Current Nursery Practice With Regard to Mycorrhizas and the Propagation of New Zealand's Native Plants©

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Mycorrhizal fungi have great potential for use within plant nurseries as they can increase plant growth by increasing plant uptake of soil nutrients. This paper reports the findings of a survey of New Zealand native nurseries to determine whether nurserymen consider mycorrhizal fungi to be important for plant growth and whether they actively incorporate them into their propagation setups. It also explores in more detail the current means by which nurseries inoculate plants with mycorrhizal fungi. The majority of nurseries do consider mycorrhizal fungi to be important for plant growth and expend time and resources on their collection and use (82%). However, the methods currently employed by nurserymen lack efficiency and do not maximise the potential benefits of utilising mycorrhizal fungi. This can be addressed with a better understanding of the basic biology of the different types of fungi and how they interact with their plant hosts.

INTRODUCTION

The vast majority of New Zealand's indigenous flora is mycorrhizal, meaning most species form symbiotic associations with mycorrhizal fungi. The type of mycorrhizal association is dependent on the plant species in question. The great bulk of species form associations with the arbuscular mycorrhizal fungi (AMF), including the iconic podocarps, the myriad species of *Coprosma*, as well as the tussock grasses and ferns (Baylis et al., 1963; Baylis, 1967; Crush, 1973; Cooper, 1976; Johnson, 1977). *Nothofagus* form purely ectomycorrhizal (EMF) associations while *Kunzea ericoides* and *Leptospermum scoparium* are unusual amongst the flora by forming associations with both the AMF and EMF (Orlovich and Cairney, 2004). The biology of the different types of mycorrhizal fungi are very different; for example the AMF sporulate within the soil or even within plant roots while the EMF typically produce wind-dispersed spores from distinctive above-ground fruiting bodies (Smith and Read, 1997).

It is well established that plants inoculated with mycorrhizal fungi can enjoy improved growth rates compared with non-mycorrhizal equivalents, due mostly to increased uptake of soil phosphorous (Baylis, 1959; Gerdemann, 1964; Daft and Nicholson, 1966; Baylis, 1967). However, while early research focussed simply on presence versus absence of mycorrhiza, with presence almost invariably resulting in enhanced plant growth, more recent studies have revealed that the association is not always a mutualism; the association is found to lie on a mutualism-parasitism continuum depending on the specific plant-fungus combination (Johnson et al., 1997; Klironomos, 2003).

As a consequence of the enhanced growth rates possible, interest in the use of mycorrhizal fungi for industrial plant propagation is increasing and numerous my-

corrhizal inoculants are now commercially available. However, these are typically based on easy-to-culture species from a particular location within a single country. When sold on a non-local scale, e.g., internationally, these products form novel mycorrhizal associations with the indigenous flora being propagated (Mummey et al., 2009; Schwartz et al., 2006). It has been demonstrated that the use of exotic mycorrhizal species does not always result in increased growth of native plants (Requena et al., 2001; Richter and Stutz, 2002), and that non-native mycorrhizal fungi are not always able to survive in environments dissimilar to their native habitat (Gianinazzi and Vosátka, 2004). As a result, interest in the collection and propagation of indigenous cultures of mycorrhizal fungi for native plant production has been increasing, both within New Zealand (e.g., Williams, 2009, 2010) and internationally (e.g., Corkidi et al., 2008).

In light of the potential that specific mycorrhizal fungi have to either improve or reduce plant growth rates, the differences in the biology of the different types of mycorrhizal fungi, and the availability of off-the-shelf inoculants, it seems timely to conduct a short survey of native nursery practices with regard to the podocarps and mycorrhizas. The podocarps are of particular interest due to their typically slow growth rates, iconic nature and the high price seedlings carry for the consumer. The podocarps also specifically form AMF associations; therefore the survey is oriented towards the use of AMF. The purpose of the survey is to ascertain the following:

1) Are mycorrhizal fungi utilised in native plant propagation?
2) If so, are off-the-shelf products used or indigenous fungi?
3) If indigenous fungi are used, what material is collected?
4) When is the inoculum incorporated into the propagation setup?
5) Are fungicides used as part of common practice?
6) How important do nurserymen consider mycorrhizal fungi to be for plant growth and health?

METHODS

A total of 22 native nurseries were contacted covering both the North and South Islands. These were identified from a database of nurseries developed by Davis et al. (2009). The questions developed for the survey are shown in Table 1. The questions were designed to provide information on nursery practice, the state of knowledge of mycorrhizal fungi, and how, if at all, mycorrhizal fungi are applied to the system. Within New Zealand, the leaf litter and top surface of the soil (highly decomposed organic matter) is often referred to as "duff." In the questionnaire, "soil" refers to the top soil — up to 20 cm depth, including but not limited to duff. Each questionnaire was emailed to the individual nursery.

RESULTS

A total of 11 questionnaires were returned, giving a return rate of 50%; five were from North Island and six from South Island. Not all questions were always answered, or were answered in a format not allowing formal analysis, for example, giving a non-numerical answer to question seven (Table 1).

A high proportion of nurseries surveyed actively incorporate mycorrhizal fungi into their setups (82%), whether consistently or occasionally, depending on the species in question (Fig. 1A). Very few nurseries invest in off-the-shelf mycorrhizal fungi products (9%) with the majority opting to collect their own fungi (55%) (Fig. 1B),

which typically comes in the form of duff or top soil (27% each) (Fig. 1C). Most nurseries incorporate the mycorrhizal inoculum during the pricking out stage (45%) (Fig. 1D), when seedlings are lifted from seed trays and placed within individual containers. The majority of nurseries use a range of fungicides to control both root and foliar pathogens (45%) (Fig. 1E).

Of the 11 questionnaires returned, seven provided a numeric response to question seven (Table 1). The average response was 9.14 ± 0.42 (1 s.e.), showing that most nurserymen consider mycorrhizal fungi to be extremely important for plant growth and health. Of those not giving a numeric response, one felt that mycorrhizal fungi are not important within the nursery environment but carried a value of 8–10 for specimens post-planting, another thought they were only important for *Nothofagus*, while another felt more research was needed in order to better understand their importance.

Table 1. The questions included in the survey questionnaire.

1) What is the primary form of propagation – from seed or from cuttings? Please provide approximate proportions if both are used.
2) What is the approximate length of time to produce a plantable specimen, whether from seed or cutting (approximately 15–30 cm shoot height)?
3) What is the retail price for a plantable specimen (15–30 cm shoot height)?
4) Are you familiar with the term mycorrhiza, and what they do?
5) The use of mycorrhiza:
   a. Are mycorrhiza incorporated into the propagating medium at any stage?
   b. If yes, at what stage (e.g., at initial sowing of seed/insertion of cuttings, or when plants are 'upgraded' to larger containers.)?
   c. Are commercially available mycorrhiza products used or is material collected from forests?
   d. If commercially available products are used, which ones?
   e. If material is collected from forests, what is collected? Leaf litter, soil (what depth)?
   f. How are the mycorrhiza incorporated into the propagating medium (e.g., 50 : 50 mix with propagating medium)?
6) Are fungicides used? If so, at what frequencies and what type (e.g., once a year, foliar applied, systemic action)?
7) How would you rate the overall importance of mycorrhiza to plant growth (speed of growth, health of plant), where 0 indicates "of no importance," and 10 indicates "extremely important"?

DISCUSSION

The results show that the majority of native nurseries are aware of the value of mycorrhizal fungi and actively attempt to incorporate them into their propagation setups. In addition, native nurseries are expending time and resources into collecting indigenous mycorrhizal fungi rather than relying on exotic commercial products. This is encouraging, particularly because many of the plants sold are used in ecological restoration projects. Furthermore, pre-inoculation of plants with exotic

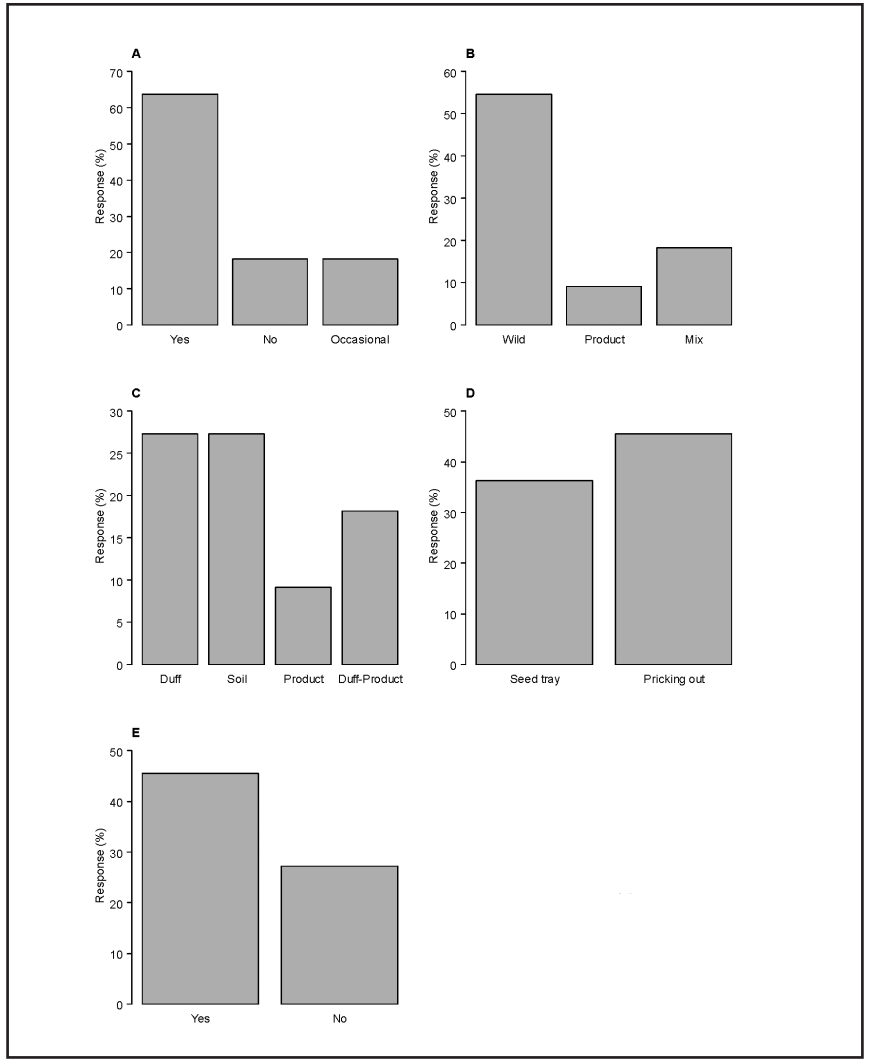

Figure 1. Questionnaire responses to the following questions: A: Do nurseries actively incorporate mycorrhizal fungi into their propagation setups? B: Where are mycorrhizal fungi sourced from? C: What type of inoculant is used? D: When is the inoculants incorporated into the propagation setup? E: Is fungicide used during plant propagation?

mycorrhizal fungi can have negative effects on realising the diversity of mycorrhizal fungi found within a natural ecosystem (Mummey et al., 2009), which can have subsequent negative effects for realising potential plant species diversity (Maherali and Klironomos, 2007). Indigenous mycorrhizal fungi can also drastically improve the growth of indigenous plants compared with nonmycorrhizal plants or those treated with exotic mycorrhizal fungi (Fig. 2).

Figure 2. Growth of *Podocarpus hallii* (mountain totara) cuttings with different AMF inoculants. From left to right, exotic AMF, mix of indigenous and exotic AMF, non-inoculated control, indigenous AMF.

However, despite this initial optimism it appears that the efforts invested in collecting indigenous mycorrhizal fungi may be being squandered. The two primary sources of inoculum used are either duff or top soil. As described earlier, duff is a term describing the leaf litter and highly decomposed organic matter found on the soil surface. This material is unlikely to contain suitable quantities of the infective AMF material necessary to initiate ecologically representative mycorrhizal associations. The podocarps, like the majority of New Zealand's native flora, form AMF associations (see Introduction). The hyphae of AMF proliferate within the soil rather than in the organic matter layer because they acquire nutrients from inorganic rather than organic sources (Abbott and Robson, 1991; Smith and Read, 1997). Furthermore, duff will consist mainly of spores rather than hyphae and will therefore only reflect the diversity of AMF species sporulating at the time of collection; this is not necessarily an accurate representation of the true diversity of the AMF community (Clapp et al., 1995). In order to collect large quantities of diverse AMF material, including hyphae, which are the primary method of AMF colonisation, the top soil down to a depth of 10–20 cm is required. This represents the rooting zone of most plants and thus ensures the rhizosphere, which contains the infective root, and hyphal and spore material, is adequately sampled (Corkidi et al., 2008). It is important to bear in mind that despite duff being a poor source of inoculum for AMF, it is the most important source of EMF material. Duff is therefore vital to ensure mycorrhizal colonisation of *Nothofagus, K. ericoides*, and *L. scoparium*.

Current nursery practice also appears to invest unnecessary time and effort in attempting mycorrhizal colonisation. The majority of respondents indicated that they add inoculum when transferring plants from seed beds or cutting trays to individual containers. In order to maximise mycorrhizal benefit the inoculum should be

incorporated into the propagation setup as early as possible, i.e., within seed beds or cutting trays (Gianinazzi and Vosátka, 2004). In addition to maximising benefit this method reduces both the quantity of mycorrhizal material necessary as well as the investment in time needed to inoculate a given number of plants.

The majority of nurseries regularly apply fungicide to their plants and propagation beds. This is an understandable practice given the loss that can occur if a pathogen were to proliferate. However, the use of such chemicals, particularly soil and systemic fungicides, is likely to detrimentally impact the mycorrhizal population. Research also indicates that the inoculation of plants with the appropriate mycorrhizal fungi can reduce the occurrence of fungal pathogens (Borowicz, 2001; Newsham et al., 1995; Whipps, 2004), meaning the use of mycorrhizal fungi could potentially reduce fungicide usage within nurseries.

In summary, it appears that the native nurseries of New Zealand appreciate the importance of mycorrhizal fungi for successful plant propagation and subsequent survival after sale. However, the full benefits of utilising indigenous mycorrhizal fungi could be optimised by a greater appreciation of both the associations that the different plant species form and the biology of the different types of mycorrhizal fungi.

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