EFFECTIVITY OF ARBUSCULAR MYCORRHIZAS IN SUSTAINABLE GRASSLAND AGRICULTURE FOLLOWING CONVERSION FROM INTENSIVE MANAGEMENT

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ABSTRACT

With increased interest in sustainable agriculture, attention has focused on the role of arbuscular mycorrhiza (AM) in the productivity of agricultural systems. AM spores were taken from grassland and grass-arable systems with either a history of high-input, conventional, or low-input, organic management, and used as a source of inoculum in host plants (*Allium amelioprasum, Trifolium repens* and *Lolium perenne*). Spores from organic management systems produced a greater yield response than those from conventional systems. Where various spore inoculum produced differences in host growth responses, it was observed that the infected root of these host plants also produced similar responses when used as a further source of inoculum. This indicated that differential effects of AM from organic and conventional systems are not solely related to differences in spore quality as a result of direct effects of conventional management (*e.g.* use of fertilisers or fungicides) but also to long term changes in AM populations.

INTRODUCTION

Arbuscular mycorrhiza (AM) are non-pathogenic fungal associations of plant roots linked with improvements in plant nutrition and health which occur in over two-thirds of all vascular plants (Brundrett, 1991). AM hyphae which extend into the soil are involved in the uptake of immobile nutrients such as phosphorus (P) (Jakobsen, 1992). Their role in conventional agriculture, however, may be limited (Bethlenfalvay, 1992). Under conventional management systems there may be a selection for AM species/strains which are adapted to these conditions (e.g. high levels of P; Manske, 1990), which may be unsuited to the conditions following conversion to low-input or organically managed systems (Bethlenfalvay, 1992). In conventional agriculture the use of chemical control agents such as fungicides may also have more direct adverse effects on AM populations (Nemec, 1980). The aim of this study was to determine what, if any, effects there were on the effectivity of AM taken from high-input, conventionally managed and low-input, organic systems, and if such effects existed, to determine how long they persisted. The work focused on grassland but also included grass-arable rotation cropping systems.

METHODS

General methods

Host plants. Leek (*Allium ameloprasum*) was chosen as it is highly mycotrophic and so a good indicator of changes in AM effectivity, measured in terms of plant dry weight, following inoculation and root infection. Ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) were used as representatives of the dominant flora in managed UK grassland. All clover plants were inoculated with *R. trifolii* (SP20 from IGER).

Growing medium. Soil of the same soil series as the source of AM inoculum was used as test growing medium. This was sterilised by irradiation (20 kGy; Isotron plc, UK) to remove all AM inoculum (to allow for non-AM controls), which was subsequently re-introduced in test treatments. All plants were grown in 1 litre pots in a glasshouse (20 ^{o}C/16 h photoperiod/automatic irrigation to field capacity).

Source soils. AM spores were taken from conventionally managed grassland (>300 kg/N/ha/yr. and 50-100 kg P/ha/yr.) and low input or organically managed soils (Anon (a), 1989). AM were also taken from the grass phase of grass-arable systems where fertiliser inputs in the conventionally managed grassland phase ranged 160-400 kg N/ha/yr. and 0-110 kg/P/ha/yr. Lower levels of fertiliser were generally applied to the arable phase (125-150 kg/N/ha/yr. and 0-150 kg/P/ha/yr.), the amount applied highly dependent on crop species.

AM inoculum. Spores were extracted from the soil using the sucrose flotation technique (Brundrett *et al.*, 1994). Approximately 1000 spores were used to inoculate each plant. Alternatively infected clover roots (equivalent to 0.5 g oven dry weight per plant) was used as inoculum.

AM assessment. Spore numbers and % root length infected on host plants were determined (Brundrett *et al.*, 1994).

P assessment. Carried out using standard procedures (Anon (b), 1986).

Principal experiments

Grassland inocula AM effectivity. AM spores taken from 13 farms (6 organic, 7 high input), all from the same soil series (Denbigh), were used as inoculum on leek, ryegrass and clover. Two non-mycorrhizal control treatments were included, one with added rock-P to test plant response to P.

Grass-arable rotation AM effectivity. AM spores were taken from a total of 25 farms managed for conventional or organic mixed grass-arable rotation, and representing three soil series (Bromyard, Denbigh and Wick). Clover and leek hosts only were used. Controls were as in the grassland trial.

Conversion AM effectivity. A more detailed study was undertaken of AM effectivity from farms that had converted recently from conventional to organic management (<10 yrs. ago), using Wick soils from the grass-arable study.

Root fragment inoculation. Infected root fragments of clover from the grass-arable study were used as inoculum on leek in order to determine if any differences in AM spore effectivity persisted to second generation inoculum.

RESULTS AND DISCUSSION

Grassland AM effectivity. Mean AM root infection in the field was higher in organic (63.5%) than in conventional soil (40.4%; P>0.001), as was spore density (organic-29.8 g/soil; conventional-12.9 g/soil; P>0.001). When used as sources of inoculum on leek and clover there were positive responses to AM in all treatments but the organic inoculum was more effective than the conventional (Table 1a). Host shoot P concentrations were similar for organic and high input treatments although there were positive response to inoculation. There were poor levels of AM infection (<20%) in ryegrass and it did not respond to inoculation or to the addition of rock phosphate (data not shown).

Although organic AM were more effective than conventional AM overall, AM from individual farms did not always follow this pattern (Scott *et al.*, 1995). With farm studies of this type there will inevitably be some uncertainty about management of individual fields (for example the amounts of fertiliser added). The differences in organic and conventional AM may also be partly attributable to the immediate direct consequences of conventional management (such as the use of fertilisers and chemicals). Evidence for this comes from the levels of AM root infection and spore density reported in the source fields (above).

Grass-arable rotation AM effectivity. Available P (mg/kg; values after irradiation) varied between the three soil series growing media used in the order Bromyard (7.65) > Wick (3.81) >Denbigh (0.40). There was a positive response to added P which was greatest in the low-P Denbigh soil (Table 1b). Most plants exhibited a positive response to AM inoculation. Generally the AM response (compared to controls) was lower in the Bromyard and Wick soils than in the Denbigh soil, in an inverse relationship to available soil P. Organic AM produced higher shoot yields in Wick and Denbigh soils in clover but only in Denbigh soil in leek. These variable effects of both added P and AM inoculation may be attributable in part to the differing soil P status of the soils investigated. The high P levels in Bromyard soil, even if under organic management, would tend to minimise the effect of P fertilisation on AM. In contrast, AM in low P Denbigh soils might exhibit greater adaptation to fertiliser inputs. Stronger selection pressures in low-P soils may have affected AM populations following fertiliser inputs. Other studies have indicated that the impact of fertilisers on AM is limited in higher fertility soils (Hayman, 1975; Jensen and Jakobsen, 1980).

Conversion AM effectivity. The effect of time of conversion from high input to organic management did not appear to affect AM effectivity although there was a progressive reduction in % AM root infection with the more recent conversions (Table 2). Although more study is required this is consistent with a progressive transition period for the recovery of AM populations following conversion to organic management.

Root fragment inoculation. There were positive responses of leek to clover root AM inoculum originating from both soil types studied (*Final Shoot dry weight (g), 63 days. Denbigh soil, Conventional: 0.18; Organic: 0.36, Control: 0.06. Wick soil, Conventional: 0.65; Organic 0.50, Control: 0.34*). Only the Denbigh soil AM produced a significant difference in plant response between organic and conventional managements (P>0.05). This suggests that earlier differences in AM spore effectivity were not solely related to the immediate consequences of management on spore quality or viability, but were also due to long term shifts in AM population structure. Further studies are underway examining the qualitative nature of such population shifts.

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