertilisers. Many crop species require only half the phosphate concentration in soil when they are colonised by AMF as they do without AMF for the same level of production.

AMF levels can be severely reduced by long periods of fallow, such as those induced by drought, or the growth of non-host crops. Knowledge of the P and Zn levels in your soil and supplementation with fertiliser if required could avoid unexpected yield reduction due to nutrient deficiencies.

TABLE 1: Mycorrhizal dependency rankings of summer and winter crops

Mycorrhizal dependency	Winter crops	Summer crops
Very high	Linseed Faba bean	Cotton Maize Pigeonpea Lablab
High		Sunflower Soybean Navybean Mungbean Sorghum
Low	Fieldpea Oats Wheat Triticale	
Very low	Barley	
Independent	Canola Lupins	

variety, and with the P and Zn status of the soil. Most pulse and oilseed crops have high to very high dependency and will therefore suffer more than a winter cereal if VAM levels are low.

Canola and lupins are not hosts of the AM fungi and are unaffected by fluctuations in AMF levels. But these non-mycorrhizal crops do not contribute to building up AM inoculum and so are not as beneficial as say wheat or sorghum in the rotation for a future AM dependent crop.

The graphs in Figure 1 illustrate how a crop's response to AM can vary with the P status of the soil. The difference between the mycorrhizal (+VAM) and the non-mycorrhizal (–VAM) line at any particular P level indicates its dependency.

Graphs such as these can also be used in a predictive sense to determine how much extra P would be needed if AMF were not present in the crop to achieve a particular growth level.

In these trials, nine summer and nine winter crops were tested on the Darling Downs for their P requirements with and without AMF.

Results confirmed that many crop species require only half the phosphate concentration in soil when they are colonised by AMF as they do without AMF for the same level of production.

The financial benefit

The phosphate benefit (measured as the cost of P fertiliser required to bring the soil to a P level where non-mycorrhizal plants grew and yielded equal to mycorrhizal plants) was in the range of $200–$500 per hectare for highly dependent crops and $90 per hectare for wheat.

Also, for the highly mycorrhizal-dependent crops, lack of AM colonisation has the potential impact of more than 50 per cent yield loss in soils with a bicarb-P level of less than 20 mg per kg soil.

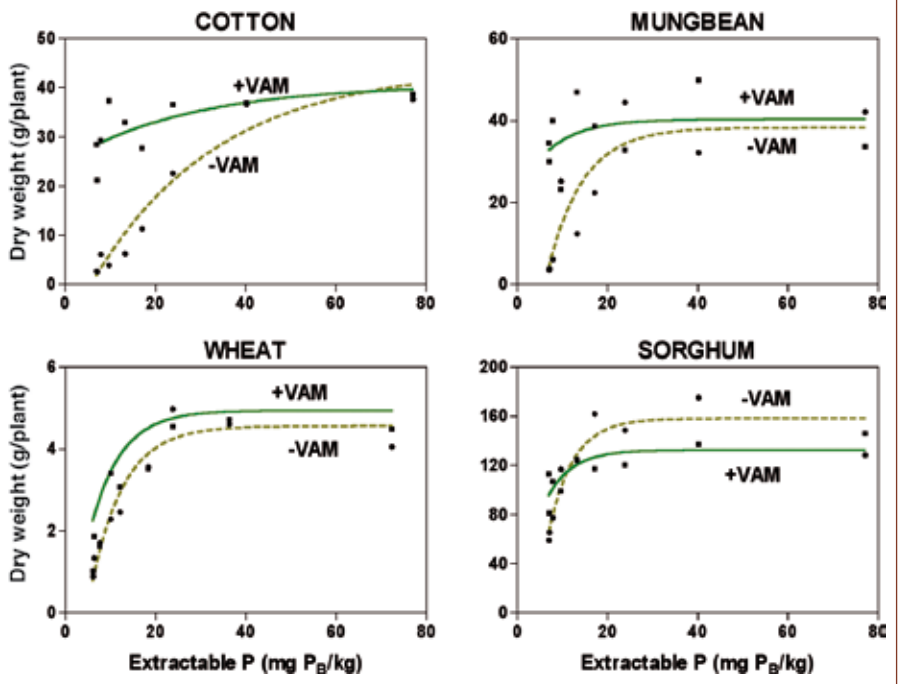
Understanding the potential level of mycorrhizal fungi in your soil can influence management decisions. High or low levels of AMF can be estimated by knowing the cropping history of the paddock – the length of preceding fallow, previous management practices and ability of previous crops to produce inoculum.

Previous research has shown that pulse crops generally perform well in producing spores as do sunflower and maize. In the cereals, wheat generally produces more spores than barley and canaryseed.

Non-mycorrhizal crops do not contribute to building up AM inoculum and should be treated like a bare fallow when considering AM inoculum potential.

Soil disturbance can also reduce VAM and so minimising tillage, especially during fallow periods, is more conducive to optimising AM levels. Heating of soil (such as, burning stubble) and flooding also negatively impact AMF numbers.

FIGURE 1: Dry weight response of crops to increasing P levels with and without mycorrhizal fungi in the soil



Predicting AM status

Predicting the mycorrhizal status of a particular crop is not straight forward; neither is estimating the optimum P and/or Zn fertiliser requirements of crops that you suspect will be low in AM. There is still much we do not know about how AM survival is influenced by soil temperatures and moisture levels – both in crop and during the fallow periods. Also, seasonal conditions can influence nutrient availability to crops.

Although wheat is generally considered to have a moderate to low dependency, the yield of wheat has been shown to be reduced by low VAM levels.

Trials on the Downs in 2000 showed that clean fallowing or growing canola instead of other crop species in the previous season resulted in lower numbers of AMF spores in the soil and in poorer root colonisation of the subsequent wheat (cv. Batavia) crop. The value of the AM to the wheat crop was quite large.

The alkaline soil (pH 8.8) was deficient in phosphorus but probably sufficient in zinc. Although P fertiliser was applied it did not correct the problem, as the fertiliser is thought to have been positionally unavailable in this dry growing season. Under these circumstances the wheat crop was clearly highly dependent on AM for adequate nutrition, growth and yield.

In other northern NSW trials around Goondiwindi and North Star, we demonstrated the value of higher AMF levels in soil to the following wheat after a break crop of millet was grown as compared to long fallowing from sorghum. Significantly increased AMF levels lead to better establishment and improved cereal growth.

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WHAT CAN YOU DO ABOUT LOW AM LEVELS?

- Grow crops with low or very low mycorrhizal dependency eg wheat or barley – they won't suffer much yield loss but will still increase the AM inoculum for following crops.
- Avoid non-mycorrhizal crops, as they will not increase AMF inoculum status.
- If you wish to grow a crop of high mycorrhizal dependency for reasons such as good price, apply high rates of P and Zn fertilisers.
- Adopt zero or reduced tillage practices during fallow periods, as this is less harmful to AMF than frequent tillage.