

DO LONG FALLOWS DECREASE MYCORRHIZAS IN COTTON?

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A partnership between plants and fungi

Most agriculturally important plants, including cotton, are colonised by soilborne fungi known as arbuscular mycorrhizal fungi (AMF). The AMF depend on the plant to supply their energy, in the form of sugars. These fungi colonise the roots internally and develop highly branched structures (arbuscules) inside individual cells of the root. Fungal filaments also grow into the soil surrounding the roots, where they absorb 'immobile' elements such as phosphorus and zinc. The phosphorus and zinc are transported to the roots and transferred to the plant in the arbuscules. Generally, the improved nutrition of the plant outweighs the cost of supplying the fungi with sugars. This type of partnership, is known as arbuscular mycorrhizal symbiosis. In the field, cotton is highly dependent upon AMF for successful growth and always forms arbuscular mycorrhizas (Nehl et al. 1994).

The AMF cannot grow on dead organic matter in the soil. If plants are absent for long periods the population of AMF may decline and mycorrhizal development in subsequent crops may be reduced. This lack of mycorrhizal development, and consequent nutritional deficiencies (phosphorus and zinc), was reported to be the primary cause of long fallow disorder in many field crops (Thompson 1987, 1994).

This concept has been extrapolated to cotton, although supporting experimental evidence is lacking. Farmers and agronomists commonly assume that long fallows (17 to 18 months) will result in reduced mycorrhizal development and growth of cotton. Pattinson and McGee (1997) observed a substantial decline in the population density of AMF when soil from cotton fields was stored for 18 months and subjected to a combination of mechanical disturbance and wetting and drying cycles. However, long fallows did not result in a decrease in mycorrhizal development of cotton in a large scale field experiment (Hulugalle et al. 1998) and in four smaller-plot experiments (Nehl et al. 1994). We now present further data confirming that long bare fallows (18 months) and rotation with canola (a non-mycorrhizal plant) do not decrease mycorrhizal development in subsequent cotton crops.

Irrigated winter-crop rotation

Cotton was sown in a field at the Australian Cotton Research Institute (ACRI) after: bare fallow, no cultivation; bare fallow with cultivation; wheat; chickpea; linseed; canola. The winter crops were sown immediately after the previous cotton crop, then harvested in November and the plots were left bare until cotton was sown the following October. The experiment was repeated once in the same field. In both years, colonisation of cotton by AMF was no lower after long bare fallow than with any of the other crops (Table 1). In the 1992/93 cotton, colonisation was greatest when the bare-fallow soil was cultivated but this was not evident in the repeat experiment (Table 1).

Table 1. Mycorrhizal colonisation and growth of cotton after bare fallow for 18 months or rotation with winter crops

Previous crop	1992/93 cotton crop		1994/95 cotton crop	
	AM root (%)	Shoot mass (g/plant)	AM root (%)	Shoot mass (g/plant)
18 months BF uncultivated	30bc	1.6	49	0.74
18 months BF cultivated	38a	1.6	40	0.67
Wheat	36ab	1.8	38	0.74
Chickpea	25c	1.5	36	0.67
Linseed	31abc	1.7	39	0.63
Canola	30bc	1.3	35	0.68
Probability	$p = 0.05$	NS	NS	NS

Values in columns followed by the same letter are not significantly different at the stated probability level ($\alpha=6$). AM = arbuscular mycorrhizal, BF = bare fallow, NS = not significant.

Rain-fed farming system

Cotton was sown every two years on a commercial farm near Warra, Queensland, with no irrigation and the following rotations between cotton crops: bare fallow; summer sorghum; winter wheat or barley (sown straight after cotton, as above). In comparison to rotation with winter or summer cereals, colonisation of cotton by AMF was not reduced by long bare fallows (Table 2). There were no significant trends in mycorrhizal colonisation over time in any of the treatments.

Table 2. Mycorrhizal colonisation of cotton after bare fallow for 18 months or rotation with winter and summer cereals in a non-irrigated farming-systems experiment

Treatment	Arbuscular mycorrhizal root (%)		
	1994/95	1996/97	1998/99
Bare fallow	65	71	56
Sorghum	62	54	68
Wheat*	64	55	55
Probability	NS	NS	NS

* Barley used as the 1993 winter crop. NS = not significant

'Nurse' crops

At a rain-fed site, on a commercial farm near Jimbour, Queensland, where a long-fallow problem for cotton was predicted, 'nurse' crops were grown with the intention of increasing the inoculum of AMF. before sowing cotton. The field had experienced 15 months of bare fallow when nurse crops, wheat, barley, field pea or sunflower, were sown in August. The nurse crops were killed with glyphosate at six weeks after sowing. Bare soil was the control, having 17 months bare fallow by the time cotton was sown in October. Adjacent to each block of treatments, two rows of linseed (1 m long) were sown as a bioassay for AMF. Soil from a nearby wheat crop was buried beneath one of the rows of linseed to provide inoculum of AMF. The mycorrhizal colonisation and growth of linseed was reduced dramatically when it was sown without the inoculum transferred from an adjacent wheat crop (Table 3). In contrast, there was no difference in colonisation of cotton by AMF following the nurse crops or long bare fallow for 17 months (Table 4). Shoot growth of cotton was significantly greater after a nurse crop of wheat but not the other crops.

Table 3. Mycorrhizal colonisation and growth of linseed after bare fallow for 15 months, with and without whole-soil inoculum from a nearby wheat crop

	No inoculum	Inoculum	Probability
Arbuscular mycorrhizal root (%)	3	24	$p < 0.001$
Shoot height (mm)	45	67	$p = 0.016$
Shoot mass (mg/plant)	19	44	$p = 0.037$

Table 4. Mycorrhizal colonisation and growth of cotton after bare fallow for 17 months or 15 months bare fallow followed by 'nurse' crops

Nurse crop	Arbuscular mycorrhizal root (%)	Shoot mass (g/plant)
None (bare fallow)	53	1.5b
Field pea	54	1.9ab
Sunflower	65	2.1ab
Barley	57	2.4ab
Wheat	53	2.9a
Probability	NS	$p \leq 0.007$

Very long fallows

With the current drought, some cotton fields have experienced bare fallows of two years or more and there is a concern that the mycorrhizal fungi will not survive such long periods. Test strips of linseed and cotton (2 m long) were sown in March 2004 in 12 eight-row plots in each of two fields at Bourke where very long bare fallows have occurred (Table 5). Mycorrhizal colonisation of cotton usually peaks at around six weeks after sowing in commercial crops, at levels around 50% or higher. Given that both fields experienced very long bare fallows, the cotton and linseed were fairly well colonised by mycorrhizal fungi at the time of sampling (Table 5). Cool temperatures were experienced from the end of April onwards, which may have slowed the rate of spread of colonisation within the root systems. The barley in field 75 only emerged 4-5 days before sampling and was not yet colonised.

Table 5. Mycorrhizal (VAM) colonisation of roots of cotton and linseed after very long fallows at Bourke

	Field 45/46	Field 75
Fallow length	28 months	35 months
Effective sowing date*	24 March	30 March
Sampling time	42 days	36 days
Linseed VAM (%)	29 ± 3.1	37 ± 2.5
Cotton VAM (%)	28 ± 1.6	35 ± 1.2

* Seed was sown in both fields on 19 March into dry soil and then irrigated at the dates indicated.

Given the length of time that the mycorrhizal fungi have survived in these fields without any host plants, it is anticipated that, a substantial amount of viable fungus will be present in both fields when cotton is sown in October 2004. The eight-row plots were sown with 'nurse' crops of barley and the effect on subsequent mycorrhizal development in the 2004/05 cotton crop will be monitored.

Discussion

The popular belief that bare fallows of 17 to 18 months reduce mycorrhizal development in cotton is misconceived. Mycorrhizal colonisation was not reduced by long bare fallows in any of the

experiments, nor by rotation with a non-mycorrhizal crop (canola). In most experiments the levels of mycorrhizal colonisation were consistent with those normally observed in cotton (Nehl et al. 1996; Pattinson and McGee 1997; Hulugalle et al. 1998). At some sites the development of mycorrhizal colonisation can be slower than elsewhere in the same field (Nehl et al. 1994) but other soil factors are involved (Nehl et al. 1996).

The increased growth of cotton after a 'nurse' crop of wheat was not related to mycorrhizal colonisation and suggests that factors other than AMF were capable of decreasing cotton growth after long bare fallows. Mycorrhizal development in linseed was clearly inadequate at the same site where it was sufficient for cotton, suggesting a differential compatibility between plant hosts and a given population of AMF (McGee et al. 1999).

Mycorrhizal colonisation of cotton can develop very rapidly from small numbers of propagules of AMF (McGee et al. 1999). While the population of AMF may decline somewhat during 18 month bare fallows (Pattinson and McGee 1997), the remaining inoculum is clearly adequate for cotton. Bare fallows for longer periods than those observed here may indeed cause a mycorrhizal problem in cotton, especially if they are accompanied by cycles of wetting and drying (Pattinson and McGee). When soil was stored in the laboratory for 18 months under dry conditions the decrease in AMF was not substantial (Pattinson and McGee). Hence, it is likely that the very dry conditions experienced at Bourke contributed to the preservation of AMF in the soil for periods of 35 months or more.

The AMF in the soils used to grow cotton in Australia are undoubtedly indigenous populations that have evolved to cope with long periods of drought. Rainfall events are likely to be accompanied by the growth of weeds, many of which will be suitable mycorrhizal host plants. Periods of very long bare fallow with wetting and drying cycles but no rotation crops or weed growth may lead to inadequate mycorrhizal development in cotton. However, such periods are unlikely to occur under the current cotton farming systems in Australia.

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