The cultivation of Lactarius deliciosus (saffron milk cap) and Rhizopogon rubescens (shoro) in New Zealand

Wang Yun¹, Ian R. Hall¹, Carolyn Dixon², Maria Hance-Halloy¹
George Strong¹ and Peter Brass³

¹ New Zealand Institute for Crop & Food Research Limited, Invermay Agricultural Centre
Private Bag 50034, Mosgiel, New Zealand.
² New Zealand Institute for Crop & Food Research Limited, Canterbury Agricultural and Science Centre
Private Bag 4704, New Zealand.
³ Evandale Gardens, 112 Boxall Street, Invercargill, New Zealand.

Summary
Isolates of Lactarius deliciosus (saffron milk cap) were imported from Europe and Rhizopogon rubescens (shoro) fruiting bodies were collected in New Zealand. A series of inoculation experiments were then carried out in the laboratory, greenhouse and/or nursery. Seedlings of Pinus radiata, Pinus densiflora and Picea abies formed good ectomycorrhizas with all the isolates of the saffron milk cap and shoro produced good infections on P. radiata seedlings raised in a commercial nursery. Growth responses in response to infection were also detected.

Several hundred P. radiata were then infected with saffron milk cap and shoro and experimental plantations established when the trees were 18 to 26 months old. After 6 to 12 months the inoculant fungi had extended onto the new host root and at most sites contamination from competing fungi was minor. The first saffron milk cap fruiting body was produced after 18 months and the first shoro after 21 months.

Introduction
Expensive mycorrhizal mushrooms, like the Périgord black truffle, warrant the expense of establishing plantations dedicated to their production (Hall et al. 1998; 2001). However, for those edible mycorrhizal mushrooms that sell for more modest prices this may not be justified (Table 1). Instead, there is the possibility of producing these mushrooms as secondary crops in plantation forests (Hall & Wang 2000). If this was done in New Zealand's Pinus radiata D. Don forests there is the potential of not only making these mushrooms more readily available out-of-season for Northern Hemisphere markets but also improving the cash flow and profitability of the forests. The mushrooms that we decided to research first were those known to grow and fruit prolifically on Pinus radiata—Boletus edulis Bull.: Fr. (Eichler 1990), Lactarius deliciosus (L.: Fr.) S.F. Gray (Hall et al. 1998), and Rhizopogon rubescens (Tul.) Tul. (Hall et al. 1998). This paper covers our research on two of these—the saffron milk cap and shoro.

Lactarius deliciosus (saffron milk cap)
The saffron milk cap (Figures 1 and 2) (chilpán in Spanish, lactare délicieux in French, lapacendro buono in Italian and meiwei rugu in Chinese), grows in a mycorrhizal relationship with coniferous trees, in particular pine and spruce (Figure 3). Young saffron milk caps have a small depression in the centre of the cap's surface that gradually deepens so that mature caps become funnel-shaped. The caps and stalks are pale orange with darker orange blotches arranged in concentric rings on the surface of the cap. Both exude a bright orange latex when damaged. Green stains develop on the caps and gills as the caps mature or if they are bruised (Figure 4). The gills, which are bright orange in young caps and turn dull carrot-coloured as they mature, are attached to the stalk and extend a short way down it.
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east Asia (Figure 5). Like most edible mycorrhizal mushrooms it has not been cultivated and so supplies are largely restricted to what can be harvested from the wild during the Northern Hemisphere autumn.

**Rhizopogon rubescens (shoro)**

While shoro (Figure 6) can be found fruiting at the soil surface, this mushroom, just like the truffle, is also found below ground. Typically, fruiting bodies are spherical, 1-7 cm in diameter, white with pinkish or reddish blotches when young, turning light to mid-brown with age. When conditions are dry, the surface of the fruiting body can crack, showing the lighter coloured interior. When young, the interior of the fruiting body is pale, spongy and edible but as they mature, the contents become darker and unpalatable.

Shoro was consumed in large quantities in Japan in the 19th century, particularly in the Osaka and Kyoto districts. However, shoro is now rare in Japan and many Japanese chefs are unsure how to cook it although it is still has a significant market amongst gourmets. Its appeal is not in its flavour, which is very mild, but in its crisp texture, which is referred to by Japanese as having a good tooth touch. The sponge-like texture of the fruiting body also allows it to absorb the flavours of food with which it is cooked.

**Materials and methods**

**Lactarius deliciosus**

Isolates of the saffron milk cap were prepared from good quality fruiting bodies collected from areas in northern Europe which had a similar climate to the area in New Zealand where it was planned to grow them. These were imported into New Zealand and subcultures prepared. A series of inoculation experiments were then carried out in the laboratory to determine the ideal strains for establishing mycorrhizas with *Pinus radiata*, *P. densiflora* and *Picea abies* (Figures 7-9). Techniques were also developed for producing sufficient *Pinus radiata* infected seedlings to establish small experimental plantations (Figure 10).

**Figure 7:** Containerized *Pinus radiata* seedling inoculated and infected with *Lactarius deliciosus* at Invermay Agricultural Centre, Mosgiel, New Zealand. 

**Figure 8** and **9:** *Lactarius deliciosus* infections synthesised on the roots of *Pinus radiata* in Crop & Food Research’s laboratories. They are bright orange when young but eventually turn dark green.

**Figure 10:** Maria-Lidia Hance and George Strong next to the first tree to produce a *Lactarius deliciosus* fruiting body in an experimental *Pinus radiata* plantation, North Otago, New Zealand.
In spring 2000, two experimental plantations were established, one in the North Island and the other in the South Island on 18 to 26 month old well infected *Pinus radiata*. The experimental area in the South Island was an existing 5 year old coastal radiata pine plantation in North Otago at 45°S. Short rows of the existing trees were first cut off at ground level and then the saffron milk cap plants interspaced between them (Figure 10). There was, therefore, some potential for contamination from the existing mycorrhizal fungi on the surrounding resident pines and the roots of the decapitated trees. The North Island site at 38°S was an area adjacent to an existing well established *Pinus radiata* plantation where there was also some potential for cross contamination.

**Rhizopogon rubescens**

If the growing of edible mycorrhizal mushrooms in plantation forests is to be an economic proposition the cost of the infected plants must be such that it does not add greatly to the cost of the plantation. Consequently, we decided to develop techniques for infecting seedlings with shoro that could be readily adopted in the nursery. The seedlings were, therefore, raised in Evandale Gardens nurseries, Invercargill, New Zealand, using its standard precision seeding techniques and its standard potting mix. Apart from some attention to additional hygiene requirements no other precautions were taken.

When the plants were 18 months old, well infected and 65 to 75 cm high (Figure 11), they were transplanted in August/September to four field sites, two near Motueka near Nelson, one in the Esk Valley, South Canterbury, and one at Hampden, North Otago. Three of these were pastoral sites while the fourth at Esk Valley was a cutover site previously occupied by radiata pine—areas where radiata pine might normally be expected to be grown. With the exception of a few plants that were planted inside Tree Guard® boxes at the very exposed Hampden site, no special precautions were taken with the infected plants. They were planted by normal contract labour and release sprayed with herbicides when necessary.

There were no uninfected controls because such plants would have been unlikely to have made reasonable growth after outplanting. Regular inspections of the plants and the mycorrhizal infections were carried out.

**Results**

**Lactarius deliciosus**

In the laboratory, seedlings of *Pinus radiata*, *P. densiflora* and *Picea abies* formed good ectomycorrhizas with all the imported isolates (Figures 7–9). The mycorrhizas were orange when young, becoming dark green with age with orange branched lactifers in the mantle (Figure 12). Growth responses as a result of the benefits the mycorrhizal relationship were also detected in the host plants.

After 6 months good infections were found on new roots in the plantations. The first saffron milk cap mushroom was collected in early March 2002 in the experimental plantation in North Otago when the pines had been in the field for only 18 months. Only one 15 cm diameter fruiting body was found but the bright orange and green mycorrhizas characteristic of the saffron milk cap were abundant on the roots of the experimental pines (Figure 13). This bodes well for further fruiting.

**Rhizopogon rubescens**

The samples of mycorrhizas taken from the plants 12 months after planting from all three pasture sites showed new shoro infections. However, there was poor survival of the shoro in the cutover site. The first shoro fruiting bodies were recovered from one of the two Nelson pastoral sites in April 2001, just 21 months after planting (Figure 14). Plant growth was very impressive with the trees making about 3 m during the first 3 years after planting (Figure 15).
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Discussion

While fruiting of the Périgord black truffle in artificial truffières can generally be expected to start 5 to 10 years after planting (Chevalier 1998; Lefevre & Hall 2000; Olivier 2000) and occasionally after only 3 years (Giovannetti 1994), in nature 20 years elapse before truffles can be expected. A similar delay is also
expected before matsutake fruits in its natural habitat in Japan (Wang et al. 1997) while the earliest Watling (pers. comm.) has observed porcini fruiting on birch in Scotland is 7 years. To get fruiting of both shoro and saffron milk cap in less than 2 years in our field experiments was, therefore, something of a surprise.

New Zealand is unique in that most of the native plants form vesicular-arbuscular mycorrhizas with only a handful of southern beeches (Nothofagus spp.) and Leptospermum the only native ectomycorrhizal plants (Hall et al. 2001). Despite the introduction of many tree species from the Northern Hemisphere and Australia which form an association with ectomycorrhizal fungi, the number of ectomycorrhizal fungi in New Zealand remains relatively small. It seems possible that this lack of competition for the saffron milk cap and shoro may have been, at least in part, responsible for their proliferation on the roots of the host plants and their early fruiting.

With the Périgord black truffle we now have been able to get three of the eight edible mycorrhizal mushrooms we are researching to fruit in New Zealand (Hall 2001). We are now reasonably confident that eventually we will be able to get Tuber borchii, Tuber uncinatum and hopefully Boletus edulis to fruit too. Hopefully our experiences with these mushrooms will lead us to success with the prix de prix of the edible mycorrhizal mushrooms—Tuber magnatum (Italian white truffle) and Tricholoma matsutake (matsutake).

References