

## VAM FUNGI IN COTTON SOILS OF EASTERN AUSTRALIA

P.A. McGee, V. Torrissi and G.S. Pattinson.  
School of Biological Sciences  
University of Sydney 2006 NSW.

VAM are important in the growth of cotton and the production of lint. VAM are a normal part of cotton plants and they are usually present in the roots. Only in their absence do we realise their importance. In syndromes like Long Fallow Decline or growth decline following land-planing, reduced plant growth and cotton production coincide with reduced VAM in roots, and reduced phosphorus content in mature plants. While we realise their importance, VAM are difficult to study.

VAM are an association between soil-borne fungi and the roots of most plants. For the fungi, the association is obligate, and growth of the fungi relies entirely on the host plant. We cannot see the fungi in soil, nor in the roots of the plant unless we use laboratory based processes. Thus study of the fungi and their effect on plants requires specialised equipment and trained staff. CRDC has funded VAM research for several years. **This paper summarises the research on the population biology of VAM fungi in cotton soils in eastern Australia completed at the University of Sydney.**

Our aim was to develop an understanding of the size, variation and changes in the fungal population so that we could predict what was likely to happen to production of cotton. Because we cannot grow the fungi independently of the plant, we first developed a system to quantify the fungi in soil. In this assay, the roots of a trap plant become progressively colonised. Figure 1 shows a typical pattern of root colonisation of a cotton seedling growing in a normal soil.

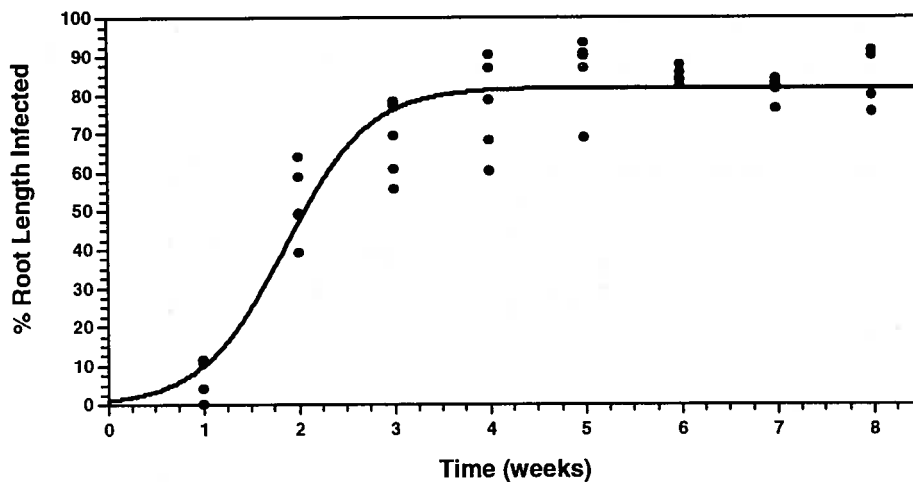


Fig. 1: Pattern of VAM colonisation of roots of cotton growing in surface soils.

Note that VAM are initiated within a week of germination of the seed. VAM spread within the root system such that by around 3 to 4 weeks, the maximal colonisation has been reached. In the laboratory, maximum is 90%, and in the field around 50 to 70%.

The rate of initiation of VAM depends mostly on the number of units of the fungus in the soil. VAM may be initiated from filaments of the fungi, from spores and/or from other colonised roots. In soil, most of the fungus consists of a dense web of filaments ramifying through the soil. We can measure the total length of fungal filament in topsoil, and use a stain to tell us if it is living (Fig. 2).

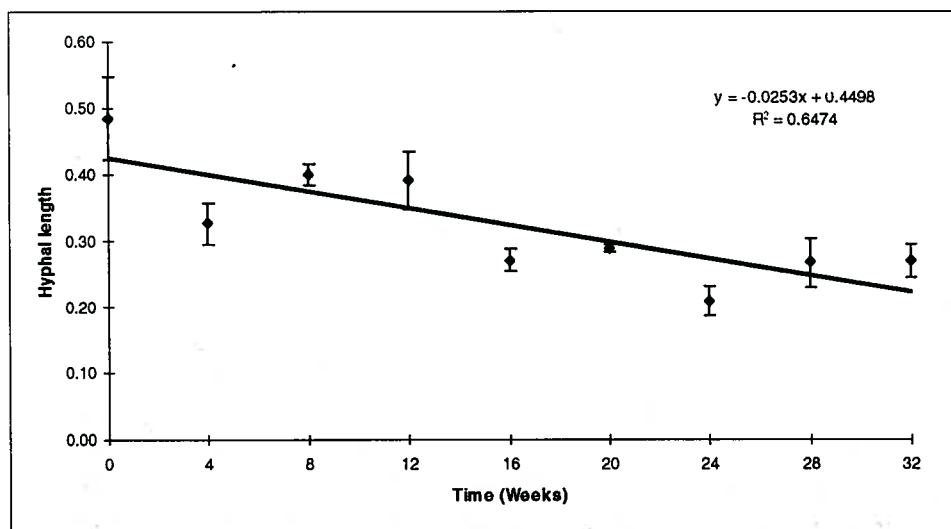


Fig. 2: Decline in viability of hyphae over 32 weeks in a typical cotton soil.

We can extract spores of VAM fungi from soil. Densities range from 3 to 200 spores per gram dry soil. Of these, about 6% are able to initiate VAM when fresh and less than 1% after 24 months. In cotton soils, roots rot very quickly, so their contribution to initiation of VAM is likely to be negligible.

We know the proportion of root colonised in normal soils. What happens when we cultivate the soil? We found that the extreme disturbance of sieving to simulate cultivation has had little effect on the colonisation pattern (Fig. 3).

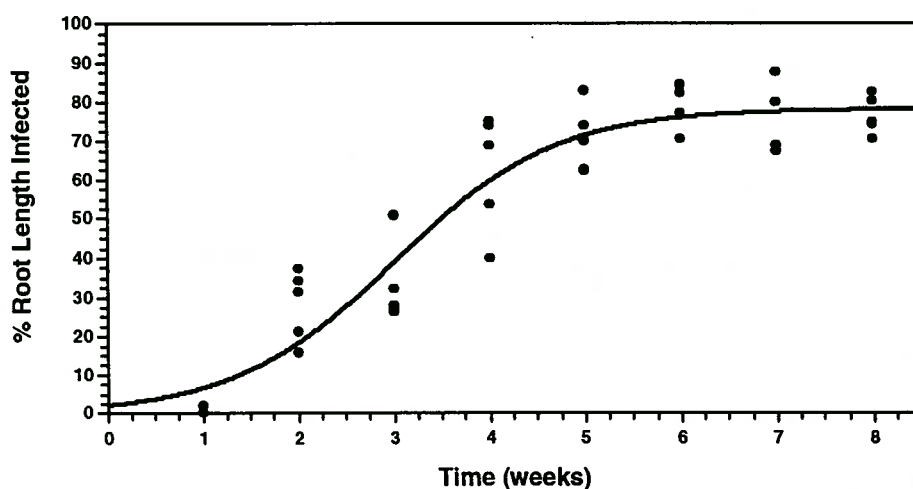


Fig. 3: Pattern of VAM colonisation of roots of cotton growing in soil that has been severely disturbed.

Note that at 3 weeks, the proportion of the root that is VAM remains higher than 35%. Cultivation of a normal soil has little effect on the population size of VAM fungi.

Soils are subject to periodic falls of rain. The rain wets the soil profile, probably germinating the VAM fungi. If the fungi cannot regain their dormancy as the soils dries, then they will die out. We wetted and dried a cultivated soil 5 times over 18 months and then measured the fungal population (Fig. 4).

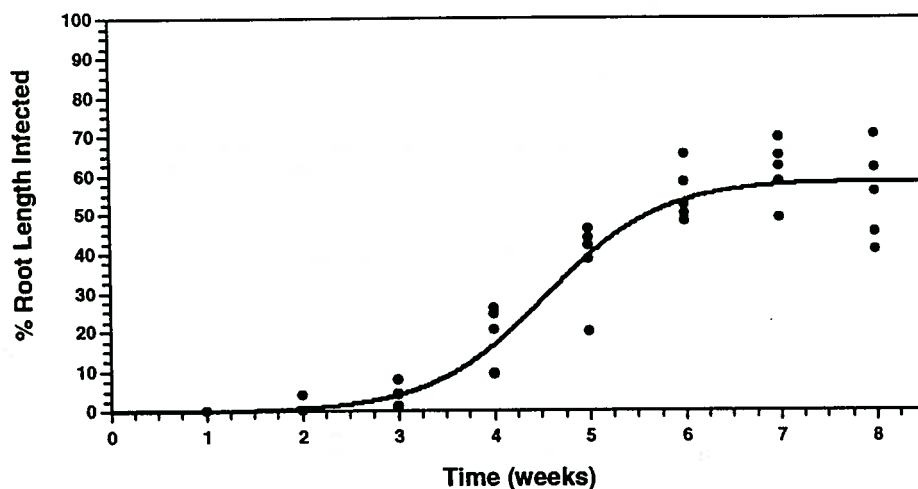


Fig. 4: Pattern of VAM colonisation of roots of cotton growing in soil that has been severely disturbed and subject to periodic wetting and drying.

Note that wetting and drying of cultivated soil has reduced quantity of VAM fungi. VAM fungi have died out. However, we cannot say how much fungus has died, and how much fungus we need to establish a normal pattern of VAM in the root system. We created soils with 1, 10 or 100 colonising units of VAM fungus using dilution of a known fungus. We placed these different densities of fungus under trap plants and monitored the development of VAM over 7 weeks, to determine the minimum number of colonising units needed for maximum VAM (Figs 5, 6 & 7).

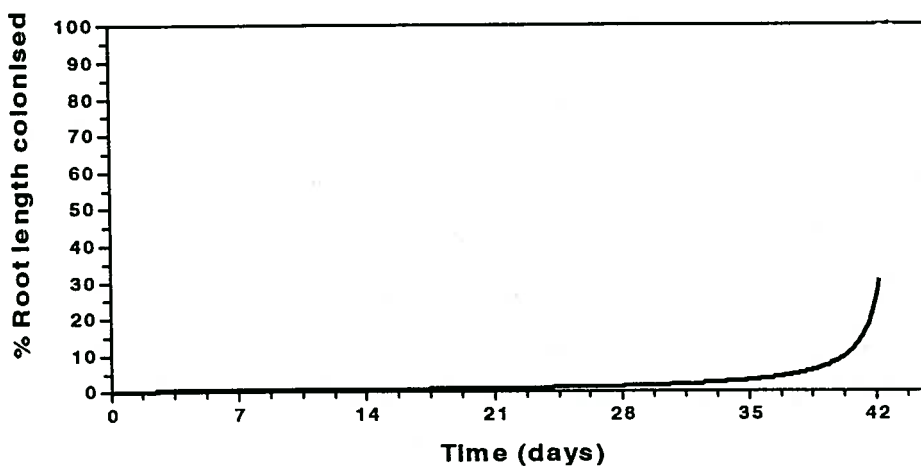


Fig. 5: Mean percent colonisation after being inoculated with 1 propagule of VAM fungi.

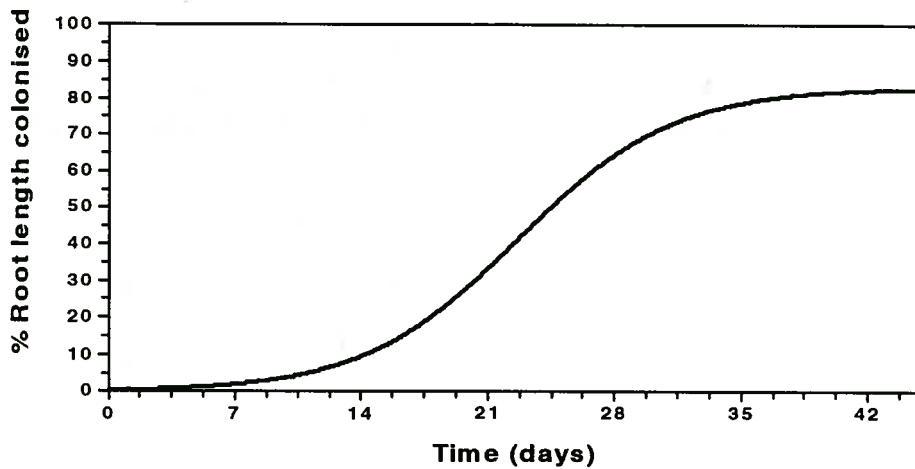


Fig. 6: Mean percent colonisation after being inoculated with 10 propagules of VAM fungi.

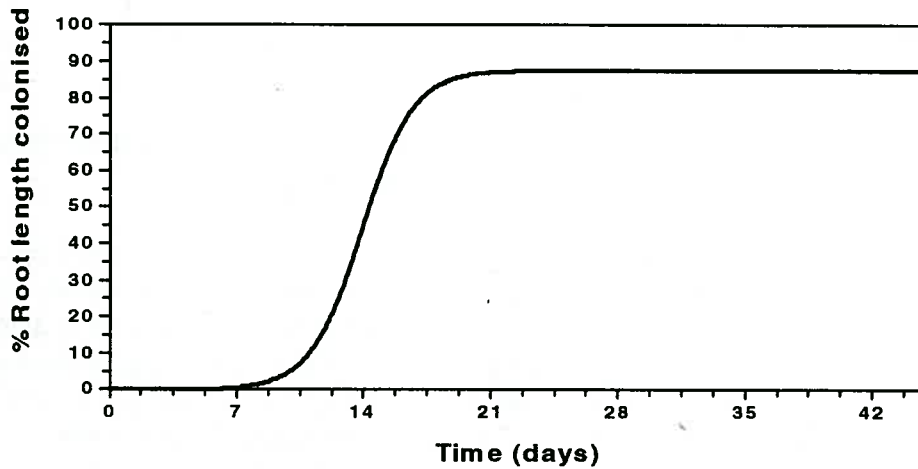


Fig. 7: Mean percent colonisation after being inoculated with 100 propagules of VAM fungi.

Note here that 100 units of VAM fungus per 100 mg soil is required to establish maximum rates of VAM in cotton. The pattern under 1 unit is typical of the VAM in cotton grown in severely depleted soils.

We now have some understanding of how many units of fungus are needed to initiate VAM for normal plant growth. Can we expect the plant become mycorrhizal all the way down the root system? We next asked where in the soil profile are the VAM fungi located? We collected soil from pits at ACRI, Narrabri, and measured the density of VAM fungi using the bioassay (Figs 8, 9 & 10).

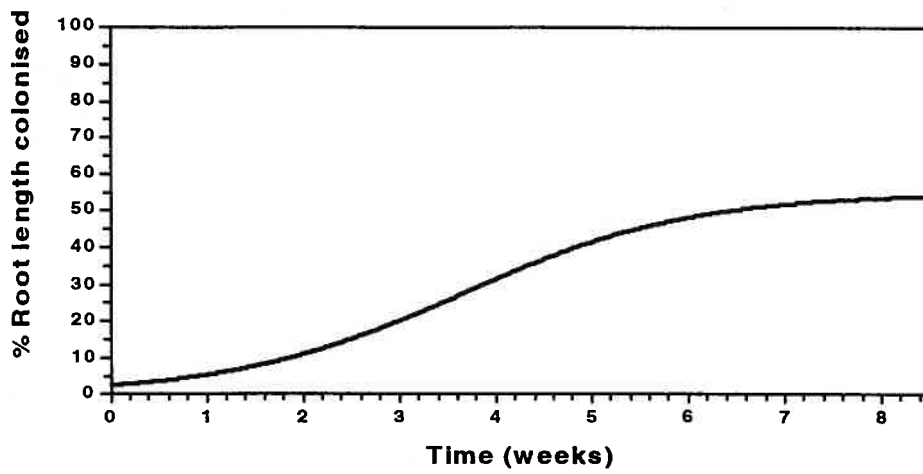


Fig. 8: Mean percent VAM colonisation of trap plants grown in soil from 20 cm

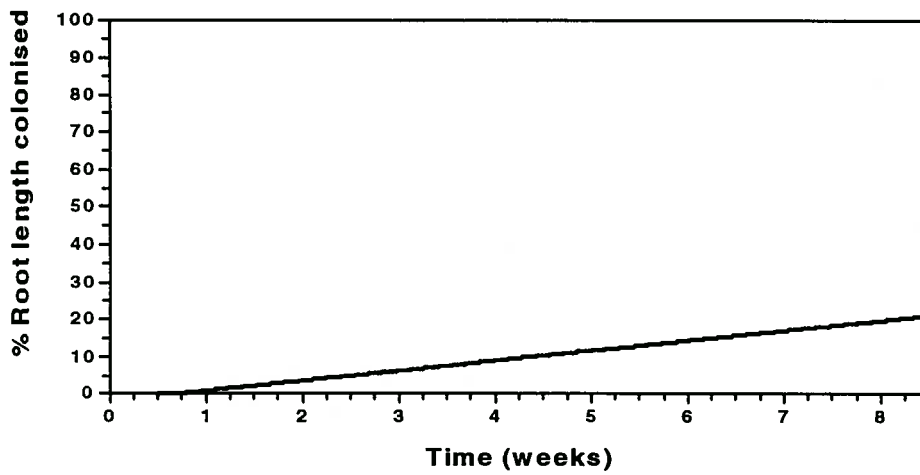


Fig. 9: Mean percent VAM colonisation of trap plants grown in soil from 50 cm

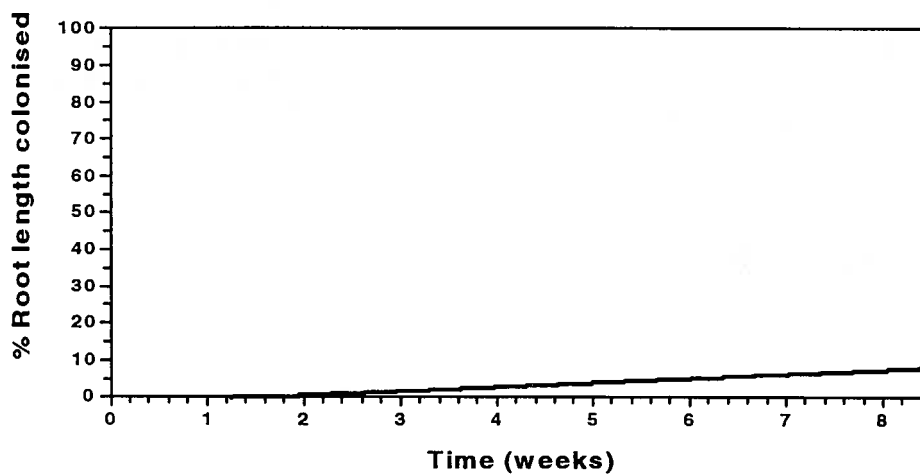


Fig. 10: Mean percent VAM colonisation of trap plants grown in soil from 100 cm

These figures shows us that the size of the population of VAM fungi declines rapidly below the soil surface. We have slightly reduced densities at about 20cm. At 50cm we would have fewer than 10 propagules per 100g soil and at 100cm, less than 1 propagule per 100g soil. Thus if we remove topsoil, if the top soil is wetted and dried or if we deplete the fungal population at the surface in some other way, we will have reduced VAM formation in our cotton plants, and possibly reduced cotton production.

The pattern of initiation of VAM is complicated by many factors. We have found that initiation of VAM also increases the local density of roots, so that root branching increases in the upper soil layers where the roots first become mycorrhizal. This has implications for water and fertiliser absorption by the plant. Increased root density following VAM colonisation in the surface soil means that most of the mineral nutrients will be taken up from the zone where fertiliser is placed, because the local densities of VAM fungi and roots are high. In roots with low VAM, not only are fewer minerals taken up by the fungi, but fewer roots will be active in the zone where fertiliser is deposited. Maintaining high densities of VAM fungi in the upper soils layers is crucial to maintaining plant health.

While VAM are found in roots down to 1m, we suspect that the VAM fungi found below about 30 cm from the surface do not grow beyond the root so are probably not helping nutrient uptake from soil. This needs to be examined more closely. If fungi do not explore soil beyond the root, they will not form survival units at depth, and we will never be able to rely on this resource when VAM fungi at the surface die out. We also suspect that the formation and function of VAM is stopped while the soil is saturated during irrigation because oxygen is absent in the soil. Also, a heavy clay soil will probably slow the rate oxygen moves to the roots and VAM fungi. Again, the issue of soil aeration and VAM fungi needs to be researched more closely. David Nehl has also found that some bacteria in soil reduce the capacity of roots to initiate VAM. Some of these bacteria appear to be very common in heavier soils. We would expect that VAM are active only when the soil is oxygenated, and if this is the case, then VAM would function for shorter periods in saturated soils, especially in heavy clays and the plants would be stressed. The stresses would be twofold: minerals such as Zinc and Phosphorus are more likely to become deficient, and the plants more vulnerable to pathogens.

**In conclusion, we can now tell you what is going on in a normal soil. We can now measure what happens when the normal pattern becomes disturbed. We understand the reasons for some changes to VAM fungi, some others remain unclear.**