Black Truffle Economics
Evaluating the Costs and Returns of Establishing and Producing *Tuber melanosporum* in the Willamette Valley, Oregon

By

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AN ABSTRACT OF THE THESIS OF

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The following paper is an objective view on the viability of growing the truffle *Tuber melanosporum* in the Willamette Valley. Included in this study are the history of the truffle, biological cycle, habitat description, method of cultivation and an enterprise budget for commercial production in the Willamette Valley.

The truffle, a fungus that grows naturally underground, has long been a delicacy in European culture and it continues to appear in expensive restaurants around the world. The cultivation of *T. melanosporum* was established first in Europe, but is gaining popularity in other parts of the world. Farms are appearing in Israel, Australia, The United States, New Zealand, and other nations. North Carolina and California also have operating truffle farms. Several species are currently cultivated in Europe, but the most prevalent and the only species cultivated outside of Europe is the Périgord (Black) truffle, *Tuber melanosporum*.

Truffles are the fruiting bodies of various fungi. Spores produced within fruiting body germinate into tiny hair-like filaments (mycelia) that eventually attach themselves to the root tips of a host species and form mycorrhiza. After about six years, secondary mycelia emanating from the mycorrhizae grow together into a knot and form the fruiting body or carpophore. Host trees vary according to the location and species of truffle, however oak and hazelnut trees are most commonly used. Host trees that have been mycorrhized with truffles can be purchased from reputable growers for about $15 each.

The climatic characteristics of the Willamette Valley are similar to those of major truffle growing regions in Europe. In addition, soils in the Willamette Valley may have an advantage because potentially competitive ectomycorrhizal fungi are adapted to acidic soils. *T. melanosporum* is grown in soils with high pH. Raising the soil pH for *T. melanosporum* could reduce the competition from native fungi adapted to acidic soils. Although few attempts have been made to cultivate truffles in Oregon, the Willamette Valley could be an ideal habitat for growing *Tuber melanosporum*.

Establishment of a truffle farm takes 7 to 12 years depending on the species and the condition of the plot. Land must be free of plants that support ectomycorrhizal fungi, have evenly mixed sand, silt and clay (or well drained soils) and have an alkaline pH. An irrigation system should be installed in case of drought. After the trees are planted, maintenance of the truffle plot involves tilling the soil once a year, liming to maintain pH and pruning the host trees. Production typically begins after about six years and full production after about 10 years. Yields are difficult to estimate because truffle

production is heavily influenced by weather conditions. In Europe, typical yields range from 50-150 kg per hectare (50-150 pounds per acre) in different plantations.

The enterprise budget for a truffle farm in the Willamette Valley considers the costs and returns for a newly established farm. The budget is, by design, only a guide and does not consider individual differences among farmers. For example, it is expected that truffle cultivation will be an enterprise added to an existing farm, however the included budget includes costs of renting machinery for tilling. For a farmer that already owns his/her machinery, the budget must be altered accordingly.

Truffles are expensive to produce. Profit and loss depend greatly on yield and price per pound. Also, commercial cultivation of truffles has not been achieved in Oregon and results are unpredictable. In good years, however some farms yield more than 100 kg per hectare (100 pounds per acre). Market prices fluctuate and may depend heavily on reputation as well as quality of truffles. In 2001, fresh truffles of the variety *Tuber melanosporum* were available on the Internet for about $225/kg ($500/pound). Other truffle species such as *T. magnatum* sell for about $765/kg ($1700/pound). The truffle industry is virtually unexplored in Oregon and there is potential to grow *T. melanosporum* in the Willamette Valley. This is a high risk crop due to the initial investment, a 10 year establishment period and fluctuations in yield and market values. Still, truffles are a low maintenance crop, can be sold worldwide and are highly acclaimed among gourmets. Also, truffle supply is limited, resulting in extreme high price. Socially and economically it appears that *Tuber melanosporum* could be a viable enterprise in the Willamette Valley.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Black Truffle Economics

Evaluating the Costs and Returns of Establishing and Producing *Tuber melanosporum* in the Willamette Valley, Oregon

I. Introduction

In the Willamette Valley (Figure 1), as in many other agricultural areas, interest in alternative enterprises has increased in recent years. Many small farmers are looking for ventures to generate additional income from their existing land resources. Others are looking to nontraditional enterprises as a way to get started in commercial farming or to help support a rural lifestyle.

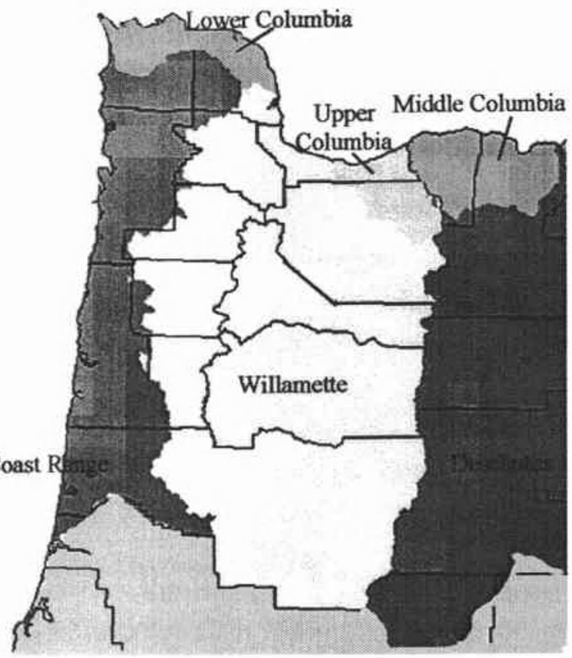


Figure 1. The Willamette Valley, Oregon (Oregon Department of Forestry 2001).

The market for edible fungi, one example of an alternative enterprise, has been expanding in many parts of the world. Among the many species of gourmet mushrooms, truffles are of particular interest. A delicacy usually associated with European forests, truffles are being produced through commercial cultivation around the world. Interest in planting new truffle orchards has increased in Europe, the United States, Israel, Australia, New Zealand and elsewhere (Olivier 2000). Although historically, truffles were only harvested from natural forests, most of the truffles currently brought to markets in France come from planted fields (Olivier 2000).

More than 30 species of truffles exist, however only the European truffles *Tuber melanosporum*, *Tuber uncinatum* and *Tuber borchii* are being commercially cultivated (Olivier 2000). *Tuber melanosporum,* commonly known as the Périgord black truffle, is the most common of the cultivated truffles. Perhaps the most attractive feature of cultivated truffles is their market value, ranging from about \$130 to about \$770 per kg

($300-1700 per pound*) depending on variety, where they are grown and the time of year (Lefevre, in press). In 2000 the average market values for *T. melanosporum* ranged from $300 to $450 per kg ($660-$990 per pound), (Olivier 2000, Lefevre, in press).

This impressive market value is placed on truffles mainly because they are highly prized by chefs around the world. They taste like earthy, garlicky, pungent mushrooms and are often among the most expensive dishes on a restaurant menu. Methods vary for preparing truffles, however they are often served uncooked because the aroma dissipates if they are exposed to too much heat (Lefevre et al., in press). Therefore, truffles are usually shaved over dishes with simple flavors such as omelets, pastas, risottos or lightly flavored meats.

Truffle cultivation can be attractive to farmers for several reasons. One is the fact that the current supply of *T. melanosporum* is limited, resulting in extreme high price. In fact, there are only 8 commercial producers of truffles outside of Europe (Lefevre, pers. comm). As well, truffle production does not require large acreage and it can be fairly easy to integrate into an existing farm under the right conditions. Further, truffles can be relatively simple to cultivate, depending on the method employed, and generally require lower maintenance than most traditional crops. Lastly, the annual harvests of Périgord black truffles can reach 50 to 150 kg per hectare (50-100 lb/acre). With an average wholesale market value of $300 per kg one hectare of black truffles could potentially yield close to $45,000 during full production years.

The Willamette Valley has two potentially important advantages for growing *T. melanosporum*. The first, and probably most important, is the fact that the Willamette Valley has similar climactic conditions to the truffle growing regions of France. Both the annual precipitation and temperatures vary seasonally in a similar manner and exhibit similar ranges. The second possible advantage is the fact that the Willamette Valley has fairly acidic soil. Initially, this means more work and more of an expense to the grower, as the soil's pH will need to be raised. In doing so, however, endemic fungal species adapted to an acidic soil type may be less likely to survive, therefore reducing outside competition with *T. melanosporum* and increasing the chances of success.

With this introduction, truffles may seem to be the perfect solution to any farmer interested in raising additional income. However, there are factors that should be taken

* All values are given in metric units and parenthetically in standard units, however all budget values are in standard units only.

into consideration before embarking on such an endeavor. It needs to be understood that entering into the truffle market is a high-risk enterprise. This is due in part to the fact that truffle cultivation is relatively new and research is slow, leaving a number of unanswered questions. Truffles have not yet been produced in the laboratory and since few people have tried to cultivate them outside of Europe, information regarding their viability in other regions is sparse. Also, the range of conditions under which truffles are capable of growing has not been thoroughly studied. Economically, truffles remain a high-risk enterprise because there are usually 7 to 12 establishment years (although there have been exceptions) before truffles appear and even then, production fluctuates.

The objective of the present review is to investigate the possibility of introducing truffles to the Willamette Valley as an alternative enterprise to traditional crops. The present state of knowledge and recent research in the science of truffle cultivation will be discussed, with special emphasis on the local environment and an example of an economic analysis for the initiation of cultivation.

II Background Information

A. Classification

The true truffles belong to the phylum called the ascomycetes. They are further classified as belonging to the *Tuberaceae* and constitute the genus *Tuber*.

The edible truffle species currently being cultivated are the Périgord black truffle, *Tuber melanosporum*, and the Burgundy truffle, *Tuber uncinatum*. Many other species of edible truffles are collected including two noteworthy species native to Oregon called the Oregon White truffle, *Tuber gibbosum*, and the Oregon Black truffle, *Leucangium (Picoa) carthusianum*. Although neither of these species are cultivated, they are harvested from the wild, marketed in the United States and could potentially be cultivated for a national or international market.

Tuber melanosporum is the well known Black truffle, or Périgord truffle, naturally fruiting in the following regions: south of France, northeast of Spain, center of Italy, north of Yugoslavia and possibly in some parts of Portugal, Switzerland and Bulgaria (between 44° and 46°N Latitude). The fruiting-body is blackish-chocolate or chestnut-black and warty; size ranges in diameter from that of a walnut to a man's fist; the interior (gleba) is a maze of whitish veins, that become dull reddish, and finally, at maturity, become purplish-black (Singer and Harris 1987). The species habitat is characterized by basic soils (pH between 7.5 and 8.3), and a Mediterranean climate with hot dry summers under oaks or hazelnut trees or other trees planted at low densities. Harvest of the truffles starts in December and the last truffles are picked in March (Saez & de Miguel 1995, Olivier et al. 1996, Olivier 2000).

Tuber magnatum is the famous 'White Italian Truffle of Piedmont'. It lacks the black color of *T. melanosporum*, but is still characterized by the same size and the maze of veins located in the interior. *T. magnatum* is collected in summer and autumn under oaks, willow or poplar, and requires more mesic environments. The species is only known in Italy and along its borders and holds the highest market value of all truffles in the world.

Tuber uncinatum is naturally found growing more often in the northeast of France and in the center of Europe. This black-gray species is collected in October and

November from oak as well as hazelnut or hornbeam forests more dense than for *T. melanosporum* (Chavalier & Frochot 1997). Given that this species is secondary in quality and less expensive than *T. melanosporum,* it is of less interest among truffle growers.

Tuber gibbosum and *Leucangium (Picoa) carthusianum* fruit only in the presence of the coastal variety of Douglas fir (*Pseudotsuga menziesii* var.*menziesii*), and are presumed to be host-specific. They range from Northern California to southern British Columbia on the west side of the Cascade Mountains (Arora, 1986, Molina et al., 1993). Little is known about these two truffle species or about the industry that has grown around their harvest and sale. However both species have won acclaim among North American chefs and are often favorably compared with the better-known truffles of Europe (Czarnecki, 1995; Boyd, 1995; Lefevre et al., in press).

B. History and Modern Day Truffles

Truffles are fungi whose gathering and consumption date far back into antiquity. An anonymous work written in 1600 B.C.E. refers to them "not as mushrooms but as mysterious products from the earth" (Delmas 1978). The Pharaohs of ancient Egypt ate truffles (Trappe and Maser 1977) and there is evidence that they were esteemed in Europe as far back as the sixth century B.C.E. (Peer 1980). The unique fragrance and flavor, which continually capture the attention of gourmets, have developed the truffle into a true delicacy. It has been hypothesized that the volatile characteristic of the truffle is an evolutionary change developed from their aboveground ancestors. As some fungi evolved hypogeous (underground) sporocarps, dispersal of spores by wind and water was rendered impossible. Over time, all truffles developed volatile compounds (Trappe and Maser 1977, Pacioni 1989) that attract animals and insects, which then ingest the fruiting body and spread the spores through their excrement.

Nutritional benefits of the truffle are also highly esteemed. Truffles are easily digested, contain the entire range of essential amino acids (Mannozzi-Torini 1984) and have a texture and flavor that is very agreeable to some people. The fresh truffle is 75% water instead of 90% as in most other mushrooms (Delmas 1978). Various species are rich in potassium, phosphorus and nitrogenous products (consisting mostly of proteins and mineral salts).

Species of truffle are used in flavoring main dishes and are responsible for the development of a many culinary traditions. This is especially true of *Tuber melanosporum* and *T. magnatum* (Mannozzi-Torini 1984), both of which command very high prices in retail specialty shops. Around 1900, worldwide production of truffles reached up to 1000 tons per year. Since the early part of the 20^{th} century, the amount of truffles harvested, primarily from regions in Europe, has declined to about 200 tons per year. Recently market demand has increased and it is believed that the current supply of black truffles (*T. melanosporum*) is low due to lack of suitable soils (Danell 2000). There are few successful truffle orchards outside the natural distribution zone of *Tuber melanosporum*. Only two orchards exist in the United States as well as four in New Zealand and two in Australia (Lefevre, in press).

C. Biology

1. Biological Cycle

The remainder of this paper is written in reference to cultivation of *Tuber melanosporum*. Although there are many species of truffle that have the potential to be cultivated, *T. melanosporum* has received the most attention from scientists and farmers. This allows for a more thorough study of the possibilities of cultivating truffles in other regions such as Oregon.

The life cycle of a typical Tuber species is depicted in Figure 2. Although there are points in the cycle that are still unclear, most mycologists agree on the following general explanation.

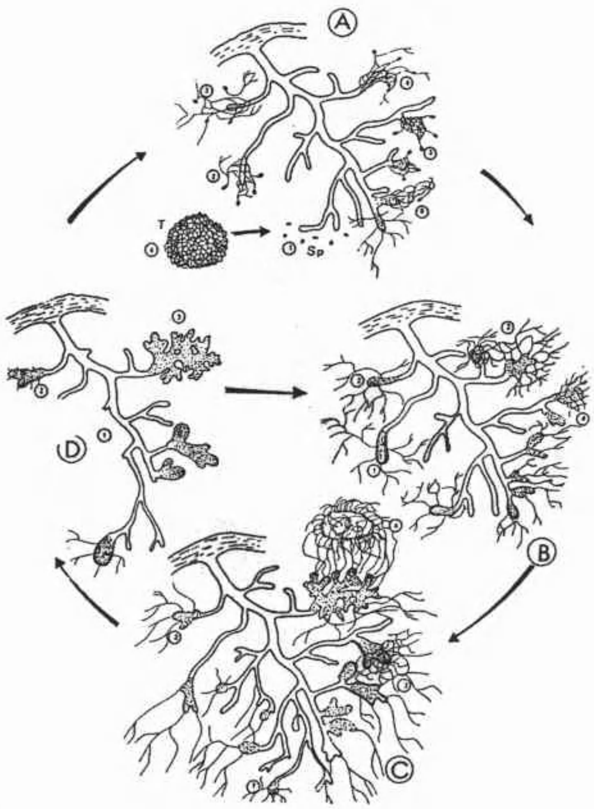


Figure 2. Biological cycle of the truffle (Delmas 1978).

(A) Each ascus releases one to four ascospores, which are oval shaped, have the appearance of a rugby ball, and are ornamented with numerous fine spines (1). The ascospore in *T. melanosporum* is 20 μm long, about on quarter the diameter of a human hair. Germination of the ascospore produces thin strands of hyphae (singular hypha) that develop into mycelia (singular mycelium), which are typically 5 μm in diameter (2). Mycelia strands establish a filamentous network in the soil. When hyphae from two different mycelia connect, they undergo cellular transformation and give rise to a type of mycelium that can form mycorrhizae (3). Mycorrhizae are mixed organs, formed by both the mycelium of the fungus and the root tips of the host tree. (B) The fungus engulfs the external layers of the root tip and surrounds it forming a tight fitting sheath (1). This kind of mycorrhitic association is known as an ectomycorrhiza, since the cells of the fungus do not penetrate the cells of the host (Hock and Bartunek 1984). (C) The fruiting process generally takes place after the fungus has completely engulfed the roots of the tree, about six to eight years after initial contact with the host (Delmas 1978). Numerous mycorrhizae must be present for the formation of the carpophore (the edible fruiting body) (1). Although the exact trigger is still unknown (Giovannetti et. al, 1993), concentrated branching of the mycorrhizae causes an entanglement of mycelia to start forming a primary structure (2). The truffle develops with the production of more and more mycelia forming a dense, ball-like structure in the soil. (D) Eventually, the hyphae connecting the truffle to the mycorrhizae disintegrate (1) leaving the truffle to develop independently in the soil (3).

The mycorrhizae are key organs in the life cycle of the truffle. According to Delmas (1978), they have several essential functions:

1. As the origin of the mycelium filaments that continue growing through the soil. They assure the spread of the fungi to the entire root system of the host tree and neighboring trees.
2. As the organ of storage and exchange of nutritive substances for energy and growth. All fungi are heterotrophs, obtaining food by direct absorption from the immediate environment. The truffle mycelia extract mineral substances such as nitrogen and phosphorus from the soil, providing useable nutrients to itself and the host tree. Simultaneously, in a mutualistic relationship with the host, the mycorrhizae absorb and store the carbon substances (sugars, organic acids and amino acids) synthesized by the tree.
3. As the conservation organ of the mushroom from year to year. Clumps of mycorrhizae persist during the winter and assure the system's perenniality, persisting even if all the ascospores are eliminated.

Microorganisms are always to be found among the hyphae of the carpophore and inside the carpophore itself starting from the earliest stages of its development (Pacioni 1989). These microorganisms may play an essential role in the production of the aromatic substances (Pacioni 1989, 1990, 1991) and carpophore development (Giovannetti et. al, 1993).

According to Singer and Harris (1987), the most aromatic portion of the truffle is the peripheral layer. The volatile substances are organic sulfur compounds in the asci (Andreoti and Casoli, 1968) and a possibly a steroidal pheromone (Claus et al. 1981) that forms on the skin of the carpophore. When the truffle is young, the skin is ornamented with thousands of small pyramids (4-6 faces about 1 mm long) that shrink at complete maturity (Delmas 1978). The concentration of the volatile compounds creates a very strong and characteristic aroma. Insects and animals are attracted to the mature truffle, whereby ingestion and defecation results in the dispersal of the spores.

In a report by Clause et al. (1981), an identical pheromone to that found in truffles called androsterone is found in the saliva of male pigs, the urine of female pigs and in the sweat of human males. The pheromone may be responsible for making truffles attractive to female pigs in heat, a characteristic exploited since ancient times. The sow is used to locate and dig up the fruiting bodies of the truffle. Also, the pheromone found in truffles might account for the historical reputation of truffles as aphrodisiacs.

2. Host Tree Species

Some truffles have a low specificity for plant hosts. The host species is chosen as a function of the soil conditions where the truffle plot lies rather than as a function of the growth or vigor of the tree itself (Delmas 1978). *Tuber melanosporum* can associate with several forest species:

i. Oak (*Quercus pubescens, Q. sessiflora, Q. pedunculata, Q. Ilex, Q. coccifera, Q. Cerris, Q. Suber* and other species). Each of these species is adapted to particular soil and climatic conditions that correspond to definite regions.

ii. Hazelnut (filbert) (*Corylus avellana* and other species). This species produces abundant roots and are an excellent carrier of mycorrhizae, but it is agriculturally more demanding than oaks (Delmas 1978).

iii. Other hardwoods, the lime tree (*Tillia*), yoke elm (*Carpinus*), poplar (*Populus*), and chestnut tree (*Castanea*). These constitute the four other principal deciduous species naturally colonized by truffles.

iv. The conifers, pine (*Pinus*), Douglas-fir (*Pseudotsuga menziesii*). The majority of conifers are excellent propagators of mycelium, however according to Delmas (1978), the acidic humus in the litter of the species does not seem favorable to the fructification of *Tuber melanosporum*.

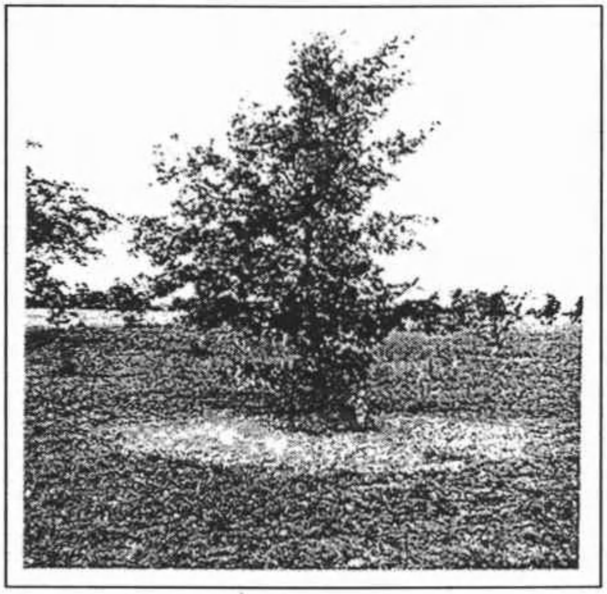


Figure 3. Burnt out clearing (Brulé) around host species (Delmas 1978).

One to two years before the fruiting bodies actually begin to form in the soil a brulé, or circular "burnt" area often appears around the host tree (Figure 3). As soon as there is an abundant mycorrhizal system, the well established mycelia destroy most surrounding vegetation (Delmas 1978). This phenomenon is especially observed in *Tuber melanosporum* and is provoked by the demand of the mycelium for water and mineral substances. Some plants are resistant to the effects.

III. Truffle Cultivation

A. Conditions Favoring Truffle Production

1. Choice of Environment

Each species of truffle has ideal climatic and soil conditions. Although the exact temperature and moisture requirements are still unknown, the optimum conditions require extreme climatic changes for different stages of truffle development. For example, high moisture and cool temperatures may be required for the growth of the mycelia and the instigation of symbiosis with the tree, whereas dry, hot conditions may initiate development of the fruiting body.

For *Tuber melanosporum*, a sufficient, but not excessive amount of extreme conditions are favorable. Large variation in temperature and precipitation throughout the year (wet and cold to dry and hot) tends to instigate truffle development. The annual rainfall (60-90 cm (23.5-35.5 in)) must be well divided: spring and summer rain for the recommencement of mycorrhiza activity and for mycelial growth, autumn and winter rain to assure maturation (although too much rain could cause the fruit body to rot). Soil moisture must be about 65%, with good drainage, and not drop below 34%. Irrigation systems can be installed to insure sufficient soil moisture throughout the year. The yearly average temperature desired is rather low (within 12°-21°C (53-70°F) (Giovannetti 1993), although summer temperature can be raised if the soil is protected (mulching) and air circulation is sufficient at soil level. More than ten days at -10°C (14°F) is detrimental to truffles because they can be damaged when exposed to temperatures at or below freezing (Delmas 1978).

2. Truffle Bearing Soils

T. melanosporum flourishes on slopes and plateaus, but never in sunken relief. As reported by Singer and Harris (1987), slopes should be resistant to erosion by water, be favorably oriented (toward or away from intense sunlight, depends on climate and latitude) and slope less than 13.5 degrees for every plot. The usable depth of the soil should be shallow to promote horizontal growth, but sufficient for vertical (normal) root development (10-30 cm (4-12 in)). The soil should contain limestone, have a high pH, and be fissured to porous. It should have a balanced texture, although this will vary according to the local conditions of climate and geology. Granular structure, with a sufficient level of organic matter (2-8%), and a C: N ration of 10 is ideal. There should be no excess or deficiency of any element required for normal plant growth in the mineral content of the soil.

In Europe, *Tuber melanosporum* requires a chalky soil or at least a soil rich in calcium with a pH of at least 7.9 (Singer and Harris 1987, Delmas 1978). The majority of productive areas are situated on a calcareous sedimentary substratum. The soil is generally very rocky (10-41 cm (4-16 in)). The presence of plentiful debris from rock material in the profile facilitates drainage as well as calcium replenishment of the soil. Rocks on the surface act as a mulch protector. Each region has its range of favorable textures, which are related to the amount of carbonates and humus in the soil. Some authors claim that red limestone produces the truffles with the best aroma. If true, this

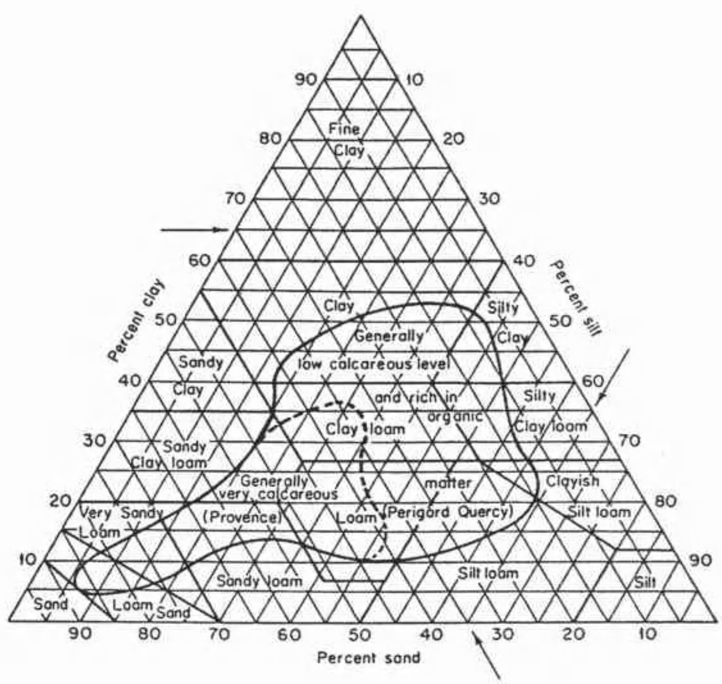


Figure 4. Limits for soil texture in the culture of *Tuber melanosporum* (Delmas 1978).

would tend to indicate that the presence of iron in the soil is favorable (Singer and Harris 1987). Figure 4 (Delmas 1978) illustrates the ranges of soils according to percentage of sand, silt and clay that are optimal for culture of *T. melanosporum*.

3. Traditional Truffle Belts

Tuber melanosporum and *Tuber magnatum* grow naturally in Atlantic and Mediterranean Europe between 44° and 46° N latitude. In Figure 5, from Giovannetti et al. 1993, two European truffle belts can be distinguished in France. The Mediterranean truffle belt coincides with Mediterranean Europe and is characterized by the endemic presence of *T. magnatum* and *T. melanosporum*. The Northern truffle belt comprises middle and Atlantic Europe. Here, *T. melanosporum*, along with other less famous truffles, find their maximum development. According to this diagram, *T. melanosporum* can survive between 91-914 m (300-3000 ft) in Europe. However, the majority of productive areas are situated between 182 and 365m (600-1200 ft) (Delmas 1978).

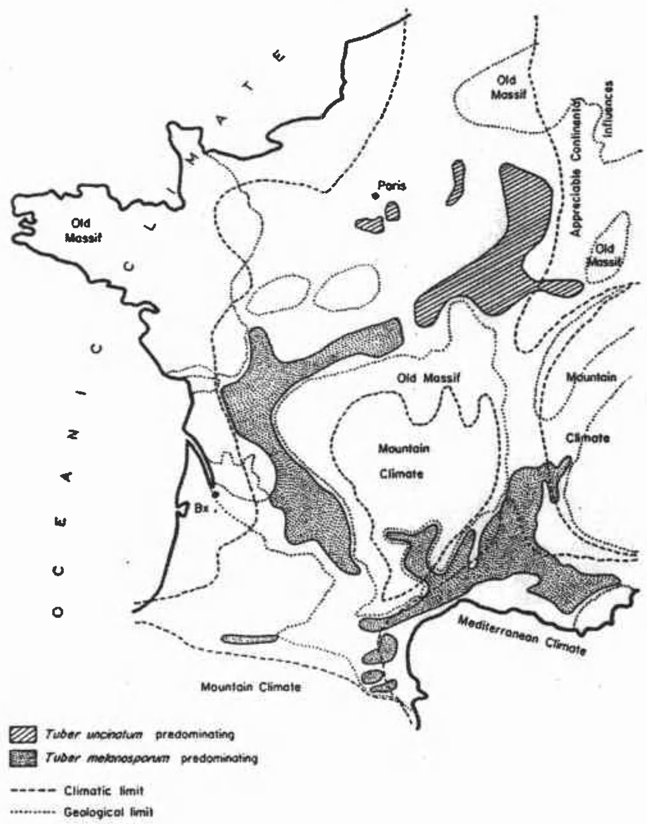


Figure 5. Truffle bearing locations for *Tuber melanosporum* and *Tuber uncinatum* in France (Giovannetti, et al. 1993)

Newer truffle plantations outside of Europe have successfully cultured some truffle species as well. In Hillsborough, North Carolina (36.3°N, 78.9°W), culture of *T. melanosporum* is at 122 m (400 ft) above sea level (Garland 2001) and the plot receives an average of 111 cm (44 in) of rain each year.

4. Climate Comparisons Between Europe and The Willamette Valley

The "V"-shaped Willamette Valley is bordered to the north by the Columbia River (45.3°N), to the south by the Calapooya Mountains (south of Eugene at 43.3°N), to the east by the Cascade Mountain foothills (122°W), and to the west by Oregon's Coast Range (124°W) (Figure 6). The average elevation of the Willamette Valley is about 131 m (430 ft). According to the United States Geological Survey (USGS) (2001), the region is an elongated lowland filled with flows of Columbia River Basalt (in the northern half of the basin) and younger unconsolidated sediment.

Figure 6. Willamette Valley and surrounding boundaries (Oregon Department of Forestry 2001).

The Mediterranean climate of the Willamette Basin is characterized by cool, wet winters and warm, dry summers. Approximately 10% of the average annual precipitation of 160 cm (63 in) occurs between May and September. Precipitation varies markedly with altitude and ranges from about 100 cm (40 in) at lower elevations to greater than 510 cm (200 in) in the mountains.

Numerous similarities exist between European truffle growing regions and the Willamette Valley. Both areas are on the western seaboard of the continent, close to the 45th parallel and experience similar seasonal variations of temperature and precipitation.

The Willamette Valley does however receive a greater overall amount of annual precipitation. Elevations of truffle producing areas are mostly around 120 m (400 ft) above sea level. Soil types vary within small regions, although both areas have mountain soils integrated throughout that are high in moisture rich soils such as alfisols (mildly acid clays), entisols (immature soils) and inceptisols (immature soils formed on clay or volcanic ash).

A major factor that could potentially set the Willamette Valley apart from other truffle growing regions is that the pH of the soil is quite low. Acidic soils (pH 6-6.5) exist throughout the valley, whereas most soils in Mediterranean Europe are calcareous with high pH values. Soils with a basic pH are critical for successful cultivation of *T. melanosporum* and, therefore, to grow it in the Willamette Valley, large amounts of limestone would have to be added to the soil. Raising the pH of a soil more than one pH unit is quite difficult and can be costly. However, because native fungi in the region are presumably better adapted to low pH they may not be able to compete effectively when the pH is raised and *T. melanosporum* may become the dominant competitor in spite of otherwise sub optimal conditions (Lefevre, pers. comm).

Figure 7. Wine producing regions of France (Grand Atlas de La France (1969)

Many of the truffle rich regions of Europe are located close to vineyards (Figure 7). The truffle landscapes border heavily cultivated areas where famous wines such as Beaujolais, Bourgogne and Champagne are produced (Giovannetti et al. 1993). Thus it may be postulated that truffles like *Tuber melanosporum* and wine grapes grow in similar habitats (well drained soils, direct sunlight, fluctuating seasonal temperatures, etc.). As well, the Willamette Valley is home to more than 160 wineries (Figure 8) (O'Hara 2001). Wine grapes grow over a much greater area than *T. melanosporum*, however because both organisms have a similar requirement for sunlight, regions suitable for vineyards in the Willamette Valley may indicate some regions suitable for growing truffles.

The similarities in seasonal variations, agricultural techniques and possibility of creating high soil pH that could give *T. melanosporum* a competitive advantage other fungi seem to indicate that Willamette Valley would be an ideal location for truffle cultivation. Only through the establishment of truffle farms in the Willamette Valley could this be determined with any certainty.

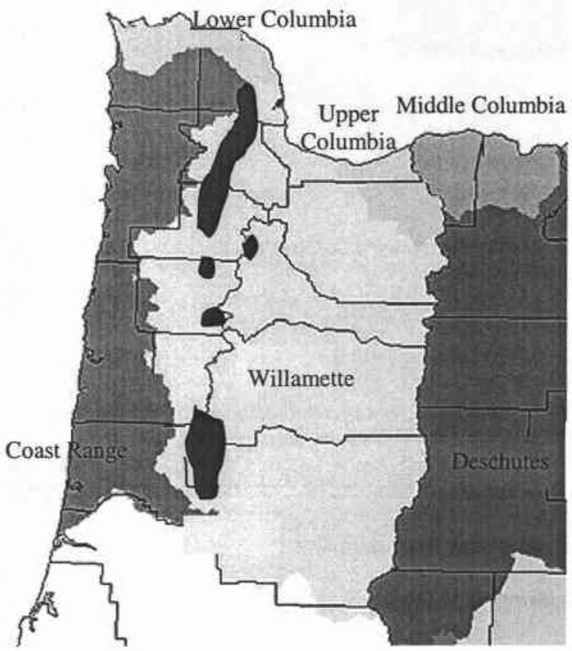


Figure 8. Wine producing regions of the Willamette Valley, Oregon

B. Where to Start

The suggestions discussed in the following sections are not absolute. In establishing a truffle crop the factors that must be considered are unique to every plot and should be determined individually. Also, there is a strong possibility that agriculturalists will already have systems implemented in their farm that can be used in place of those listed here. In writing this section, the author has attempted to address most issues and concerns commonly encountered by existing truffle cultivators. It can be assumed that not all of the equipment and procedures listed here are essential for every situation. Also, some situations may require additional equipment or methodology. The objective is to err by suggesting too many rather than not enough of the requirements a grower may have to consider before establishing a truffle crop.

1. Choice of Environment

An important component in determining a site for truffle cultivation is choosing an area, like the Willamette Valley, with similar climatic conditions to the native habitat of the species. Second in importance is the soil type and structure. To minimize the growth of competitive fungi in the soil, the plot should be free of growing trees for at least ten years prior to planting. Also, soil should be very rich in lime with an optimal pH of 7.9. In the case of the Willamette Valley, most soils are between 6 and 6.5, a pH below the optimal level. If the soil is too acidic (low pH), lime should be added and worked into the soil at least one year prior to planting. A liming chart can be used similar to that in Table 1 to determine the exact amount of lime needed for various types of soil. The only way to determine the quality and quantity of minerals in a soil is to have it analyzed, which is a process that can be done through various private soil analysis laboratories. The test should yield balanced texture, granular structure, sufficient organic matter (2-8%), C: N ratio near 10 and a mineral composition without an excess or deficiency of any essential element (Delmas 1978). Soil characteristics must be suitable for the desired host species as well as the truffles.

Table 1. Tons of lime needed to raise soil pH to 7.0 (Tree Fruit 2000)

Soil pH	Sands	Sandy loams	Loams & silt loams	Silty clay loams
4.5	4.5	10.0	16	22
4.6-4.7	4.5	10.0	15.5	21.5
4.8-4.9	4.5	9.5	14.5	20.5
5.0-5.1	3.5	8.5	13.0	18.0
5.2-5.3	2.5	7.0	11.0	14.5
5.4-5.5	1.7	5.0	7.0	10.2
5.6-5.7	1.7	3.5	5.0	7.7
5.8-5.9	1.2	2.5	4.5	6.0
6.0-6.1	1.0	2.5	3.5	5.0
6.2-6.3	0.7	1.7	2.5	3.5
6.4-6.5	0.5	1.2	1.7	2.5
6.6-6.7	0.4	0.9	1.2	1.7

Also, a sun-exposed site is preferable to a cool, shaded site, especially where rain accumulates in late winter. Sites north (south in the southern hemisphere) of 46 degrees latitude are not recommended (Singer and Harris 1987). The slope of the site should be less than 13.5 degrees to allow for ease of tilling and other mechanical work as well as to resist erosion. If the site is windy, the feasibility of installing a shelter, such as wind netting should be considered.

2. Choice of Host Tree

Today, most new truffle plantations are established using seedlings that have been previously mycorrhized by the desired species of truffle in a nursery. Hazelnut seedlings (*Corylus avellana*) colonized by *T. melanosporum* are most commonly available in the United States. After about one year, the trees are transplanted and under the right conditions production of truffles can be expected after 7-10 years.

When choosing hazelnuts as the host tree species in the Willamette Valley, one must consider the danger of Hazelnut blight, a disease that has recently affected some local hazelnut crops. This disease is detrimental to the tree and likewise, any truffles that might grow underneath it. Research is being done on the development of a resistant strain of hazelnut trees, however no results have been determined.

The host species, generally oak or hazelnut trees, can be purchased from truffle farms over the Internet or from independent growers. The current rate for a mycorrhized seedling is about $15 depending on the quantity desired. When ordering the plants, root tips should have at least 70% colonization by *T. melanosporum* and lack other species of ectomycorrhizal fungi.

Trees should be planted in densities of 250 to 500 trees per acre with a spacing ranging from 10 to 15 feet (Garland, pers. comm). As trees grow, it may be necessary to thin the stand. Planting may be carried out from October to December, or alternatively from February to April depending on local weather conditions (Bencivenga et al. 1983; Signorini and Valli 1990). The advantage to planting in the fall is that trees are ready for rapid growth in the spring, although frost and cold weather may affect them. If an irrigation system is installed, which is highly recommended, seedlings can be planted in early spring, just after the last frost. Truffle production can be expected to start after six to eight years and full production (often fluctuates) is usually achieved after ten years.

Truffle growers generally follow one of three general cultivation methods. The traditional method, the Pallier method and the Tanguy method all differ in the amount of labor required by the grower and opinions vary as to which is the most productive.

The traditional method of cultivation is used when one finds a stand of trees where truffles are already being produced. In this method, used mainly with oak trees, the grower plants additional tree seeds (acorns) around the colonized tree and once the seeds germinate, he/she transplants the germinated seeds to new areas. The trees are left to grow naturally with little maintenance. The resulting seedlings from this method were often mycorrhized by truffles, however they were also mycorrhized by competitive fungi. Although the traditional method of cultivating truffles was used for two hundred years, it is not possible in Oregon and is now considered unreliable because many of the resulting trees never produce truffles.

The most common types of culture are the Pallier and the Tanguy methods, both of which have yielded excellent results (Chevalier, 1998, Lefevre, in press). The Pallier method is most intensive and requires regular tilling, pruning and irrigation. The Tanguy method is less intensive and replaces tilling with mowing and the trees are not pruned (Delmas 1978). The Pallier method is more expensive than others however production of truffles is often earlier (Lefevre, in press). The Pallier method is described in detail in the following sections and is used in the economic analysis in this paper.

3. Land Preparation

One year before the trees are planted, the plot should be treated with the appropriate amount of agricultural lime. Lime treatments should be applied to the plot as often as necessary to keep the soil at the correct pH (about 7.9) for the truffles. In year zero, before the trees are planted, plow to a depth of 38 to 50 cm (15-20 in) and remove all existing plant or weed cover (use of glyophosphate (Round-Up) is accepted by some growers) (Renowden 2001). This minimizes the amount of plants that harbor undesirable fungi and microorganisms in the soil. The ability of *Tuber melanosporum* to compete with other ectomycorrhizal fungi is limited (in less than ideal conditions), so it is essential to choose ground that is as free as possible from competitive organisms (Mamoun and Olivier 1989).

Next, the layout of the plot should be marked with wooden stakes that will also serve as tree supports. Spacing of the trees can vary depending on the needs of the truffles and the host species (*T. melanosporum*, for example, requires more sun than *T. magnatum* (Giovannetti 1993)). Plots with 400 to 500 trees per acre (considered the maximum density) are suitable for small trees such as hazelnuts. This density enables more rapid colonization of the soil by roots as well as early production of truffles (Giovannetti 1993).

Irrigation lines should be installed to insure that the trees and the truffles have adequate water in dry seasons. In regions where rainfall is consistent, it is not imperative that a grower installs an irrigation system. However, it is almost certain that a rainless summer leads to a winter without truffles, and a shortage of water does reduce the yield (Guillaume, 1972). According to Renowden (pers. comm), the system needs to be able to deliver an equivalent of one inch of rain twice a week, especially in mid to late summer. Variation in climate and precipitation, however, are still crucial to truffle growth.

Therefore, an alternation of dry and wet conditions is recommended (Singer and Harris 1987). The irrigation system could be a permanent underground structure or a less permanent drip line. Some growers prefer spray sprinkler systems to drip systems because they may promote horizontal root growth. Keeping the root system close to the surface is thought to increase yield and simplify the harvest (Renowden 2001).

4. Pest Control

The existence of pest insects and animals varies with the location of the truffle plantation. Some insects may actually be more useful than harmful to a truffle grower because they are known to be good indicators of mature truffles. The truffle flies, such as *Helomyza tuberivora*, and about a dozen other flies which feed on *Tuber melanosporum*, have not been studied enough to determine their effect on truffle production (Singer and Harris 1987).

There are certain rodents, specifically the Pacific flying squirrel and the California red vole, for which hypogeous fungi constitute a large part of their diet (Trappe & Maser 1976). At night they descend from the trees and dig up the fungus. There may be other rodent-like animals and deer that forage for truffles. Hypogeous mycorrhizal fungi appear to depend on animals that consume truffles in the wild. For example, Tassel-eared squirrels can serve as vectors of spore dissemination (Farentinos, 1984). It is also possible some fungal species require the physical and chemical scarification from a rodent digestive tract to induce germination (Fogel and Trappe, 1978, Kotter and Farentinos 1984).

Due to the strong volatile character of the species, cultivated truffles must definitely be protected from predatory rodents, deer and even slugs. In France, electric fences are installed to keep animals away. Slugs are controlled in New Zealand by use of selective bait (Renowden 2001). Trees can also be encircled by deeply implanted barbed wire or by a ring of branches soaked in a mixture of oil and lime (Delmas 1978). When the host trees are young, it is recommended to protect the root system as well as the tree by surrounding it loosely with mesh fencing or another type of animal deterrent.

In the wild, animals and insects appear to aid the biological cycle of the truffle. In truffle cultivation, however, it is important to keep young saplings and truffle zones free of any major predators. Simple measures can be taken to protect a tree plantation that won't harm the fungi. Fencing, baiting and use of plant guards are common and recommended, while the use of pesticides is strongly discouraged.

5. Plantation Maintenance

After the initial year, maintenance is relatively simple. Weeds and surrounding grasses should be mowed or removed throughout the year, using herbicides (Round-up) sparingly. In the Willamette Valley, appropriate amounts of lime should be applied in consecutive years or alternating years depending on the pH of the soil. If hazelnut trees are planted, they will need pruning during the winter to establish the right shape. A single stem is preferred for the first foot of the tree (Renowden 2001).

The soil should be tilled every year before spring to allow for proper storage and retention of water in the dry seasons. It is recommended that the depth of tillage start at about 15 cm (6 in) and decrease with each subsequent year (Delmas 1978). When the burnt-out clearing (brulé) appears around the base of the tree, tilling should be replaced with superficial weeding in those areas, although some people continue to till after production begins. No fertilization of the soil is advised unless there are symptoms of deficiency or an obvious imbalance (Delmas 1978). Also, it is recommended that one use light mechanical tools to scratch the surface of the truffle zone (in the brulé) in early spring to aerate the soil and promote truffle activity (Delmas 1978). One must only work the soil if it is well dried out, never after a hard rain, which can lead to root asphyxiation.

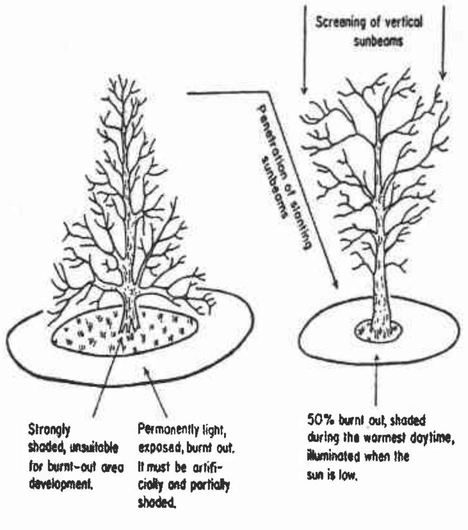


Figure 9. Pruning methods for host species of *Tuber melanosporum* (J. Grente).

To ensure the proper health of the truffles, trimming of the host species should begin in the first year. For *Tuber melanosporum*, a species requiring slightly more sunlight than other species, the host trees should be trimmed in the shape of an inverted cone (Figure 9) (Signorini and Valli 1990). The coned shape will enable the sun's rays to penetrate the soil except during the hottest hours when the sun is directly overhead. This will also ensure that gentle showers reach the ground, while still providing protection against heavy rainfall.

6. Choice of Harvesting Technique

The sporophore of *Tuber melanosporum*, initiated during the summer and autumn, enlarges and ripens within a few months. Ripening of the fruiting body is signified by the strong, sweet, characteristic odor of the truffle, giving it all of its value (Delmas 1978). It is important to remember that not all truffles reach maturity. The truffles that are too small for the market should be crushed upon retrieval and replaced in the soil. Large truffles can be frozen and sold to growers for seedling inoculation. They can also be sold on the market. Truffles mature between November and March, which determines the duration of the harvest season.

Different methods of harvest are utilized among growers. Traditionally sows were used to sniff out the truffles however, currently in Europe, more trained dogs are used to sniff out truffles (e.g., Peer 1980). The advantages to using dogs are that they are less interested than sows in eating the fungi, dogs can be easily trained and they have the desire to please their master. According to Grente (1973), "the training of a truffle dog is a complex art and demands much psychology on the part of the master".

In the wild, truffle harvesters may rake the soil, allowing for rapid collection of all or most of the truffles in a given area. The raking method helps to determine what portions of the soil have already been searched, however the impacts of tearing up the soil could be detrimental to the mycorrhizal system and the progress of the truffle patch. Also, truffles extracted with a rake are sometimes broken or gouged and frequently lack aroma (Lefevre et al., in press). Spore maturation proceeds in conjunction with the fragrance and flavor of the truffle, so that when the fruiting bodies lack aroma, they are likely to be immature and without flavor. Incidentally, it has been suspected that sales of immature truffles in the early years of the industry gave the Oregon truffles, *Tuber gibbosum* and

Leucangium (Picoa) carthusianum a bad reputation that continues to hurt the industry (Lefevre et al., in press).

Different authors report annual yields of *Tuber melanosporum* that vary from 20 to 150 kg per hectare (20-150 lbs/acre). These values depend directly on weather conditions as well as differences in soil quality and microclimatic conditions. It is difficult to predict the overall production of a truffle plantation because of differences in growing environments. In the opinion of some growers, greater tree density leads to a better harvest. It can be expected that only 10-50% of the trees will produce truffles in a given year (Delmas 1978, Shaw 1995) and according to Garland (2001) one can predict an average annual production of about 0.1 kg (0.25 lb) per tree each year.

7. Post-Harvest

In the first month of the harvest, usually December, truffles appear and must be cleaned and sorted immediately. According to one source, washed truffles keep as well as truffles that are left in the earth (Saint Alvere 2001). However, once the mature or nearly mature fruiting body is removed from the soil, the aroma begins to intensify and peak ripeness can occur quickly within a few days.

Truffles must be stored under proper conditions to minimize the effects of storage on their aroma and flavor. Truffles should be soaked before washing (not to exceed one hour) and then brushed lightly in drinking water (Saint Alvere 2001). After the truffles are removed from the water, they should be wiped dry in a cool environment to reduce the difference in temperatures between drying and storing. Finally, they should be placed in a storage container lined with absorbent paper. Some growers prefer not to wash truffles and store them in dry rice. However, rice may dehydrate the fungus, resulting in a reduction of truffle quality (Lefevre et al. in press).

A storage refrigerator kept between 0° and 2°C (32-35.6°F), used solely for truffles, is recommended (Renowden 2001). It is important to keep the truffles at low temperatures to slow the rates of respiration and oxidation, which lead to the ripening and eventual spoiling of the carpophore.

IV. Economics of Starting Truffle Cultivation in the Willamette Valley

A. Market

Truffle prices vary depending on the species, season, quality of the harvest, and regions in which they are bought and sold. The Italian white truffle is worth considerably more than the Périgord black truffle, however it has not been successfully produced outside of its natural habitat, which is in a small region in Italy. According to Olivier (2000), the Périgord black truffle, *T. melanosporum* averages a market value between $300 and $450 per kg ($660 and $990 per lb) in Europe. The same species has a much higher market value in the United States, which has been upwards of $770 per kg ($1700 per pound) (as cited in Lefevre, in press). Still, in New Zealand, *T. melanosporum* sells for more than $1400 per kg ($3080 per pound).

Commercial truffle producers sometimes offer products other than fresh truffles to the consumers. Truffles have been used for making liqueurs, scenting tobacco and as an ingredient of certain perfumes; they have been recognized as aphrodisiacs in several countries. Some growers offer alternative products that cost less than fresh truffles. For example, truffle powders, pastes and oils are available for purchase in various sizes and prices. The truffle can also be frozen or canned, although often times the flavor diminishes compared to the fresh truffle. Opinions differ on the quality of flavor one gets from added value options, however more research could be done to develop improved truffle products.

It is difficult to accurately predict market values for a crop like *T. melanosporum* for several reasons. The species is susceptible to changes in weather, and production yields can vary considerably from year to year (Pilz et al., 1999, Olivier, 2000, Vogt, et al,. 1992, Lefevre, in press). Also, harvesters have underestimated the volume of truffles produced, and therefore the US government lacks specific records on the annual harvest of *T. melanosporum* (Olivier, 2000, Lefevre, in press). It is known, however, that the mass of truffles produced worldwide has decreased dramatically in the last century from more than 1000 tons at the end of the 1900's (Delmas, 1978) to 40-50 tons now (Olivier, 2000, Lefevre, in press).

B. Constructing the Enterprise Budgets

Currently there is no commercial harvest of truffles in the Willamette Valley. Therefore, it is difficult to establish any concrete information on the costs and returns of starting a truffle enterprise in Oregon. Native species of truffle have never been commercially cultivated and therefore the European variety *Tuber melanosporum* is used here. To objectively determine if a truffle enterprise would be feasible it is important to consider the variations in individual plots and the possibility of crop failure. This enterprise budget estimates the hypothetical costs and returns associated with truffle cultivation in the Willamette Valley region. It should be used only as a guide to estimating actual costs and is not representative of any particular farm. The major assumptions used in constructing this budget are discussed below.

1. Assumptions

Land

This budget is based on a ten-acre establishment within an existing farm. The land was once a vineyard and has been cleared of trees for the previous ten years. Soil is uniform throughout, has an initial pH of 6.5 and is sandy loam. Three tons of lime are applied biannually to every acre. A land lease charge of $150 is included to reflect the costs of owning or leasing the land.

Labor

Owner labor is valued at $14 per hour and is used for tree planting, irrigation installation, rodent control, pruning, dog training, harvest, packaging and marketing.

Hired labor is valued at $9.50 per hour, which including all costs associated in withholding taxes, record keeping and payroll. All hired labor is paid on an hourly basis and used for irrigation installation, tree planting, pruning and weed and rodent control.

Machinery and Equipment

Machinery and equipment are rented for major land preparation and treatment. Prices reflect the cost for renting the equipment for one day and assume that all ten acres can be treated in this time. In the first three years a 50-horsepower 2-wheel-drive tractor equipped with disc and harrow is used. In years 4 through 6, the field is plowed using the same tractor equipped with tines. In subsequent years soil is lightly raked by hand. A four-wheel drive truck is previously owned by the grower and is used for miscellaneous tasks and transportation related to truffles. Gasoline and diesel costs per gallon are $1.20 and $0.80. Both the labor and product are included in the price for the hired biannual applications of lime.

Establishment Costs

Mycorrhized hazelnut trees are purchased at a rate of $15 each. In year 0, weeds are removed, the soil is tilled again and an underground irrigation system is installed. Water is pumped from a well, situated on the property, with a 44 GPM submersible pump. Electricity is charged at $0.06 per kilowatt-hour.

Each acre is marked with wooden stakes into 20 rows and 20 columns. Each row is equipped with 11 ten-foot spray jets spaced 20 feet apart and connected by 2" PVC pipe. Each acre is separated into ten irrigation zones so water is automatically pumped to only 22 sprinklers at any one time. Each acre is planted with 400 trees spaced 10 ft x 10 ft. Tree roots are surrounded with three circular feet of 2 ft mesh fencing and the saplings are surrounded with conical plastic spray guards.

Capital

The interest rate on operating capital is 8.0% percent and treated as a cash expense. The owner pays all cash expenses and interest on intermediate and long-term capital (8%) is treated as a noncash opportunity cost.

Operations

The cultivation operations are listed approximately in the order in which they are performed. A manual 2-gallon spreader is used to spray Round-up. Five dogs are purchased for the harvest of all ten acres. Dogs are trained mostly by the owner and are treated as noncash costs with depreciation and interest charges. An upright refrigerator is purchased for truffle storage. Packaging costs reflect the prices of small and medium boxes and biodegradable packing material.

Harvest and Market

The first establishment year is referred to as year –1 and the trees are planted in year 0. There are a total of 12 establishment years. In the seventh year of establishment small harvests begin, in the twelfth year full production begins and it continues at a steady production rate for an additional 15 years. The harvests are separated into three categories depending on the yield received. A "high" yield is equivalent to 100 pounds of truffles, whereas a "medium" yield is 50 pounds and a "low" yield is 25 pounds. The Price per pound of truffle is set at $300/lb, which is a low average of the market value for *T. melanosporum* in the year 2000.

A summary of the costs and returns for the production cycle of *T. melanosporum* are listed in Table 2, pages 31-32. Detailed budgets are shown in Appendix Tables as referred to in the year-by-year narrative below. The numbers in bold can be changed by the user in a spreadsheet version of these tables. (Totals of variable and fixed costs are rounded to whole dollar amounts.)

2. Full Production Cycle

After 12 establishment years the amortized establishment payment for each acre is $3,731, which is "charged" against the 15 years of full production (with medium production). This is the average cost to the grower for every year in the production cycle. Annual profit to the grower is $9,678/acre and the total production net profit is $145,169/acre. The maximum "debt" to the grower occurs three years before full production and is $35,020. This is hypothetically the amount of money the grower would have accumulated (including principal and interest) if all costs for establishing a truffle crop were alternatively invested in a savings account at an 8% interest rate. When full production begins, 3 years before full production, a positive cash flow ensues and the costs and returns break even 2 years after full production (Figure 10, page 33).

Break-even analyses are helpful in determining prices and yields the grower must meet for the enterprise costs to equal the returns (Figure 11). Prices in the break-even analysis represent the market price necessary to earn zero net returns when full production yield is constant. Similarly, Yields in the analysis represent the pounds of truffles necessary for a farmer to have net returns of zero (after the full production cycle) when the market value is constant.

The long-run price analysis is the lowest price for which the grower can sell truffles and still recover all costs. In order to break-even in the short-run, returns must only cover the variable production costs. In other words, in a particular year, the producer would be better off producing rather than not producing if price or yield exceeds the short-run break even.

Break Even Value Criteria	Price per pound (US$)	Full Production Yield (lb)
Long-Run Price	$131	50
Short-Run Price	$29	50
Long-Run Yield	$300	17
Short-Run Yield	$300	4

Figure 11. Break Even Value Criteria for Full Production Cycle of *Tuber melanosporum* (per acre)

Figure 12 shows major cost components related to total cash expenses. The cost of the trees comprises 34% of this total. The second greatest expense comes from irrigation installation and electricity use, making up 21% of the total. Lime application, owner labor and operating capital interest also use 21% of the total cash costs and 24% are included in machinery, taxes, miscellaneous purchases, fuel and oil.

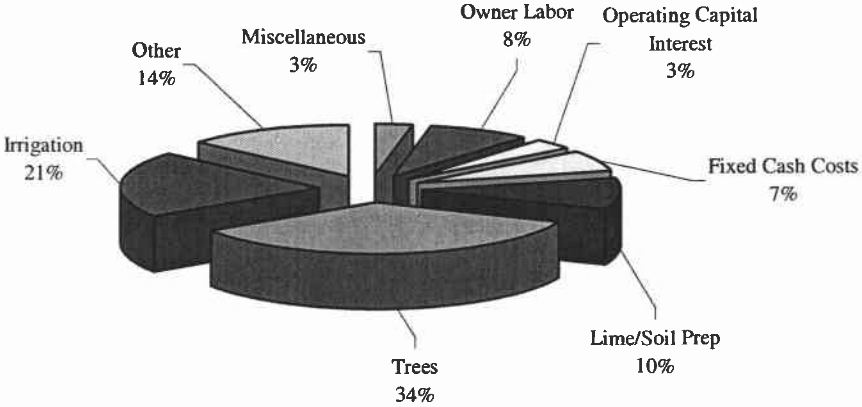


Figure 12. Cash costs to Establish Tuber melanosporum for the First 12 Years of Establishment

Figure 13 shows overall cost components in relation to all of the expenses. The assumed interest rate of 8% encompasses 28% of the total costs and is the largest item. The cost of trees, however, is still 25% of the total costs and irrigation costs comprise 15%.

The expenses included in this summary are for the 12 year establishment period described in this paper. Yearly budgets are included in Appendix B, pages 37 through 50. Costs are likely to fluctuate and changes in assumptions for irrigation methods, owner labor wages, equipment purchase or rental and interest rates will cause shifts in each individual cost analysis.

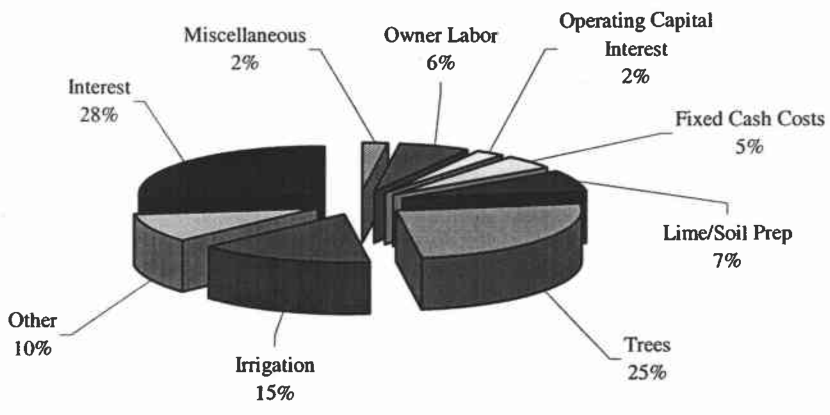


Figure 13. Economic Costs to Establish Tuber melanosporum for the First 12 Years of Establishment

Perennial Crop Break-Even Calculator

Crop and location	***Truffles + New Stand of Trees***								
Number of establishment years	12								
Final (salvage) value of investment	***$0***								
Number of full production years	***15.0***								
Interest rate for ammortization	***8.00***								
	-11	-10	-9	-8	-7	-6	-5	-4	-3
Item	**Establishment Year -1**	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**
Price	***$300.000***	$300.000	$300.000	$300.000	$300.000	$300.000	$300.000	$300.000	$300.000
Yield	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***	***2.00***	***4.00***
Annualized value of tree harvest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gross revenue	0.00	0.00	0.00	0.00	0.00	0.00	0.00	600.00	1,200.00
Non-yield-related variable costs	***516.72***	***11,039.76***	***1,535.55***	***1,307.80***	***1,436.51***	***1,380.09***	***1,497.22***	***2,349.65***	***1,567.74***
Yield-related var. costs per yield unit	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	***3.000***	***3.000***
Total of all variable costs	516.72	11,039.76	1,535.55	1,307.80	1,436.51	1,380.09	1,497.22	2,355.65	1,579.74
Returns above variable cost	-516.72	-11,039.76	-1,535.55	-1,307.80	-1,436.51	-1,380.09	-1,497.22	-1,755.65	-379.74
Fixed costs for current year	***151.00***	***219.83***	***165.26***	***165.26***	***273.29***	***153.09***	***153.09***	***176.85***	***153.09***
Current year net return	-667.72	-11,259.59	-1,700.81	-1,473.06	-1,709.80	-1,533.18	-1,650.31	-1,932.50	-532.83
Interest carryover from prev. years	0.00	-53.42	-958.46	-1,171.20	-1,382.74	-1,630.14	-1,883.21	-2,165.89	-2,493.76
Gain (loss) + interest carryover	-667.72	-11,313.01	-2,659.27	-2,644.26	-3,092.54	-3,163.32	-3,533.52	-4,098.39	-3,026.59
Cumulative gain (loss)	-667.72	-11,980.73	-14,640.00	-17,284.26	-20,376.80	-23,540.12	-27,073.64	-31,172.03	-34,198.62

Summary Results	
Ammortized establishment payment	($3,730.92)
Annual Profit	$9,677.93
Production Cycle Profit	$145,168.93

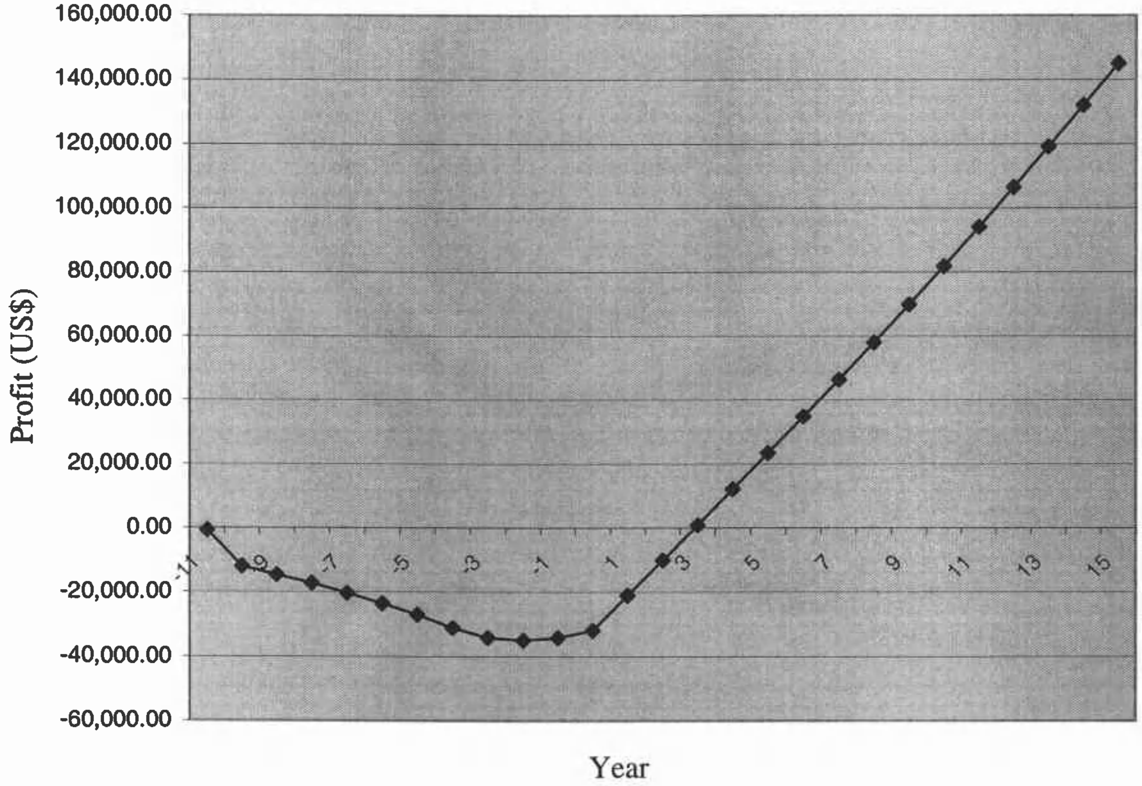
Table 2. Summary of Enterprise Budget for Tuber melanosporum, Medium Production Cycle per Acre

Perennial Crop Break-Even Calcu

Crop and location	***Truffles + New***								
Number of establishment years	12								
Final (salvage) value of investment	***$0***								
Number of full production years	***15.0***								
Interest rate for ammortization	***8.00***								
	-11	-2	-1	0	1	2	3	4	5
	Establishment				**Full Production**				
Item	**Year -1**	**Year 8**	**Year 9**	**Year 10**	**Year(s)**				
Price	***$300.000***	$300.000	$300.000	$300.000	$300.000	$300.000	$300.000	$300.000	$300.000
Yield	***0.00***	***12.00***	***18.00***	***22.00***	***50.00***	***50.00***	***50.00***	***50.00***	***50.00***
Annualized value of tree harvest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gross revenue	0.00	3,600.00	5,400.00	6,600.00	15,000.00	15,000.00	15,000.00	15,000.00	15,000.00
Non-yield-related variable costs	***516.72***	***1,496.06***	***1,656.48***	***1,288.06***	***1,288.06***	***1,288.06***	***1,288.06***	***1,288.06***	***1,288.06***
Yield-related var. costs per yield unit	***0.000***	***3.000***	***3.000***	***3.000***	***3.000***	***3.000***	***3.000***	***3.000***	***3.000***
Total of all variable costs	516.72	1,532.06	1,710.48	1,354.06	1,438.06	1,438.06	1,438.06	1,438.06	1,438.06
Returns above variable cost	-516.72	2,067.94	3,689.52	5,245.94	13,561.94	13,561.94	13,561.94	13,561.94	13,561.94
Fixed costs for current year	***151.00***	***153.09***	***153.09***	***153.09***	***153.09***	***153.09***	***153.09***	***153.09***	***153.09***
Current year net return	-667.72	1,914.85	3,536.43	5,092.85	13,408.85	13,408.85	13,408.85	13,408.85	13,408.85
Interest carryover from prev. years	0.00	-2,735.89	-2,801.57	-2,742.78					
Gain (loss) + interest carryover	-667.72	-821.04	734.86	2,350.07					
Cumulative gain (loss)	-667.72	-35,019.66	-34,284.81	-31,934.74	-21,080.67	-10,132.51	917.27	12,076.80	23,354.86
Summary Results									
Ammortized establishment payment	($3,730.92)			-3,730.92	($3,730.92)				
Annual Profit	$9,677.93				$9,677.93				
Production Cycle Profit	$145,168.93				$145,168.93				
				Princ. part of amm. pmt.	$1,176.14	$1,270.23	$1,371.85	$1,481.60	$1,600.13
				Int. part of am. pmt.	$2,554.78	$2,460.69	$2,359.07	$2,249.32	$2,130.79

Table 2. Summary of Enterprise Budget for Tuber melanosporum, Medium Production Cycle per Acre

Figure 10. Cumulative Net Returns for *Tuber melanosporum* , High Production Cycle per Acre



V Conclusion

The intent of this paper has been to present an objective view of the important factors involved with establishing and cultivating *Tuber melanosporum*, the "Périgord black truffle" in the Willamette Valley. While it may be difficult to draw strong conclusions from the information presented, this paper is meant to be a starting point for someone in the Willamette Valley looking to truffles as a possible alternative enterprise. This conclusion will recapitulate the important points of this paper and attempt to focus the reader on the aspects most pertinent to the establishment of a truffle farm in the Willamette Valley.

The truffle is a hypogeous fungus that forms a symbiotic relationship with a host tree and continues to develop underground. The fungus emits a unique and pungent odor when ripe, giving rise to its popularity, and has captured the attention of gourmets for centuries.

Commercial cultivation of the Périgord black truffle began in Europe during the late 1970's and since then, the truffle enterprise has developed in several countries around the world. Most truffle plantations are located in Europe, however growers are currently establishing crops in Israel, the United States, New Zealand, Australia Tasmania, and other nations.

Although many species of truffles exist, *T. melanosporum* is the most commonly cultivated and the only species known to produce truffles out of its natural habitat. *T. melanosporum* is consistently valued as the second most expensive truffle on the market ranging from $300 to $450/kg ($660 to $990/lb). The Italian white truffle, *Tuber magnatum* is worth more than $1000/kg ($2200/lb), however it is only known to grow in a small region of Italy.

The reasons a farmer may consider the cultivation of the Périgord black truffle are as follows: supply is not meeting the demand, there are only about 8 commercial truffle producers outside of Europe, truffles can be relatively easy to maintain and harvest and annual truffle production can exceed 100 kg/ha (100 lb/acre), which could potentially generate a gross income of more than $30,000/ha ($30,000/acre). In the Willamette Valley, there are two additional factors that could potentially increase the success of truffiéres. First, the Willamette Valley has a similar climate to common truffle growing regions of France. Both the temperature and moisture differences between seasons are important for development. Truffles require large variations of both of these factors in order to form. Second, raising the pH of the naturally acidic soil by using large additions of lime could impede the growth of native fungi (adapted to acidic soils) that would normally compete with *T. melanosporum*. In other areas where the pH of the soil is naturally high, native fungi may compete with the black truffles for mycorrhizal associations and cause a reduction in truffle production.

Even though the advantages of establishing and maintaining a truffle crop may sound inviting, there are several factors that make truffle cultivation a high risk enterprise. Truffle cultivation is a relatively new practice and there has been little research done on the viability of starting such an enterprise outside of Europe. More research is being done in areas where truffle cultivation is taking place, however several unanswered questions remain. Scientists are not certain of the factors that induce the development of the fruiting body of the truffle. Such factors could include combinations of different soil types, moisture concentrations, temperatures, pH levels, types of host species and other environmental factors.

Economically, truffles are also considered a high risk enterprise. According to most growers, on average, truffles will not reach full production until the tenth establishment year. Including the first year of soil preparation and the year trees are planted as year zero, 12 establishment years were included in the enterprise budget for this paper. Using this system, the grower accumulates a maximum investment of $35,000 in year 8. Yearly budgets are included in Appendix B showing a budget analysis for each of the 12 years of establishment. Growers can expect to break even in year 15, three years after full production ensues. Assuming that the market value of *T. melanosporum* and the yields produced on a farm are consistent, the grower can expect to earn an annual profit of $9,677/acre and a production cycle profit of $145,168/acre.

Although growing the specialty crop *Tuber melanosporum* appears be a viable enterprise in the long run, risks involved should not be ignored. In an ideal situation the establishment costs of the crop would be returned with the full production period of the cycle. However, there is no guarantee that truffles will develop and inconsistent yields are common in existing truffle plantations. Supply of truffles is currently low, resulting in an enticingly high market price, however if the number of black truffle plantations increases, market value for cultivated truffles has the potential to decrease dramatically. Some even argue that the mysterious nature of the fungus will be destroyed if it becomes widely available. One must consider that centuries ago truffles were abundant in the wild all across Europe and people consumed them regularly. In the United States however, many people don't consider truffles a regular food since they have largely been unavailable to most. The potential does exist for an increase in popularity and demand of truffles, especially outside of Europe where truffles have been extremely rare for the average consumer. It is important to weigh these factors when considering the establishment of a truffle farm and although the potential profit is large, it is very possible that a farm will be unsuccessful in producing truffles.

Possible areas of future study in the cultivation of *T. melanosporum* could include research on inoculation methods, effects of different soil types, temperatures, moisture and pH on the mycorrhizal associations truffles form with their hosts. It is clear that a plethora of questions remains about truffles in general. Perhaps, with time and money, interest in the species will evoke more researchers to gather enough data and reduce the risk of establishing truffles as an alternative enterprise.

Economic Costs & Returns
Establishing and Producing
Tuber Melanosporum (Black Truffle)
In the Willamette Valley, Oregon (Year -1)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Tuber Melanosporum & Hazelnut			0.00	**0.00**
Total GROSS Income				0.00

VARIABLE COST Description

	Materials Details					Total Cost
	quantity	*$/quantity*	*$/acre*	*$/acre*	*$/acre*	*$/acre*
PREHARVEST						
Soil Test			19.50	0.00		**19.50**
Addition of Calcium Carbonate					**154.25**	**154.25**
Ag 2 tn	1.50	51.50				
Dolmite 1 ton	2.00	38.50				
Disc & Harrow			8.47	8.97		**17.44**
Total PREHAVEST						191.19
HARVEST						
Total HARVEST						0.00
POST HARVEST						
Total POST HARVEST						0.00
OTHER						
Miscellaneous			25.00	0.00		**25.00**
Owner Labor			280.00	0.00		**280.00**
Operating Capital Interest			20.53	0.00		**20.53**
Total OTHER						325.53
Total VARIABLE Cost						516.72

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	**1.00**
Land Lease	150.00	**150.00**
Total CASH		151.00
NONCASH Cost		
Total NONCASH		0.00
Total FIXED Cost		151.00

TOTALS	
Total of VARIABLE Cost	516.72
Total of FIXED Cost	151.00
GROSS INCOME minus VARIABLE COST	-516.72
GROSS INCOME minus VAR. and CASH FIXED COST	-667.72
NET PROJECTED RETURNS	-667.72
Short-run Break-even Price, Total Variable Cost	#DIV/0!
Long-run Break-even Price, Total Cost	#DIV/0!

ECONOMIC COSTS and RETURNS
Establishing and Producing
Tuber Melanosporum (Black Truffle)
In the Willamette Valley, Oregon (Year 0)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Tuber Melanosporum on Hazelnuts	0.00	xxxx	0.00	0.00
Total GROSS Income				0.00

VARIABLE COST Description

	Materials Details quantity	$/quantity	$/acre	$/acre	$/acre	Total Cost $/acre
PREHARVEST						
Order trees			0.00	0.00	5600.00	5600.00
Inoculated Seedlings	400.00	14.00				
Mark Layout of Trees			5.00	3.00	7.50	15.50
Wooden stakes	1.00	7.50				
Clear Weeds and Grass			5.65	2.12	11.00	18.77
Glyphosate (Round-Up)	1.00	9.00				
Sticker	1.00	2.00				
Plow Field			10.50	8.97	265.00	284.47
Tractor (50HP)	1.00	200.00				
Flail (6-8 ft)	1.00	30.00				
Rotero/Packer (10 ft)	1.00	30.00				
Gasoline (Diesel)	4.00	1.25				
Irrigation Installation			1300.00	0.00	1621.90	2921.90
Varijet Spray Nozzles	132.00	1.20				
16 mm tubing	2520.00	0.05				
1/4 " tubing	700.00	0.06				
12" stake complete	132.00	0.85				
16 mm figure 8	15.00	0.22				
44 GPM submersible pu	1.00	755.00				
1" drop pipe	50.00	1.25				
2" #40 PVC pipe	250.00	0.65				
Miscellaneous	1.00	200.00				
Plant Trees			950.00	0.00	304.00	1254.00
Electricity to Irrigate	3.00	100.00				
Ties	400.00	0.01				
Plant Protection			0.00	0.00	492.00	492.00
Spray guards	400.00	0.18				
Mesh Fencing	1200.00	0.35				
Total PREHAVEST						10586.64
HARVEST						
Total HARVEST						0.00
POST HARVEST						
Total POST HARVEST						0.00
OTHER						
Pickup 4 WD			5.39	2.32		7.71
Miscellaneous			25.00	0.00		25.00
Operating Capital Interest			0.00	0.00	420.41	420.41
Total variable cost	10510.31	0.04				
Total OTHER						453.12
Total VARIABLE Cost						11039.76

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	1.00
Land Lease	150.00	150.00
Total CASH		151.00
NONCASH Cost		
Machinery & Equipment Deprec. & Interest	68.83	68.83
Total NONCASH		68.83
Total FIXED Cost		219.83

TOTALS	
Total of VARIABLE Cost	11039.76
Total of FIXED Cost	219.83
GROSS INCOME minus VARIABLE COST	-11039.76
GROSS INCOME minus VAR. and CASH FIXED COST	-11190.76
NET PROJECTED RETURNS	-11259.59
Short-run Break-even Price, Total Variable Cost	#DIV/0!
Long-run Break-even Price, Total Cost	#DIV/0!

ECONOMIC COSTS and RETURNS
Establishing and Producing
Tuber melanosporum (Black Truffle)
In the Willamette Valley, Oregon (Year 1)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Type in name of crop	0.00	xxxx	0.00	0.00
Total GROSS Income				**0.00**

VARIABLE COST Description

	Materials Details					Total Cost
	quantity	*$/quantity*	*$/acre*	*$/acre*	*$/acre*	*$/acre*
PREHARVEST						
Weed Control			10.00	2.00	**144.25**	**156.25**
Glyphosate (Round-Up	1.00	9.00				
Manual Spreader	1.00	135.25				
Tree Protection Maintenance			20.00	0.00	**14.00**	**34.00**
Stakes	20.00	0.25				
Spray Guards	50.00	0.18				
Plow to 6"			8.76	250.00	**154.25**	**413.01**
Ag 2 tn	1.50	51.50				
Dolmite 1 tn	2.00	38.50				
Pruning			200.00	0.00		**200.00**
Irrigation			5.65	0.00	**300.00**	**305.65**
Electricity	3.00	100.00				
Total PREHAVEST						**1108.91**
HARVEST						
Total HARVEST						**0.00**
POST HARVEST						
Total POST HARVEST						**0.00**
OTHER						
Pickup 4 WD			5.39	2.32		**7.71**
Miscellaneous			75.00	0.00		**75.00**
Owner Labor			290.00	0.00		**290.00**
Operating Capital Interest			0.00	0.00	**53.93**	**53.93**
Total Variable Cost	1348.24	0.04				
Total OTHER						**426.64**
Total VARIABLE Cost						**1535.55**

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	**1.00**
Land Lease	150.00	**150.00**
Total CASH		**151.00**
NONCASH Cost		
Machinery & Equipment Deprec. & Interest	14.26	**14.26**
Total NONCASH		**14.26**
Total FIXED Cost		**165.26**

TOTALS	
Total of VARIABLE Cost	1535.55
Total of FIXED Cost	165.26
GROSS INCOME minus VARIABLE COST	-1535.55
GROSS INCOME minus VAR. and CASH FIXED COST	-1686.55
NET PROJECTED RETURNS	-1700.81
Short-run Break-even Price, Total Variable Cost	#DIV/0!
Long-run Break-even Price, Total Cost	#DIV/0!

ECONOMIC COSTS and RETURNS
Establishing and Producing
Tuber melanosporum (Black Truffle)
In the Willamette Valley, Oregon (Year 2)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Type in name of crop	0.00	xxxx	0.00	**0.00**
Total GROSS Income				0.00

VARIABLE COST Description

	Materials Details					Total Cost
	quantity	*$/quantity*	*$/acre*	*$/acre*	*$/acre*	*$/acre*
PREHARVEST						
Weed Control			10.00	2.00	**9.00**	**21.00**
Glyphosate (Round-Up	1.00	9.00				
Tree Protection Maintenance			20.00	0.00	**14.00**	**34.00**
Stakes	20.00	0.25				
Spray Guards	50.00	0.18				
Plow to 6"			8.76	250.00		**258.76**
Pruning			200.00	0.00		**200.00**
Irrigation			5.65	0.00	**375.00**	**380.65**
Electricity	3.00	125.00				
Total PREHAVEST						894.41
HARVEST						
Total HARVEST						0.00
POST HARVEST						
Total POST HARVEST						0.00
OTHER						
Pickup 4 WD			5.39	2.32		**7.71**
Miscellaneous			75.00	0.00		**75.00**
Owner Labor			290.00	0.00		**290.00**
Operating Capital Interest			0.00	0.00	**40.68**	**40.68**
Total Variable Cost	1017.12	0.04				
Total OTHER						413.39
Total VARIABLE Cost						1307.80

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	**1.00**
Land Lease	150.00	**150.00**
Total CASH		151.00
NONCASH Cost		
Machinery & Equipment Deprec. & Interest	14.26	**14.26**
Total NONCASH		14.26
Total FIXED Cost		165.26

TOTALS	
Total of VARIABLE Cost	1307.80
Total of FIXED Cost	165.26
GROSS INCOME minus VARIABLE COST	-1307.80
GROSS INCOME minus VAR. and CASH FIXED COST	-1458.80
NET PROJECTED RETURNS	-1473.06
Short-run Break-even Price, Total Variable Cost	#DIV/0!
Long-run Break-even Price, Total Cost	#DIV/0!

ECONOMIC COSTS and RETURNS
Establishing and Producing
Tuber melanosporum (Black Truffle)
In the Willamette Valley, Oregon (Year 3)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Type in name of crop	0.00	xxxx	0.00	0.00
Total GROSS Income				0.00

VARIABLE COST Description

	Materials Details quantity	Materials Details $/quantity	$/acre	$/acre	$/acre	Total Cost $/acre
PREHARVEST						
Weed Control			10.00	2.00	9.00	21.00
Glyphosate (Round-Up)	1.00	9.00				
Tree Protection Maintenance			20.00	0.00	14.00	34.00
Stakes	20.00	0.25				
Spray Guards	50.00	0.18				
Plow to 6"			8.76	250.00	154.25	413.01
Ag 2 tn	1.50	51.50				
Dolmite 1 tn	2.00	38.50				
Pruning			200.00	0.00		200.00
Irrigation			5.65	0.00	300.00	305.65
Electricity	3.00	100.00				
Total PREHAVEST						973.66
HARVEST						
Total HARVEST						0.00
POST HARVEST						
Total POST HARVEST						0.00
OTHER						
Pickup 4 WD			37.73	11.60		49.33
Miscellaneous			75.00	0.00		75.00
Owner Labor			290.00	0.00		290.00
Operating Capital Interest			0.00	0.00	48.52	48.52
Total variable Cost	1212.99	0.04				
Total OTHER						462.85
Total VARIABLE Cost						1436.51

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	1.00
Land Lease	150.00	150.00
Total CASH		151.00
NONCASH Cost		
Machinery & Equipment Deprec. & Interest	122.29	122.29
Total NONCASH		122.29
Total FIXED Cost		273.29

TOTALS

Total of VARIABLE Cost	1436.51
Total of FIXED Cost	273.29
GROSS INCOME minus VARIABLE COST	-1436.51
GROSS INCOME minus VAR. and CASH FIXED COST	-1587.51
NET PROJECTED RETURNS	-1709.80
Short-run Break-even Price, Total Variable Cost	#DIV/0!
Long-run Break-even Price, Total Cost	#DIV/0!

ECONOMIC COSTS and RETURNS
Establishing and Producing
Tuber melanosporum (Black Truffle)
In the Willamette Valley (Year 4)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Tuber Melanosporum	0.00	xxxx	0.00	0.00
Total GROSS Income				0.00

VARIABLE COST Description

	Materials Details					Total Cost
	quantity	*$/quantity*	*$/acre*	*$/acre*	*$/acre*	*$/acre*
PREHARVEST						
Weed Control			10.00	2.00	**9.00**	**21.00**
Glyphosate (Round-Up'	1.00	9.00				
Tree Protection Maintenance			20.00	0.00	**14.00**	**34.00**
Stakes	20.00	0.25				
Spray Guards	50.00	0.18				
Plow to 6"			8.76	250.00		**258.76**
Pruning			300.00	0.00		**300.00**
Irrigation			5.65	0.00	**300.00**	**305.65**
Electricity	3.00	100.00				
Total PREHAVEST						919.41
HARVEST						
Total HARVEST						0.00
POST HARVEST						
Total POST HARVEST						0.00
OTHER						
Pickup 4 WD			37.73	11.60		**49.33**
Miscellaneous			75.00	0.00		**75.00**
Owner Labor			290.00	0.00		**290.00**
Operating Capital Interest			0.00		**46.35**	**46.35**
Total Variable Cost	1158.74	0.04				
Total OTHER						460.68
Total VARIABLE Cost						1380.09

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	**1.00**
Land Lease	150.00	**150.00**
Total CASH		151.00
NONCASH Cost		
Machinery & Equipment Deprec. & Interest	2.09	**2.09**
Total NONCASH		2.09
Total FIXED Cost		153.09

TOTALS

Total of VARIABLE Cost	1380.09
Total of FIXED Cost	153.09
GROSS INCOME minus VARIABLE COST	-1380.09
GROSS INCOME minus VAR. and CASH FIXED COST	-1531.09
NET PROJECTED RETURNS	-1533.18
Short-run Break-even Price, Total Variable Cost	#DIV/0!
Long-run Break-even Price, Total Cost	#DIV/0!

ECONOMIC COSTS and RETURNS
Establishing and Producing
Tuber melanosporum (Black Truffle)
In the Willamette Valley (Year 5)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Tuber Melanosporum	0.00	xxxx	0.00	0.00
Total GROSS Income				**0.00**

VARIABLE COST Description

	Materials Details					Total Cost
	quantity	*$/quantity*	*$/acre*	*$/acre*	*$/acre*	*$/acre*
PREHARVEST						
Weed Control			10.00	2.00	**9.00**	**21.00**
Glyphosate (Round-Up)	1.00	9.00				
Tree Protection Maintenance			20.00	0.00	**14.00**	**34.00**
Stakes	20.00	0.25				
Spray Guards	50.00	0.18				
Plow to 6"			8.76	250.00	**154.25**	**413.01**
Ag 2 tn	1.50	51.50				
Dolmite 2 tn	2.00	38.50				
Pruning			300.00	0.00		**300.00**
Irrigation			5.65	0.00	**300.00**	**305.65**
Electricity	3.00	100.00				
Total PREHAVEST						**1073.66**
HARVEST						
Total HARVEST						**0.00**
POST HARVEST						
Total POST HARVEST						**0.00**
OTHER						
Pickup 4 WD			5.39	2.32		**7.71**
Miscellaneous			75.00	0.00		**75.00**
Owner Labor			290.00	0.00		**290.00**
Operating Capital Interest			0.00		**50.85**	**50.85**
Total Variable Cost	1271.37	0.04				
Total OTHER						**423.56**
Total VARIABLE Cost						**1497.22**

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	**1.00**
Land Lease	150.00	**150.00**
Total CASH		**151.00**
NONCASH Cost		
Machinery & Equipment Deprec. & Interest	2.09	**2.09**
Total NONCASH		**2.09**
Total FIXED Cost		**153.09**

TOTALS	
Total of VARIABLE Cost	1497.22
Total of FIXED Cost	153.09
GROSS INCOME minus VARIABLE COST	-1497.22
GROSS INCOME minus VAR. and CASH FIXED COST	-1648.22
NET PROJECTED RETURNS	-1650.31
Short-run Break-even Price, Total Variable Cost	#DIV/0!
Long-run Break-even Price, Total Cost	#DIV/0!

ECONOMIC COSTS and RETURNS
Establishing and Producing
Tuber melanosporum (Black Truffle)
In the Willamette Valley (Year 6)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Tuber Melanosporum	2.00	pounds	300.00	600.00
Total GROSS Income				600.00

VARIABLE COST Description

	Materials Details					Total Cost
	quantity	$/quantity	$/acre	$/acre	$/acre	$/acre
PREHARVEST						
Weed Control			10.00	2.00	9.00	21.00
Glyphosate (Round-Up)	1.00	9.00				
Tree Protection Maintenance			20.00	0.00	5.00	25.00
Stakes	20.00	0.25				
Spray Guards	10.00	0.00				
Plow to 6"			8.76	250.00		258.76
Pruning			400.00	0.00		400.00
Irrigation			5.65	0.00	300.00	305.65
Electricity	3.00	100.00				
Dog Training			20.00	0.00	75.00	95.00
Dogs	0.50	150.00				
Total PREHAVEST						1105.41
HARVEST						
Use Dogs to Find Truffles			300.00	0.00		300.00
Total HARVEST						300.00
POST HARVEST						
Packaging			2.00	0.00	465.00	467.00
Refrigerator 32-35 deg	1.00	465.00				
Total POST HARVEST						467.00
OTHER						
Pickup 4 WD			135.84	41.76		177.60
Miscellaneous			1.00	75.00		76.00
Owner Labor			140.00	0.00		140.00
Operating Capital Interest			0.00	0.00	83.64	83.64
Total Variable Cost	2091.01	0.04				
Total OTHER						477.24
Total VARIABLE Cost						2349.65

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	1.00
Land Lease	150.00	150.00
Total CASH		151.00
NONCASH Cost		
Machinery & Equipment Deprec. & Interest	25.85	25.85
Total NONCASH		25.85
Total FIXED Cost		176.85

TOTALS

Total of VARIABLE Cost	2349.65
Total of FIXED Cost	176.85
GROSS INCOME minus VARIABLE COST	-1749.65
GROSS INCOME minus VAR. and CASH FIXED COST	-1900.65
NET PROJECTED RETURNS	-1926.50
Short-run Break-even Price, Total Variable Cost	1174.83
Long-run Break-even Price, Total Cost	1263.25

ECONOMIC COSTS and RETURNS
Establishing and Producing
Tuber melanosporum (Black Truffle)
In the Willamette Valley (Year 7)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Tuber Melanosporum	4.00	pounds	300.00	**1200.00**
Total GROSS Income				1200.00

VARIABLE COST Description

	Materials Details quantity	$/quantity	$/acre	$/acre	$/acre	Total Cost $/acre
PREHARVEST						
Weed Control			10.00	2.00	**9.00**	**21.00**
Glyphosate (Round-Up)	1.00	9.00				
Pruning			400.00	0.00		**400.00**
Lime			0.00	0.00	**154.25**	**154.25**
Ag 2 tn	1.50	51.50				
Dolmite 1 tn	2.00	38.50				
Irrigation			5.65	0.00	**300.00**	**305.65**
Electricity	3.00	100.00				
Total PREHAVEST						880.90
HARVEST						
Use Dogs to Find Truffles			300.00	0.00		**300.00**
Total HARVEST						300.00
POST HARVEST						
Packaging			25.00	0.00	**75.95**	**100.95**
Boxes	1.00	75.95				
Total POST HARVEST						100.95
OTHER						
Pickup 4 WD			7.55	2.32		**9.87**
Miscellaneous			1.00	75.00		**76.00**
Owner Labor			140.00	0.00		**140.00**
Operating Capital Interest			0.00	0.00	**60.02**	**60.02**
Total Variable Cost	1500.45	0.04				
Total OTHER						285.89
Total VARIABLE Cost						1567.74

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	**1.00**
Land Lease	150.00	**150.00**
Total CASH		151.00
NONCASH Cost		
Machinery & Equipment Deprec. & Interest	2.09	**2.09**
Total NONCASH		2.09
Total FIXED Cost		153.09

TOTALS

Total of VARIABLE Cost	1567.74
Total of FIXED Cost	153.09
GROSS INCOME minus VARIABLE COST	-367.74
GROSS INCOME minus VAR. and CASH FIXED COST	-518.74
NET PROJECTED RETURNS	-520.83
Short-run Break-even Price, Total Variable Cost	391.93
Long-run Break-even Price, Total Cost	430.21

ECONOMIC COSTS and RETURNS
Establishing and Producing
Tuber melanosporum (Black Truffle)
In the Willamette Valley (Year 8)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Tuber Melanosporum	12.00	pounds	300.00	3600.00
Total GROSS Income				3600.00

VARIABLE COST Description

	Materials Details quantity	$/quantity	$/acre	$/acre	$/acre	Total Cost $/acre
PREHARVEST						
Weed Control			10.00	2.00	9.00	21.00
Glyphosate (Round-Up)	1.00	9.00				
Pruning			400.00	0.00		400.00
Irrigation			5.65	0.00	300.00	305.65
Electricity	3.00	100.00				
Total PREHAVEST						726.65
HARVEST						
Use Dogs to Find Truffles			300.00	0.00		300.00
Total HARVEST						300.00
POST HARVEST						
Packaging			25.00	0.00		25.00
Total POST HARVEST						25.00
OTHER						
Pickup 4 WD			135.84	41.76		177.60
Miscelleneous			1.00	75.00		76.00
Owner Labor			140.00	0.00		140.00
Operating Capital Interest			0.00	0.00	50.81	50.81
Total Variable Cost	1270.25	0.04				
Total OTHER						444.41
Total VARIABLE Cost						1496.06

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	1.00
Land Lease	150.00	150.00
Total CASH		151.00
NONCASH Cost		
Machinery & Equipment Deprec. & Interest	2.09	2.09
Total NONCASH		2.09
Total FIXED Cost		153.09

TOTALS

Total of VARIABLE Cost	1496.06
Total of FIXED Cost	153.09
GROSS INCOME minus VARIABLE COST	2103.94
GROSS INCOME minus VAR. and CASH FIXED COST	1952.94
NET PROJECTED RETURNS	1950.85
Short-run Break-even Price, Total Variable Cost	124.67
Long-run Break-even Price, Total Cost	137.43

ECONOMIC COSTS and RETURNS
Establishing and Producing
Tuber melanosporum (Black Truffle)
In the Willamette Valley (Year 9)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Tuber Melanosporum	18.00	pounds	300.00	**5400.00**
Total GROSS Income				5400.00

VARIABLE COST Description

	Materials Details					Total Cost
	quantity	*$/quantity*	*$/acre*	*$/acre*	*$/acre*	*$/acre*
PREHARVEST						
Weed Control			10.00	2.00	**9.00**	**21.00**
Glyphosate (Round-Up	1.00	9.00				
Pruning			400.00	0.00	**154.25**	**554.25**
Lime, Ag 2 tn	1.50	51.50				
Dolmite 1 tn	2.00	38.50				
Lime			0.00	0.00	**154.25**	**154.25**
Lime, Ag 2 tn	1.50	51.50				
Dolmite 1 tn	2.00	38.50				
Irrigation			5.65	0.00	**300.00**	**305.65**
Electricity	3.00	100.00				
Total PREHAVEST						1035.15
HARVEST						
Use Dogs to Find Truffles			300.00	0.00		**300.00**
Total HARVEST						300.00
POST HARVEST						
Packaging			25.00	0.00		**25.00**
Total POST HARVEST						25.00
OTHER						
Pickup 4 WD			135.84	41.76		**177.60**
Miscellaneous			1.00	75.00		**76.00**
Owner Labor			140.00	0.00		**140.00**
Operating Capital Interest			0.00	0.00	**56.98**	**56.98**
Total Variable Cost	1424.50	0.04				
Total OTHER						450.58
Total VARIABLE Cost						1810.73

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	**1.00**
Land Lease	150.00	**150.00**
Total CASH		151.00
NONCASH Cost		
Machinery & Equipment Deprec. & Interest	2.09	**2.09**
Total NONCASH		2.09
Total FIXED Cost		153.09

TOTALS

Total of VARIABLE Cost	1810.73
Total of FIXED Cost	153.09
GROSS INCOME minus VARIABLE COST	3589.27
GROSS INCOME minus VAR. and CASH FIXED COST	3438.27
NET PROJECTED RETURNS	3436.18
Short-run Break-even Price, Total Variable Cost	100.60
Long-run Break-even Price, Total Cost	109.10

ECONOMIC COSTS and RETURNS
Establishing and Producing
Tuber melanosporum (Black Truffle)
In the Willamette Valley (Year 10)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Tuber Melanosporum	22.00	pounds	300.00	**6600.00**
Total GROSS Income				6600.00

VARIABLE COST Description

	Materials Details					Total Cost
	quantity	*$/quantity*	*$/acre*	*$/acre*	*$/acre*	*$/acre*
PREHARVEST						
Weed Control			10.00	2.00	**9.00**	**21.00**
Glyphosate (Round-Up)	1.00	9.00				
Pruning			200.00	0.00		**200.00**
Irrigation			5.65	0.00	**300.00**	**305.65**
Electricity	3.00	100.00				
Total PREHAVEST						526.65
HARVEST						
Use Dogs to Find Truffles			300.00	0.00		**300.00**
Total HARVEST						300.00
POST HARVEST						
Packaging			25.00	0.00		**25.00**
Total POST HARVEST						25.00
OTHER						
Pickup 4 WD			135.84	41.76		**177.60**
Miscellaneous			1.00	75.00		**76.00**
Owner Labor			140.00	0.00		**140.00**
Operating Capital Interest			**0.00**	0.00	**42.81**	**42.81**
Total Variable Cost	1070.25	0.04				
Total OTHER						436.41
Total VARIABLE Cost						1288.06

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	**1.00**
Land Lease	150.00	**150.00**
Total CASH		151.00
NONCASH Cost		
Machinery & Equipment Deprec. & Interest	2.09	**2.09**
Total NONCASH		2.09
Total FIXED Cost		153.09

TOTALS	
Total of VARIABLE Cost	1288.06
Total of FIXED Cost	153.09
GROSS INCOME minus VARIABLE COST	5311.94
GROSS INCOME minus VAR. and CASH FIXED COST	5160.94
NET PROJECTED RETURNS	5158.85
Short-run Break-even Price, Total Variable Cost	58.55
Long-run Break-even Price, Total Cost	65.51

ECONOMIC COSTS and RETURNS
Establishing and Producing
Tuber melanosporum (Black Truffle)
In the Willamette Valley (Medium Production Year)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Tuber Melanosporum	50.00	pounds	300.00	**15000.00**
Total GROSS Income				15000.00

VARIABLE COST Description

	Materials Details					Total Cost
	quantity	*$/quantity*	*$/acre*	*$/acre*	*$/acre*	*$/acre*
PREHARVEST						
Weed Control			10.00	2.00	**9.00**	**21.00**
Glyphosate (Round-Up)	1.00	9.00				
Pruning			200.00	0.00		**200.00**
Irrigation			5.65	0.00	**300.00**	**305.65**
Electricity	3.00	100.00				
Total PREHAVEST						526.65
HARVEST						
Use Dogs to Find Truffles			300.00	0.00		**300.00**
Total HARVEST						300.00
POST HARVEST						
Packaging			25.00	0.00		**25.00**
Total POST HARVEST						25.00
OTHER						
Pickup 4 WD			135.84	41.76		**177.60**
Miscellaneous			1.00	75.00		**76.00**
Owner Labor			140.00	0.00		**140.00**
Operating Capital Interest			0.00	0.00	**42.81**	**42.81**
Total Variable Cost	1070.25	0.04				
Total OTHER						436.41
Total VARIABLE Cost						1288.06

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	**1.00**
Land Lease	150.00	**150.00**
Total CASH		151.00
NONCASH Cost		
Machinery & Equipment Deprec. & Interest	2.09	**2.09**
Total NONCASH		2.09
Total FIXED Cost		153.09

TOTALS

Total of VARIABLE Cost	1288.06
Total of FIXED Cost	153.09
GROSS INCOME minus VARIABLE COST	13711.94
GROSS INCOME minus VAR. and CASH FIXED COST	13560.94
NET PROJECTED RETURNS	13558.85
Short-run Break-even Price, Total Variable Cost	25.76
Long-run Break-even Price, Total Cost	28.82

ECONOMIC COSTS and RETURNS
Establishing and Producing
Tuber melanosporum (Black Truffle)
In the Willamette Valley (Highest Production Year)

GROSS INCOME Description

	Quantity/ acre	Unit	$/Unit	Total/ acre
Tuber Melanosporum	100.00	pounds	300.00	**30000.00**
Total GROSS Income				30000.00

VARIABLE COST Description

	Materials Details					Total Cost
	quantity	*$/quantity*	*$/acre*	*$/acre*	*$/acre*	*$/acre*
PREHARVEST						
Weed Control			10.00	2.00	**9.00**	**21.00**
Glyphosate (Round-Up)	1.00	9.00				
Pruning			200.00	0.00		**200.00**
Irrigation			5.65	0.00	**300.00**	**305.65**
Electricity	3.00	100.00				
Total PREHAVEST						526.65
HARVEST						
Use Dogs to Find Truffles			300.00	0.00		**300.00**
Total HARVEST						300.00
POST HARVEST						
Packaging			99.00	0.00		**99.00**
Total POST HARVEST						99.00
OTHER						
Pickup 4 WD			135.84	41.76		**177.60**
Miscellaneous			1.00	75.00		**76.00**
Owner Labor			140.00	0.00		**140.00**
Operating Capital Interest			0.00	0.00	**45.77**	**45.77**
Total Variable Cost	1144.25	0.04				
Total OTHER						439.37
Total VARIABLE Cost						1365.02

FIXED COST Description

		Total/ acre
CASH Cost		
Machinery & Equipment Insurance	1.00	**1.00**
Land Lease	150.00	**150.00**
Total CASH		151.00
NONCASH Cost		
Machinery & Equipment Deprec. & Interest	2.09	**2.09**
Total NONCASH		2.09
Total FIXED Cost		153.09

TOTALS	
Total of VARIABLE Cost	1365.02
Total of FIXED Cost	153.09
GROSS INCOME minus VARIABLE COST	28634.98
GROSS INCOME minus VAR. and CASH FIXED COST	28483.98
NET PROJECTED RETURNS	28481.89
Short-run Break-even Price, Total Variable Cost	13.65
Long-run Break-even Price, Total Cost	15.18

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