TARIM EKONOMİSİ ARAŞTIRMALARI DERGİSİ
The Journal of Agricultural Economics Researches

Economic Comparison of Truffle Cultivation Methods in Türkiye

Türkiye'de Trüf Mantarı Yetiştiriciliği Yöntemlerinin Ekonomik Yönden Karşılaştırılması

Esra TEPİKOĞLU KARABULUT
M.Sc., Ondokuz Mayıs University, Faculty of Agriculture, Department of Agricultural Economics
esratepikoglu@gmail.com
ORCID: 0000-0001-6640-5332

Selime CANAN
Corresponding Author / *Sorumlu Yazar*
Assoc. Prof. Dr., Ondokuz Mayıs University, Faculty of Agriculture, Department of Agricultural Economics
selime.canan@omu.edu.tr
ORCID: 0000-0002-8041-3272

Cite as /*Atıf:* Tepikoğlu Karabulut, E., Canan, S. (2024). Economic Comparison of Truffle Cultivation Methods in Türkiye, The Journal of Agricultural economics Researches (JAER), 10 (2), 201-214

JEL classification codes / *JEL sınıflaması kodları*: Q0 - Q12 – Q23

DOI: 10.61513/tead.1576939

Note: This study was produced from the corresponding author's Ph.D. Thesis titled "Economıc Possıbılıtıes and Lımıtatıons of Truffle Mushroom Cultıvatıon Through Inoculatıon in Hazelnut Orchards", Ondokuz Mayıs Univesity, Agricultural Economics Department

Article Type / *Makale Türü*: Research Article / *Araştırma Makalesi*

Received date / *Geliş tarihi*: 31.10.2024 Accepted date / *Kabul tarihi*: 27.11.2024

e-ISSN: 2687 – 2765

Volume / *Cilt*:10, Issue / *Sayı*:2, Year / *Yıl*: 2024

Economic Comparison of Truffle Cultivation Methods in Türkiye

Abstract

Currently, in Türkiye, there are truffle mushroom garden businesses established only through inoculated oak saplings, and economic analyses have been conducted on this approach. For Türkiye, which holds approximately 75% of the world's hazelnut cultivation areas, the income of hazelnut farms can be significantly increased through dual cultivation of hazelnuts and truffle mushrooms. In this context, this study aims to compare the establishment costs and profitability rates of a truffle orchard business established using inoculated oak saplings and a truffle orchard business created through spore inoculation onto mature hazelnut orchards.

The materials related to the research were obtained through the secondary data collection method. Financial analyses of the Truffle Mushroom Orchard Project Feasibility Report and Investor Guide were brought to the present day using the compound interest method. Additionally, based on literature and market research, the cost of the inoculation material required for the inoculation process was calculated, and two different methods of establishing truffle mushroom garden facilities were analyzed in terms of formation and profitability through a comparative approach.

As a result of the study, it was found that the hazelnut project has a lower initial investment cost compared to the oak project, reached the break-even point in a shorter time frame, and therefore, the cash flow method was considered easier and more profitable due to these advantages, coupled with the advantage of hazelnut dual production. It is recommended to conduct an economic feasibility study considering hazelnut and truffle mushroom dual production as a single business entity.

Keywords: Truffles, Truffle cultivation, Economic aspects, Türkiye.

Türkiye'de Trüf Mantarı Yetiştiriciliği Yöntemlerinin Ekonomik Yönden Karşılaştırılması

Özet

Türkiye'de sadece aşılanmış meşe fidanları kullanılarak kurulan trüf mantarı işletmeleri bulunmaktadır ve bu üretim sistemi üzerine ekonomik analizler yapılmıştır. Dünya fındık yetiştirme alanlarının yaklaşık %75'ine sahip olan Türkiye için fındık işletmelerinin gelirleri, fındık ve trüf mantarı ikili üretimiyle önemli ölçüde artırılabilir. Bu bağlamda, bu çalışma aşılanmış meşe fidanları kullanılarak kurulan bir Trüf mantarı işletmesi ile olgun fındık bahçelerine spor aşılama yoluyla oluşturulan bir trüf mantarı işletmesinin kuruluş maliyetlerini ve karlılık oranlarını karşılaştırmayı amaçlamaktadır.

Araştırmayla ilgili materyaller ikincil veri toplama yöntemi ile elde edilmiştir. Türkiye'de trüf mantarı yetiştiriciliğine uygun koşullar ve yöntemler ikincil veri derleme yöntemiyle belirlendikten sonra Tarım ve Orman Bakanlığı Orman Genel Müdürlüğü tarafından yayınlanan Trüf Mantarı Bahçe Tesisi Projesi Fizibilite Raporu ve Yatırımcı Rehberi (2020) mali analizleri TÜİK verileri kullanılarak bileşik faiz yöntemiyle günümüze taşınmıştır. Ayrıca literatür ve piyasa araştırmalarına dayanarak aşılama işlemi için gerekli aşılama materyalinin maliyeti hesaplanmış ve iki farklı trüf mantarı tesisinin karlılığı karşılaştırmalı bir yaklaşımla analiz edilmiştir.

Çalışma sonucunda fındık projesinin meşe projesine göre daha düşük ilk yatırım maliyetine sahip olduğu, daha kısa bir zaman diliminde zarar etme noktasına ulaştığı ve bu avantajlara fındık üretimi avantajı da eklendiğinde nakit akışı yönteminin daha karlı olduğu görülmüştür. Türkiye'de trüf mantarı ve fındık ikilisini bir işletme olarak ele alan ve her iki ürün için optimal koşulların belirlenip; bu koşullarda harcanacak ortak ve farklı maliyetler ile gelirlerin hesaplanarak fındık ve trüf mantarı ikili üretim tesisinin ekonomik fizibilite raporunun oluşturulması önerilmektedir.

Anahtar kelimeler: Trüf mantarı, Trüf mantarı yetiştiriciliği, Ekonomik analiz, Türkiye.

1. INTRODUCTION

Türkiye is home to 67 species of truffle mushrooms belonging to 23 genera within 15 families (Şen et al., 2016). Different studies have provided evidence that 12 species of the *Tuber genus*, also known as "True Truffles," naturally grow in various regions of Türkiye (Türkoğlu, 2015a). According to an article titled ‘’Black Diamond: Truffle Mushroom’’ published in the Turkish Agriculture and Forestry Journal in 2021, as of 2020, around 200 truffle hunters in Türkiye had collected approximately 50 tons of various truffle mushroom species from nature (Özkan, 2021). The commercial volume of truffle mushrooms in Türkiye in 2020 was around 180 million Turkish Liras (₺). Türkiye has the potential to produce as much truffle as the combined production of France, Spain, and Italy, given its size, which is one and a half times that of France. In Türkiye, various truffle species can be grown in every region. *Tuber melanosporum* can be cultivated in regions with a temperate climate, *Tuber aestivum* in regions with harsher winters, and *Tuber borchii* can be grown in any climate with low soil pH (Türkoğlu, 2015). The natural occurrence of truffle mushrooms in Türkiye suggests a higher likelihood of success with truffle inoculation methods. Therefore, before establishing an artificial truffle mushroom garden, it is essential to study the natural conditions of the intended region and compare them with the natural growth conditions, depending on the truffle mushroom species. This way, both the success rate can be increased, and the expenses during cultivation can be minimized.

The establishment of a truffle mushroom garden involves the use of truffle-inoculated seeds or tree saplings. In the examples of Türkiye, it's observed that inoculated oak saplings are commonly used, and it is possible to purchase grafted oak saplings. However, there are currently no artificially truffle-inoculated hazelnut orchards or hazelnut saplings available in Türkiye, which has approximately 75% of the world's hazelnut cultivation areas (Turkish Grain Board, 2021), yet it is known that *Tuber brumale* genus naturally grows on hazelnut rootstock in the Samsun province (Türkoğlu, 2015a).

In the world and in Türkiye, numerous studies have been conducted on truffle mushrooms in various fields. Prominent books and academic articles written worldwide provide information about truffle mushrooms and truffle cultivation, the establishment of cultivation areas, the management of cultivation areas, cultivation alongside other crops such as hazelnuts and lavender, the management of natural truffle areas, inoculation of adult trees, truffle harvesting, the economic aspects of truffle cultivation, truffle phylogenesis, biotic and abiotic environments, spore distribution and biochemistry, truffle species, and the natural habitat of commercially valuable species (Morcillo et al., 2015, Zambonelli et al., 2016, Hall, Ian Robert et al., 2007, Renowden, 2005, Reyna and Barreda, 2007, Reyna et al., 2014). Additionally, laboratory studies and research are also available on topics such as truffle inoculation of adult trees (Reyna et al., 2002), inoculation of hazelnut cuttings with *Tuber melanosporum* and its effects (Moya et al., 2010), different inoculation methods in adult hazelnut (*Coryllus avellana*) orchards with *Tuber brumale* and *Tuber melanasporum* species (Iotti et al., 2012, Zambonelli et al., 2012), and the percentages of mycorrhiza formation in hazelnut roots over the years through sporal inoculation method (Morcillo et al., 2007). Limited resources are available regarding the economic returns and market size of truffle mushroom cultivation (Morcillo et al., 2015, Oliach et al., 2021, General Directory of Forestry, 2013). In Türkiye, there is a limited number of studies on truffle mushrooms. There is only one book dedicated to truffle mushrooms in Türkiye, which introduces 48 naturally occurring truffle species in Türkiye and provides information about the importance of truffle mushrooms, their ecological characteristics, cultivation, establishment and management of truffle orchards, and harvesting (Türkoğlu, 2015). There is also a guide available regarding the establishment of truffle mushroom orchard operations with oak seedlings inoculated with truffles, along with a financial analysis and

feasibility study (General Directory of Forestry, 2020). In addition to these resources, various projects have aimed to contribute to Türkiye's biodiversity by revealing the country's truffle flora, promoting the introduction of truffle species, encouraging truffle harvesting, creating truffle markets, and promoting truffle cultivation (Türkoğlu, 2015, 2015a, Şen et al., 2016, Çaka and Türkoğlu, 2016). Furthermore, there are studies available on the current status of truffle mushroom cultivation and hunting, the relationship between truffles and ectomycorrhiza, truffle mushroom cultivation, and studies related to the inoculation of hazelnut trees with truffle fungus (Saka et al., 2016, Özkan, 2021). However, there is no study on the inoculation of truffle mushrooms into mature hazelnut trees. Nonetheless, there are numerous sources available for making inferences about the conditions necessary for truffle mushroom growth, such as hazelnut, climate, and soil conditions (Agricultural Economic and Policy Development Institute, 2019, Turkish Grain Board, 2021). There is also no information available on the establishment cost and project profitability of a truffle mushroom orchard created through the inoculation of mature hazelnut trees.

There is no study related to truffle mushroom inoculation materials in Türkiye, but it is possible to obtain information through market research from private companies in European countries (Robin Pepinieres EARL, 2023). This study aims to fill the gap in the literature by examining the economic possibilities and limitations, such as the establishment cost and project-based profitability of a truffle mushroom orchard in a mature hazelnut plantation, based on a comparison with the oak project (General Directory of Forestry, 2020).

2. MATERIAL AND METHOD

The main source of the literature for the study consists of secondary data obtained from the research conducted by Morcilla et al. (2015). Additionally, the secondary data compilation method has been utilized in other literature studies that examine the truffle mushroom industry and cultivation.

In order to determine the most suitable economic methods for establishing a truffle mushroom cultivation facility in Türkiye, the appropriate natural conditions for truffle mushroom cultivation were first identified. To start a truffle facility, two different cultivation approaches were compared in terms of their economic aspect; establishing a truffle facility through summer truffle *(Tuber aestivum)* inoculated oak saplings and spore inoculating onto existing mature hazelnut sites. The cultivation of truffle mushrooms on mature hazelnut trees was referred to as " the hazelnut project," while the establishment of a truffle growing facility using inoculated oak saplings was referred to as " the oak project."

The primary material for the comparative analysis obtained from the Truffle Mushroom Orchard Project Feasibility Report and Investor Guide prepared by General Directory of Forestry (2020). To make the project more accessible to small-scale hazelnut producers, the project area and the data by General Directory of Forestry (GDF) were scaled down to 10 hectares from 100 hectares. Subsequently, the financial data comprising the initial investment expenses, annual expenses for pesticides, labor and other costs, project revenues, and net cash flows were adjusted to the March 2023 period using the compound interest calculation method. The Consumer Price Index (CPI) and Producer Price Index (PPI) data from Turkish Statistical Institute (TSI) were utilized for the compound interest calculation. While updating the costs including tillage, land preparation, planting site marking, saplings cost, pesticide applications, labor, and other expenses to March 2023, the PPI rates from Table 1 were employed.

Table 1. Domestic Producer Price Index (PPI) Rates by Periods (TSI, 2023)

Period	PPI Rates
December 2020-2021 (12 months)	% 43,86
December 2021-2022 (12 months)	% 128,47
December 2022- March 2023 (3 months)	% 4,15

While updating the costs of wire-fencing, drip irrigation system, project fees, mechanization-tools, and equipment prices to the present day, the Consumer Price Index (CPI) rates provided in Table 2 were employed.

Table 2. Domestic Consumer Price Index rates by periods (TSI, 2023)

Period	CPI Rates
December 2020-2021 (12 months)	% 19,60
December 2021-2022 (12 months)	% 72,31
December 2022- March 2023 (3 months)	% 6,65

While projecting the project revenues to the year 2023, the first step was to determine the unit price of summer truffle *(Tuber aestivum)* that constitutes the revenues. Instead of using compound interest calculation, a different approach was taken. The markets of Italy, Türkiye, and Bulgaria were examined, and the method deemed most accurate and consistent with current markets was adopted. This method involved converting the kilogram price determined by GDF in 2020 into the 2020 Euro exchange rate and then further converting the unit Euro price to the TL exchange rate in March 2023. In this process, the exchange rates provided by the Central Bank of the Republic of Türkiye were employed. The average Euro (€) exchange rate for the year 2020 was calculated as 8.04 using effective selling rates, and the average Euro exchange rate for March 2023 was calculated as 20.78.

Once the project revenues were calculated, the annual net cash flow for the 0–5-year period until the project starts production was determined with the following formulas:

$$NPV: \sum_{t=1}^{n} \frac{NCF_t}{(1+i)^t} - l$$

NPV: Net present value

NCF: Net cash flow (cash revenues-cash expenses)

Where; n was Economic life of investment, t was period, i i was the interest rate for cash expenses (exchange rate conversion was used instead of compound interest for cash revenues), l was initial investment amount.

Additionally, for the years following the commencement of production, a 5-year net cash flow projection has been prepared. The primary reason for bringing the financial values of this project to the present day was the comparison of the establishment cost and profitability of the truffle plantation facility obtained through the inoculation of adult hazelnut orchards. In order to compare the net present value of the projects, a separate economic feasibility report was worked on for dual production; the combined production of hazelnuts and truffles was considered as a single farm. Economic conclusions have been drawn by comparing the income and expense statements for both projects.

In calculation of the costs of establishing a truffle cultivation facility by inoculating adult hazelnut orchards with truffle spores, identical cost items were assumed to be the same, and factors such as terrain slope that could affect costs were considered constant. In the initial investment expenditures of the project, the cost items of Wire-Fence, Drip Irrigation System, Soil Preparation, Cultivation, Project Fee, and Mechanization-Equipment were treated as the same since they were assumed to be consistent across the different projects. The presence of Wire-Fence and Drip Irrigation Systems in existing adult hazelnut orchards was seen as an advantage as they would reduce costs, so these cost items were included even though they might not be present in all cases.

As there would be no need for planting trees in the establishment of a truffle cultivation facility from adult hazelnut orchards, costs related to tree planting, including digging holes and planting, were excluded from the initial investment expenditures. Instead, the costs of truffle spore materials and the labor for inoculation were included. The cost of truffle spore solution was calculated based on the method used by Morcillo et al. (2007) for inoculating hazelnut trees with *Tuber brumale* and *Tuber melanosporum*. The

assumption was that hazelnut trees were planted in rows with 5x6 meters spacing, resulting in approximately 33.33 trees per acre. The spore application was calculated for 33 hazelnut trees. As the irrigation system was included in the costs, it was assumed that there would be a water source and a water tank available for the spore application process.

For the calculation of truffle spore material costs, the inoculum of Robin Pepineres brand *Tuber aestivum,* which had a certified control certificate INRAe, containing 10,000,000 spores per liter, was used. Each hazelnut tree would receive at least 1,000,000 spores, and thus, 33 litres of inoculum were calculated. The price for 1 liter of inoculum on the company's digital sales platform was €17.49 (Robin Pépinières EARL, 2023). The total cost for 33 liters of inoculum, including shipping and taxes, amounted to €627.27. These costs were converted to Turkish Lira using the March exchange rate of the Central Bank of the Republic of Türkiye (TCMB, 2023).

As for the labor cost for the spore application, assuming that the application was done following the methods described in Morcillo et al. (2012) and GDF (2020), the daily labor cost per person was calculated as 684.63 ₺ for March 2023, based on the provided data. The costs related to soil preparation, cultivation, and mechanization were accounted for as they were presented in the feasibility study.

For the truffle spore application process, it was assumed that 2 people would be required for the application on a 10-acre orchard, based on the specified methods. The cost of labor was determined based on the provided data and was consistent with the inflation rates. The costs for the truffle spore application process were then calculated.

In the calculation of project revenues, a market study was conducted to ensure the suitability of the price. However, for reliable cost-benefit comparison, the price used for the oak project was the 2020 price of 750 ₺ per kg of truffle, converted to euros using the average exchange rate for 2020 and then converted to Turkish Lira using the March 2023 exchange rate. The projected revenues were calculated accordingly.

3. RESEARCH FINDINGS

3.1. Optimal approaches to establish a truffle mushroom facility in Türkiye

There are various methods of establishing and managing a truffle mushroom orchard. First and foremost, after determining the type of truffle mushroom to be cultivated based on climate, soil conditions, geographical, geological, and topographic features, a suitable host tree species should be chosen for the specific truffle variety. The tree species that truffle mushrooms can form mycorrhiza with also vary according to variety of the truffle. Oak and hazelnut species can serve as host trees for *Tuber melanosporum*, *Tuber borchii*, and *Tuber aestivum/uncinatum* species. Furthermore, despite the existence of numerous inoculation methods, three methods are commonly used: spore inoculation, mycelial pure cultures (vegetative inoculation), and colonized roots (symbiotic inoculation) (Iotti et al., 2012).

Truffle mushroom orchard management is a relatively new sector in Türkiye, and currently, truffle orchards are established using oak saplings inoculated with summer truffle (*Tuber aestivum*) through vegetative methods. In European countries, in addition to oak species, hazelnut (*Corylus avellana*) and other species allowing dual production such as Pecan nuts are preferred as rootstocks for the cultivation of *Tuber melanosporum* and *Tuber aestivum/uncinatum*, allowing for dual production. Considering the extensive area covered by hazelnut orchards in Türkiye, the Black Sea region holds significant potential for the dual production of truffle mushrooms and hazelnuts. Although there is a lack of sufficient research in Türkiye, inoculating truffle mushrooms onto hazelnut orchards is expected to have lower costs compared to truffle orchards established with inoculated oak saplings due to reduced expenditure items, resulting in higher economic returns. However, economic opportunities and constraints such as marketing

and management strategies should be considered as well.

3.2. Financial analysis and feasibility study of establishing a truffle mushroom orchard through truffle inoculated oak seedlings

Truffle mushroom cultivation is a long-term investment, and in cases where examining different projects, the average payback period is around 17 years, with a projected useful life of 45 years (GDF, 2020; Morcillo et al., 2015). In the year 2020, the General Directorate of Forestry (GDF) prepared a project plan covering a total of 100 acres with 55 saplings per acre. The project costs outlined by GDF have been adapted using the methods detailed in the materials and methods section for the year 2023, and the costs have been scaled down to cover 10 acres for the purpose of comparison with hazelnut orchards. The report prepared by GDF foresees positive returns beginning from the 6th year of the investment. During the first year, considered as the investment year, activities such as digging holes for plantation and planting saplings will be carried out. At the project's outset, expenses related to labor, irrigation, and other processes have been planned to increase proportionally with the development of the orchard. Irrigation has been implemented through drip irrigation investments (GDF, 2020).

3.2.1. The initial investment expenses of the oak seedlings project

The expenses of the project consist of fixed investment costs incurred in the investment year, as well as operational expenses that will be incurred annually for production purposes. Calculations have been made separately for each increasing year throughout the economic life of the project. The investment costs associated with the project are presented in Table 3. Within the project scope, drip irrigation will be used for watering, and activities such as soil preparation, digging planting holes, weed control, and pest control will be carried out. Truffle dogs will be employed to locate mature truffles in the truffle orchard (GDF, 2020).

Table 3. The fixed investment costs for the oak seedlings project

Expenses	Unit	Quantity	Unit Price (₺)	Total (₺)
Field Plowing	₺/ da	10	205,36	2.053,55
Soil Preparation	₺/ da	10	342,32	3.423,17
Marking Plantation Spots	₺/ da	10	102,70	1.026,95
Trellis fence	₺/ km	2,2	3.296,81	7.252,98
Digging Holes	₺/ da	10	205,39	2.053,90
Drip Irrigation System	₺/ da	10	2.857,23	28.572,34
Sapling Cost	₺/ number	550	290,97	160.033,21
Project Cost	Number	1	10.989,37	10.989,37
Mechanization - Tools and Equipment	₺			6.593,62
Total				221.999,10

3.2.2. Yearly pest control expenses

During the adaptation period of truffle-inoculated saplings to the project site, the establishment and reinforcement of the planted saplings are crucial, especially in the first three years. The initial tasks involve keeping the area free from wild weeds during the early years. It is recommended not to fertilize truffle-inoculated saplings to avoid interfering with the organic development of truffle mushrooms (GDF, 2020).

3.2.3. Distribution of labor and other expenses

The labor requirements for activities such as planting, harvesting, pest control, irrigation, and similar tasks during the investment and operational periods of the truffle orchard have

been planned with increasing proportions over the years. Annual operational expenses have been calculated for a 10-acre area, and these expenses have been added to the expenditure items (Table 5).

3.2.4. Project revenues of the oak seedlings project

Operational revenues are derived from the sales revenue of the produced goods throughout the economic life of the project. The product price has been calculated for the year 2023 using the methods detailed in the Truffle Mushroom Orchard Project Feasibility Report and Investor Guide (GDF, 2020) in the materials and methods section (Table 6).

Table 4. Pest control expenses by years

Years	Pesticide (₺)	Total Cost (₺)
1	171,16	1.711,59
2	205,39	2.053,90
3	239,57	2.395,72
4	-	-
5	-	-
6-45	-	-
Total		6.161,21

Table 5. Distribution of labor and other expenses by years

Years	Decare (da)	Labor cost / Unit price (₺)	Total cost (₺)
1	10	684,63	6.846,34
2	10	684,63	6.846,34
3	10	684,63	6.846,34
4	10	684,63	6.846,34
5	10	684,63	6.846,34
6-10	10	684,63	6.846,34
11-15	10	1.711,59	17.115,85
16-20	10	1.711,59	17.115,85
21-25	10	1.711,59	17.115,85
26-30	10	1.711,59	17.115,85
31-35	10	1.369,27	13.692,68
36-40	10	1.369,27	13.692,68
41-45	10	1.369,27	13.692,68
Total			150.619,50
Other Expenditure Items			
Field Rent	10	85,58	855,79
Electricity and Fuel	10	68,46	684,63
Management Expenses	10	476,16	4.761,63
Unexpected Expenses			1.026,95
Total Other Expenses			7.329,01

3.2.5. Net cash flow of the oak seedlings project

Over the course of the project's 45-year lifespan, it is anticipated that a total revenue of ₺4.445.721,00 will be generated against an investment amount of ₺1.174.136,40. In this case, a total gross profit of ₺3.281.584,60 will be achieved. Throughout the project's economic life, the difference between the calculated total expenses and the generated revenues, along with the gross profits for each year, have been calculated. The negative values in the first 5 years represent the investment years.

Table 6. Project revenues of the oak seedlings by years

Years	Decare (da)	Yield (kg/ da)	Total Products (kg)	Price (₺)	Total Income (₺/year)	Total Profit (₺)
1	10	-	-	-	-	-
2	10	-	-	-	-	-
3	10	-	-	-	-	-
4	10	-	-	-	-	-
5	10	-	-	-	-	-
6-10	10	3	30	1.937,27	58.118,10	290.590,50
11-15	10	5	50	1.937,27	96.863,50	484.317,50
16-20	10	8	80	1.937,27	154.981,60	774.908,00
21-25	10	8	80	1.937,27	154.981,60	774.908,00
26-30	10	7	70	1.937,27	135.608,90	678.044,50
31-35	10	6	60	1.937,27	116.236,20	581.181,00
36-40	10	5	50	1.937,27	96.863,50	484.317,50
41-45	10	4	40	1.937,27	77.490,80	387.454,00
Total						4.455.721,00

In projects with a lifespan of more than one year, calculating the depreciation of the value of money over time is important to determine the project's profitability. In essence, comparing the present value of all calculated expenses and revenues throughout the investment with the present value of the income over the project's lifespan allows for the evaluation of the purchasing power of the unit capital spent today against the purchasing power of the income generated over the project's duration. This calculation provides investors with clearer insights into the profitability of the undertaken investment. However, as this paper focuses on to make a comparison between two different method's start-up costs, it doesn't cover the depreciation of the value of money over time.

Table 7. NCF of the oak seedlings project by years

Years	Fixed Investment Expenses (₺)	Facility Expenses (₺)	Facility Revenues (₺)	Profit (₺)
1	221.999,10	15.886,94	-	-237.886,04
2		16.229,25	-	-16.229,25
3		16.571,07	-	-16.571,07
4		14.175,35	-	-14.175,35
5		14.175,35	-	-14.175,35
6-10		70.876,76	290.590,50	219.713,75
11-15		122.224,30	484.317,50	362.093,20
16-20		122.224,30	774.908,00	652.683,70
21-25		122.224,30	774.908,00	652.683,70
26-30		122.224,30	678.044,50	555.820,20
30-35		105.108,46	581.181,00	476.072,54
35-40		105.108,46	484.317,50	379.209,04
40-45		105.108,46	387.454,00	282.345,54
NPV				3.281.584,60

3.3. Establishing a garden facility by inoculating existing hazelnut orchards with truffle mushrooms

According to the 333 numbered Turkish General Communiqué of the Tax Procedure Law, the estimated useful life for hazelnut plants is 25 years. Therefore, it is assumed that the useful life of hazelnut orchards is 25 years, and the depreciation rate is 4%. However, since the calculation of yield for truffle mushroom orchards is based on truffle yield rather than hazelnut yield, the useful life for this project has been calculated as 45 years. Hazelnut varieties (*Corylus avellana)* produce offshoots and have a rapid and dense root development, making the spread and attachment of truffle mycelium easy. This allows for rejuvenation efforts in hazelnut trees. However, finding a management approach that maximizes benefits from both hazelnuts and truffles and deals with the associated costs is a subject of further research.

Based on field studies, successfully inoculated adult hazelnut trees can start production in the first year following inoculation (Morcillo et al., 2020). However, due to lower yields in the initial years, commercial-scale production in this project begins from the 6th year. To obtain more reliable data under Turkish conditions, further field studies with Turkish hazelnut varieties are needed.

3.3.1. Initial investment expenses for the hazelnut project

The project's expenses were prepared for comparison with the economic feasibility of a truffle mushroom orchard using inoculated oak saplings, as outlined by the General Directorate of Forestry (GDF). Common expenses such as shared costs, land conditions, and other factors that could impact costs were assumed to be the same. The costs prepared in 2020 were brought forward to March 2023 using the compound interest method. Since mature trees will be inoculated, costs such as marking planting spots and digging holes will not apply. Some hazelnut orchards may have facilities such as wire fencing and drip irrigation, which could lead to lower costs, but calculations were made assuming no such systems are in place. Hazelnut saplings were assumed to be planted in 5x6 meter intervals, suitable for truffle cultivation. In terms of inoculation costs, the calculation was based on approximately 33 hazelnut trees per acre. Truffle inoculation costs can vary depending on the truffle species. While multiple truffle species can be cultivated with hazelnut varieties, this project specifically considered costs and revenues for the summer black truffle (*Tuber aestivum)* for comparison with the oak project.

3.3.2. Net cash flow of the hazelnut project

Operational revenues are generated from the sales revenue of the produced goods throughout the economic life of the project. The product price has been calculated as in the oak project. While there are sources indicating that hazelnut yields start production earlier and have a higher production rate (Morcillo, 2007; 2015; Iotti et al., 2012), due to the lack of information, revenues have been assumed to be the same as in the oak project.

There are numerous examples of hazelnut shoots taken from hazelnut orchards naturally having truffle mycorrhizae (Morcillo, 2015). If these shoots are separated through mycorrhiza observation, truffle-inoculated hazelnut saplings could become an additional source of income. However, this aspect has not been included in the project revenues as it requires technical knowledge and specialized equipment.

3.2.3. Comparison of the establishment costs and productivity of both methods

In comparison of the establishment costs of a truffle orchard using oak saplings inoculated truffles with vegetative method and the spore inoculation of truffles onto mature hazelnut trees, it's observed that the establishment cost of a 10-acre hazelnut project is ₺99,765.23, whereas the cost of the oak project is ₺221,999.10. In terms of establishment costs, the hazelnut project is ₺121,433.87 more profitable. Considering the significant disadvantage of delayed production

initiation and the maintenance expenses of ₺77,037.96 during the first 5 years until production begins in truffle cultivation, the establishment cost of the hazelnut project can cover the costs with the income obtained from hazelnut production until truffle production starts and consequently it could be more feasible with the capital invested.

Table 8. Initial investment expenses for the hazelnut project

Expenses	Unit	Quantity	Unit Price (₺)	Total (₺)
Trellis Fence	₺/km	2,2	3.296,81	7.252,98
Drip Irrigation System	₺/da	10	2.857,23	28.572,34
Field Plowing	₺/da	10	205,36	2.053,55
Soil Preparation	₺/da	10	342,32	3.423,17
Inoculation Solution	kg/da	33	395,02	13.035,67
Inoculation Labouring	day	2	684,63	1.369,26
Project Cost	number	1	10.989,37	10.989,37
Mechanization- Tools and Equipment	₺			6.593,62
Total				73.289,96
				2nd Inoculation (6 Months Later)
Field Plowing	₺/ da	10	205,36	2.053,55
Soil Preparation	₺/da	10	342,32	3.423,17
Inoculation Solution	kg/ da	33	395,02	13.035,67
Inoculation Labouring	day	2	684,63	1.369,26
Mechanization- Tools and Equipment	₺			6.593,62
2nd Inoculation Total Cost				26.475,27
Fixed Expenses in Total				99.765,23

Table 9. NCF of the hazelnut project by years

Years	Fixed Expenses (₺)	Facility Expenses (₺)	Facility Revenues (₺)	Profit (₺)
1	99.765,23	15.886,94	-	-115.652,17
2		16.229,25	-	-16.229,25
3		16.571,07	-	-16.571,07
4		14.175,35	-	-14.175,35
5		14.175,35	-	-14.175,35
6-10		70.876,74	290.590,50	219.713,77
11-15		122.224,29	484.317,50	362.093,21
16-20		122.224,29	774.908,00	652.683,71
21-25		122.224,29	774.908,00	652.683,71
26-30		122.224,29	678.044,50	555.820,21
30-35		105.108,44	581.181,00	476.072,56
35-40		105.108,44	484.317,50	379.209,06
40-45		105.108,44	387.454,00	282.345,56
NPV				3.403.818,59

For the oak project, the payback period for the total pre-production cost of ₺299,037.06 is between 11-15 years. For the hazelnut project, the payback period for the total pre-production cost of

₺176,803.19 is between 6-10 years. The profit after 45 years for the oak project is ₺3,281,584.60, while for the hazelnut project, it's ₺3,403,818.59. Evaluating all these data, it can be concluded that the hazelnut project is more advantageous in terms of reaching the break-even point in a shorter term and having a higher profitability due to lower start-up cost.

4. RESULTS and DISCUSSION

There is not enough up-to-date data available to establish the economic feasibility of dual production of truffle mushrooms and hazelnuts as a single enterprise in Türkiye. The Truffle Mushroom Orchard Facility Project, which examines the truffle mushroom (*Tuber aestivum)* business using oak seedlings inoculated by vegetative methods, is based on Truffle Mushroom Orchard Project Feasibility Report and Investor Guide (GDF, 2020). This project compares the establishment costs and profitability ratios of truffle mushroom orchard operations through spore inoculation in hazelnut orchards, based on the oak project.

Firstly, the financial analysis of the oak project was adapted to the present day (March 2023) and narrowed down to 10 acres to be more appealing to hazelnut farmers. The initial investment costs for the project are calculated as 222,991.10 Turkish Lira (₺). For the first 3 years, pesticide costs for weed control, aimed at preserving the mycelium structure, amount to a total of ₺6,161.21. Over the 45-year period considered as the depreciation period for truffle mushroom businesses, labor costs required for activities such as planting, harvesting, and irrigation are estimated to be ₺150,619.50 for 10 acres. Land rent, electricity-petrol, management expenses, and unexpected expenses calculated as ₺7,329.01.

Project revenues are calculated starting from the 6th year in cases where production begins, and it is expected to reach a total of ₺4,455,721.00 by the 45th year. Examining the net cash flow table of the project, it is expected to generate a revenue of ₺4,455,721.00 against an investment amount of ₺222,991.10, with ₺3,281,584.60 of this being the projected profit. While the business is expected to become profitable in the first 6-10 years of operation, the recovery of the total cost of ₺369,913.82 for the first 10 years and reaching the break-even point is expected to occur between the 11th and 16th years.

In conducting the financial analysis of the hazelnut project, it was assumed that the amortization period for truffle mushrooms is 45 years, despite the stipulations of General Communique No. 333 of the Tax Procedure Law states that the useful life of hazelnut orchards is 25 years. The financial analysis of the hazelnut project was conducted for the purpose of comparison with the oak project in terms of establishment costs and profitability ratios. Therefore, land conditions that could affect costs such as irrigation, fencing, and rent were assumed to be the same. Since adult hazelnut trees are inoculated through spore methods, costs such as marking the planting location, digging holes, and planting seedlings were not considered, and the cost of spore inoculation, as detailed in the materials and methods, was added instead. Accordingly, the establishment cost of the hazelnut project is calculated as ₺99,765.23.

In the literature on weed control for hazelnuts, despite differences in rootstock, the methods used are assumed to be the same as those applied in the oak project; therefore, pesticide costs were considered identical. Additionally, as it might affect the revenues, the impact of fertilizers used in hazelnuts such as 15:15:15 NPK effect on truffle productivity was examined and it was determined that there was no positive or negative effect on truffle production rate.

Similarly, to the oak project, labor costs consisting of the same items, such as inoculation, harvesting, and pesticide application, were also assumed to be the same in the hazelnut project instead of planting seedlings. In calculation of the revenues of the hazelnut project, it was assumed that the yield and product price are the same as in the oak project due to the lack of clear data on higher yields in truffle cultivation on hazelnut rootstocks. Accordingly, in cases where examining the net cash flow of the hazelnut project, it is expected to generate a

revenue of ₺4,455,721.00 against an investment amount of ₺99,765.23, with ₺3,403,818.59 of this being the projected profit.

While it is expected that the business will become profitable in the first 6-10 years of operation, the recovery of the total cost of ₺247,679.93 for the first 10 years and reaching the break-even point is expected to occur in the 10th year of the 6–10-year period.

In Türkiye, the methods used for the establishment of truffle mushroom orchard management were examined, the most suitable methods were discussed, and they were economically compared in terms of establishment costs and return on investment. The findings clearly show that the hazelnut project reaches the break-even point faster compared to the oak project. Since the establishment cost is lower, profitability is higher in the hazelnut project.

To further reduce the establishment cost, it is possible to produce truffle mushroom grafting material in Türkiye. Therefore, creating grafting material from truffle mushroom species native to this geography and adapted to these geographical conditions, instead of importing grafting material with foreign currency, will reduce costs, preserve the genetic diversity of the species, and increase the likelihood of successful grafting. Hence, there is a need for research in this regard.

Additionally, in cases where hazelnut orchards and truffle mushroom cultivation are considered as a single operation, many costs such as wire cages, drip irrigation, and soil preparation will be shared between the two products. Therefore, it is expected that these costs will be halved, leading to increased profits. However, more research is needed on hazelnut and truffle mushroom dual production. While some sources claim that truffle mushrooms grown on hazelnut roots have better yields (Morcillo, 2007; 2015; Iotti et al., 2012), there is no definitive information regarding yield quantity. Moreover, yield quantity may vary depending on the hazelnut species commonly grown in Türkiye. Therefore, creating test fields with widely cultivated hazelnut species in Türkiye and monitoring long-term data is necessary to determine optimal conditions for yield in hazelnut and truffle mushroom dual cultivation. Once optimal conditions are determined, it is recommended to prepare an economic feasibility report for hazelnut and truffle mushroom dual production facility. After all these studies are conducted, support programs for truffle mushroom production can be specifically designed for hazelnut farmers, and a contract farming model can be adopted. Additionally, the suckers obtained from these orchards can be used for mycelium formation through university-private sector collaboration, and they can be offered for sale as naturally truffle-grafted hazelnut seedlings, creating an additional source of income for the operation.

Considering the vast areas covered by hazelnut orchards in Türkiye, increasing truffle mushroom production through this method can not only benefit hazelnut farmers but also allow Türkiye to have a larger and faster-growing presence in the global truffle mushroom market. While the projects have been evaluated in terms of the known presence of *Tuber aestivum* in Türkiye, they can also be applied for more valuable truffle mushroom species such as *Tuber melanosporum*.

In conclusion, the hazelnut project is more advantageous in terms of return on investment and profitability compared to the oak project. Through research and development efforts, the establishment cost of the hazelnut project can be reduced, yield can be increased, and profitability can be improved accordingly. From a social perspective, especially in the Black Sea Region where hazelnut orchards are prevalent, this approach can create employment opportunities and potentially reverse migration trends. For all these reasons, further research is essential on hazelnut and truffle mushroom dual cultivation, particularly with the spore inoculation methods that enable its application in mature hazelnut orchards.

REFERENCES

Agricultural Economic and Policy Development Institute (2019). Agricultural Commodity

Markets, Fındık. Republic of Türkiye Ministry of Agriculture and Forestry.

Çaka, Ş. & Türkoğlu, A. (2016). Some Commercial Truffles and Their Natural Habitats. Muğla Journal of Science and Technology, Special Issue, 13-14.

General Directory of Forestry (2013). Truffle Forestry Action Plan 2014-2018. Ankara: Ministry of Agriculture and Forestry, Republic of Türkiye, Directorate General of Non-Wood Products and Services. Web site: https://kutuphane.tarimorman.gov.tr/vufind/Record/1177088/Description. (Accessed: 26.05.2022).

General Directory of Forestry (2020). Truffle Mushroom Orchard Project Feasibility Report and Investor Guide. Ed. Özgür Balcı, Republic of Türkiye Ministry of Agriculture and Forestry.

Hall, I.R., Brown, G., & Zambonelli, A. (2007). Taming the Truffle: The History, Lore, and Science of The Ultimate Mushroom. Timber Press.

Iotti, M., Piattoni, F., Zambonelli, A. (2012). Techniques for Host Plant Inoculation with Truffles and Other Edible Ectomycorrhizal Mushrooms. 10.1007/978-3-642-33823-6_9.

Morcillo, M., Sanchez, M., Vilanova, X. (2015). Truffle Farming Today: A Comprehensive World Guide. Micologia Forestryryal & Aplicada.

Morcillo, M., Sanchez, M., Vidal. J.M., Gràcia, E. (2007). Inoculation of Hazelnut Groves with *Brumale*& *Tuber melanosporum Vitt.*

Moya, S.R., Palfner, G. (2010). Controlled Rhizogenesis and Mycorrhization of Hazelnut (Corylus Avellana L.) Cuttings with Black Truffle (Tuber Melanosporum Vitt.). Chilean Journal of Agricultural Research, vol. 70, no.2.

Oliach, D., Vidale, E., Brenko, A., Marois, O., Andrighetto, N., Stara, K., Martínez de Aragón, J., Colinas, C., Bonet, J.A. (2021). Truffle Market Evolution: An Application of the Delphi Method. Forestry, 12, 1174. https://doi.org/10.3390/f12091174

Özkan M. (2021). Black Diamond: Truffle Mushroom. Turkish Agriculture Forestry Journal. http://www.turktarim.gov.tr/Haber/596/kara-elmas-truf-mantari-. (Accessed: 26.05.2022).

Reyna, S. & Garcia-Barreda, S. (2014). Black truffle cultivation: A global reality. Forestry Systems. 23. pp. 317-328. 10.5424/fs/2014232-04771.

Reyna, S., Rodriguez Barreal, J., Folch, L., Perez-Badia, R., Dominguez, A., Saez-De-Omenaca, J., Zazo. (2002). Techniques for inoculating mature trees with *Tuber melanosporum* Vitt. In: I. Hall, Y. Wang, E. Danell, A. Zambonelli(eds). Edible mycorrhizal mushrooms and theircultivation. Proceedings of the Second International Conferenceon Edible Mycorrhizal Mushrooms. CD ROM Crop & FoodResearch. New Zealand.

Robin Pépinières EARL (2023). Truffle inoculum tuber uncinatum2023. Robin Pépinières EARL. https://www.robinpepinieres.com/en/truffle-inoculum-melanosporum/740-truffle-inoculum-tuber-uncinatum.html

Şen, İ., Allı, H., Civelek, H.S. (2016). Checklist of Turkish Truffles. Turkish Journal of Life Sciences. 1/2:103-109.

Turkish Grain Board (2021). 2020 Hazelnut Sector Report- Tmo.gov.tr. https://www.tmo.gov.tr/Upload/Document/sektorraporlari/findik2020.pdf. (Accessed: 26.05.2022).

Turkish Statistical Institute (TSI). (2023). https://www.tuik.gov.tr/

Türkoğlu A (2015). The Hidden Treasure Underground: Truffles. Republic of Türkiye Ministry of Forestry and Water Affairs, General Directorate of Forestry.

Türkoğlu A (2015a). Determination of Genetic Diversity of Tuber Species Found Naturally in Türkiye and Investigation of Migration Map of European and Asian Truffles. Truffle Projects | Prof.Dr.Aziz Türkoğlu. http://aturkoglu.com/truf_projeler.aspx. (Accessed: 26.05.2022).

Zambonelli, A., Lotti, M., Murat, C., (2018). True Truffle (Tuber Spp.) in the World Soil Ecology, Systematics and Biochemistry. Springer International Publishing, vol. 47.