

The Socioeconomic Impact of Truffle Cultivation in Rural Spain

-and its potential to encourage pioneer cultivation in Sweden.

Nicklas Samils



**Department of Forest Mycology and Pathology
Master thesis 20c
2002**

Index

Summary.....	p. 3
Introduction.....	p. 3
Material and Methods.....	p. 4
Results & Discussion	
Background to the truffle cultivations in Sarrión.....	p. 5
Truffle Seedlings and Truffle Orchard Management.....	p. 6
Problems	
Diseases and Insect Pests in the Truffle Orchards.....	p. 7
Damage Caused By Animals.....	p. 8
Theft.....	p. 8
Other Management Issues.....	p. 8
Environmental Concerns	
Pesticides and Chemicals.....	p. 9
Environmental Improvement.....	p. 9
Economy	
Marketing and Economy.....	p. 9
Financing.....	p. 10
Land Prices.....	p. 11
Cereal Production vs. Truffle Production.....	p. 12
The Future.....	p. 13
The Future Market.....	p. 14
The Truffle As a Reliable Crop vs. Production.....	p. 14
The Local Truffle Association.....	p. 14
Restaurants.....	p. 15
Gotland, Sweden.....	p. 16
Acknowledgements.....	p. 17
References.....	p. 18
Appendix	
Questionnaire, Sarrión	
Interview Answers, Sarrión	

*Front page: 7-year old truffle orchard in Sarrión with *Quercus ilex* and *Corylus avellana*.

Summary

The world market for truffles (all truffle species) was estimated at 260 tons in the year 2000. The production of the Périgord truffle, *Tuber melanosporum* (Vitt.) was estimated at 45-50 tons. Production of *T. melanosporum* from pre-inoculated host plants started in Europe in 1975. Theoretically truffle plantations may have a positive impact on rural economy, and also improve biodiversity by reintroducing oaklands. To promote such truffle cultivation in new areas, evidence of its economical benefits are necessary, but such studies are scarce. I therefore conducted a socioeconomic study in Sarrión, Spain. The results showed a raise of land prices in the municipal area and a strong belief in the new crop. Many of the orchard owners wanted to expand their orchards. There was a local truffle association with 148 members, which was equivalent to the total number of people in the agricultural sector in Sarrión. The association was important for the orchard owners when applying for subsidies and for sharing experience. The most common host tree used in the area was *Quercus ilex*. Dogs were used for finding truffles at the harvest. Many of the orchard owners believed that it was the same amount of work with a truffle orchard as their previous crop. Most of the orchard owners have never experienced problems caused by diseases on host trees or truffles. The greatest damage caused by animals were the wild boars that eat the truffles and pull up the seedlings. Also the rabbits were considered a problem since they feed upon young seedlings. The truffles were sold at the local market "Estacion de Mora". The prices ranged from 45-600 €/kg but the average price was 180-245 €/kg. A majority of the orchard owners used their own savings when financing the establishment of their orchards. More than half of the orchard owners claimed they do not have any production of truffles yet, but most of them believed that *T. melanosporum* was a reliable crop. According to the local banks, the price of land has increased. Half of the orchard owners claimed they look more positively upon the future due to the establishment of truffle orchards. All of the orchard owners believed that truffle production is environmentally sustainable. In Sweden 18 commercial truffle orchards with *Tuber aestivum* syn. *T. uncinatum* started in 2000-2001 with a total of 3000 *T. aestivum* syn. *T. uncinatum* inoculated *Q. robur* seedlings. I sampled the mycorrhized roots of seedlings from 25 commercial and experimental orchards. All of the orchards still have *T. aestivum* syn. *T. uncinatum* mycorrhized seedlings. Because of the very young age of the Swedish orchards there is no production. With the Spanish case-study in mind, I discuss the future for Swedish truffle cultivation, and compare with traditional crops such as cereal.

Introduction

The Périgord black truffle *Tuber melanosporum* is a hypogeous fungus, i.e. with its spore producing sporocarps underground. This life form makes it more resistant to desiccation or frost. (Pegler *et al.* 1993). Truffles can not spread their spores actively, but are dependent upon animals for spore dispersal (Trappe 1988). *T. melanosporum* produce phytotoxic compounds to inhibit vegetation in the soil around the host plant, and this burnt area is referred to as a brûlé or "truffle burn" (Pacioni 1991). *T. melanosporum* lives in ectomycorrhizal symbiosis with a broad range of hosts (e.g. *Carpinus*, *Castanea*, *Cedrus*, *Cistus*, *Corylus*, *Fagus*, *Helianthemum*, *Ostrya*, *Pinus*, *Populus*, *Quercus*, and *Tilia*) and grows in calcareous, well drained soils. (Hall *et al.* 1994). Most mycorrhizal fungi are obligate symbionts since they can not grow without being associated with a host plant from which they derive carbohydrates (Smith & Read 1997). The host plant also benefits from the symbiosis since it receives minerals from the fungi, especially when growing in soils low in

phosphorous. Ectomycorrhizal roots are covered by a mantle or sheath of fungal tissue like a glove on the plant root tip. The fungus occupies the space between the plant cortex cells, forming a structure known as the *Hartig net*. From the fungal mantle there are outwardly growing hyphae that connect to the soil and on which the sporocarps of the fungus are formed (Smith & Read 1997). The price implies that truffles can only be used as a spice, but like most mushrooms they contain more protein than many vegetables and are rich in fiber, minerals and vitamins (Danell & Eaker 1992).

The reason for cultivating truffles was the declining production of wild truffles and the high demand for them (Olivier *et al.* 2002). *T. melanosporum* of good quality has a very high price, in Stockholm up to 920 €/kg (8500 SEK) (Wedén & Danell 1998). In London fresh truffles at a high quality retail store were sold for about 5040 €/kg (3300 £) (Hall *et al.* 1994). In 2001 the wholesale price of out-of-season truffles sold to the Northern Hemisphere from New Zealand was 1413 €/kg (US\$1450) (Lefevre & Hall 2001). The world production of *T. melanosporum* is estimated to be 45-50 tons (pers. comm. Olivier 2002). Considering the high prices it can seem like a lucrative alternative to the more common crops in Sarrión (i.e. cereals, almonds, olives etc.). In favourable conditions suitable host seedlings can form mycorrhiza with *T. melanosporum* in the greenhouse (inoculation). The seedlings with *T. melanosporum* mycorrhizae are then planted in orchards, approx 400 seedlings per ha in calcaerous, well drained soils (Olivier *et al.* 2002). In 1975 the first truffle from a plantation established with *T. melanosporum* green house inoculated plants was produced in Italy (pers. comm. Chevalier 2002). The same result was achieved in France in 1977 (Chevalier & Grente 1979). This technique has made it possible to establish truffle plantations in places where truffles have not previously grown (Hall *et al.* 1994).

In the Sierra de Albarracín, Spain, *T. melanosporum* occurs naturally, but during the last 15 years people in the area of the town Sarrión south of Teruel have also started truffle orchards with the intention to grow and sell this culinary treasure. The purpose of this study was to investigate the socioeconomic impact of truffle orchards in the town of Sarrión and its rural surroundings. One of the reasons for making a study like this is the present lack of case studies on the benefits of truffle production. Information from these case studies are very important when negotiating with politicians about investments in mycological research, when discussing with land owners to create an interest for a new crop, and as an example where biological knowledge result in the survival of small scale farms at the same time as it could benefit the biodiversity. Non-timber forest products have lately received attention from biologists, economics and politicians (Danell 2001; Pilz & Molina 2002; Alexander *et al.* 2002; Liegel *et al.* 1998; Molina *et al.* 1997). I considered this study important for Swedish farmers that consider or that recently started truffle orchards on the islands of Gotland and Öland situated in the Baltic Sea, Sweden.

Material and Methods

For this case study I selected Spanish truffle orchards since they were established quite recently, often by people who were unfamiliar with truffle consumption, thereby resembling the current situation in Sweden. In Sweden experimental truffle orchards with *T. aestivum* started in 1999 and commercial orchards were established in 2000-2001 (Wedén *et al.* 2001). I developed a questionnaire (appendix) in collaboration with Susan J. Alexander (PhD Natural Resource Economist, USDA Forest Service, Pacific Northwest Research Station, Corvallis,

Oregon), Eric Danell (Associate professor in forest microbiology at the Department of Mycology and Forest Pathology, SLU, Uppsala, Sweden), Carlos Colinas González (PhD in Forest Science, Profesor de Patología Forestal Departament de Producció Vegetal i Ciència Forestal Universitat de Lleida, Spain), Antoni Olivera Ruestes (Ph. D. student, Centre Tecnològic Forestal de Catalunya, Solsona, Spain), Sofia Lindgren (Rural area advisor, Kungälv & Tjörn, Sweden) and Lars-Göran Karlsson (Sparbanken HHS, Hedemora, Sweden). This questionnaire was used in interviews, conducted anonymously in and around the town of Sarrión in the district of Aragón with 18 orchard owners, one spokesman for the local truffle orchard association, two bank officials, four town council officials, one notary and three chefs at local restaurants. The study in Spain was made in July 9-23, 2002.

On Gotland I laid the basis for a future evaluation of the socioeconomic impact, by interviewing 11 orchard owners, using the same standard questionnaire as in Sarrión. I also took root samples from five seedlings at each orchard. There is a total of 25 orchards in sizes varying from 8-560 seedlings/orchard on Gotland. The mycorrhiza analysis was made by morphotyping using a dissection microscope. In addition to literature illustrations, I used ethanol preserved reference mycorrhizae obtained from the seedlings when they arrived from the inoculation nursery (Robin Pepinères, France). If *T. aestivum* mycorrhiza was present in any of the five samples, the orchard still hosted *T. aestivum*. I also conducted PCR of rDNA ITS of mycorrhizal root-tips (Mello *et al.* 1996; Bergius & Danell 2000) as an alternative to morphotyping.

Results & Discussion

Background to the truffle cultivations in Sarrión

The town of Sarrión is situated in Southwest Aragón 37 km south of the city of Teruel, Spain, at the altitude of 981 m. The average precipitation is 466.8 mm/year and the mean temperature is 12.8° C (INM- The National Meteorological Institute 1985-2001). The municipal area of Sarrión had 1021 inhabitants where 40% are senior citizens (Sarrión city council, July 2002). Among the workers, 70% are in the industrial sector, 15% in the hotel business and 15% in the agricultural sector. According to the city council of Sarrión there is no unemployment. There is a rather high influx of immigrants but they do not stay in the town. Although there is a higher death rate than birth rate the population grew 1.3% in the year of 2001 so some of the immigrants must have settled down in the area. Because of the job opportunities offered they have a lot of young people staying in the town compared to other villages in the area. But the young people that move away for work or higher studies usually do not return. The municipal area amounts to 14 000 ha, where 65% of it is constituted of forests, mainly unproductive Mediterranean forest called "*Monte Bajo*". The most common tree species are *Pinus nigra*, *Quercus ilex* ssp. *ballota* and *Juniperus thuriferae*. About 35% of the land is cultivated of wich cereal constitute 25% of the land (Sarrión city council, July 2002).

In 1987 an agronomy engineering student by the name of Francisco Edo Navarrete, gave a course on truffle cultivation in Sarrión. He collaborated with INEM (Instituto Nacional de Empleo - The National Employment Office). This course is referred to as an important factor for the beginning of truffle orchards in Sarrión. Of the interviewed truffle orchard owners, 94.4% were born in the municipal area of Sarrión. The increase of the numbers of orchards was due to the dynamics among the locals, people curious about what their neighbours were planting and the possibility of receiving subsidies. The 33.3 % of the interviewed truffle

orchard owners who used to hunt wild truffles claimed that the production of natural wild truffles had decreased. This was to them another factor for establishing truffle orchards.

Due to the rapid establishment of truffle orchards in the Sarrión area there are no data on how much land is used for truffle orchards, but an estimate by the city council is ca. 10% of the total 14 000 ha (i.e. 1400 ha). Furthermore, reforestation of unproductive land is subsidised. The orchards are mainly planted in areas not suitable for cereal production. The promotion of truffle orchards has increased since farmers became aware of French truffle orchards and the possibility of receiving subsidies from the DGA (La Diputación General de Aragón - The autonomic government of Aragón). Five years ago The DGA gave 30 000 € designated for planting mycorrhized truffle seedlings in Sarrión. As the number of applications for subsidies grew, the subsidy per seedling decreased. Today the subsidies are used for fencing in order to prevent animal damage and theft. The fences are not popular among the game hunters who have to walk around them when hunting. The town council can not receive taxes from the orchards since they are registered as *Monte Bajo* without any production but they do receive fees from the hunters (14 000 € per year) and an income from the cereal production. A wish is that the orchard owners do not lock the gates of their fences, so that the hunters can cross the orchards. Up to date there have not been any problems, but the city council suspects that the fences could lead to problems in the future. The town council believes that the truffle orchards will be prolific in the future and they wish to improve the infrastructure for access to water. The officials of the city council also believe that since the truffle growers do not use any pesticides or fertilisers the orchards do not pose any threat to the environment.

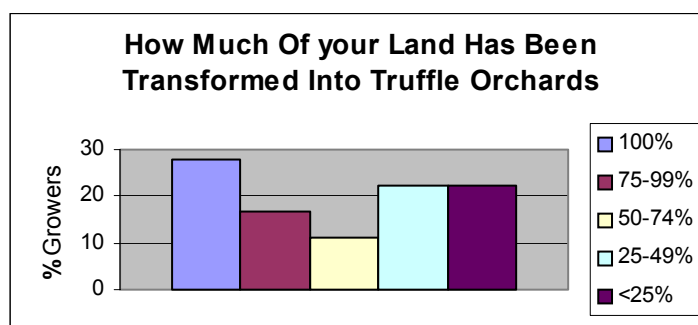
One important fact to point out is that 94.4% of the orchard owners have not had any contact with scientists, but 77.8% of them have books about truffles. Today there is no available education or courses in truffle cultivation, except for the help received through the local truffle association, and truffle orchard owners and neighbours helping each other. My field observations of brûles and interviews indicated high variations in success, possibly due to lack of official management plans and cultivation guidelines. Everyone who has started truffle orchards still cultivates truffles, and many of them expand their orchards. A strong driving force beside the local association are the nursery owners. The local truffle cultivator association has grown continuously since it started in 1997, from 12 to 148 members. The interviewed truffle orchard owners are all members of the local association and they are very positive about the association. They believe it plays an important role both in obtaining subsidies and retrieving information.

Truffle Seedlings and Truffle Orchard Management

The host trees used in Sarrión are mainly *Quercus ilex* (100% of the orchard owners have *Q. ilex*), *Q. humilis* (55.6%), *Corylus avellana* (44.4%) and *Q. coccifera* (11.1%). Regarding inoculum, 61.1% of the orchard owners inoculate their own seedlings. Growers who buy their seedlings from nurseries, buy them from several different nurseries to reduce the risk of planting seedlings with badly developed mycorrhiza. In the beginning the truffle cultivating pioneers of Sarrión bought their seedlings from France and Aroz (Soria, Spain), but today there are seven official nurseries in Sarrión and two more in Teruel. There are also 15 people in the area that produce their own seedlings and occasionally sell the excess. The seedlings cost about 6 € per piece in the area, but 16.7% paid a lower price for their seedlings (at a minimum of 3 €/piece). When harvesting the truffles all of the interviewed orchard owners use dogs to find them. According to one farmer a good truffle dog costs 2400-4200 €. When it comes to the amount of property turned into truffle orchards the ratios vary, 27.8% of the

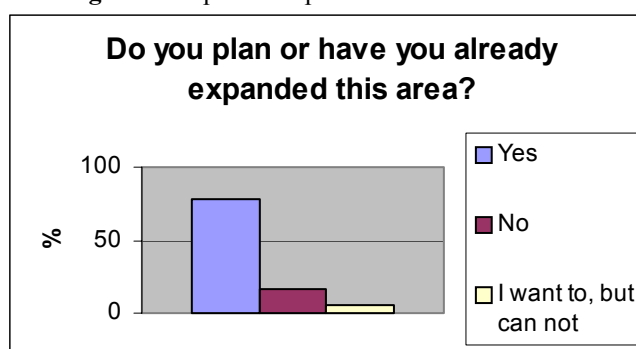
orchard owners use 100% of their land for truffle production and 22.2% use less than 25% (Figure 1). Other common crops cultivated in the area are cereals, almonds and olives.

Figure 1. Percentage of land transformed into truffle orchards.



About 78% of the truffle orchard owners already have or are planning to expand their orchards. Only one orchard owner wants to but is not able to expand (Figure 2).

Figure 2. Expected expansion of truffle orchards.



When asked if truffles as a crop demand more work and effort than their previous crop, 66,7% believed that it is more work, but 27,8% also believed that there will be less amount of work when the trees get older. Only 27,8% thought that the amount of work was the same as for their previous crop. Practically the orchards are maintained by mechanical harrowing with tractors between the rows of trees, and manually the weeds close to the trees are removed with a hoe. It was however evident that some of the truffle growers spend lot of time "gardening" their orchards, to create a nice view or as a "hobby", in addition to the necessary management of weeding and irrigation (Olivier *et al.* 2002)

Problems

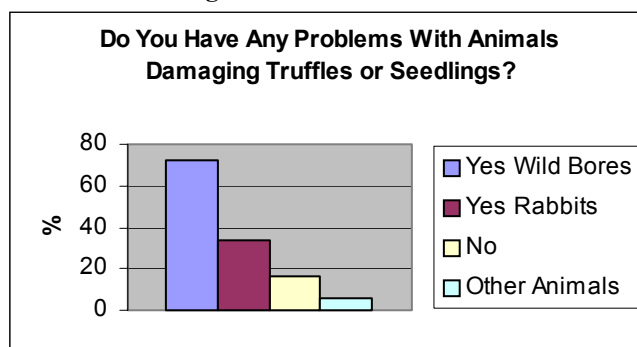
Diseases and Insect Pests in the Truffle Orchards

When asking the orchard owners if they had experienced any problems with diseases on their host trees or the truffles, 83.3% answered that they had no problems. One orchard owner had caterpillar, that had fed upon the leaves of his trees, and he had seen malformations on some tree trunks. Furthermore he and another grower had seen leaf pathogens on some of the *Q. ilex*. Another orchard owner claimed that the most important problems he had was aphids. But the aphids had only appeared a couple of times.

Damage Caused by Animals

The animal that causes the greatest problem in the area is the wild boar (Figure 3). The wild boars eat truffles and can also pull up the seedlings. One orchard owner had lost 20% of his seedlings due to the wild boars. Another problematic animal is the wild rabbit that mainly cause problems in young orchards where rabbits feed upon the small seedlings, 33.3% of the orchard owners had problems with rabbits. One of the orchard owners had problems with animals he could not identify.

Figure 3. Animal Problems



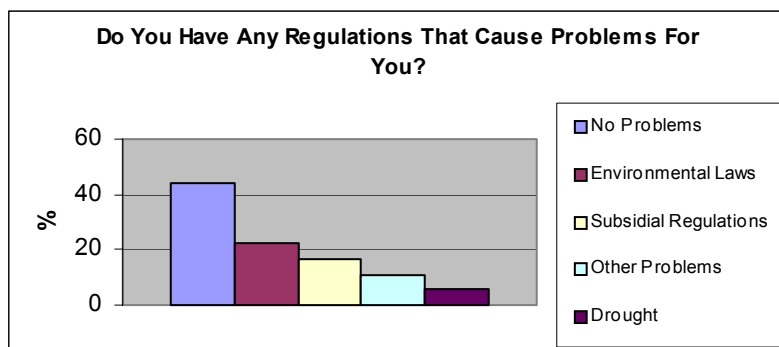
Theft

Most (88.9%) of the orchard owners had never experienced theft of truffles. The remaining 11.1% called this a minor problem. One of the orchard owners thought that theft could be a greater problem in the future. In France the situation is different, where truffle thieves have been shot (Rocchia 1992).

Other Management Issues

The interview showed that 44.4% of the orchard owners claimed that they had not experienced any environmental problems at all (Figure 4), 22.2% said that problems could arise due to the environmental laws, mainly that they are not allowed to remove the natural vegetation, 16.7% identified some problems with the subsidial help that they received from the government. These subsidies are aimed at reforestation, not specifically at truffle orchards. The subsidised seedlings have to stay in the soil for at least 20 years. If the orchard owner discovers that these seedlings will not produce any truffles he is not allowed to remove them and plant new ones. Therefore it is of great importance that the seedlings are inoculated correctly and checked before planting them. One of the truffle orchard owners claimed that he had a friend who only had production on 6% of his inoculated plants, this low production could depend on a low quality of the inoculated plants. However when I visited two other orchards, more than five years old, I could not see a single host tree without a truffle burn on the ground. Two of the orchard owners had experienced problems of other kinds (e.g. planting and other restrictions). One orchard owner had experienced problems from drought.

Figure 4. Problems.



Further problems can arise with cattle owners and hunters. One orchard owner mentioned that there exists some envy between truffle orchard owners, though it was not considered a big problem. Other possible problems mentioned are that due to land division you might have to pass through another orchard to reach your own and this might not be considered appropriate by every landowner.

Environmental Concerns

Pesticides and Chemicals

Most (88.9%) of the truffle orchard owners did not use any pesticides or chemicals in their orchards. One grower used some pyrethroids and another grower used *Osmocote Plus* (a fertilizer).

Environmental Improvement

All of the orchard owners believed that the orchards were positive for the environment. The reason for this was that the land they planted their seedlings in would otherwise be abandoned and without trees. They consider their planting of inoculated seedlings as reforestation (and they receive subsidies for the reforestation). The orchard may function as a fire break in case of forest fires. Birds such as partridge are favoured because cattle and foxes can not enter through the fences, so the birds can nest without foxes preying upon them or cattle destroying their nests on the ground. One orchard owner said that the fences could create a “negative visual impact”, while another truffle grower remarked that orchards look nice. In the long run, I believe that the return of oaklands may benefit biodiversity, as *Quercus* spp. Create ecosystems vital to thousands of insects, fungi and plants (Gärdenfors 1994).

Economy

Marketing and Economy

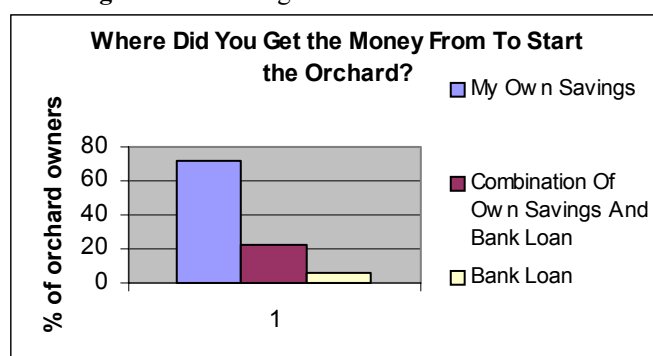
The most common channel for selling truffles is the local market "*Estacion de Mora*", held at a restaurant outside the center of Sarrion where there is a weekly market during the harvesting period. Here the people sell wild truffles and cultivated truffles to wholesale dealers. Some sell their truffles directly to consumers. Because of the very young age of many orchards only one of the orchard owners reported that the orchards resulted in an improved economy. Other markets and channels for selling truffles are other Spanish markets, such as "*Morella*" and "*Vich*" (The most important Catalan market). Some even go to French markets, such as the "*Carpentras*" in Provence. In addition there are buyers that visit orchard owners in their

homes. Most of the orchard owners (88.9%) reported having visited the local market "*Estacion de Mora*". Only one orchard owner did not sell his truffles in the local market, but instead uses the truffles for his own inoculations and sells the rest to wholesale dealers. The price of the truffles at the local market ranges from the lowest 45 €/kg to a maximum of 600 €/kg. These prices are extreme values depending on the demand and quality of the truffles. The average price paid to the producer of truffles in the region ranges from about 180 to 245 €/kg.

Financing

A majority of the orchard owners (72.2%) used their own savings when financing the establishment of their truffle orchards. Only one orchard owner took a bank loan in order to start orchards, and 22.2% used a combination of a bank loan and their own savings (Figure 5). From the income of the truffle orchards 44.4% invest the money in new orchards. One orchard owner repays his loans and another uses his profit for other uses. As many as 55.6% of the interviewed truffle orchard owners claimed they did not have any production yet, but many (66.7%) of them have a positive view upon the coming five years. Some (16.7%) claimed that production depends on the climate, which is critical for a good harvest. According to Bencivenga & di Massimo (2000) irrigation and proper management is crucial for success.

Figure 5. Financing of the orchard establishment



Relations with the banks are considered good by 83.3% of the truffle orchard owners. Only one orchard owner had negative bank experiences.

People who make their living on producing truffles in this area mainly do it by their own economic means, though subsidies can be received through the banks. If someone would want a loan, the banks would lend the money. They report that they are not afraid of not being paid back since it is a small community and they know the farmer's financial situations. This was reflected by the fact that the bank rely more on the reputation of the loan taker than on his or her asset holdings. If a farmer asks for a loan for irrigation or constructing a well they bring a plan to the bank and make sure that they do not ask for more money than needed. As collateral the banks can use houses, land, savings etc. The time of repayment for someone who starts a truffle orchard would be about 10-15 years since production is expected to start after 6-8 years. In one bank, the bank officer claimed that he had observed that orchard owners are constantly improving their financial situation. When an orchard owner asks for a loan the money is most commonly used for irrigation. The purchase of land is frequently made with the orchard owner's personal savings. In the recent past the land was so cheap it was practically given away. Nobody wanted to buy land. Instead they wanted to sell it. Today

there are a few dominating landowners that own most of the land. These land owners are investing in improved fencing and wells for the truffle orchards. The high price of truffles generates high expectations, particularly when compared with the decreasing price of cereals.

Land Prices

According to Departamento de Agricultura de la Diputación General de Aragón (1999), land prices differ between the land types and their use. I compared the changes in land prices 1995-1999, published by the Agrarian statistical yearbook for 3 different provinces: Teruel, Huesca and Zaragoza. On this provincial level there is no significant difference between the provinces regarding increase of the agricultural land prices (Departamento de Agricultura de la Diputación General de Aragón, 1999) (Table 1). However on the municipal level in Sarrión there has been an increase up to 300% in the price of agricultural land. According to the other bank in the town, it is true that the cost of land has increased a lot, but the bank officer is not sure whether it is because of the truffle orchards. It could also be due to demand for the cereal production and cattle.

The central government of Aragon has recently made revisions of the property register and thanks to this they now take in account the area, type of crop and in what town the property is situated. The price of cultivated land is 13.2 pts/m² (0.0792 €/m²) and the price of “*Monte Bajo*” is 2 pts/m² (0.012 €/m). Because of this difference in land values the land owners often register their land as “*Monte Bajo*” in order to pay less tax even though it is cultivated land. Furthermore many people have not registered the ownership of their properties, something which applies especially for the elder people of the region. Recently there has been an increasing interest in registering properties. The land has been divided in small fractions between owners, who could not agree on fusing the properties after the civil war. With the establishment of truffle orchards, there is now an attempt to fuse these property fractions together.

The notary's statement that more people register their land and that he believes it is for selling could point to the fact that it is becoming more profitable to sell land or that the people registering land want to be assured of their ownership.

Table 1. The Change in land values in 3 different provinces in Aragón 1995-1999

	Teruel	Huesca	Zaragoza
Non-irrigated cereal	+75.8%	+32%	+14.4%
Irrigated cereal	+32.3%	+20.5%	+32.8%
Non-irrigated fruit tree plantation	---	+15.9%	-1.5%
Non-irrigated vineyards	+55.1%	---	+184.1%
Meadow land	+3.0%	+2.5%	---
Pasture land	+7.3%	-13.4%	---

Cereal Production vs. Truffle Production

Cereal production depends on whether the land is irrigated and on annual precipitation. The price of cereals differ between species and variety of cereal (Table 2).

Table 2. Annual cereal production and prices (Anuario Estadístico Agrario, 2000).

Year	Province	Crop	Area		Yield		Price (€/kg)
			No Irrigation (ha)	Irrigation (ha)	No Irrigation (kg/ha)	Irrigation (kg/ha)	
1988	Teruel	<i>Hordeum</i> 2 cc	93027	669	3202	5024	0,110

1999	Teruel	<i>Hordeum</i> 2 cc	86685	882	1299	3424	0,121
2000	Teruel	<i>Hordeum</i> 2 cc	78178	629	2535	3296	0,116
1989	Teruel	<i>Hordeum</i> 6 cc	35514	6830	3748	3919	0,114
1999	Teruel	<i>Hordeum</i> 6 cc	36420	6367	1363	4474	0,118
2000	Teruel	<i>Hordeum</i> 6 cc	42872	6481	2780	3791	0,114
1999	Teruel	<i>Triticum</i> soft	34522	3244	1208	4460	0,141
2000	Teruel	<i>Triticum</i> soft	39315	3612	2509	3653	0,142

Source: Anuario Estadístico Agrario, 2000. Gobierno de Aragón. Departamento de Agricultura. (2 cc and 6 cc are two different varieties of barley depending on how the grains are arranged in the ear, 2 cc= *Hordeum vulgare* var. *distichon*. 6 cc=*Hordeum vulgare* var. *vulgare*) (Mossberg *et al.* 1997).

The cereal harvest in the area gives about 3000 kg/ha (Table 2). This is a considerably lower production compared with the wheat production on Gotland, Sweden, where the average is 4800 kg/ha in fall and 4300 kg/ha in spring (pers. comm. Medhammar 2002).

In Italy *T. melanosporum* production is reported to reach 50-60 kg/ha/year or even up to 80-100 kg/ha/year in well-managed orchards (Givannetti *et al.* 1994, Bencivenga & di Massimo 2000). In France general production data are not available, but economic calculations have been made on successful orchards with an average production of 30 kg/ha/year (Olivier *et al.* 2002). A minimum production of 8-10 kg/ha/year is needed to pay for the investments made in installing and maintaining a French truffle orchard (Olivier 1997). In table 3 I have used the lower of the reported average truffle prices together with different, possible productions of truffle/year. In tables 4-5 I have used the production data and the average price in €/kg from table 2 (year 2000). The tables visualise the estimated income from the different crops. The economic profit however is not to be regarded the same as the total income. The profit varies between individual conditions (i.e. land ownership, number of employees, irrigation, etc).

Table 3. Overview of possible income from truffle orchards. The prices are based on the lowest of average prices paid by wholesale dealers buying *T. melanosporum* in Sarrión, stated by the interviewed orchard owners.

Truffle Orchards

Crop	Yield (kg/ha)	Orchard size (ha)	Price (€/kg)	Total income (€)
<i>T. melanosporum</i>	10	1	180	1800
<i>T. melanosporum</i>	20	1	180	3600
<i>T. melanosporum</i>	40	1	180	7200
<i>T. melanosporum</i>	60	1	180	10800

Table 4. Overview of possible income from cereal production at irrigated cereal fields. The yields and prices are based on information from Anuario Estadístico Agrario, 2000.

Irrigated Cereal

Crop	Yield (kg/ha)	Field size (ha)	Price (€/kg)	Total income (€)
<i>Hordeum</i> 2cc	3296	1	0.116	382.34
<i>Hordeum</i> 6cc	3791	1	0.114	432.17
<i>Triticum</i> soft	3653	1	0.142	518.73

Table 5. Overview of possible income from cereal production of non-irrigated fields. The yields and prices are based on information from Anuario Estadístico Agrario, 2000.

Non-Irrigated Cereal

Crop	Yield (kg/ha)	Field size (ha)	Price (€/kg)	Total income (€)
<i>Hordeum 2cc</i>	2535	1	0.116	294.06
<i>Hordeum 6cc</i>	2780	1	0.114	316.92
<i>Triticum soft</i>	2509	1	0.142	356.28

In conclusion, even though it is hard to receive income data from truffle orchard owners, the information in tables 3-5 indicate that truffles seem to be a profitable crop in well managed orchards.

The Future

Today after the introduction of truffle orchards half of the truffle orchard owners interviewed claimed to look more positively upon the future. The remaining half claimed that they “feel the same as before”. There is a will to expand the activity which was reflected when 83.4% say that they want to expand their truffle orchards. When it came to the truffle orchard owners view upon population stability in the area, 50% of the interviewed believed that the population is decreasing and many young people move out from the area for work and higher studies. Many of the truffle orchard owners hoped that the truffle cultivation will encourage young people to stay in Sarrión. The interviewed truffle orchard owners believed that most sectors in the area will draw economic benefits from the truffle orchards (such as truffle orchard owners, truffle collectors, the hotel trade, wild truffle hunters, nursery owners, the building trade). The rate of unemployment in Sarrión was 11.95% in 1991 (Instituto Nacional de Estadística 2002). If the city council was right about the present absence of unemployment there exists a positive trend in employment in the area. It is not known if this is due to the establishment of truffle orchards. Some of the orchard owners need to hire labour, especially during harvest which creates more job opportunities in the area. Some of the interviewed claimed that more than 50% of the inhabitants owns an truffle orchard, others said that "every family" has an orchard. Regarding the relationship between truffle orchard owners and the farmers cultivating other crops 88.9% believe that the relationship was good. All of the interviewed believe that the truffle orchards will remain in the future. Only one orchard owner pointed out the fact that the enthusiasm will decrease in the future.

"I believe that the new truffle orchard enthusiasm will decrease in the coming few years but then it will become stable. We should think about that there are not any other agricultural alternatives for these areas except for cattle combined with fodder production." (orchard owner)

The belief in environmental sustainability in truffle orchards (100% of the orchard owners) implies a long time perspective. None of the orchard owners believed that the price of truffles will decrease in the future. The main reasons for this is that they could see a decrease in production of wild truffles and demand for truffles exceeds supplies.

The Future Market

Today there are truffle orchards producing *T. melanosporum* in many countries around the world, in France, Italy, the USA and New Zealand (Olivier *et al.* 2002, Bencivenga & di Massimo 2000, Hall *et al.* 1994). In 1985 Ian Hall started research in establishing truffle orchards in New Zealand to meet the demand for truffles in the northern hemisphere when its production was out of season (New Zealand Truffle Association 2001). In 1987 the first truffle infected seedlings were produced and planted in 2 orchards. In July 1993, five years after establishing a truffle orchard near Gisborne, the first truffles were found. In 1997 between May and early September the harvest gave a yield of 9 kg truffles in the 0.5 ha

Gisborne truffle orchard and more than 20 kg truffles were harvested in the year 2000. (New Zealand Truffle Association 2001)

The worlds' supply of truffles and the worldwide demand is hard to determine. It is very difficult to get good information on supply and demand. This is partly because of under-the-counter sales and the covert substitution of one species by another less valuable species. One thing that is definite is that production in Europe over the past 100 years has suffered a catastrophic decline (pers. comm. Hall 2002).

According to Jean-Marc Olivier the official total world production of truffles (all species) was estimated to be 260 tons in the year 2000 (a year with poor production). The official production of *T. melanosporum* is estimated to be 45-50 tons (22 from France, 14 from Spain and 8-10 from Italy). These values do not include direct sale or family use estimated at 15% of the official production (pers. comm. Olivier 2002). In Spain there has been large variations of production, from 7-100 tons/year, mainly depending on the climate (pers. comm. Olivier 2002). It is believed that a European *T. melanosporum* production of 200 tons could be sold without any real effect of the prices. (pers. comm. Olivier 2002). Between 1991-94 a Spanish production of 20 tons was reported (Garcia Falces & de Miguel Velasco 1995). In addition, Asian truffles have reached the European market (Riousset *et al.* 2001). It is however likely that the cultivations in Sweden will open new markets, i.e. the awareness and knowledge about truffle cooking may increase as a result of domestic production.

The Truffle as a Reliable Crop vs. Production

T. melanosporum is regarded as a potentially reliable income crop by 72.2% of the truffle orchard owners, even though 38.9% did not have any production yet when interviewed. Due to the very young age among many of the truffle orchards production has not been expected yet. The ages of the orchards vary from 0-15 years. According to Hall *et al.* (1994) production in an *T. melanosporum* orchard is not expected before the 7:th to 10:th year even though *T. melanosporum* infected *C. avellana* may begin their production as early as the fourth year. Truffles can appear as early as 3 years after plantation but a full production usually takes about 10-20 years to reach (Lefevre & Hall 2001). Of the interviewed orchard owners 55.6% had orchards older than 7 years.

The Local Truffle Association

The "*Asociacion de truficultores y recolectores de trufa de la provincia de Teruel*" (T.R.P.T.) started in 1997 with 12 members to strengthen this sector and to receive more institutional support. Today there are 148 members in the area and all of them have their own orchards. This is equivalent to the total number of people engaged in the agricultural sector (pers. comm. Sarrión city council officials, 2002). Since the city council claimed that about 1400 ha were used for truffle orchards this gives an average of about 9.5 ha/person which is a lot compared to French recommendations that a suitable truffle orchard size is about 0.5-1 ha (Olivier *et al.* 2002). One of the interviewed orchard owners said that he used 70 ha (40% of his total land) for truffle cultivation. The association wants to represent both the harvesters of wild truffles and the truffle orchard owners in the province of Teruel in negotiations with different public administrations. The association has helped members applying for subsidies administrated from Diputación Provincial (a province level entity) and the DGA (La Diputación General de Aragon - The Autonomic Government of Aragon). The association's present tasks are to negotiate with the public administrations about setting up programs and supporting the development of truffle orchards. Another current task is to negotiate about the

rules for collection and commercialization of truffles. They organize “open days”, symposiums, lectures and other events destined to give publicity to scientific and technical discoveries related to truffle orchards. They give publicity to the truffle in the aspect related to its collection, cultivation, commercialization and other possible areas of interest. A map with the truffle region has been published aimed at tourists, to promote the interest for truffles in the long run. Furthermore the spokesman of the association told me that there are no women that cultivate truffles except for the orchard owners wives and daughters helping out on the fields during harvest or when removing weeds.

It is believed that the aims and tasks of the truffle association will change and they will work with different ideas to favour the cooperation and the denomination of truffle origin. During the last 2 years the association has continuously increased their activities and participants. They cooperate with other local associations in Spain as well as other EU countries. The association believes that people in the area have a positive attitude about the truffle orchards, but the response of the youth has been weak. The weak response on truffle cultivation of the youth is according to the spokesman of the truffle association probably due to their lack of economic resources, their money are usually spent on other things such as buying houses, and the fact that they do not own land. Today there is no preservation or processing of the truffles, but when the orchards produce more truffles there will be more job opportunities within the food processing sector. The association does not believe in experimenting with other truffle species since that could lead to a diversification of the product. They believed there are many things left to do in the improvement of *T. melanosporum* cultivation. The spokesman underlines the fact that when the farmers sell their truffles they rather let them get ruined than selling them for a price they consider too low.

Restaurants

The restaurants have various truffle dishes on their menus and the chefs at the restaurants have special training in cooking truffle dishes. Two of the restaurants charged 25% extra for truffle dishes. The third restaurant charged 50% extra for truffle dishes. Two of the restaurants could see that truffle dishes had become more popular in the last 10 years. All of them believed that they will sell more truffle dishes in the future. The most common clients to order truffle dishes are tourists, especially the French and Spanish. There are a few locals that order them. The ones that seemed to enjoy truffles the most and gave a positive response were the ones that had tried them before. One restaurant bought the truffles from the local market in town. Two restaurants bought from private sellers and one of these restaurants goes hunting for truffles themselves. Each restaurant use 12-15 kg/year and pay 110-115 €/kg for them. Two of the restaurants believed that the price of the truffles is a limiting factor. When buying truffles the restaurants considered the aroma the most important feature. They did not care whether they are cultivated or wild, but one of the restaurants claimed that they could distinguish between different proveniencies.

Gotland, Sweden

Another noble black truffle which has a similar, but less pronounced aroma than *T. melanosporum*, is *T. aestivum* (Vitt.) syn. *T. uncinatum* (Chatin). The first reported finding of *T. aestivum* syn. *T. uncinatum* in Sweden was in 1978 (Sunhede 1978).

In 1999 a Ph. D. project started at the Department of Forest Mycology and Pathology, Swedish University of Agricultural Sciences, Uppsala in collaboration with the University College of Gotland, Visby (Wedén *et al.* 2001). One of the aims with the project was to study the possibilities of *T. aestivum* syn. *T. uncinatum* cultivation in Sweden. The progress of 250 *T. aestivum* syn. *T. uncinatum* inoculated seedlings planted at 10 different sites on the island of Gotland, Sweden is being followed annually by root sampling of host plants. In 2000-2001, 22 commercial orchards with a total of about 3000 *T. aestivum* syn. *T. uncinatum* inoculated *Quercus robur* seedlings started on different sites on the island of Gotland (Wedén *et al.* 2001). The largest of these truffle orchards has 560 inoculated oak seedlings. There is a small truffle grower association (Gotlands Tryffelodlarförening) with 6 members which was founded in 2000 (pers. comm. Wedén 2002). This Spanish case study may influence Swedish growers by showing the benefits of truffle cultivation cooperation. It is clear that the Spanish growers association is important for education and governmental contacts. Most Spanish growers are members of the local truffle association. It also seemed that the Spanish truffle growers were satisfied with their investments. Quality of seedlings, fencing, irrigation, weeding and truffle dogs are important for success. Theft is a small problem, and in contrast to the very secret Gotlandic land owners, the Spanish are proud and even publish maps to attract tourists. Spanish growers tend to share each others experiences and everybody sell their crops at the same market. The maintenance of orchards on Gotland varies between growers. Some do not perform any weed control at all, and some do it until there is no other vegetation at all present in the orchards. One reason why the orchard owners did not perform weed control was that they believed that the vegetation would keep the dew, and thereby benefit the mycorrhizal seedlings. Some of the orchard owners used cellulose pads at the trunk base of the seedling for blocking adjacent weeds. I noticed that under the pads, it was very common with ants. Another difference from the Spanish truffle growers is that on Gotland, many of the truffle cultivating pioneers are women.

Because of the very young age of the truffle orchards on Gotland, there is no production of truffles yet but my sampling of mycorrhiza in every orchard revealed that all orchards still contain *T. aestivum* syn. *T. uncinatum* mycorrhiza. The *T. aestivum* syn. *T. uncinatum* PCR-amplification of rDNA ITS of mycorrhizal root-tips and dried sporocarps did not give any results, but when using dried samples of *T. melanosporum* and *Cantharellus cibarius* sporocarps, results of the rDNA ITS were obtained.

According to Leif Medhammar at Länsstyrelsen, Gotland (The Swedish County Administrations on Gotland) the average production of wheat (sown in autumn) is about 4800 kg/ha but it varies between years and areas on the island. Tables 6-7 are based on an production and income from wheat production and a theoretic production and income truffle orchards. Olivier *et al.* have made cost estimations on French truffle orchards (Olivier *et al.* 2002).

Table 6. The table is based on information from Leif Medhammar, Länsstyrelsen, Gotland.

Crop	Yield (kg/ha)	Field size (ha)	Price (€/kg)	Total income (€)
<i>Triticum</i> (Fall)	4800	1	0.105	504

The present price for fresh *T. aestivum* syn. *T. uncinatum* from Gotland is around 218 €/kg (2000 SEK) (Danell 2002).

Table 7. The table is based on a hypothetical production serie and price from Danell (2002).

Crop	Yield (kg/ha)	Orchard size (ha)	Price (€/kg)	Total income (€)
<i>T. aestivum</i>	10	1	218	2180
<i>T. aestivum</i>	20	1	218	4360
<i>T. aestivum</i>	40	1	218	8720
<i>T. aestivum</i>	60	1	218	13080

Up to date there is no production of truffles, but wild truffles are sold. There is a significant difference of income/ha between the crops. The price per truffle seedling made in France from Nordic seeds and Gotlandic truffles was about 10 €.

Because of the young age of the orchards and thereby the absence of production, the results of the interviews are not adequate for indicating a socioeconomic effect. The results will be archived for future case studies on the topic. The economic effect of Swedish truffle orchards is yet too early to see. However the relatively low investment cost and the fact that there is no hired labour promotes a future profit if the orchards produce truffles.

A truffle orchard may be a profitable investment if the following facts are considered: 1) The establisher of an orchard must have an income until the orchard is old enough to produce truffles. 2) That seedlings and soil are optimised. 3) The orchard owner must also maintain the orchard properly (i.e. weed control, irrigation, pruning) to maximize a harvest. If these facts are met, I hope Swedish truffle growers will be as satisfied as the Spanish are today.

Acknowledgements

I wish to thank the following for their invaluable guidance and support.

Eric Danell (Supervisor), Carlos Colinas (Ass. Supervisor in Spain), Susan Alexander (Ass. Supervisor), Christina Wedén (Ass. Supervisor), Antoni Olivera, Mari Carme Vergés, Sofia Lindgren, Lars-Göran Karlsson, Pablo Sebastián, *Asociacion de truficultores y recolectores de trufa de la provincia de Teruel* (The local truffle association of Sarrión), My family, Everyone at the Department of Forest Mycology and Pathology, SLU-Uppsala (for their inspiration and being my great muse).

References

- Alexander, S. J., Weigand, J. & Blatner, K. (2002). Nontimber Forest Product Commerce. In *Nontimber Forest Products in the United States* (ed Jones, E. T., Mclain, R. J. & Weigand, J.), 115-150. University Press: Kansas, USA.
- Alexander, S. J., Pilz, D., Weber, N. C., Brown, E. & Rockwell, V. A. (2002). Mushrooms, Trees, and Money: Value Estimates of Commercial Mushrooms and Timber in the Pacific Northwest. *Environmental Management*, 30: 129-141.

- Bencivenga, M & di Massimo, G. (2000). Risultati Produttivi di Tartufai Coltivate di Tuber melanosporum Vittad. In Umbria. *Mic. Ital.* 2: 38-44.
- Bergius, N. & Danell, E. (2000). The Swedish matsutake (*Tricholoma nauseum* syn. *T. matsutake*): Distribution, Abundance and Ecology. *Scandinavian Journal of Forest Research* 15: 318-325.
- Burgos, M. B. Area de Informacion, Instituto Nacional de Estadistica (2002). Paseo de la Castellana, 183, 28071 Madrid, Spain.
- Chevalier, G. (2002). Pers. comm. Station de Pathologie Vegetale, INRA, 12, avenue du Brezet, F-63039 Clermont-Ferrand Cedex, France.
- Chevalier, G. & Frochot, H. (1997). La truffe de Bourgogne. Pétrarque, Levallois-Perret, France.
- Chevalier, G. & Grente, J. (1979). Application Pratique de la Symbiose Ectomycorhizienne: production a grande echelle de plants mycorhizes par la truffe (*Tuber melanosporum* Vitt.). *Mushroom Science X* (part II): 483-505.
- Danell, E. (2001). Mushrooms as a non-timber forest product and its potential for maintaining biodiversity. *Currents* 25/26: 28-30.
- Danell, E. & Eaker, D. (1992). Amino Acid and Total Protein Content of the Edible Mushroom *Cantharellus cibarius* (Fries). *J. Sci. Food Agric.* 60: 333-337.
- Departamento de Agricultura, Gobierno de Aragón. (2000). *Anuario Estadístico Agrario*.
- Departamento de Agricultura de la Diputación General de Aragón. (1999). *Anuario Estadístico Agrario de Aragón*.
- Garcia Falces, R. S. & de Miguel Velasco, A. (1995). Guia practica de truficultura. I.T.G. Agricola S.A., Pamplona, Spain.
- Giovannetti, G., Roth-Bejerano, N., Zanini, E. & Kagan-Zur, V. (1994). Truffles and Their Cultivation. *Horticultural Reviews* 16: 71-107.
- Gärdenfors, U. (1994). Eken – utnyttjad av tusentals organismer. In *Ekfrämjandet 50 år* (ed Olsson, U.). 77-82. Ekfrämjandet och Skogsvårdsstyrelsen, Ronneby, Sweden.
- Hall, I., Brown, G., Byars, J. (1994). The Black truffle 2:nd ed. New Zealand Institute for Crop and Food Research Limited: Christchurch, New Zealand.
- Hall, I. (2002). Pers comm. Crop & Food Research, Invermay Agricultural Centre, P.B. 50034, Mosgiel, New Zealand.
- Instituto Nacional de Meteorologia (INM) (2002). *Aragon, a Rioja y Navarra*. Spain.

- Liegel, D., Pilz, D., Love, T. & Jones, E. (1998). Integrating Biological, Socioeconomic, and Managerial Methods and results in The MAB Mushroom Study. *Ambio Special Report 9*: 26-33.
- Lefevre, C. & Hall, I. R. (2001). The Status of Truffle Cultivation: A Global Perspective. In *Fifth international congress on hazelnut*, Corvallis, Oregon, August 2000, (ed Mehlenbacher, S. A.) *Acta Horticulturae* 556: 513-520.
- Medhammar, L. Länsstyrelsen Gotland (2002). Pers. comm. Länsstyrelsen i Gotlands län, 621 85, Visby, Sweden.
- Mello, A., Nosenzo, C., Meotto, F. & Bonfante, P. (1996). Rapid typing of truffle mycorrhizal roots by PCR amplification of the ribosomal DNA spacers. *Mycorrhiza* 6: 417-421.
- Ministero De Agricultura, Pesca y Alimentación Secretaría General Técnica, Madrid (2002). *Hechos y cifras del sector agroalimentario y del medio rural español*. (6^a edition. Revisada, actualizada y impliada). Madrid, Spain.
- Molina, R., Vance, N., Weigand, J. F., Pilz, D. & Amaranthus, P. (1997). Special forest products: Integrating social, economic, and biological considerations into ecosystem management. In *Creating a forestry for the 21:st century*. (ed Kohm, K. & Franklin, J.). 315-336. Island Press, Washington, D.C. USA.
- Mossberg, B., Stenberg, L., Ericsson, S. (1997). Den Nordiska Floran 7:th edition. Walhström & Widstrand, Stockholm, Sweden.
- New Zealand Truffle Association Incorporated (2001). *Newsletter* 26, 3.
- Olivier, J.M. (1997). Biologie de la Truffe et Actualité de la Trufficulture. *C.R. Acad. Agric. Fr.* 83: 47-54.
- Olivier, J. M. (2002). Pers. comm. Jean-Marc Olivier. Unité de Recherches sur les Champignons, INRA, Bordeaux, France.
- Olivier, J.M., Savignac, J.C., Sourzat, P. (2002). Truffe et trufficulture. Editions, Fanlac, Périgueux, France.
- Pacioni, G. (1991). Effects of *Tuber* metabolites on the rhizospheric environment. *Mycological Research* 95: 1355-1358.
- Pegler, D.N., Spooner, B.M., Young, T.W.K. (1993). British Truffles: A Revision of British Hypogeous Fungi. Royal Botanic Gardens, Kew, England.
- Pilz, D. & Molina, R. (2002). Commercial harvests of edible mushrooms from the forests of the Pacific Northwest United States: issues, management, and monitoring for sustainability. *Forest Ecology and Management* 155: 3-16.
- Riousset, L. Riousset, G. Chevalier, G. Bardet, M.C. (2001). *Truffes d'Europe et de Chine*. INRA, Paris, France.

Rocchia, J.-M. (1992). Des Truffes en général et de la Rabasse en particulier. Éditions A. Barthélemy, Avignon, France.

Smith, S. E. & Read, D. J. (1997). Mycorrhizal symbiosis, 2:nd edition. Academic Press Ltd, London, England.

Trappe, J. M. (1988). Use of truffles and false-truffles around the world. *Atti del II Congresso Internazionale sul Tartufo*, Spoleto 24-27/11 1988: 19-29.

Wedén, C. & Danell, E. (1998). Sommartryffel, *Tuber aestivum*, och andra tryfflar i Sverige. *Svensk Botanisk Tidskrift* 92: 65-80.

Wedén, C., Ericsson, L. & Danell, E. (2001). Tryffelnyheter från Gotland. *Svensk Botanisk Tidskrift*. 95: 205-211.

Wedén, C. (2002). Pers. comm. Institutionen för Skoglig Mykologi och Patologi, Box 7026, SE-750 07, Uppsala, Sweden.