MYCORRHIZAS AND PLANT NUTRITION: LONG FALLOW DISORDER AND COTTON

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Mycorrhizas are symbiotic associations between the roots of plants and fungi. They come into existence when the plant's root system becomes infected with an appropriate fungus.

It is now known that mycorrhizas are essential for the establishment and growth of some plant species eg. orchids. In other plants growth can occur in the absence of mycorrhizas but growth is much better when mycorrhiza are present, particularly in soils that are deficient in immobile nutrients such as phosphorus. There are however some plant families that rarely form mycorrhizas. These include Chenopodiaceae (eg. saltbush), Cruciferaeae (eg. canola, brassica crops), Cyperaceae (eg. nut grass) and Juncaceae (eg. rushes). Moreover, in some plant families which are typically mycorrhizal (eg. Fabaceae - legumes) there are some species that do not form extensive mycorrhizas (eg. lupins). Trappe (1977) estimated that about 95% of the world's present species of vascular plants belong to families which are characteristically mycorrhizal.

In most types of mycorrhiza the fungus utilizes carbohydrate that has been produced by the plant as a result of photosynthesis. It is likely that the fungus also obtains other nutrients from the plant such as amino acids and vitamins. The host plant also provides the fungus with a habitat that is free from competition from other micro-organisms, antagonists and predators. The fungal mycelium grows out from the infected root into the surrounding soil and acts as an extension of the plant's root system absorbing nutrients such as phosphorus and zinc as well as water from the soil and translocating these through the fungal hyphae into the plant. Mycorrhizal plants with their "extended fungal root system" can therefore explore and exploit a much greater volume of soil than non-mycorrhizal plants. This often results in mycorrhizal plants being healthier and more vigorous than those that are non-mycorrhizal.

There are several different types of mycorrhiza, however the most common type is called a **V**esicular-**A**rbuscular endo**M**ycorrhiza (**VAM**). This type of mycorrhiza probably occurs in about 70 - 80% of plant species. The fungi involved are Zygomycetes belonging to the family Endogonaceae. At least four fungal genera form **VAM** i.e. *Acaulospora, Gigaspora, Glomus* and *Sclerocystis*. The name Vesicular-Arbuscular Mycorrhiza originated because the fungus produces dichotomously branched haustoria-like structures (called arbuscules) in the cortical cells of the root and characteristic vesicles between or within the cortical cells and on the surface of the root. Many important agricultural crop species form VAM including cereals, grasses and clovers, citrus, coffee, oilpalm, rubber, sunflower, cotton, linseed, etc. etc.

VAM fungi are obligate symbionts. They cannot be cultured on artificial media nor can they survive as saprophytes in soil. They are dependent on their host plant "partner". It is not surprising then that evidence is accumulating to suggest that VAM fungi survive poorly in disturbed soils that are devoid of vegetation. This applies to weed free, fallowed agricultural soils as well as to sites that have been seriously disturbed by operations such as mining and road construction. There are indications that the so-called 'long fallow disorder' that has been observed in crops such as wheat and cotton is related to the failure of VAM fungi to survive during long fallows. When plants are subsequently grown in this soil they fail to become mycorrhizal and show symptoms of nutritional deficiencies and slow early season growth.

VAMS AND PLANT GROWTH

Most plants can be grown in the absence of mycorrhizas provided that mineral nutrient supplies are adequate. However, the presence of VAM often stimulates plant growth particularly in soils that are deficient in elements such as available phosphorus and zinc. For example, Daft and Nicholson (1966) reported that the dry weight of tomato plants infected with *Glomus* sp. was 4.5 times greater than the dry weight of tomato plants without VAM. There are numerous reports that show similar effects in a whole range of crop species (Harley and Smith, 1983). The presence of VAM have also been shown to increase plant growth and nodulation in legumes.

Much of the work done on the part played by mycorrhizas in the uptake of nutrients by plants has involved the element phosphorus. Phosphorus normally exists in soil in immobile forms such as iron or aluminium phosphate and organic forms such as inositol phosphate. Although these forms of phosphorus are relatively immobile they are rapidly absorbed by plant roots that are directly in contact with them. This results in the zone around plant roots becoming depleted of phophorus. It has been shown that hyphae of VAM fungi explore large volumes of soil, very efficiently absorb phosphorus and other elements and translocate them to the plant root. The roots of plants infected with VAM fungi are larger and contain more phosphorus than uninfected roots. Work with onions infected with *Glomus* sp. showed that the inflow of phosphorus into the roots was 3 - 4 times greater in infected roots (Sanders and Tinker, 1973). It is also possible that hyphae can utilize sources of phosphorus that are unavailable to plants. Little information is available to support or refute this possibility.

The principles outlined for phosphorus can be applied to other nutrients including nitrogen and even water. Mosse and Hayman (1971) noticed that VAM-infected onions did not wilt when transplanted whereas uninfected plants did. Subsequent workers have reported similar findings and have shown that VAM-infected plants wilt at lower water potentials and recover faster after being exposed to water stress than uninfected plants.

VAM AND EARLY SEASON GROWTH OF COTTON

Rich and Bird (1974) investigated the increased early-season growth and development of cotton that was associated with early-season infection by VAM fungi in Georgia, U.S.A. They found that VAM infection resulted in an increased rate of growth and development of cotton root and shoot systems and earlier flowering and boll maturation. They also showed that VAM were present within five days of seedling emergence and that VAM infection proceeded rapidly between 5 and 25 days after seedling emergence. Up to 71% of roots eventually became infected by VAM fungi.

Afek et al. (1988) compared the growth of VAM-infected and uninfected cotton plants in fumigated and unfumigated soil in California. Fumigation eliminates most micro-organisms including VAM fungi from the soil. The dry weight of VAM-infected seedlings was 8.8 times greater in fumigated soil and 3.3 times greater in unfumigated soil.

PRELIMINARY STUDIES AT NARRABRI A.R.S.

(i) Methyl bromide was used to fumigate eight plots (each 2m X 10m) in an area (16 rows X 75m) of a field at the Narrabri Agricultural Research Station in September, 1989. Half of the area was planted with cotton on 5th October, 1989 and the other half was planted on 2nd November, 1989. The growth of seedlings in the fumigated plots was significantly reduced in comparison with the seedlings in the unfumigated area. Apart from being stunted the seedlings from the fumigated plots exhibited a range of symptoms which included pronounced zinc deficiency, death of leaf margins and dropping of cotyledons. Estimates of VAM infection and the results of tissue analyses are presented in Table 1. The greatest differences induced by soil fumigation and the consequent inhibition of VAM formation were reductions in phosphorus, zinc, copper and sodium and increases in manganese, iron, boron and aluminium. Nitrogen, sulphur, potassium, calcium, magnesium and chloride showed smaller differences associated with the fumigation treatment.

Table 1. An estimate of VAM infection (6 weeks after planting) and results of tissue analyses of cotton seedlings from fumigated and unfumigated plots in a field at the Narrabri Agricultural Research Station.

planting date	5/10/89		2/11/89	
fumigated	yes	no	yes	no
% VAM infection	0.5	72.0	8.1	56.0
phosphorus (%)	0.16	0.36	0.11	0.36
sodium (%)	0.06	0.12	0.05	0.06
copper (ppm)	11	15	9	12
zinc (ppm)	20	27	15	30
manganese (ppm)	90	52	100	62
iron (ppm)	170	88	173	96
boron (ppm)	109	47	120	41
aluminium (ppm)	104	39	72	46

The stunted plants in the fumigated plots eventually recovered and grew vigorously, becoming taller than plants in unfumigated plots. There was no significant difference in seed cotton yield from fumigated and unfumigated plots sown in early October. However, fumigated plots yielded 23.7% less seed cotton than did unfumigated plots for the early November sowing.

(ii) In December, 1989 samples were received from a property in the Brewarrina area. Plants from a newly developed field exhibited very poor early season growth when compared with plants from a nearby field which had been planted with cotton for the fourth successive year. Field history, planting dates, an estimate of VAM infection and the results of tissue analyses are shown in Table 2. Stunting and a lower level of VAM infection were accompanied by reductions in phosphorus, zinc, sodium, chloride and sulphur and increases in aluminium, iron and boron when compared with apparently healthy plants. Nitrogen, potassium, calcium, magnesium, copper and manganese showed small differences between healthy and unhealthy plants.

Table 2. A comparison between plants from two fields on a property near Brewarrina at eight weeks after planting.

field history	cotton cotton cotton	cleared of timber land levelling bare fallow
planting date	12-14/10/89	10-12/10/89
plant height	>25cm	<15cm
% VAM infection	61%	16%
sulfur (%)	0.53	0.34
phosphorus (%)	0.19	0.11
sodium (%)	0.21	0.09
chloride (%)	1.35	0.58
zinc (ppm)	15	5
iron (ppm)	44	75
boron (ppm)	53	66
aluminium (ppm)	25	65

According to the grower the stunted plants eventually recovered and grew vigorously. The observed differences in the levels of phosphorus, zinc, sodium, aluminium, iron and boron were consistent with those differences induced by soil fumigation in the experiment at the Research Station (Table 1).

CONCLUSIONS

There is evidence to suggest that low levels of VAM infection may be associated with slow early season growth of cotton especially where cotton is grown following a long fallow or extensive land levelling and development. There also appears to be differences relating to soil type with symptoms of long fallow disorder not appearing in some fields despite long fallow periods and present in other fields which have not been fallowed. Cotton grown in fields in the Galathera creek area near Narrabri commonly exhibit symptoms very similar to those observed in the plants from fumigated plots at the Research Station and those plants from the newly developed field near Brewarrina. We hope to use these data to help in future diagnoses of VAM problems.

The importance of mycorrhizas to early-season growth of cotton in Australia requires further investigation and consequently a study has been commenced with support from the Cotton Research Council.

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