This article is cited as: Özderin, S. & Allı, H. (2024). Examination of The Aegean Region in Terms of Truffle Potential, *Mantar Dergisi*, 15(Special issue) 91-97.

Recevied :14.10.2024 ***Research Article***
Accepted :04.12.2024 **Doi: 10.30708/mantar.1567087**

Examination of The Aegean Region in Terms of Truffle Potential

Sevgin ÖZDERİN[1*], Hakan ALLI[2]

**Corresponding author:sevginozderin@mu.edu.tr*

[1] Muğla Sıtkı Koçman University, Truffle Application and Research Center Muğla / sevginozderin@mu.edu.tr
[2] Muğla Sıtkı Koçman University, Faculty of Science / hakanalli@gmail.com

Abstract: Truffles, belong to the *Tuber* genus of the *Tuberaceae* family and are the fruit of a mycorrhizal fungi and have been worldwide regarded as ecologically and commercially valuable. Truffle mushroom, known for its culinary value, has a very high nutritional value. Truffles, are a distinct category of hypogeous fungi known for their unique aroma and exceptional nutritional value. Truffles are expensive because they are rare and difficult to grow, making them one of the most expensive foods in the world. The fact that it is difficult to find in nature and is gastronomically valuable has led to the development of culturing methods for truffle mushrooms. Truffles can grow in temperate climates, including regions of Türkiye Italy, France, Spain, Australia and the US. Interest in truffle hunting and trade in Türkiye has been increasing in recent years.

In this study, truffle species were determined in different localities of Aydın, Denizli, Muğla, and Uşak and the truffle potential of these provinces were revealed. Naturally growing in Aegean region, obtained from the field studies constitute the main materials. Photographs of the collected specimens were taken and their ecological and morphological characteristic were recorded. The aim of the study is to determine the naturally growing truffle habitats in the Aegean Region and to highlight the regions with truffle potential.

Keywords: Truffle, Mushroom, Aegean Region, Türkiye

Ege Bölgesi'nin Trüf Potansiyeli Açısından İncelenmesi

Öz: Trüf mantarları, *Tuber* cinsine ait olan ve *Tuberaceae* familyasında yer alan mikorhizal mantarlardır ve ekolojik ve ticari açıdan büyük öneme sahiptir. Mutfak değeri ile tanınan trüf mantarları, nadir olmaları ve yüksek besin içeriği nedeniyle dünyadaki en pahalı yiyeceklerden biridir. Doğada zor bulunmaları ve gastronomik cazibeleri, kültür yöntemlerinin geliştirilmesine yol açmıştır. Trüf mantarları, Türkiye, İtalya, Fransa, İspanya, Avustralya ve ABD gibi ılıman iklimlerde yetişmektedir. Son yıllarda Türkiye'de trüf avcılığı ve ticaretine olan ilgi artmaktadır.

Bu çalışmada, Aydın, Denizli, Muğla ve Uşak'taki farklı lokalitelerde trüf türleri belirlenmiş ve bu illerin trüf potansiyeli ortaya konulmuştur. Ege Bölgesi'nde doğal olarak yetişen trüf örnekleri, saha çalışmalarından elde edilmiştir. Toplanan örneklerin fotoğrafları çekilmiş ve ekolojik ile morfolojik özellikleri kaydedilmiştir. Çalışmanın amacı, Ege Bölgesi'nde doğal olarak yetişen trüf habitatlarını belirlemek ve trüf potansiyeli taşıyan bölgeleri vurgulamaktır.

Anahtar kelimeler: Trüf, Mantar, Ege Bölgesi, Türkiye

Introduction

Türkiye's location at the intersection of the continents of Asia, Europe, and Africa, along with its diverse geomorphological regions, geographical and topographical variations, and elevation differences ranging from 0 to 5000 meters, contributes to its extraordinary biological diversity. The presence of various ecological and climatic characteristics, as well as the European-Siberian, Mediterranean, and Irano-Turanean phytogeographic regions and their transition zones, are among the factors explaining Türkiye's rich biodiversity (Kence, 1987; Özhatay and Kültür, 2006). Parallel to the richness of its flowering plant flora, Türkiye also boasts a diverse mushroom flora (Öztürk et al., 2019). Due to its climate and variety of vegetation, as well as different altitudes, Türkiye is one of the countries with high mushroom diversity. The number of recorded mushroom species in the country is listed as 5865 (Sesli et al., 2020). It is also noted that there are approximately 300 edible wild mushroom species (Şimşek and Önek, 2021).

Edible mushrooms have attracted human interest for centuries and have made significant economic contributions to their respective countries. Edible mushroom species are classified within macrofungi (Boa, 2007). Additionally, due to their high nutritional value, mushrooms can serve as alternatives to both meat and vegetable groups, making them a unique food product (Nicholas and Ogamé, 2006). Furthermore, many mushroom species are utilized for their properties to enhance the quality and shelf life of food products and for medicinal purposes (Valverde et al., 2015; Bakratsas et al., 2021).

Approximately half of the edible mushroom species found worldwide belong to the ectomycorrhizal group (Yun and Hall, 2004). This type of symbiosis, which is particularly common in the roots of tall trees and shrubs, is generally more prevalent in temperate and northern regions compared to tropical areas. The establishment of ectomycorrhizal relationships occurs in three distinct phases: recognition of a suitable host by the fungus, invasion of the host root tissues, and finally, the production of an outer sheath that envelops the root like a glove (Kibar and Pekşen 2007). Edible ectomycorrhizal mushrooms represent one of the most economically significant groups of fungi, possessing a substantial market share globally, with their total market value reaching billions of US dollars (Yun and Hall, 2004).

Truffles are the fruiting bodies of underground fungi that grow beneath the soil. They resemble potatoes and, unlike other mushrooms, require animals for the dispersion of their spores, completing their development entirely underground. The edible part, known as the sporocarp, forms 5 to 20 cm below the soil near the roots of trees. Truffle species can develop through a symbiotic life cycle with ectomycorrhizal plant species such as beech, oak, birch, hornbeam, hazel, and pine trees (Benucci and Bonito, 2016; Zambonelli, et al., 2016). Truffle mushrooms are highly sought after due to their strong aromas, high culinary and economic values, and significance in both human and animal diets. In the culinary world, truffle mushrooms hold a prestigious status, often referred to as the "underground gold" or "apple of the kitchen." Their unique aromatic compounds derived from dimethyl sulfide distinguish truffles from other mushrooms, contributing to their special appeal (Üstün et al., 2018, Lee et al.,2020).

Edible truffle mushrooms not only serve as food but also provide positive contributions to the national economy and serve as a source of livelihood for rural communities (Pekşen and Akdeniz, 2012). Truffle species belonging to the *Tuber* genus are economically valuable fungi that belong to the Ascomycetes division and the Pezizales order, exhibiting ectomycorrhizal symbiosis (Hall et al., 2007; Mello and Balestrini 2018). *Tuber* genus truffles form mycorrhizae as a result of their symbiotic relationships with tree species that are fundamental to forest ecosystems, such as pine, cedar, fir, and oak, as well as with shrub species like *Cistus creticus* L. (Chevalier and Frochot, 2002; Stobbe et al., 2012). In particular, truffle mushrooms predominantly develop ectomycorrhizae with oak species (*Quercus* spp.). Biodiversity and mycorrhizae are essential components of oak forests.

The genus *Quercus*, within the Fagaceae family, contains the most diverse range of species and is widely distributed in the temperate and subtropical regions of the Northern Hemisphere. Türkiye is particularly rich in oak species, with a wide range of pure and mixed oak forests naturally growing at elevations up to 2300 meters above sea level across various regions and climate types (Yaltırık, 1984). Türkiye hosts 17 species and 24 taxa of oaks (*Quercus* spp.) across diverse habitats, from the humid conditions of the Black Sea Region to the steppes of Central Anatolia. The oak genus includes a total of 24 taxa, including species, subspecies, and varieties, among which *Q. vulcanica*, *Q. macranthera* subsp. *syspirensis*, and *Q. trojana* subsp. *yaltirikii* are endemic to Türkiye while *Q. aucheri* is found in Southwest Anatolia and the nearby Aegean Islands (Akkemik, 2016).

In the Aegean Region where this study was conducted, the following oak species naturally occur *Quercus coccifera* L., *Q. ilex* L., *Q. pubescens* Willd., *Q. cerris* L., *Q. ithaburensis* Decne and *Q. infectoria* Oliver (*Q. ithaburensis* subsp. *ithaburensis, Q. infectoria* subsp. *veneris* (Yaltırık, 1984). This indicates the high potential for truffle mushrooms in Aegean region.

Although it is estimated that there are between 180 and 230 species of truffle mushrooms in the world, only about 13 of these are commercially traded. The most recognized and economically valuable truffle species include *Tuber magnatum* Picco (Italian white truffle), *Tuber melanosporum* Vittad. (black truffle), and *Tuber aestivum* (Wulfen) Spreng (summer truffle). Due to their known significance and economic value in various parts of the world, research has intensified to determine their systematic, nutritional, and medicinal properties as well as their commercial potential, leading to increased genetic, molecular, and cultivation studies (Hall et al., 2007; Zambonelli et al., 2016; Lazzari, et al.,1995; Kamle, et al., 2017; Kagan-Zur, and Roth-Bejerano, 2008; Özderin et al., 2018). In Türkiye studies have revealed a rich diversity of truffle species, with common species including *T. aestivum, T. borchii,* and *T. brumale*. Recent research has introduced many new species to the scientific community (Kaya, 2009; Gezer et al., 2014; Türkoğlu and Castellano, 2014). According to the existing literature, 67 truffle species belonging to 23 genera within 15 families grow in Türkiye (Şen et al., 2016). Currently, scientific research continues on truffle hunting and truffle cultivation (Özderin and Allı, 2020).

T. aestivum is the most widely distributed and consumed truffle species globally. It is known as the black summer truffle due to its harvest period between May and October. Its aroma and taste are less intense compared to *T. melanosporum* and *T. melanosporum* is known worldwide as the Périgord truffle. It is harvested between December and March, earning it the name black winter truffle. It has a very strong aroma and flavour and grows in temperate climates with an average rainfall of 900-1800 m³ and summer rains. It is hypothesized that it could exist in very specific microclimatic areas in the Eastern Black Sea region or Mediterranean climate zone of Türkiye although its presence has not yet been confirmed. *Tuber magnatum* is the truffle species with the highest aroma and taste, making it one of the most expensive food products in the world. It is a rare species due to its limited and specific growing areas, and its distribution ranges from Italy to Türkiye Although suitable environments for its growth are known to exist in Türkiye its presence has not yet been confirmed.

Material and Metod

In this study, truffle species were determined in different localities of Aydın, Denizli, Muğla, Uşak and the truffle potential of these provinces were revealed. Growing naturally in the Aegean region, obtained from the field studies constitute the main material. Photographs of the collected specimens were taken and their ecological and morphological characteristic were recorded. Examples of truffle mushrooms were brought to the laboratory, where they were diagnosed under suitable environmental conditions and then processed into fungarium material for storage.

Studies related to the identification of mycorrhizal plant samples in fieldwork have determined that truffle mushroom species grow in association with various host plants. Specifically, *Quercus cerris* L. (Figure 2a), *Coryllus avellana* L. (Figure 2d), *Pinus nigra* Arnold (Figure 2b,2c), *Quercus coccifera* L., and *P. brutia* Ten. (Figure 2e) were identified. These identifications were compared with samples from the Herbarium of Muğla Sıtkı Koçman University Faculty of Science, following the guidelines of Davis (1970,1984-1985). For the identification of the truffle samples, the relevant literature was used (Trappe & Castellano 1991, Pegler et al. 1993, Montecchi & Sarasini 2000, Breitenbach &Kränzlin 1983).

Figure 1. Map of the research area

Results

In the field studies conducted in the Aegean region, the species *T. aestivum* (Wulfen) Spreng, *Tuber macrosporum* Vittad, *Tuber borchii* Vittad. and *Tuber rufum* Picco have been identified.

Family: *Tuberaceae*

Genus: *Tuber*

Species: *Tuber aestivum* (Wulfen) Spreng.

Location1: Uşak, Eşme, Kayapınar mevkii, 764m, A 6893. (Figure2a)

Host species: *Quercus cerris* L.

Date of collection: 14 May 2023

Location2: Kütahya-Tavşanlı mevkii, 1050m, A 7451. (Figure2b)

Host species: *Pinus nigra* Arnold

Date of collection: 16.05.2023.

Location3: Denizli, Honaz, 843m, A 7120. (Figure2c)

Host species: *P. nigra* Arnold.

Date of collection: 16.05.2023.

Location4: Aydın, Çine, Madran mevki, 970m, A 6942 (Figure 2d)
Host species: *Coryllus avellana* L.
Date of collection: 27.04.2023
Location5: Muğla, Kötekli Mevkii, A 6923 (Figure 2e)
Host species: *P. brutia* Ten.
Date of collection: 22. 04.2023

Figure 2. *Tuber aestivum* (Wulfen) Spreng. Location1(a), Location2(b), Location3(c), Location4(d), Location5(e)

Species: *Tuber borchii* Vittad. (Figure3)
Location: Aydın, Çine, Madran mevki, 780m, A 6926
Host species: *Pinus brutia* Ten-*Quercus coccifera* L.
Date of collection: 22.04.2023


Figure 3. *Tuber borchii* Vittad

Species: *Tuber macrosporum* Vittad. (Figure4)
Location: Muğla-Fethiye Üzümlü mevkii, 645m, A 6924.
Host species: *P. brutia* Ten.
Date of collection: 22.04. 2023


Figure 4. *Tuber macrosporum* Vittad

Species: *Tuber rufum* Picco (Figure 5)
Location: Uşak, Eşme, Kayapınar mevkii, Muğla Menteşe, Yaraş Mevkii, 645m, A 6925.
Host species: *Pinus brutia* Ten-*Quercus coccifera* L
Date of collection: 22.05.2024


Figure 5. *Tuber rufum* Picco

Discussions

This study area encompasses the Aegean region, specifically situated in the C2 quadrant according to Davis's grid system. As a result of the research conducted between 2022 and 2023, truffle samples were collected, leading to the identification of four taxa belonging to the *Tuber* genus. The identified species include *Tuber aestivum* (Wulfen) Spreng., *Tuber rufum* Picco, *Tuber macrosporum* Vittad., and *Tuber borchii* Vittad.*Tuber* species are highly valuable due to their excellent texture, pleasant aroma, culinary quality, and various medicinal properties. Despite Türkiye's rich diversity of *Tuber* spp.,

there is insufficient utilization of these resources. The ongoing climate change and the unregulated collection of truffle mushrooms pose significant threats to this emerging sector in the country, resulting in decreasing yields and even endangerment of these species.

With the establishment of truffle plantation areas in many countries around the world, accelerating efforts to grow truffles in Türkiye can both prevent the extinction of these mushrooms and make a significant contribution to the rural economy by encouraging the use of arid and semi-arid lands that are not suitable for traditional agriculture. As a result, high yields can be achieved with proper planning and conscious practices.

Türkiye has significant potential in the global trade of edible wild mushrooms. Considering the country's resources, increasing mushroom production and exports could contribute greatly to the economy by adding value and generating foreign exchange.

In order to benefit from this potential, initiatives to increase mushroom production and exports should be encouraged and supported. Encouraging entrepreneurs in the sector, implementing training and support programs, and adopting sustainable production methods will increase Türkiye's competitiveness in mushroom trade.

Additionally, developing effective marketing strategies and supporting local producers through various incentives can accelerate growth in this sector. Thus, Türkiye can establish a stronger presence in international markets and become a major player in mushroom exports.

With this study, truffle locations that grow naturally in the Aegean region were identified. These locations will be a guide for entrepreneurs who want to establish a truffle garden

Author contributions

All authors have equal contributions

Conflicts of interest

The authors declare no competing interests.

Ethical Statement: It is declared that scientific and ethical principles have been followed while carrying out and writing this study and that all the sources used have been properly cited (Sevgin ÖZDERİN, Hakan ALLI)

Acknowledgement

This study was presented as an abstract text at the "4th International Eurasian Mycology Congress (EMC'24) ".

References

Akkemik, Ü. (2016). Türkiye'nin Doğal Meşe (*Quercus* L.) Türlerinin Yayılışı ve Botanik Özellikleri. Uluslararası Katılımlı Meşe Çalıştayı Bildiriler Ve Sonuç Bildirgesi, (pp.83-94),Ormancılık Genel Müdürlüğü Marmara Ormancılık Araştırma Enstitüsü, 18-20 Ekim 2016, İğneada/Kırklareli.

Bakratsas, G., Polydera, A., Katapodis, P. and Stamatis, H. (2021). Recent trends in submerged cultivation of mushrooms and their application as a source of nutraceuticals and food additives, *Future Foods*, 4, 100086.

Benucci, G. M. N. and Bonito, G. M. (2016). The truffle microbiome: species and geography effects on bacteria associated with fruiting bodies of hypogeous Pezizales. *Microbial ecology*, 72,4-8

Boa, E. (2007). Wild Edible Fungi a global overview of their use and importance to people, in Biology. *Food and Agriculture* Organization of the United Nations, Roma 2007.

Dennis, R. W. G., Breitenbach, J., & Kranzlin, F. (1985). *Fungi of Switzerland. Vol. 1 Ascomycetes*. Kew Bulletin, 40(3), 663.

Chevalier, G., and Frochot, H., (2002). *La Truffe de Bourgogne* (*Tuber uncinatum* Chatin), Editions Petrarque, Levallois-Perret Cedex. ISBN-13: 978-2911730139, 257p.

Davis PH (1970-1984-1985). *Flora of Turkey and the Aegean Islands*. Edinburg University Press 3: 8-9.

Gezer, K., Kaygusuz, O., Çelik, A., & Işıloğlu, M. (2014). Ecological characteristics of truffles growing in Denizli Province, Turkey. *Journal of Food, Agriculture & Environment*, 12(2), 1105-1109.

Hall, I., Brown, G. & Zambonelli, A. (2007). *Taming the truffle*. *The istory, lore, and science of the ultimate mushroom*. Timber press.304

Kagan-Zur, V. and Roth-Bejerano, N., (2008). *Desert truffles, Fungi,* 1: 32-37, ISBN 978-3-319-31434-1, Springer International Publishing AG Switzerland.

Kamle, M., Bar, E., Lewinsohn, D., Shavit, E., Roth-Bejerano, N., Kagan-Zur, V., Barak Z., Guy O., Zaady E., Lewinsohn E. and Sitrit, Y. (2017). Characterization of morphology, volatile profiles, and molecular markers in edible desert truffles from the negev desert, *Journal of Agricultural and Food Chemistry*, 65(14), 2977-2983.

Kaya, A. (2009). Macromycetes of Kahramanmaraş Province (Turkey), *Mycotaxon*, 108 (1), 31-34

Kence, A. (1987). *Türkiye'nin Biyolojik Zenginlikleri*. Türkiye Çevre Sorunları Vakfı Yayını, (87.06), 17-24, Ankara.

Kibar, B. and Pekşen, A. (2007). Ektomikorizanin Tarim Ve Ormancilik Bakimindan Önemi, *Anadolu Tarım Bilimleri Dergisi,* 22(2), 232-238.

Lazzari, B., Gianazza, E. and Viotti, A. (1995). Molecular characterization of some truffle species. Biotechnology of ectomycorrhizae: *Molecular Approaches*, 161-169.

Lee, H., Nam, K., Zahra, Z. and Farooqi, M. Q. U. (2020). Potentials of truffles in nutritional and medicinal applications: A review. *Fungal biology and biotechnology*, 7, 1-17.

Pegler, D. N. (2000). A. Montecchi, M. Sarasini, *Funghi ipogel d'Europa, Associazione Micologica Bresadola*, Trento, Italy (2000), p. 714.

Mello, A. and Balestrini, R. (2018). Recent insights on biological and ecological aspects of ectomycorrhizal fungi and their interactions. *Frontiers in Microbiology*, 9, 216.

Nicholas, L. G., and Ogame, K. (2006). Psilocybin mushroom handbook: easy indoor & outdoor cultivation. Ed Rosenthal.

Özderin, S., Yılmaz, F. and Allı, H. (2018). Determining mycorrhiza rate in some oak species inoculated with Tuber aestivum Vittad. (summer truffle). *Turkish Journal of Forestry*, 19(3), 226-232.

Özderin, S. and Allı, H. (2020). Determination of mycorrhizal developments in pecan nut seedlings inoculated with *Tuber aestivum* Vittad. (summer truffle). Turkish Journal of Forestry, 21(2), 131-135.

Özhatay, N. and Kültür, Ş. (2006). Check-list of additional taxa to the Supplement Flora of Turkey III. *Turkish Journal of Botany,* 30(4), 281-316.

Öztürk, M., Soylu, M. K., Temel, M., Pezikoğlu, F. and Bilen, G. M. (2019). Türkiye'nin Dünya Mantar Dış Ticaretindeki Yeri. *Uluslararası Anadolu Ziraat Mühendisliği Bilimleri Dergisi*, 1(5), 102-107.

Pegler, D. N., Spooner, B. M., and Young, T. W. (1993). *British truffles: a revision of British hypogeous fungi* (pp. 216-pp).ISBN 0947643397, Royal Botanic Gardens, Kew, London.

Pekşen, A. and Akdeniz, H. (2012). Organik ürün olarak doğa mantarları. Düzce Üniversitesi, *Orman Fakültesi Ormancılık Dergisi*, 8(1), 34-40.

Sesli, E., Asan, A., Selçuk, F., Abacı Günyar, Ö., Akata, I., Akgül, H., Aktaş, S., Alkan, S., Allı, H., Aydoğdu, H., Berikten, D., Demirel, K., Demirel, R., Doğan, H.H., Erdoğdu, M., Ergül, C.C., Eroğlu, G., Giray, G., Haliki Uztan, A., Kabaktepe, Ş., Kadaifçiler, D., Kalyoncu, F., Karaltı, İ., Kaşık, G., Kaya, A., Keleş, A., Kırbağ, S., Kıvanç, M., Ocak, İ., Ökten, S., Özkale, E., Öztürk, C., Sevindil, M., Şen, B., Şen, İ., Türkekul, İ., Ulukapı, M., Uzun, Ya., Uzun, Yu. and Yoltaş, A (2020). *Türkiye Mantarları Listesi*. Ali Nihat Gökyiğit Vakfı Yayını. İstanbul. P. 1177

Stobbe, U., Büntgen, U., Sproll, L., Tegel, W., Egli, S. and Fink, S. (2012). Spatial distribution and ecological variation of re-discovered German truffle habitats. *Fungal Ecology*, 5(5), 591-599.

Şen, İ., Allı, H. and Civelek, H. S. (2016). Checklist of Turkish truffles. *Turkish Journal of Life Sciences*, 1(2), 103-109.

Şimşek, A. and Önek, Ü. M. (2021). Yenilebilir mantar tüketimi ve yemekleri üzerine bir inceleme: Kastamonu örneği. *OCAK*: *Türk Mutfak Kültürü Araştırmaları Dergisi*, 1(1), 21-30.

Türkoğlu, A. and Castellano, M. A. (2014). New records of some Ascomycete truffle fungi from Turkey. *Turkish Journal of Botany*, 38(2), 406-416.

Trappe, J. M. and Castellano, M. A. (1991). *Keys to the genera of truffles (Ascomycetes). McIlvanea*, 10, 47-65.Ten Speed press, Berkeley, Toronto.

Üstün, N., Bulam, S. and Peksen, A. (2018) Biochemical properties, biological activities and usage of truffles. In Proceedings of the Conference: International Congress on Engineering and Life Science, Kastamonu, Turkey (pp. 26-29).

Yaltırık, F. (1984). *Türkiye meşeleri*: *teşhis kılavuzu*. Yenilik Basımevi, İstanbul. P. 77

Yun, W. and Hall, I. R. (2004). Edible ectomycorrhizal mushrooms: challenges and achievements. *Canadian Journal of Botany*, 82(8), 1063-1073.

Valverde, M. E., Hernández-Pérez, T. and Paredes-López, O. (2015). Edible mushrooms: improving human health and promoting quality life. *International journal of microbiology*, 2015(1), 376387.

Zambonelli, A., Iotti, M. and Murat, C. (2016). *True Truffle (spp.) in the world*: *soil ecology, systematics and biochemistry*. (47), 436pp. ISBN 978-3-319-31434-1, Springer International Publishing AG Switzerland.