Truffles and Mushrooms

(Consulting Ltd)

Cultivation of the Périgord black truffle in New Zealand on limed, naturally acidic soils.

a translation of a paper originally published in French:

Ian R. Hall & Wang Yun. 2003. Culture de la truffe noire du Périgord en Nouvelle-Zelande sur sols naturellement acides, amendes. Resumes des interventions, Journee nationale de la trufficulture. 28 March 2003, Cuzance, pres de Martel, Lot. CTIFL, Paris. Pp. 3-8.

P.O. Box 268, Dunedin, New Zealand
telephone +64-3-454 3574
mobile: +64-27-226 1844
email: info@trufflesandmushrooms.co.nz
web www.trufflesandmushrooms.co.nz

Contents

1 Summary

Research on the cultivation of *Tuber melanosporum* (Périgord black truffle) began in New Zealand in the mid 1980s. Few of the edible mycorrhizal mushrooms of commercial importance have made the accidental journey from their natural home in the Northern Hemisphere to the Southern Hemisphere. For quarantine reasons it was not possible to import infected plants from Europe but techniques were eventually devised for producing commercial numbers of *T. melanosporum* infected plants. These plants had to be free of contaminating ectomycorrhizal fungi because only a handful of New Zealand's native trees form ectomycorrhizas and, consequently, large areas of the country are more or less free of ectomycorrhizal fungi. Most of these plants were planted into naturally acidic soils that had been heavily limed.

The first Southern Hemisphere truffles were harvested on 29 July 1993, five years after planting, in a truffière near Gisborne on the east coast of the North Island. There then followed a period of several years when *Tuber maculatum* and *Tuber dryophilum*, probably from a nearby willow tree, invaded the truffière and appeared to replace the Périgord black truffle. However, after a modified management regime was put in place the first commercial harvest was made in June 1997.

Of the eleven truffières established prior to 1990, *T. melanosporum* truffles have now been found in six, five of which were establish on naturally acidic soils. Because these truffles are produced counter season to Europe, premium quality New Zealand *T. melanosporum* truffles currently sell for around €1650—about the price of preserved truffle in Australia.

2 Introduction

Very few European mycorrhizal mushrooms eaten in the Northern Hemisphere occur in the Southern Hemisphere. Some of the exceptions are cèpe de Bordeaux (*Boletus edulis*), saffron milk cap (lactaire délicieux, *Lactarius deliciosus*), bianchetto (truffe blanche de borch, *Tuber borchii*) and shoro (*Rhizopogon rubescens*). These are assumed to have made the accidental journey from their natural habitats in the Northern Hemisphere to the Southern Hemisphere on the roots of small oaks and other ectomycorrhizal plants taken by the early European settlers as reminders of the lands of their birth. Regrettably few French, Italian and Spanish were amongst those early settlers and so most of the edible ectomycorrhizal mushrooms of commercial importance do not occur in the Southern Hemisphere, for example, the Périgord black truffle (truffe de Périgord, *Tuber melanosporum*), Italian white truffle (truffe blanche d'Alba et du Piémont, *Tuber magnatum*) and chanterelle (girolle, *Cantharellus cibarius*). For the same reason the Japanese mushroom delicacies matsutake (*Tricholoma matsutake*) and honshimeji (*Lyophyllum shimeji*) are also absent. Because of this out-of-season chefs and gourmets in the Northern Hemisphere must rely on preserved edible mycorrhizal mushrooms.

In the early 1970s the first author became aware of the pioneering work being conducted in France and Italy on infecting plants with various species of *Tuber* under controlled conditions (e.g. Chevalier 1973; Fontana & Bonfante Fasolo 1971). When the first fruiting bodies were produced in experimental truffières (e.g. Chevalier & Grente 1978; Delmas & Poitou 1978) he decided that if it could be done in Europe then it might be possible to do the same in New Zealand.

3 Soil and climatic considerations

After convincing directors that there was a market for edible mycorrhizal mushrooms—a significant problem at a time when wild mushrooms didn't feature in New Zealand's cuisine—the first step in the research was to determine the climatic conditions in those areas of France and Italy where *T. melanosporum* was found. This was achieved by superimposing climatic maps of France and Italy (Arléry 1970; Cantù 1977) on Delmas's (1978) map of the distribution of the *T. melanosporum* in France (Figures 1 and 2). Those areas in New Zealand with similar climatic conditions were then determined (New Zealand Meteorological Service 1980). Because New Zealand has a predominantly oceanic climate, summer temperatures are lower and winter temperature higher than similar latitudes in France (Figure 3). Irrigation water is plentiful in many parts of New Zealand and, consequently, rainfall was not considered a problem except in very wet parts of the country.

The second important consideration in the mid 1980s were the characteristics of the soils where the Périgord black truffle was found in Europe. This information was more difficult to obtain because the techniques used in French and Italian laboratories to measure nutrient concentrations were rather different from those used in New Zealand. However, sufficient information was eventually collected to enable comparisons to be made.

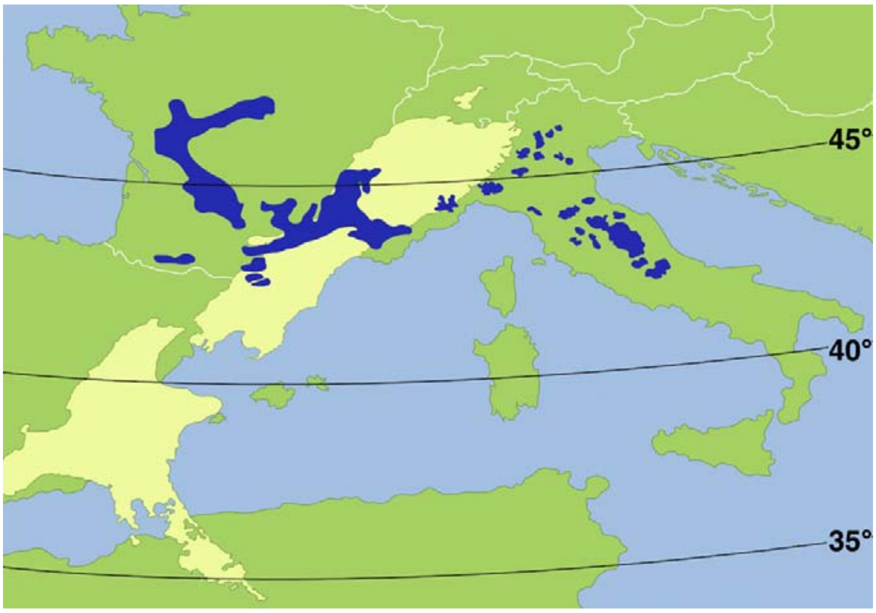

Figure 1. Distribution of the Périgord black truffle in France (blue) with New Zealand superimposed on France with equivalent latitudes.

Figure 2. Mean daily July temperatures in France (from Arléry 1970).

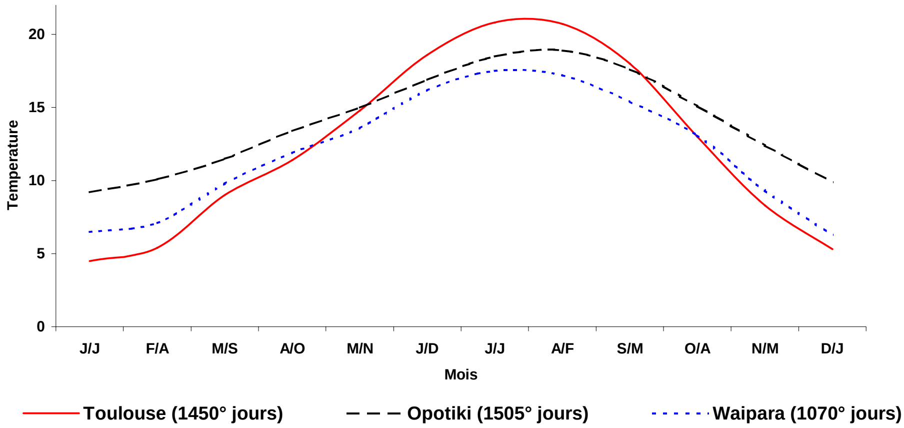

Figure 3. Temperature curves for Toulouse, France, and Opotiki and Waipara, New Zealand.

4 Production of Périgord black truffle infected plants

The third and most important hurdle that had to be overcome was to source *T. melanosporum* infected plants. In the mid to late 1800s when cèpe de Bordeaux accidentally entered New Zealand, there were no controls on what could or could not be imported. However, the serious ecological problems caused by introducing animals such as rabbits and plants like gorse (*Ulex europaeus*) has resulted in ever tightening controls on the importation of exotic organisms. It was, therefore, impossible to import *T. melanosporum* infected plants from Europe because of the chance that these might carry plant pathogens such as *Cronartium quercuum* – a rust that can attack pines. Needless to say French and Italian companies producing *T. melanosporum* infected plants were not prepared to release confidential information regarding the details of producing truffle infected plants. Consequently, the first author had to develop his own methods from basic principles relying heavily on techniques he had used in the previous decade when researching arbuscular mycorrhizal fungi.

In 1987, within two years of beginning research, a few hundred *T. melanosporum* infected plants were produced in New Zealand and these were used to establish two small truffières in North Otago (45°S) on rendzina soils with pH 7.8 - 8.1. Considerable publicity surrounded these first experiments and generated a demand for *T. melanosporum* infected plants by the general public. It was therefore decided to set up a small facility to produce sufficient T. melanosporum infected plants to meet market demand.

Because almost all New Zealand native plants form arbuscular mycorrhizas there are very large areas free of ectomycorrhizal fungi that might compete with *T. melanosporum*. It was, therefore, considered unacceptable to supply potential growers with *T. melanosporum* infected plants contaminated with other ectomycorrhizal fungi on their roots. While the currently used techniques are not perfect we expect a success rate of around 95%.

5 The first truffières

Prospective growers of our *T. melanosporum* infected plants were advised that the ideal conditions were:

- Warm summers and cool winters,
- A free draining, high pH (above 7.5 with an optimum of 7.9), well aerated soil with a well defined structure, about 400 mm deep overlying a limestone base e.g. rendzina and related soils,
- Irrigation water,
- The absence of other trees that may have competing fungi on their roots.

However, many people who expressed an interest in the New Zealand *T. melanosporum* programme owned land with naturally acidic soils. After testing their soils these people were given an estimate of how much lime would need to be applied to their soil to raise the pH to the optimum of 7.9. The soils were then retested at intervals to determine when sufficient lime had been applied. Overall approximately 2 tonnes of lime needed to be applied to raise the pH by 0.1 pH unit. The soil conditions before and after liming in the eventually successful truffières are presented in Table 1. Prior to planting weeds were eliminated, the soils worked to about 150 mm and irrigation equipment installed (extended periods of drought can occur almost anywhere in New Zealand).

Fences or windbreaks were erected around the perimeter of most of the truffières to keep out stock and wild pigs. Between 1987 and 1993 we followed French recommendations (Grente & Delmas 1974) that planting densities should be around 800 per hectare. However, we now believe a planting density of 400 per hectare is better particularly in the cooler parts of the country (Hall et al. 2001, 2002). The most significant problem we encountered was a very large fall in available iron concentrations as the pH was raised, that occasionally led to iron deficiency particularly in oaks (Figure 4). This is now treated by mixing iron chelates with the soil in the rooting zones. Pruning, tillage and general maintenance were similar to recommendations published by Sourzat (1989) and largely follow the Pallier method (Figure 5-10).

By 1990 eleven *T. melanosporum* truffières had been established between the Bay of Plenty in the North Island (38°S) and North Otago (45°S) in the South Island. Some information on the climate in these areas is presented in Table 2.

Table 1: Average soil conditions in some productive New Zealand truffières.

Truffière	Soil	Previous use	pH natural / current	Total calcium (%) after modification	Available calcium after modification MAF units	C/N ratio	Phosphorus ppm	Magnesium MAF units	Iron ppm
Bay of Plenty	Volcanic	Pasture	6.2 / 8.0	2.4	18	12.9	3	9	71
Gisborne	Alluvium	Miscellaneous crops	6.9 / 7.9	*c.* 0.8	31	*c.* 10.0	20	34	87
Taumarunui	Volcanic	Pig pen	5.3 / 7.8	2.6	20	13.8	66	10	90
Paraparaumu	Sand dune	Pasture	5.8 / 7.8	1.6	29	*c.* 9.1	6	22	96
Nelson	Heavy clay	Pasture	5.9 / 7.6	*c.* 3.0	13	*c.* 13.3	60	8	36
Canterbury	Rendzina	Pasture	8.0	5 - 37	31	*c.* 10.5	5	10	31

To convert available calcium, potassium and magnesium MAF units to ppm multiply by 125, 20 and 5 respectively.

Table 2: A rough comparison of the climatic conditions in the Périgord black truffle-growing areas of France and Italy and at New Zealand Meteorological Service stations (1983) adjacent to productive and non-productive Périgord black truffle truffières.

	Range in France, Italy and Spain	Productive areas							Non-productive areas	
		Opotiki	Gisborne	Taumarunui	Paraparaumu	Nelson	Waipara	Ashburton	Christchurch	North Otago
Latitude	41 - 47°	38	39	39	41	41	43	44	43	45
Elevation (m above sea level)	200 - 1300	6	9	171	7	10	64	101	7	70
Annual rainfall (mm)	600 - 1200	1400	4058	1443	1054	986	729	757	648	522
Accumulated degree days (>10°C)	900 - 1900	1493	1430	1292	1167	1038	1049	896	974	600-900
Mean daily temperature in summer (July in Northern Hemisphere, January in Southern Hemisphere)	(16.5°C -) 17.5 - 22°C	18.5	18.3	18.3	17.1	17.2	17.5	16.5	17.0	16.4
Mean daily temperature in winter (January in Northern Hemisphere, July in Southern Hemisphere)	1 - 8°C	9.2	9.0	7.9	8.3	6.5	6.5	5.2	5.6	4.9
Annual sunshine hours	1900 - 2800	2169	2172	1704	2043	2397	1999	1892	1999	1095
"Summer" sunshine hours (April to September in Northern Hemisphere, October to March in Southern Hemisphere)	1200 - 1800	1227	1238	1079	1227	1377	1175	1092	1175	1221

Figure 4. Iron deficiency has been the most significant problem encountered in New Zealand when raising the pH of soils.

Figure 5. Prior to planting a Tuber melanosporum truffière on an alluvial silt near Gisborne, North Island, New Zealand. Note the 4.4 m high windbreak and a willow tree which was probably the source of the contaminant Tuber maculatum (see Figure 7).

Figure 6. Brûlés 11 months after planting the Gisborne truffière shown in Figure 5.

Figure 7. The contaminating fungus Tuber maculatum *that overran the Gisborne truffière six years after planting.*

Figure 8. Aeration of the ground with spring tines is a common practice in New Zealand truffières.

Figure 9. Gisborne truffière five years after planting showing the extensive brûlés.

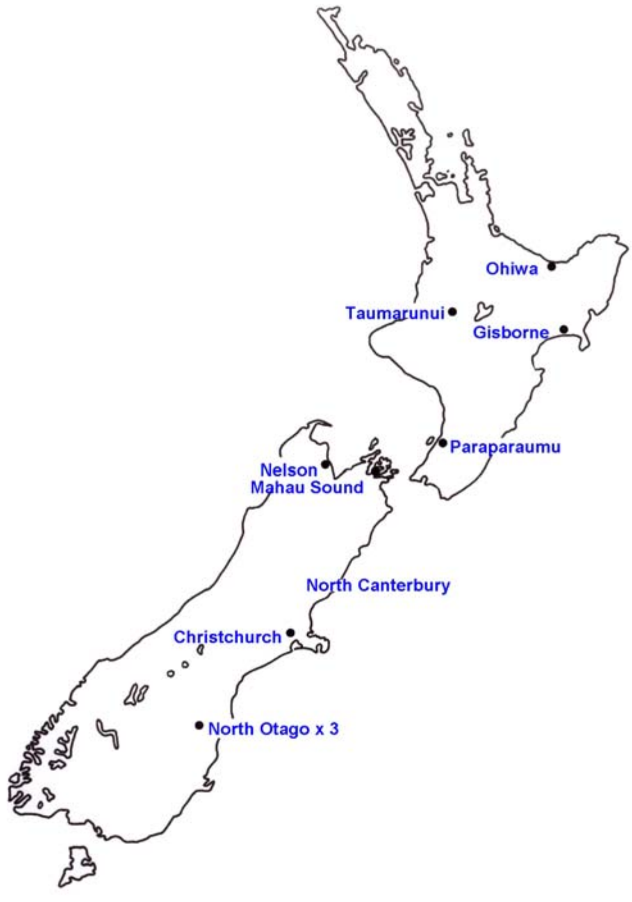

Figure 10. Location of the first eleven truffières established in New Zealand prior to 1990.

6 *First truffles*

The first Southern Hemisphere *T. melanosporum* truffles were found on 29 July 1993, exactly five years after planting, in a truffière near Gisborne on the east coast of the North Island (39°S). There then followed a period of several years when *Tuber maculatum* and *Tuber dryophilum*, probably from a nearby willow tree, invaded the Gisborne truffière and appeared to replace T. melanosporum. However, after a modified management regime was put in place, in June 1997 the first commercial harvest was made (Figures 11 – 13).

Figure 11. The first commercial Tuber melanosporum *truffle was harvested by Dr Alessandra Zambonelli in June 1997.*

Figure 12. The average size of Tuber melanosporum *truffles produced in Gisborne is around 200 g although some have approached 1 kg.*

Figure 13. Despite the high planting density (800 trees/ha) and almost complete canopy the Gisborne truffière continued to produce Tuber melanosporum *truffles in 2002.*

T. melanosporum truffles have now been found in six of the original 11 truffières established prior to 1990. All of these are situated north of Christchurch (38°S to 43°S) while none of the truffières in or south of Christchurch have produced any truffles so far. Of the six productive truffières, five were established on naturally acidic soils. We understand that of all of the productive *T. melanosporum* truffières outside of Europe—in North Carolina, northern California, New Zealand and Tasmania—only one has been established on a soil with a suitably high pH. It seems likely that the reason for this is simply because the vast majority of the truffières outside of Europe were established on naturally acidic soils. However, it is also possible that by liming an acidic soil the conditions become unsuitable for any ectomycorrhizal fungi that might be naturally present and that this results in relatively little competition for *T. melanosporum*.

The highest New Zealand yield has been from a small truffière near Ohiwa in the Bay of Plenty (38°S) that had been established in 1988 on a volcanic ash soil with a natural pH of 6.2. In 2002 this truffière produced 12 kg of *T. melanosporum* from 30 trees (Figure 14).

There are now around 100 *T. melanosporum* truffières in New Zealand containing about 30,000 trees. There are a similar number of trees planted in Australia, in particular Western Australia, Tasmania, Victoria and southern New South Wales.

Figure 14. The highest New Zealand production has been from a small 30 tree truffière near Ohiwa in the Bay of Plenty (38°S). Note the poorly formed brûlé.

7 *Prices for New Zealand produced* Tuber melanosporum *truffles*

Because New Zealand growers are producing truffles counter season to France, Italy and Spain and sell directly to the consumer, they are receiving around €1650/kg for premium quality *T. melanosporum* truffles–about the same price as preserved truffles retail in Australia. Most of these truffles have been consumed in New Zealand although small quantities have been exported to Australia, eastern Asia and North America.

8 *The future*

Research on *T. melanosporum* in New Zealand is now concentrating on soil, climatic and other factors that seem to be related to fruiting. This has been funded by a research levy of €2.5 paid on the sale of each *T. melanosporum* infected plant plus a €3.75 research grant from central government. In New Zealand we do not pretend that we have a thorough understanding of the way that *T. melanosporum* interacts with its edaphic, climatic and biotic environment, for example, what conditions are necessary to trigger fruiting. However, because of the lack of competing ectomycorrhizal fungi and wide range of climates and soils (and perhaps too, a lack of traditional beliefs) we have the opportunity to conduct long term experiments in what is in effect a large, open-air laboratory.

In addition to the production of *T. melanosporum* truffles we have also established experimental truffières with Burgundy and bianchetto[1] truffle infected plants. Other edible mycorrhizal mushrooms being investigated are those that might be produced as secondary crops in *Pinus radiata* plantations. So far shoro and saffron milk cap have been collected in experimental *P. radiata* plantations. Laboratory and greenhouse research is also being conducted on other edible mycorrhizal mushrooms such as matsutake, cèpe de Bordeaux and Italian white truffle.

[1] The first bianchetto truffles were harvested in August 2006 from a truffière just south of Christchurch.

9 References

Arléry, R. 1970: The climates of France, Belgium, The Netherlands and Luxembourg. In: Wallen, C.C. *ed.,* Climates of North and Western Europe, Volume 5. Amsterdam. Elsevier. pp. 135-193.

Cantù, V. 1977: The climates of France, Belgium, The Netherlands and Luxembourg. In: Wallen, C.C. *ed.,* Climates of North and Western Europe, Volume 6. Amsterdam. Elsevier. pp. 127-183.

Chevalier, G. 1973: Synthèse axénique des mycorrhizes de *Tuber brumale* Vitt. ā partir de cultures pures du champignons. *Annales de phytopathologie* 5: 163-182.

Chevalier, G.; Grente, J. 1978: Application pratique de la symbiose ectomycorhizienne: Production a grande echelle de plantes mycrhizes par la truffe (*Tuber melanosporum* Vitt.). *Mushroom science* 10: 483-505.

Delmas, J. 1978: *Tuber* spp. In: Chang, S.T.; Hayes, W.A. *eds,* The Biology and cultivation of edible mushrooms. London. Academic Press. pp. 645-681.

Fontana, A.; Bonfante Fasolo, P. 1971: Sintesi micorrizica di *Tuber brumale* Vitt. con *Pinus nigra* Arnold. *Allionia* 17: 15-18.

Grente, J.; Delmas, J. 1974: Perspectives pour une trufficulture moderne (edit. 3). Institut national de la recherché agronomique, Clermont-Ferrand.

Hall, I.R.; Brown, G.; Byars. J. 2001: The black truffle: its history, uses and cultivation. Reprint of second edition on CD ROM plus booklet. New Zealand Institute for Crop & Food Research Limited, Christchurch, New Zealand.

Hall, I.R.; Buchanan, P.; Wang, Y.; Cole, A.L.J.; Stephenson, S. 2003: Edible and poisonous mushrooms of the world. Timber Press, Portland.

Hall, I.R.; Wang, Y.; Danell, E.; Zambonelli, A. (eds) 2002: Edible mycorrhizal mushrooms and their cultivation. Proceedings of the second international conference on edible mycorrhizal mushrooms, CD-ROM. New Zealand Institute for Crop & Food Research Limited, Christchurch.

New Zealand Meteorological Service 1980: Summaries of climatological observations to 1980. Wellington. New Zealand Meterological Service miscellaneous publication 177.

Sourzat, P. 1989. Guide practique de trufficulture. Nouvelle edition. Cahors-Le Montat. Délégation Départementale des Services d'Agronomie du Lot.