



A NEW ACTIVITY IN TURKEY'S AGRICULTURAL FORESTRY: TRUFFLE MUSHROOM CULTIVATION

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ABSTRACT

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Forest ecosystems, which are among the important components of the natural environment, stand as one of the significant sources of life. In addition to the natural, cultural, and economic functions of forest products and services, wild foods such as fruits, mushrooms, and leaves that are obtained from forests generate significant amounts of additional food for the poor rural population. Countries have to come up with serious policies to prevent rural populations settling around forest areas from moving to urban areas and to increase their income sources. This study deals with the cultivation of truffle mushroom in Turkey and its potential. In line with the aim of the study, suggestions are made on its cultivation by calling attention to its ecology and potential. In this study, as a method, descriptive survey model has been used. In this method, existing situation on a subject is interpreted by searching. Research material consists of data obtained from the Republic of Turkey Ministry of Forestry and Water Affairs. ArcGIS 10.3 package was utilized in the preparation of cartographic materials. Turkey is a country in the middle belt where four seasons are experienced and different climates prevail because geographical features change at short distances. The different ecological environment Turkey incorporates increases biological diversity there. The presence of various plant and fungi species in Turkish forests is about different ecological environments. Among the forested areas spreading in Turkey, Mediterranean, Aegean, Marmara, and Black Sea forests provide more suitable ecological environments for truffle species. *Tuber aestivum*, *Tuber borchii*, *Tuber brumale*, *Tuber candidum*, *Terfezia arenaria*, *Terfezia leptoderma*, *Choiromyces meandriformis*, and *Terfezia boudieri* naturally exist in Turkey. Truffle mushrooms, which naturally maintain their lives in Turkish forests and have high economic value in the world, will bring high income to forest villagers and interested producers by providing agricultural forestry activities in outdoor open areas in addition to natural areas of propagation.

Contribution/ Originality: The research is very first and foremost work on Truffle in the area of Physical Geography in Turkey making it significant one. As for as, other disciplines are concerned the research on Truffle Fungus is too limited to be considered.

1. INTRODUCTION

Countries have the responsibility of providing a sustainable forest ecosystem and make use of them for the living creatures and human communities in their territories. They have to try to increase the benefit made from the existing human activities that shrink the borders of the natural system instead of expanding the limits of these

activities; which, in fact, push the coverage of the concepts like protection and sustainability. If the cultural understanding of preserving the ecosystem and the idea of sustainability in societies are not achieved, ecosystems will fall apart and lose their functions. Forest ecosystems that exist within the terrestrial ecosystems are one of the seriously important resources for the life of living organisms. Natural, cultural and economic functions of forest products and services are inarguable. As well as these functions, natural foods that are obtained from forests like fruit, mushrooms and leaves pose a supplementary food especially for poor sections of the society living in rural areas. Countries have to produce serious policies in order to prevent rural population living in the forest areas from migrating to urban areas, and to increase the income resources. Agricultural forest activities are among important policies that are made for the people living in rural areas. Opening proper forest areas for agricultural activities without damaging the natural tissue is in fact the activity that will make the existing areas of a country become more economic and functional. It has been understood in economic indicators in recent years that the forest ecosystem provides important revenues for the countries that have immense forest existence with activities such as wood production, non-wood products, medical and aromatic plants, agricultural forestry, etc. Aside from the economic indicators, the contributions of forest ecosystems to food safety and nutrition have been observed well in recent years. FAO targets to perform the suggestion of the UN Secretary General, “*Zero Hunger*” in order to end the hunger in the whole world. In this context, the contribution of the forests to nutrition and food safety is also reflected in the national development plans and food safety strategies. In recent years, the “Truffle mushroom” has been included as a medical-aromatic plant in the Forestry Activities in Turkey. The Ministry of Forest and Irrigation has prepared a Truffle Forest Action Plan (2014-2018). Truffle mushroom is known as “the black diamond” or “the kings’ food” in the world, and grows under the soil with roots of trees, resembles potatoes, carries spores, and is named as *the fruit of the underground mushrooms*. Truffle harvest is observed in certain areas in the Mediterranean Climatic area and is performed with specially-trained dogs.

In this study, the aim is to examine the Truffle mushroom cultivation and its potential in Turkey. In this context, the ecology and potential of the Truffle mushroom are examined in the study and recommendations are made about its cultivation.

Some of the national and international studies on this topic are as follows; Castellano and Turkoğlu [1]; Claridge, et al. [2]; Solak, et al. [3]; Türkoğlu and Castellano [4]; Kirk, et al. [5]; Delmas [6]. Attracting the attention to Truffle mushroom cultivation in Turkey as an agricultural forestry activity, and contributing to the literature makes the study important.

2. MATERIAL AND METHOD

The systematic approach has been adopted as the study method in the study. In addition to this, the descriptive review method has also been made use of in the study. In this method, the existing situation on a subject is investigated and interpreted. These kinds of studies are conducted by obtaining systematic and regular data on the study phenomena. In a descriptive study, whether a situation exists or not is investigated. The results of descriptive studies are determined with tables and graphics, and the existence of a correlation between the variables is determined [7]. Current literature review has been conducted in the study for the first thing, then the statistical data were collected, and the materials were prepared. The data were evaluated and supported with the literature. The data received from the Ministry of Forestry and Irrigation have been made use of in the study.

3. FINDINGS AND DISCUSSION

3.1. The Background of Truffle

In actual fact, it is not known exactly when Truffle first appeared in the world; however, scientists have found some clues about the roots of this plant. The oldest fossil based on these clues shows about 50 million years ago. The pines today and the ancestors of some other trees were related with Truffle since very old times [8]

This situation shows us that Truffle has existed on the Earth for over 50 million years. Since old times, humans though that Truffle mushroom grew without roots and seeds; however, it was later understood that it lived together with other plants in a symbiotic way, and spread with spores. The increase on Truffle mushroom gave rise to the more recognition of this plant and therefore its consumption also increased. This caused that studies were conducted on this mushroom in cultural terms.

Some of the Truffle mushrooms that are very popular today are as follows; *Tuber magnatum*, *Tuber melanosporum* and *Tuber aestivum*. The Truffle types whose economic values are high are named after the places where they grow naturally. *Tuber magnatum* grows in the Piedmont Region of Italy, *Tuber melanosporum* grows in Périgord Region of France, *Tuber aestivum* grows in the Burgundy Region of France. The data on Truffle have been collected and accumulated since 19th Century. It was understood that Truffle actually established a mycorrhizal symbiotic life with other plants; however, formerly it was thought that it grew on its own without seeds. As of the second half of 1900s, especially French and Italian researchers conducted studies on Truffle cultivation, and succeeded in cultivating grafted saplings with Truffle in greenhouses. However, different problems appeared in this process. The other mushrooms were infected to the saplings, and the processes had to receive certain applications, which made it difficult to cultivate Truffle with culture production. Especially in Piedmont, Périgord and Burgundy in Europe where Truffle grows naturally, the information of humans on Truffle mushroom dates very back in history [9].

The forests in these areas consist of oak, nut and linden tree, and have calcareous soil structure. Truffle mushroom is collected in these areas in late autumn and early winter. In France and Italy, trees like oak, nut and linden tree are planted to facilitate mycorrhizal symbiotic life with Truffle. Including Truffle in culture production and collecting it from the natural area have produced an important income source, and studies have been conducted on Truffle mushroom.

3.2. Ecology of Truffle Mushrooms

Truffle mushrooms generate mycorrhizal relation with high trees. All of the oak species, pine species, nuts, linden, hornbeam, poplar, alder are the trees that host the generation of truffle (trufder.org/index.php/truf-mantarlari/truf-mantari-ekolojisi) [2].

Most of the truffle mushrooms develop in a mycorrhizal symbiotic manner. The word mycorrhizal is translated as *the mushroom root* in the literature. Mycorrhizal mushrooms work as an extension of root system of the plant, transmit more water and food that a plant can achieve. Truffle mushrooms lead a symbiotic life with the connected tree. Thus, they can both maintain their life and provide development of the plant. Proper soil structure, proper climate conditions and plants that can generate mycorrhizal relation with truffle are required for the growth of a truffle mushroom in an environment. When the given conditions are provided, the ecologic environment for truffle is completed.

Truffle mushrooms grow well in the calcareous soil and 7,5-9 ph soil (trufder.org/index.php/truf-mantarlari/truf-mantari-ekolojisi) [2]. As the plants ease the intake of calcium cation to truffle mushrooms in basic soil, truffle mushrooms are found in this characteristic soil. Indication of calcareous soil is the will of both providing the Ca need and resistance against freeze as the temperature of calcareous soil is higher than other soils.

Soil texture characteristics are sandy, clay or graveled. Plants don't use the hygroscopic water in clay soil. So, they are known as useless water in the soil. However, truffle hypha which is at least 10 times smaller than the absorbing hairs of the plant roots and constitutes mycorrhizal gives this water to the plant faster than its roots by taking the water from the clay granules. Truffle heifers take the water from the clay by increasing the contact surface to the soil. In the soil, mycorrhizal activity regulates the plant-water relationship well when soil water is weak or there is drought. Thus, they also increase the resistance of the plant against drought.

Truffle has an important role in food and water transfer between plant and soil. It accelerates and facilitates the intake of cations such as N, K, Ca, Fe, Mn and especially P (phosphorus) that are required by the plant which has

established a symbiotic bond. Furthermore, plants need the microorganisms to adjust the soil in the habitat and lead their lives. Apart from the given characteristics, truffle mushrooms embrace and hold together the soil in which they spread and create a resistance against erosion.

While spring and summer rains provide the start over of mycorrhizal activity and micelle growth in truffle mushroom, autumn and winter rainfall helps the plant to ripen. Taking too much rain more than it needs may cause the fruit to rot. The humid of the soil should be 65% and the drainage should not be under 35%. In addition, there should be very rich soils in terms of lime with an optimum pH of 7.9. Acid grade should be preferred to non-acidic soil or lime should be added to the soil [10].

Truffle mushrooms generally grow in the Mediterranean climate, in its transition zone, which is warmer than this climate or the continental climate. Regions that do not take summer rains are the regions of summer truffle (*tuber aestivum*), and regions with warm rain and also summer rain in winter are the regions of winter truffle (*tuber melanosporum*). High humidity and a period which has cool atmosphere during the year are needed for the growth of micelle tree and the beginning of symbiotic partnership with the tree. On the contrary, dry and hot conditions are necessary for the growing period of the fruit.

Truffle which has completed its growing phases under the soil is also a very significant part of the forest ecosystem when it is considered as a food resource. When it matures it spreads a strong odor, this odor is recognized by the animals and truffle is found by digging the soil. Besides, unlike other mushrooms, truffle needs animals to spread its spores as it grows underground. Spores of truffle mushrooms pass through the digestive tract of the animals and spread to large areas. The spores that spread around the environment regenerate truffle colonies by germinating. Just like the partnership with the plants during the growing phases, it creates a partnership with animals during the spreading process. The wide presence of truffle mushrooms in the forest ecosystem may provide evidence that the forests and forest life are well-maintained.

3.3. Types of Truffle Mushroom in the World

The types of truffles that are common in the world are as follows:

Melano, Rabasse, Périgord or Tricastine truffle: It is the most precious one among the truffles grown in France. The value of this truffle in the market is nearly equivalent to gold. Its shape is round in the calcareous and sandy soil and it has a lumpy-bumpy appearance in the gravelly soil. Its skin is black and rough, its flesh is reddish black and it has a lot of very thin marble veins.

Truffle brumale (or Tuber brumale): Brumale is musky and it is the most-purchased species in Rhone-Alpes after Melano. Its botanic characteristic with round shape is very close to Melano. The fruit's aroma fermented with musk is very strong. It grows in calcareous and humid soil that has adapted to the Mediterranean climate.

Summer truffle or white truffle (Tuber aestivum): It is named as *White truffle, Saint Jean truffle, and Maienque*. It is collected between early June and late August. When it is ripe, it is very thin, and a volatile aroma develops. Because of this characteristic, truffle is consumed raw in butter.

Bourgogne truffle (or Tuber uncinatum): Grey or greyish truffle. It has an aroma similar to nuts. Its crops are low and it is not heavier than a few hundred kilos. It is picked from September to December.

Meuse or Loraine truffle: This species has the strongest aroma. It has a very distinct taste, it is resistant against cooking and mostly used in pulverization and stew fabrication.

White Alba truffle: Mainly, it is grown in the south of Piedmont in small quantities. It is seen in Urbino and Pessaro and in high areas. Symbiotic underground mushrooms are processed in clay-soil and water with broad leaves of poplar, linden trees and oak trees. It appears during summer, autumn and winter in a few centimeters or one meter under the soil in depths (www.alainwursching.com/wp-content/uploads/2014/05/karaf50-Truffles-sommelier) [1].

Tuber aestivum and *Tuber melanosporum*: It is one of the most valuable truffle species. Symbiotic partnership has an important role in its generation and its mycorrhizal species are given in (table 1).

Table-1. Truffle Species and Mycorrhizal Trees

Truffle Species	Mycorrhizal Trees
Tuber aestivum	Oak species (<i>Quercus spp.</i>) Nuts species (<i>Corylus spp.</i>) Pine species (<i>Pinus spp.</i>) Cedar (<i>Cedrus libani</i>) Hornbeam (<i>Carpinus betulus</i>) Common birch (<i>Betula sp.</i>) Beech tree (<i>Fagus sylvatica</i>)
Tuber melanosporum	Nuts (<i>Corylus spp.</i>) Oak (<i>Quercus spp.</i>) Cedar (<i>Cedrus libani</i>) Linden (<i>Tilia cordata</i>)

Source: General Directorate of Forestry, Truffle Action Plan.

Although there are hundreds of truffle species, there are 3 types of truffles known by the whole world and sold economically in the world market. *Tuber aestivum*, *Tuber melanosporum* and *Tuber magnatum*. Apart from these 3 species, there are other species growing in different climatic zones but they are not well known outside their growing places. *T. indicum*, *T. himayalensis*, grow in Far East region and named as Chinese truffles and *T. gibbosum*, *T. californicum*, *T. oregonense*, known as North America truffles, which are some examples of these.

3.4. The Truffle Mushroom and Its Cultivation in Turkey

Turkey is a geologically young structure country that has been tectonically raised at the end of the Tertiary. Therefore, it has significant elevation differences over short distances. Turkey is surrounded by sea on three sides. Moreover, topographic differences such as the mountains in Northern/Southern Anatolia being parallel to the sea coast, the mountains in Western Anatolia being perpendicular to the sea edge and the elevation rising from west towards east in Turkey produce various ecological environments. *Maritime*, *maritime-continental* transitional and *continental* climates are seen together in our country. It has a variety soil and plant diversity as well as different climates. There are over 10,000 plant species and about 4,000 endemic plant species in Turkey. High plant diversity occurred due to experiencing the Quaternary glacial and interglacial periods. Plants which migrated from the north in the glacial period has spread into Turkey. These plants migrated to the higher parts of the mountains in the interglacial period. While they had been living there, they were replaced by plants which require more heat. Quaternary climate changes and plant migrations have enabled that our country hosts many plants. Today, there are various plant communities which are found as relict in our country. Turkey is rich in terms of relict and endemic plant species. One of the richest forest areas in the northern hemisphere is our country. Especially, it includes three distinct phytogeographical regions such as the species of Europe-Siberia, Mediterranean and Iran-Turan floras. These three important phytogeographical regions contain a high number of plant taxa. Limestone is a very common rock as lithological structure. When the situations briefly summarized above are considered, the truffle mushroom also has an important place among these plant taxa because the truffle mushroom shares a common life with plants. The species such as *Tuber aestivum*, *Tuber borchii*, *Tuber brumale*, *Tuber candidum*, *Terfezia arenaria*, *Terfezia leptoderma*, *Choiromyces meandriformis*, and *Terfezia boudieri* naturally grow in Turkey.

The fact that truffle mushroom naturally grows in our country indicates that we have suitable conditions for cultivation. The three most important criteria for truffle production are soil structure, climate and annual precipitation. Mediterranean climate and calcareous soils are the perfect environment for truffle production. Our country, one and a half time bigger than France, has the potential to produce as much truffle as the total amount of

France, Spain and Italy. There are different types of truffle in our country that can be produced in every region where soil parameters are appropriate. It is possible to produce *Tuber melanosporum* in regions where temperate climate prevails, to produce *Tuber aestivum* in regions which have colder winter months, and to produce *Tuber borchii* in all climatic conditions where soil pH is low [9].

Turkey has started the Truffle Forest Action Plan as of 2014. Truffle cultures are established throughout the country under this plan. Within the scope of detection of natural truffle fields and transformation of these areas into natural truffle fields and development of them, the artificial truffle forest was formed in an area of 20 decares in Isparta Beşkonak Village and an area of 15 decares in Bucak between 2014–2015.

Under the Truffle Forest Action Plan, seedling production is made in the following way: the seeds to be used in the grafting are sterilized and germinated in vermiculite or perlite. Germinated plants are removed from vermiculite and then they are trimmed to encourage side roots. After each seedling is grafted with enough suspension to contain 2-3 gr truffles, they are placed in violets. Then these seedlings are placed in a fully controlled greenhouse. The roots of these seedlings are examined with a stereo microscope after 6 months. If the entire root is found to be mycorrhizal with the desired truffle mushroom, the seedling is approved to be planted on the soil. This process is the most important stage in the cultivation of the truffle mushroom. The goal of grafting is to provide that the plant root forms mycorrhizal by 100%. Plants which do not form mycorrhizal or meet other mushroom spores are clearly and easily targeted by foreign ecto-mycorrhizal mushrooms that grow rapidly after being planted on the soil. In this case, unwanted mushroom species are grown instead of truffle [11].

The truffle mushroom has become widespread with the support of the Ministry of Forestry and Irrigation Affairs. It would be a serious winner for both the manufacturer and the forest villagers if grafted oak seedlings are planted and spread. Supporting truffle production in open forest areas will contribute to the existence of healthy forest and soil in future. An important point to be considered in truffle cultivation is the field selection. Therefore, the fields to be cultivated must be inclined in such a way that they does not hold too much water. This is an important step to prevent truffle from being damaged or decayed by water. The presence of organic matter in the soil and the field containing clay, sand and alluvium have positive effects.

Another factor to be aware of when forming truffle cultivation is that the seedlings to be grafted must belong to the area to be planted. It should not be forgotten that the seedlings brought from different regions carry risks such as not adapting to the field. After the planting period is completed, the soil should be ventilated regularly.

3.5. Medical Benefits and Nutritional Value

Truffle mushrooms are distinguished from other mushrooms in terms of rich protein and minerals. It is said that it has 53-76% water, 9% protein, 7% carbohydrate and 8% mineral as nutritional values. Scientific studies have shown that truffle has antioxidant, anti-tuberculosis and anti-inflammatory effects and therefore contains some compounds which are important for human health. Moreover, Napoleon also believed that truffle was an aphrodisiac. The studies of scientists confirm this belief. In previous studies, it has been reported that truffle mushrooms contain a specific steroid [9]. Today, which disease truffle mushroom cures or which nutritious elements it has are not fully explained in studies.

4. RESULT AND RECOMMENDATIONS

As truffles collected from natural areas around the world are decreasing day by day, the demand for truffles is increasing. This is accompanied by increases in prices. Different types of truffle are sold at different prices depending on their quality and flavor. Truffle is sold from 150-200 Euros to 3500 Euros per kilogram. Official statistics on truffle production in the world do not reflect reality. However, it is known that it is widely used and produced in France, Spain and Italy according to the existing data.

Truffle has an economic value and it is important for ecosystem. It is a valuable vegetable-aromatic mushroom in terms of agricultural forestry. When truffle production is widespread and open forest areas are assessed, natural and cultivated forests will bring significant revenues to those interested.

One of the genetic resources of Turkey is truffle mushrooms. The protection, dissemination and promotion of truffle species is important for sustainable agroforestry. Some truffle species which we refer to as our biological richness and have an important place in animals in the forest ecosystem are in danger of extinction. Therefore, truffle gardens where protection measures are taken must be established. Ecto-mycorrhizal seedlings brought from abroad to our country should be controlled and also it must be checked whether there is damage to our native species. It should be avoided in this way that the invasive species in different countries enter to our country.

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