

Extract from:  
The cultivation of mycorrhizal mushrooms - still the next frontier!

Keynote address – 18th Congress of the International Society for Mushroom Science,  
Beijing, 26-30 August 2012

In: J. Zhang, H Wang & M Chen (Eds). Mushroom Science XVIII. Beijing, China  
Agricultural Press. Pp 16-27.

Ian R. Hall

*Truffles and Mushrooms (Consulting) Limited and  
Edible Forest Fungi New Zealand Limited,  
P.O. Box 268, Dunedin 9054, New Zealand  
truffle1@ihug.co.nz*

and

*Alessandra Zambonelli  
Dipartimento di Protezione e Valorizzazione Agroalimentare,  
Università di Bologna, via Fanin 46, 40126 Bologna, Italy  
zambonel@agrsci.unibo.it*

After discussing the trials and tribulations of the cultivation of slow-growing mycorrhizal mushrooms, such as the truffles, over long timeframes, Ian Hall and Alessandra Zambonelli finished their Keynote address at the 18th Congress of the International Society for Mushroom Science, Beijing, 26-30 August 2012, with a brief look at applied research and its funding.

### **The future**

With fewer than a dozen edible mycorrhizal mushrooms having been cultivated [out of a total of 1000 species], and then not without significant difficulties [Figure 1], it can hardly be stated that science has made spectacular progress over the past 200 years. Supplies of two of the most commercially important edible mycorrhizal mushrooms, *Boletus edulis* (porcini) and *Cantharellus cibarius* (chanterelle), are still only available from the wild, and there is only a glimmer of hope that methods might become available (Hall unpublished data; Guerin-Laguette *et al.*, 2011).

We now have sufficient data showing that the income from moderately priced edible mycorrhizal mushrooms harvested from a plantation forest over one or two years can exceed the value of the timber at maturity (Figure 7). Despite this foresters seem reluctant to take advantage of this opportunity, presumably because it is not their “core business”.

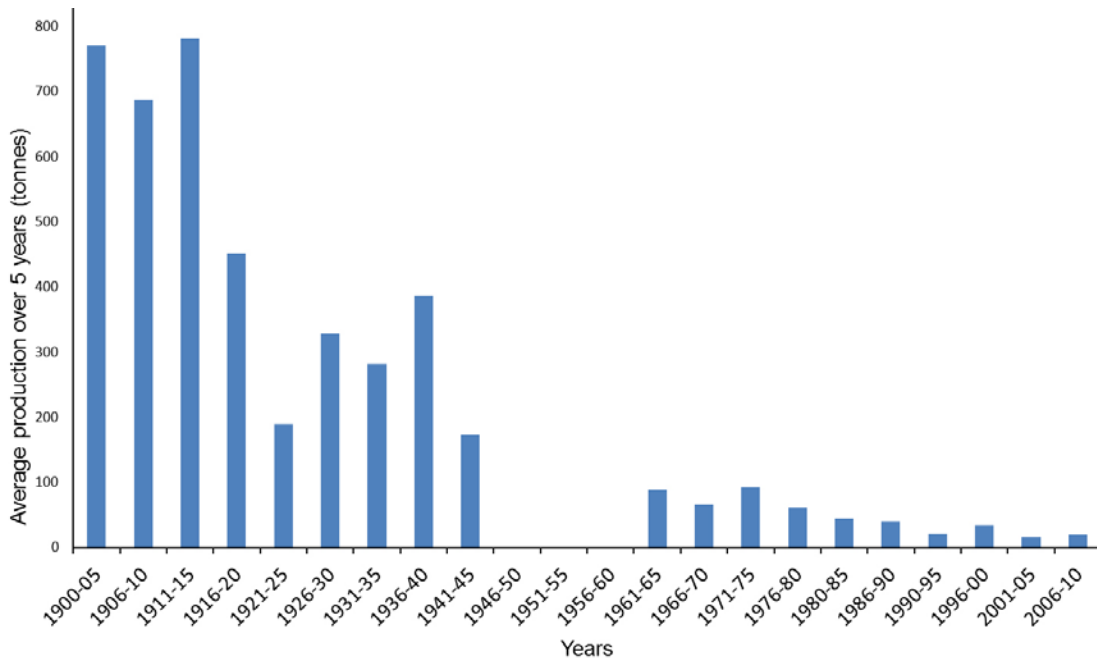


Fig. 1. Annual production of *Tuber melanosporum* in France between 1900 and 2010 averaged over 5 year periods. (Based on data from AFP 2010; Hall et al., 2007, 2009; Lee 2008; Provence beyond 2012; Sourzat 2007. Data from Sourzat multiplied by 1.89 to convert from market sales to estimated total harvests). [Current retail price > €1000/kg]

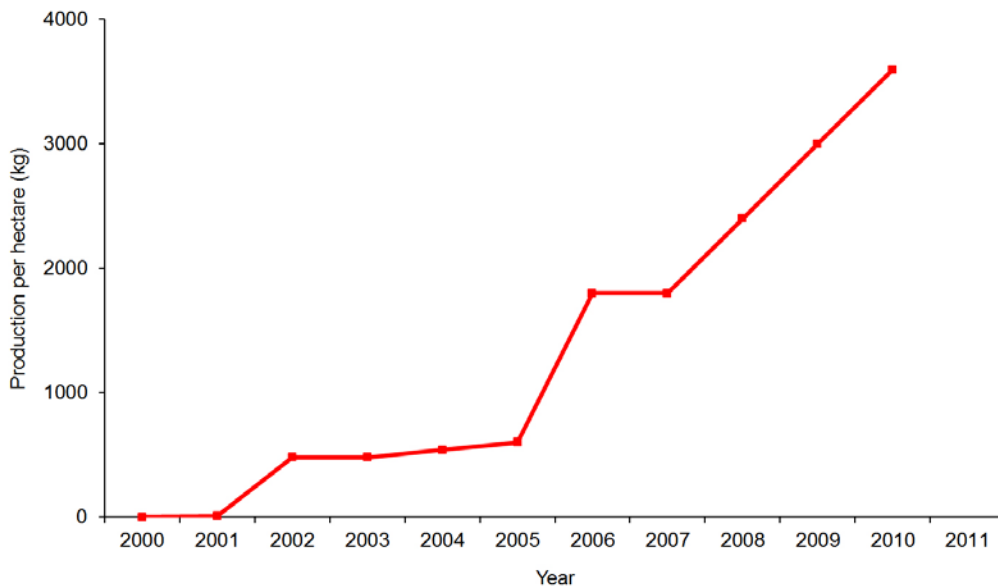


Fig. 7. Annual production of *Lactarius deliciosus* on *Pinus radiata* near Nelson, New Zealand, over 10 years after planting. [Current retail price ≈ €20/kg which gives an income from mushrooms in year 9 alone greater than the timber would be worth at felling.]

The science system has also been at fault. Research papers reporting the cultivation of a mycorrhizal mushroom in forests are not glamorous and are unlikely to attract space in high impact factor journals. In contrast, a study on say gene switching in a mycorrhizal mushroom

using the latest high tech molecular techniques, would, no doubt, attract one of the “best” journals. It would also prove enormously attractive to funding bodies despite having no immediate impact on the production of that mundane commodity – food. This situation is reflected in the numbers of papers on the production of edible mycorrhizal mushrooms over the past 20 years. Out of more than 11,000 scientific papers listed on the Mycorrhizal Literature Exchange web site (<http://mycorrhiza.ag.utk.edu/>) covering 1991 to 2009, only 15 papers mentioned *Boletus* and 22 mentioned *Cantharellus*, with only a small proportion of these reporting attempts at cultivation. It is often argued that pure research is needed to underpin the applied although in reality the transfer of information from one to the other is not common.

It is unfair to criticise researchers from shunning long term applied mycorrhizal research particularly if they have a contract that requires three scientific papers a year published in the upper third impact factor journals (Anon, 2012). Instead the blame can be placed firmly at the foot of the those who have fostered the impact factor model of assessing scientists and the requirement to publish rather than deliver something of real value. Surely, scientific papers are not what governments, industry and society really expects from science.

## References

- AFP 2011. Global warming threatens France's precious truffle. France 24. <http://www.france24.com/en/20111215-global-warming-threatens-frances-precious-truffle>
- ANON. 2012. Things to do in the Languedoc: eating: truffles. [www.languedoc-france.info/041305\\_truffles.htm](http://www.languedoc-france.info/041305_truffles.htm)
- ARLÉRY R. 1970. The climate of France, Belgium, The Netherlands, and Luxembourg. In: WALLÉN CC (ed). World Survey of Climatology, Vol. 5, Climates of Northern and Western Europe. Amsterdam, Elsevier. 135–193.
- BERTAULT G *et al.* 1998. Trifling variation in truffles [J]. Nature 394: 734.
- BONITO G TRAPPE J, DONOVAN S, *et al.* 2010. The Asian black truffle *Tuber indicum* can form ectomycorrhizae with North American host plants and can complete its life cycle in non-native soils [J]. Fungal Ecology 1:83-93.
- BREWER S, CHEDDADI R, DE BEAULIEU JL, *et al.* 2002. The spread of deciduous *Quercus* throughout Europe since the last glacial period [J]. Forest ecology and management 156:27-48.
- BUTLER G. 2007. The evolution of MAT: the Ascomycetes. In: HEITMAN J, KRONSTAD JW, TAYLOR JW, CASSELTON LA (eds). Sex in fungi: molecular determination and evolutionary implications. Washington, DC, ASM Press. 3–18.
- BRUNI F. 1891. Tartufi [M]. Hoepli, Milano.
- CANTÙ, V. 1977. The climate of Italy. In: WALLÉN CC (ed). World Survey of Climatology, Vol. 6, Climates of Central and Southern Europe. Amsterdam, Elsevier. 127–183.
- CHEVALIER G, DUPRÉ C. 1990. Recherche et expérimentation sur la truffe et la trufficulture en France. In: BENCIVENGA M, GRANETTI B (eds). Atti del secondo congresso internazionale sul tartufo. Spoleto, Italy, 24–27 November 1988. Spoleto, Comunità Montana dei Monti Martani e del Serano. 157–166.
- CHINAMAPS.ORG. 2012. China climatic maps: China Climate Map - average temperature in January, average temperature in July. [www.chinamaps.org/china/china-temperature-map.html](http://www.chinamaps.org/china/china-temperature-map.html)
- CHINA METEOROLOGICAL ADMINISTRATION. 2012. China Meteorological data sharing service system. <http://data.cma.gov.cn/index.jsp>

COELHO, MA, SAMPAIO, JP, and GONÇALVES P. 2010. A deviation from the bipolar-tetrapolar mating paradigm in an early diverged basidiomycete [J]. *PLoS Genetics* 6:1-13.

DE LAPLANE TD. 2000. La trufficulture – une opulente page d’histoire, commencée à Beuxes au XVIIIe siècle par le meunier Pierre Mauléon, 1744-1831, SHPL, Mai 2000. [www.truffevienne.fr/page\\_association.html](http://www.truffevienne.fr/page_association.html)

DELMAS J. 1978. *Tuber*. In: CHANG ST, HAYES WA (eds). The biology and cultivation of edible mushrooms. London, Academic Press. 645–681.

FONTANA A, PALENZONA M. 1969. Sintesi micorrizica di *Tuber albidum* in coltura pura con *Pinus strobus* e pioppo euroamericano. *Allionia* 15:99–104.

GIOMARO GM, SISTI D, and ZAMBONELLI A 2005. Cultivation of edible ectomycorrhizal fungi by in vitro mycorrhizal synthesis. In: DECLERCK S, STRULLU DG, FORTIN JA (eds). In vitro culture of mycorrhizas. Heidelberg, Springer. 253-267.

GUERIN-LAGUETTE A, CUMMINGS N, and WANG Y. 2011. Research, challenges and prospects for the development of a truffle and mushroom industry in New Zealand. Oral presentation at the New Zealand Truffles Association’s Annual General Meeting, Wellington, 30-31 July 2011. CDROM.

HALL IR, BROWN G, and ZAMBONELLI A. 2007. Taming the truffle: the history, lore, and science of the ultimate mushroom [M]. Portland, Timber Press.

HALL IR, BROWN G, and ZAMBONELLI A. 2009. Trufas: historia, ciencia, cultivo y recolección : con las últimas investigaciones y experiencias [M]. Madrid, Tutor.

HALL IR, FRITH A, and HASLAM W. 2008. A rough climatic comparison of various centres adjacent to or with similar climates to Périgord black, Italian white, Burgundy and bianchetto truffle producing areas. Dunedin, Truffles and Mushrooms (Consulting) Ltd. [www.trufflesandmushrooms.co.nz/General%20climatic%20table%20x%20truffle.pdf](http://www.trufflesandmushrooms.co.nz/General%20climatic%20table%20x%20truffle.pdf)

HALL IR, HASLAM W. 2012. Truffles in the Southern Hemisphere. In: ZAMBONELLI A, BONITO G (eds). Edible ectomycorrhizal mushrooms. Dordrecht, Springer.

HALL IR, WANG Y, and AMICUCCI A. 2003. Cultivation of edible ectomycorrhizal mushrooms [J]. *Trends in biotechnology* 21:433-438. <http://www.scribd.com/doc/36926291/Cultivation-of-Mycorrhizal-Fungi>

HALL IR, ZAMBONELLI A. 2012. Laying the foundations. In: ZAMBONELLI A, BONITO G (eds). Edible ectomycorrhizal mushrooms. Dordrecht, Springer.

HONG KONG OBSERVATORY. 2012. Climatological information for China and Mongolia. [www.hko.gov.hk/wxinfo/climat/world/eng/asia/china/china\\_e.htm](http://www.hko.gov.hk/wxinfo/climat/world/eng/asia/china/china_e.htm)

KAMAL S. 2011. Effect of nutrient sources and plant hormones on mycelial morphology of the black Périgord truffle *Tuber melanosporum*. In: Savoie J-M, Foulongne-Oriol M, Largeteau M, Barroso G (eds). Proceedings of the 7th International conference on mushroom biology and mushroom products (ICMBMP7), 4 to 7 October 2011, Arcachon, France. 514-520.

KIPPO NEWS. 1996. Kyoto scientists grow hon-shimeji mushrooms. *Kansai Window* 3 (114) Tuesday, 19 November 1996. [http://www.kippo.or.jp/e/news/kipponews\\_detail\\_114.html](http://www.kippo.or.jp/e/news/kipponews_detail_114.html)

LEE B. 2008. Taking stock of the Australian truffle industry. Canberra, Rural industries research and development corporation, Publication No 08/124. <https://rirdc.infoservices.com.au/items/08-124>

LEE G. 2011. Determination of key volatiles in Australian black truffles aroma by combined GCMS and organoleptic techniques. Proceedings of the Australian Truffle Growers’ Association, Manjimup, Australia, 5-7 August 2011. [www.trufflegrowers.com.au/wp-content/uploads/2011/08/UWA\\_ProfGarryLee.pdf](http://www.trufflegrowers.com.au/wp-content/uploads/2011/08/UWA_ProfGarryLee.pdf)

LINDE C, SELMES H. 2011. Investigations into causes of poor truffle yield in Australia. Annual General Meeting of the Australian Truffle Growers' Association, 6 August 2011, Manjimup, Western Australia.

METEOROLOGISK INSTITUTT MET NO. 2012. Weather statistics for Östra Vi, Gotland (Sweden). [www.yr.no/place/Sweden/Gotland/Östra\\_Vi~2685177/statistics.html](http://www.yr.no/place/Sweden/Gotland/Östra_Vi~2685177/statistics.html)

MARTIN F *et al.* 2010. Périgord black truffle genome uncovers evolutionary origins and mechanisms of symbiosis [J]. *Nature* 464, 1033-1038.

MORTE A, *et al.* 2009. Desert truffle cultivation in semiarid Mediterranean areas. In: AZCÓN-AGUILAR C, BAREA JM, GIANINAZZI S, GIANINAZZI-PEARSON V (eds). *Mycorrhizas - functional processes and ecological impact*. Dordrecht, Springer.

MURAT C, DÍEZ J, LUIS P, *et al.* 2004. Polymorphism at the ribosomal DNA ITS and its relation to postglacial re-colonization routes of the Périgord truffle, *Tuber melanosporum* [J]. *New phytologist* 164: 401–411.

MURAT C, ZAMPIERI E, VIZZINI A, *et al.* 2008. Is the Périgord black truffle threatened by an invasive species? We dreaded it and it has happened [J]! *New phytologist* 178: 699–702.

OHTA A. 1994. Production of fruit-bodies of a mycorrhizal fungus, *Lyophyllum shimeji*, in pure culture [J]. *Mycoscience* 95: 147-151.

OLIVERA A, FISCHER CR, BONET JA, *et al.* 2011. Weed management and irrigation are key treatments in emerging black truffle (*Tuber melanosporum*) cultivation [J]. *New forests* 42: 227-239.

PETIT RJ *et al.* 2002. Identification of refugia and post-glacial colonisation routes of European white oaks based on chloroplast DNA and fossil pollen evidence [J]. *Forest ecology and management* 156: 49–74.

POITOU N, MAMOUN M, DUCAMP M, *et al.* 1989. Mycorrhization controlee et culture experimentale du champ de *Boletus* (= *Suillus*) *granulatus* et *Lactarius deliciosus*. In: GRABBE K, HILBER O (eds). *Proceedings of the twelfth international congress on the science and cultivation of edible fungi*. Braunschweig, Germany. 551–563.

PROVENCE BEYOND. 2012. Truffles- France Provence themes. [www.beyond.fr/themes/truffles.html](http://www.beyond.fr/themes/truffles.html)

RAUDASKOSKI M, KOTHE E. 2010. Basidiomycete mating type genes and pheromone signalling [J]. *Eukaryotic cell* 9: 847-859.

REBETEZ M, MAYER H, DUPONT O, *et al.* 2006. Heat and drought 2003 in Europe: a climate synthesis [J]. *Annals of forestry science* 63: 569-577.

RICCIONI C, BELFIORI B, RUBINI A, *et al.* 2008. *Tuber melanosporum* outcrosses: analysis of the genetic diversity within and among its natural populations under this new scenario [J]. *New phytologist* 180: 466–478.

RITTERSMA RC. 2011. Not only a culinary treasure: trufficulture as an environmental and agro-political argument for reforestation. [www.drstuesser.de/uploads/media/Rittersma\\_Historia\\_Magistra\\_-\\_23II.pdf](http://www.drstuesser.de/uploads/media/Rittersma_Historia_Magistra_-_23II.pdf)

RUBINI A, BELFIORI B, RICCIONI C, *et al.* 2010b. *Tuber melanosporum*: mating type distribution in a natural plantation and dynamics of strains of different mating types on the roots of nursery-inoculated host plants [J]. *New phytologist* 189:723-735.

RUBINI A, BELFIORI B, RICCIONI C, *et al.* 2010a. Isolation and characterization of MAT genes in the symbiotic ascomycete *Tuber melanosporum* [J]. *New phytologist* 189:710-722.

SOURZAT P. 2007. La trufficulture en Francia. In: REYNA DOMENECH S (ed). *Trufficulture: fundamentos y técnicas*. Madrid, Ediciones Mundi-Prensa. 399-431.

SUNDBERG H. 2010. Phylogeny of *Lyophyllum* section *Difformia*: does hon-shimeji (*L. shimeji*) occur in Sweden? [http://dpes.gu.se/digitalAssets/1325/1325222\\_henriksundberg.pdf](http://dpes.gu.se/digitalAssets/1325/1325222_henriksundberg.pdf)

TAKARA AGURI COMPANY LTD. 2001. Method for artificially culturing *Lyophyllum shimeji*. Japanese patent JP2001120059. [http://worldwide.espacenet.com/publicationDetails/biblio?CC=JPandNR=2001120059andKC=&FT=Eandlocale=en\\_EP#](http://worldwide.espacenet.com/publicationDetails/biblio?CC=JPandNR=2001120059andKC=&FT=Eandlocale=en_EP#)

TEDERSON L, *et al.* 2006. Molecular and morphological diversity of pezizalean ectomycorrhiza [J]. *New phytologist* 170: 581-596. [http://www.botany.ut.ee/Tederson,Hansen,Perry,Kjoller,2006\\_Pezizales\\_ectomycorrhiza.pdf](http://www.botany.ut.ee/Tederson,Hansen,Perry,Kjoller,2006_Pezizales_ectomycorrhiza.pdf) normally or <http://onlinelibrary.wiley.com/doi/10.1111/j.1469-8137.2006.01678.x/full>

TRUFFES.ORG. 2011. La truffe noire du ventoux et du comtat venaissin. L'histoire: au début du 19e siècle. <http://melano.free.fr/index.php/De-la-Truffe-a-la-Trufficulture/Au-debut-du-19e-siecle.html>

VISNOVSKY SB, GUERIN-LAGUETTE A, WANG Y, *et al.* 2010. Traceability of marketable Japanese shoro in New Zealand using multiplex PCR to exploit phylogeographic variation among taxa in the *Rhizopogon* subgenus *roseoli* [J]. *Applied and environmental microbiology* 76: 294–302. 0099-2240/10/\$12.00 doi:10.1128/AEM.02191-09

WANG Y, HALL IR. 2004. Edible mycorrhizal mushrooms: challenges and achievements [J]. *Canadian journal of botany* 82: 1063–1073.

WANG Y, HALL, I.R, DIXON C, *et al.* 2002. Potential for the cultivation of *Lactarius deliciosus* (saffron milk cap) and *Rhizopogon rubescens* (shoro) in New Zealand. In: HALL IR, WANG Y, DANELL E, ZAMBONELLI A (eds). *Edible mycorrhizal mushrooms and their cultivation*. Proceedings of the second international conference on edible mycorrhizal mushrooms. Christchurch, New Zealand Institute for Crop and Food Research Limited.

WEISS S, FERRAND N (eds). 2007. *Phylogeography of southern European refugia: evolutionary perspectives on the origins and conservation of European biodiversity* [M]. Dordrecht, Springer.

WIKIPEDIA. 2011a. Mont Ventoux. [http://fr.wikipedia.org/wiki/Mont\\_Ventoux#D.C3.A9forestation\\_et\\_reboisement](http://fr.wikipedia.org/wiki/Mont_Ventoux#D.C3.A9forestation_et_reboisement)

WIKIPEDIA. 2012. Climate change. [http://en.wikipedia.org/wiki/Climate\\_change](http://en.wikipedia.org/wiki/Climate_change)

Yamanaka K. 2009. Commercial Cultivation of *Lyophyllum shimeji*. *Mushroom news*, February 2009. [http://goliath.ecnext.com/coms2/gi\\_0199-10127392/Commercial-cultivation-of-Lyophyllum-shimeji.html](http://goliath.ecnext.com/coms2/gi_0199-10127392/Commercial-cultivation-of-Lyophyllum-shimeji.html)

YAMASA SHOYU COMPANY LTD. 2006. New strain of *Lyophyllum shimeji* and use of the same. Japanese patent JP2006271234. [http://worldwide.espacenet.com/publicationDetails/biblio?CC=JPandNR=2006271234andKC=&FT=Eandlocale=en\\_EP](http://worldwide.espacenet.com/publicationDetails/biblio?CC=JPandNR=2006271234andKC=&FT=Eandlocale=en_EP)

ZAMBONELLI A, BONITO G. 2012. Edible ectomycorrhizal mushrooms [M]. Springer, Soil series. In press.

ZAMBONELLI A, DI MUNNO R. 1992. Indagine sulla possibilità di diffusione dei rimboschimenti con specie tartufigene: aspetti tecnico-colturali ed economici [M]. Rome, Ministero dell'Agricoltura e delle Foreste.

ZIMBECK M. 2012. Truffles 101- black diamond basics. <http://parisbymouth.com/truffles-101-black-diamond-basics>