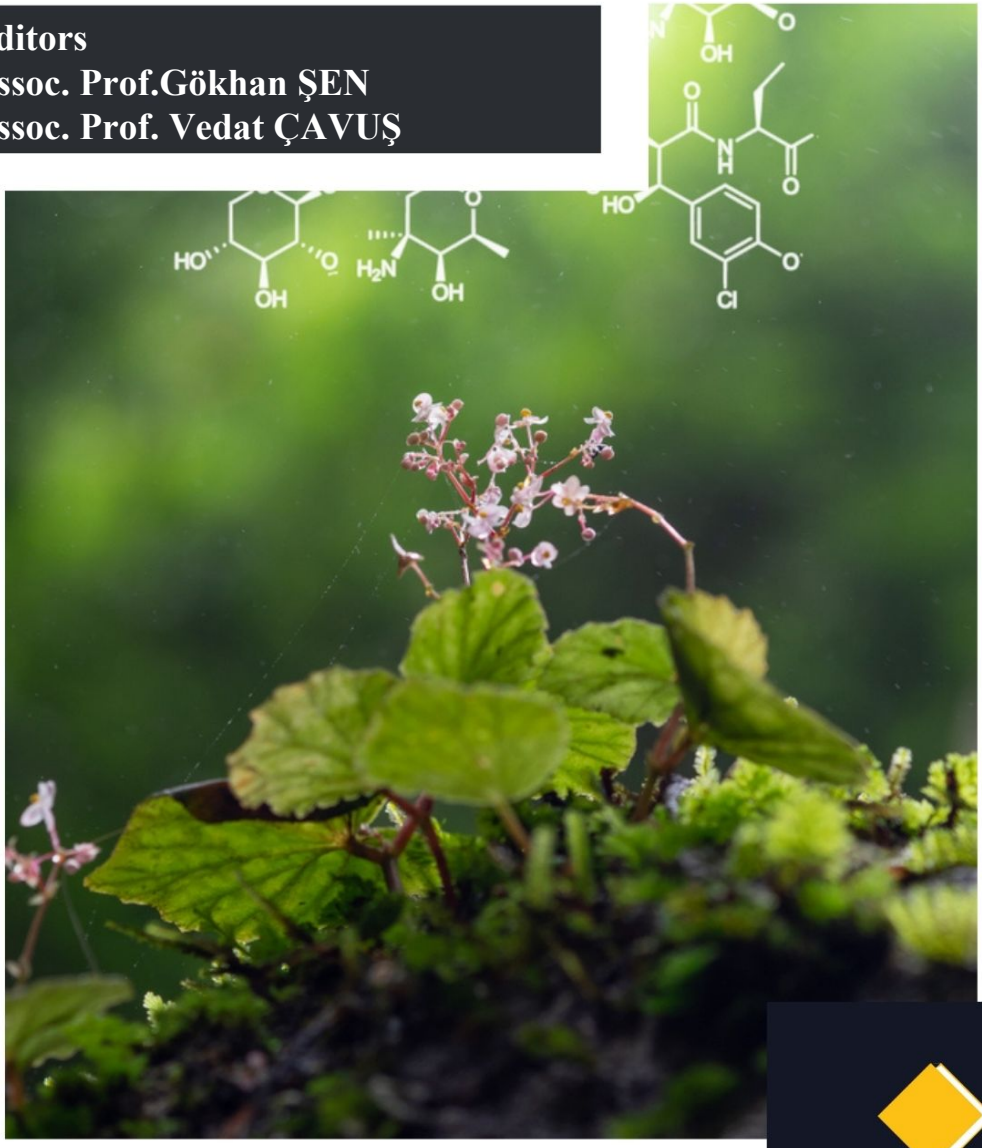
NEW FRONTIERS IN AGRICULTURE, FOREST AND WATER ISSUES

Editors
Assoc. Prof.Gökhan ŞEN
Assoc. Prof. Vedat ÇAVUŞ



DUVAR

NEW FRONTIERS IN AGRICULTURE, FOREST AND WATER ISSUES

Editors:

Assoc. Prof.Gökhan ŞEN

Assoc. Prof. Vedat ÇAVUŞ

New Frontiers in Agriculture, Forest and Water Issues
Editors: Assoc. Prof.Gökhan ŞEN, Assoc. Prof. Vedat ÇAVUŞ

Editor in chief: Berkan Balpetek
Cover and Page Design: Duvar Design
Printing : October -2023
Publisher Certificate No: 49837
ISBN: 978-625-6585-08-9

853 Sokak No:13 P.10 Kemeraltı-Konak/İzmir
Tel: 0 232 484 88 68

www.duvaryayinlari.com
duvarkitabevi@gmail.com

TABLE OF CONTENTS

Chapter 1

Evaluation of Success Criteria in Land Consolidation Studies

Şerife ÖZDAMAR[1], Duygu BOYRAZ ERDEM[2]

[1] Zir. Yük. Müh; Kaplan Harita ve İnşaat L.Ş.
ozdamarserife17@gmail.com ORCID No: 0000-0002-8604-5896

[2] Doç. Dr; Tekirdağ Namık Kemal Üniversitesi Ziraat Fakültesi, Toprak Bilimi ve Bitki Besleme Bölümü.
dboyraz@nku.edu.tr ORCID No: 0000-0002-9130-8769

ABSTRACT

Land consolidation has been implemented in Türkiye since 1960. The work done after the adoption of the Soil Conservation and Land Use Law and the Regulation on the Protection, Use and Land Consolidation of Agricultural Lands has become more effective. It is aimed to ensure the most profitable production under agricultural production and irrigation conditions through land consolidation operations. For this purpose, it is profitable to bring scattered lands together as much as possible through consolidation processes, to combine small parcels to larger sizes, to ensure that each parcel has easy access to roadside and irrigation conditions, to transform common title deeds into individual title deeds, and to reduce time, labour, and costs in agricultural production. situation is passed. During the realization of all these processes, it is necessary to provide awareness raising processes by explaining the project stages to the people of the region where consolidation will be carried out. Since the process is not explained sufficiently to the people of the region and the procedure is approached with prejudice, they are not satisfied with anything and focus entirely on the negative aspects, and the advantages of the procedure are ignored

Keywords: Land consolidation, benefits, problems, success criteria

INTRODUCTION

One of the factors that can cause development in the world is the most effective and appropriate regulation in rural areas. The problems brought by the increasing population have negatively affected the people dealing with agriculture and animal husbandry. These problems brought about the problem of fragmentation by dividing agricultural lands (plots) day by day. As urbanization and industrialization increased, the population density in villages where migration from rural areas to cities decreased, the number of enterprises increased due to fragmentation, but there were decreases in agricultural production and efficiency despite increased agricultural operations. Factors such as the decrease in productivity in the agricultural sector, the fragmentation of the lands, the migration to the cities, misuse, the increase in the number of enterprises, the increase in the shareholding status in agricultural lands, and the poor relations with relatives and other shareholders have been effective, and the most effective and solution way to eliminate these factors is to re-use the lands. It is one of the most important elements that are effective in the regulation and development of the countries in the world (Yoğunlu, 2013)

In land consolidation projects where land arrangement is made, collection in agricultural lands and making improvement of field roads are one of the effective and important factors on agricultural lands in rural areas. Infrastructure works and land consolidation in rural areas are two factors that are directly proportional to the other. When these two factors are carried out together, a significant increase in agricultural production will be observed (http://www.e-kutuphane.imo.org.tr Access date: 15.04.2020).

Soil and water are important for agricultural production. Land consolidation, which forms the basis of regulation in agricultural lands, is one of the most effective practices in the regularization of these factors; The planning and arrangement of agricultural infrastructure and agricultural field roads, water resources and irrigation projects, and improvement studies enable them to continue their activities in this area (Yılmaz and Çiftçi, 2005).

When land Consolidation is made, the road plans, road widths and the shapes of the lands are rectangular or square, which is of great importance in reducing expenditures in agricultural mechanization. (Çevik ve Tekinel,1988).

In our country, the inadequacy of the lands used in agricultural enterprises, the fact that they are not dispersed to a certain extent, the problem of fragmentation of the parcels and the fact that they are located in other regions cannot benefit from factors such as transportation and irrigation, making it difficult to contribute to agricultural production. For these reasons, it is seen

that agricultural lands should be rearranged, and improvement and development processes should be carried out.

Land consolidation has been practiced in Türkiye since 1960. After the adoption of the Law on Soil Conservation and Land Use and the Regulation on the Protection, Use and Land Consolidation of Agricultural Lands, the work has become more effective.

Muyombano (2019) investigated the effects of land consolidation on food security and local communities and saw that there are local communities with limited land, they face food insecurity, and it is stated that when consolidation is made, the product variety will increase so that farming and families can have the opportunity to eat.

The process of combining and arranging agricultural lands, which is based on the farmer and the increase in agricultural production, which is a negative factor in agricultural production for different reasons and causes people with insufficient economic opportunities to not make arrangements in the agricultural field (such as the presence of misshapen parcels, lack of field roads), is called "land consolidation".

Necessity of Land Consolidation

Today, technology and innovations exist in the agricultural sector as well as in every sector. It is necessary to take some measures in order to use technology in agriculture, to improve enterprises, to organize agricultural lands and to ensure that they work continuously and sustainably. All of these measures are within the scope of consolidation and on-farm development services. In this context, land consolidation aimed to develop in rural areas as well as to solve the problem of fragmentation of agricultural lands that can be used efficiently and fragmentation for various reasons.

It has been stated that land consolidation is the technical services carried out to increase productivity in agriculture by arranging agricultural lands along with roads, irrigation networks, leveling and settlement areas (Çay and İnceyol, 2000).

When we compare the developed countries with Turkiye, while the number of enterprises is decreasing, the size of the enterprises is increasing and they are producing efficiently with the technology suitable for modern agriculture. However, fragmented and still fragmented agricultural lands in Turkey constitute small businesses and small business sizes. Accordingly, they become family businesses that are large enough to make a living. The fragmented and uneven distribution of land deteriorates the income situation and negatively

affects the country's economy by causing resignation in production (Taşdemir, 2001).

Land fragmentation can be defined as the division of an agricultural land into more than one agricultural land or parcels for various reasons day by day. We can list various reasons that may cause the fragmentation of agricultural land as follows (Karaman and Gökalp, 2018).

- There are usage differences with cadastral maps,
- Existence of parcels not connected to irrigation and transportation network,
- The parcel forms are not suitable for agricultural mechanization and irrigation,
- Public practices breaking up parcels,
- Disintegration through death and inheritance,
- Renting and joint use due to lack of labor and capital,
- Encountering with various natural disasters and fragmentation according to geographical locations,
- The increase in population in rural areas engaged in agriculture causes fragmentation.

Legal Basis of Land Consolidation Studies

Land consolidation has been implemented in the following institutions and organizations in Turkey, respectively.

. General Directorate of Soil and Water
• General Directorate of Rural Services
• General Directorate of Agricultural Reform
• General Directorate of State Hydraulic Works.

Land Consolidation was first carried out in 1961 in accordance with Article 678 of the civil law and the Land Consolidation Regulation. Consolidation studies were carried out by the General Directorate of Rural Services in 1984, and the works continued on the basis of the Agricultural Reform Law, which will be carried out in the irrigated areas numbered 3083 or with the arrangement of the new irrigation lines to be planned.

Land Consolidation implementation services, "Article 24 of the Law on Soil Conservation and Land Use No. 5403 and the Law on Services Performed by the General Directorate of State Hydraulic Works dated 18/12/1953 and numbered 6200" and "General Directorate of State Hydraulic Works; It continues its work today with the Law No. 3083, 5403 and 6200. In order to start the work, it starts with the decision of the President or the Council of

Ministers. While Preparing the Research; During the social studies and interviews prepared in line with the information gathered from the one-to-one interviews with the village people, the information learned from the conversations with the village people, the documents and data of the Cadastre Land Registry Directorate, the information of the Regional Directorate of Meteorology Affairs, the data of the Turkish Statistical Institute and the State Hydraulic Works Regional Directorate are used.

Land Consolidation Implementation Stages

Detailed process steps in the implementation of land consolidation projects in our country can be listed as follows (Ortaçay, 2020).

- Taking the decision of the President or the Council of Ministers, and entering into force of the decision,
- Obtaining land registry records and cadastral parcels from the Land Registry and Cadastre Directorates,
- Preparation and reporting of social studies in the declared areas to learn the social structure in the village,
- Taking or providing current maps and current aerial photographs that will reflect the current state of the land,
- Determination of fixed facilities that will prevent the transportation of existing parcels on the land,
- Preparing grading and grading maps by conducting soil surveys and according to surveys,
- Block planning and preparation of the road network in the direction of the created base,
- Making interviews (farmer preferences) by interviewing the owners,
- Making distribution, preparation and announcement of parceling plans, taking into account the interviews
- Receiving objections to the pending parcelling plans and evaluating the objections and renewing them in the parcelling plans,
- Announcement and approval of the subdivision plan after all objections have been evaluated and raised to 3 suspensions,
- Checking the title deed information and cadastral areas before registration,
- Delivering the newly formed parcels to the citizens by applying them on the land,

Registration of new parcels,

- Preparation of new title deeds to be issued to citizens and handed over to landowners.

Purpose of Land Consolidation

To use all the possibilities in the unit area in the agricultural lands in the best way, to get the highest level of products, to use the limited resources in the best way, İntensive agriculture is required. In order to carry out intensive agriculture, the selection of the appropriate plant variety, quality soil, suitable environmental climate and water must be available.

Many difficulties are encountered while operating the soil and land, which is known as the production place of agricultural products. These difficulties negatively affect the high productivity on the one hand, and the labour force for production, on the other hand, and the costs in terms of time and investments. In this respect, the factors that reduce productivity in agriculture are generally the characteristics of the cultivated soil, the imbalance in the soil-water system, unsuitable environmental climate, irregular plot locations and shapes, and their distribution to the enterprises. In solving these problems to the extent possible, measures for the structural condition of the land, among other measures, have a great role.

We can define land consolidation as increasing the production in agricultural lands, bringing together scattered and small parcels, improving the rural structure, expanding the enterprises and further developing the agricultural sector and making a structure suitable for modern agriculture principles possible.

Benefits of Land Consolidation

It is among the most effective methods in consolidation practices, systematizing irrigation, arranging field roads, even planning roads to unruly parcels, agricultural construction problems, providing development in rural areas and making them liveable again by landscaping.

- Increases agricultural productivity.
- It prevents the division and shrinkage of the land, provides the merger of the divided and shrunken parcels.
- It enables the conversion of common title deeds into individual title deeds.
- Meeting the needs of the land and the community, such as irrigation line, road network and drainage channels, and animal husbandry area planning, and making these operations by making common deductions from all are a beneficial factor.

- It creates an "Agricultural Road Network" by creating channels for drainage and determining irrigation lines.
- Protects and improves uncultivated unproductive soil.
- It makes landless people the owner of land where they can earn their livelihood.
- It ensures the protection of areas with historical and cultural values.
- It ensures that the settlement areas are developed and improved according to their needs from their current state.
- It creates jobs that will enable young people to stay in the village.
- It ensures the construction of social and cultural facilities.
- It supports agriculture.
- Renovates and develops villages.
- It meets the land and land requirements.
- It eliminates the expropriation problem and the expropriation cost.
- Renews the cadastre.
- It provides social peace to the rural area.
- Allows regression and evaluation of leisure time.
- It ensures the protection of nature and the environment.
- It provides "Business Integrity" in rural area.
- The lands that are not evaluated due to fragmentation or shareholding become usable.
- Irrigation efficiency increases.
- The labor force used in agriculture decreases.
- Within the scope of the project, productivity in agriculture is increased.
- Land values increase due to the added value provided.
- Problems of water passage between farmers are prevented.
- Time and fuel savings are achieved by shortening the distance between the settlement area and agricultural lands.
- An area is created for livestock in the village.
- There is pastureland within the borders of the village, and pasture lands can be made suitable for animal husbandry by consolidating them. Land Registry and Cadastre records will be updated and previous mistakes and deficiencies in Land Registry and Cadastre will be corrected within the scope of this study.

Other Resistance Points for Land Consolidation in the Village

The issues that the village people are worried about in the villages where consolidation is made:

- Handover of lands,
- Giving irrigated farming lands to dry farming areas,
- Transporting flat lands to areas with high slopes,
- There are people who argue that it is not necessary,
- Fear of being allocated unproductive land while using fertile land,
- No expropriation for abandonment areas,
- Concerns about loss of space in the real estate after consolidation,
- Fear of being favoured by powerful people,
- The fact that the cadastral boundaries are not clear and therefore the errors will increase gradually,
- Shareholders cannot agree among themselves,
- The thought that the regulation partnership share deduction will be high,
- Removal of financial treasuries from the area used by the public,
- Thinking that the farmers will move away from the wells they have already used,

Misapplications made in the surrounding villages and the dissatisfaction of the landowners in these regions.

Problems Encountered in Land Consolidation Studies

The combination of scattered parcels, soil, landforms, weather conditions and external factors, as well as the parcel status and traditions of the planned area are effective on these situations. For this reason, the consolidation of parcels is carried out differently in 7 regions. While we can solve the obstacles that we encounter in the Central Anatolia region by meeting face to face, it is seen that the patriarchal family elders that the authorities cannot solve due to reasons such as blood feuds in the Southeastern Anatolia and Eastern Anatolia regions. In order to find a solution to all these problems, it is necessary to examine the problems experienced with administrative and technical conditions and produce solutions.

1-Problems Regarding the Determination of the Project Site

Since it is also aimed to solve the structural problems of the rural area with land consolidation, the study area should be arranged in such a way that it is neither too small nor too large to extend the application abnormally. The small

size of the area will expand the applications in large areas and increase the costs of planning, projecting and implementation. Each village area is independently studied, planned, designed and tendered separately. This prevents the area from being organized as a whole and increases the costs per unit area.If the land consolidation area is kept large, it causes coordination to become difficult, planning, projecting and implementation studies take a lot of time, insecurity and uneasiness in producers, and even demanding the payment of product prices after a certain period of time.

If the land consolidation area is located within the new irrigation area, the participation rate for the common facilities is high due to the main canal, secondary canal and road routes in the villages close to the water source, and less in the remote areas, which makes fair implementation difficult.

Since the irrigation system depends on the location of the water source and the topography, some of the lands of the same settlement can be irrigated, while some cannot be connected to water. In this case, there are businesses that will want to switch from dry farming to irrigated farming, and if accepted, it causes problems among businesses.

2-Problems in the Creation of Block Plans

Block planning is done using 1/5000 scale maps. In these maps, an elevation curve passes every 5 meters. For this reason, major problems arise on the ground when block planning is applied. Major changes are made in the block planning after the base maps are obtained. While planning the road, irrigation and drainage channels in the block system, the topography of the land, soil properties, soil properties, irrigation methods, agricultural forms and business sizes etc. should be taken into account. elements must be evaluated together. When this situation is ignored, it is not possible to place parcels of appropriate size on the blocks created. Since land consolidation in Turkey is generally carried out in DSI irrigation areas where irrigation systems have been applied before, block plans are planned according to the existing system. Existing systems are not suitable for the block system in the area where consolidation is made, since the furrow irrigation method is passed by considering the parcel boundaries and according to the expropriation method.

The road, irrigation and drainage systems in which the block system is created should be compatible with the land consolidation project and if necessary, they should be planned together.

3-No Solution for Inheritance Parcels.

It is the planning of the places that have not been transferred in the land registry records and still appear in the name of the deceased, by correcting them in the land consolidation works.

4-Mistakes in the Works of Institutions

In the past years, the parcels that were expropriated incorrectly in the projects carried out by institutions such as the State Hydraulic Works and the General Directorate of Highways remained in the same form.

These are the situations that occur when the field in the planned area receives the wages of the individuals before, and the places where the expropriation is made do not fall into the system of official institutions.

5-Stream Bed Problems

It is the preservation of the existing streams in their old form, the flood analysis and the minimization of the stream area, and no stream improvement work.

It is another problem that is experienced due to the possibility of flooding, obtaining approval for the usable areas of the streams and taking a long time in the official process.

6-Existence of Unregistered Parcels

These are the problems that arise in the presence of places that are not processed in official documents, although the expropriation process is carried out and the wages of the right holders are paid.

7-Defendant Parcel Issues

Another problem experienced is that people are included in the project before the end of the legal process they started due to the differences in the size of the area. In the lawsuit filed for the area; When the case is concluded, when the regulation enters, there will be a change in the area of the parcel and there will be an inconsistent change in the areas each time.

8- Problems Caused by Legislation

There are problems related to the legislation, and it is another problem that arises due to the fact that the places that are not registered in the application area are the defendants.

9-Cadastral Issues•

The outer lines of the villages formed by the planning are not drawn on the official maps of the village, and the separation procedures are not carried out when distinguishing between two different villages,

At the land registry and cadastre directorates, the cadastral maps are worn out and the sheets are not re-digitized and continue with their aging,

Lack of address etc. in the notifications of Article 41 made in the study area. because there are notification problems. Article 41 is the correction of errors arising from the measurement and limitation calculations of the immovable during and after the cadastre. When these errors are corrected, the property owners are notified (eg, the notice is sent on behalf of the deceased).

There are problems within the scope of the pasture law due to the inclusion of pasture areas within the scope of consolidation. The pasture law covers the protection of rangelands, and there are problems with the pasture commission and the society when there is a small change of place in the pasture parcels included in the regulation.

Boundary problems between the village settlement not included in the study and the parcels that constitute the legal boundary in terms of ownership and remain in the study area.

10- Social Issues

There are problems that arise as a result of the citizen's point of view and misinformation against consolidation. Due to the prejudice of the property owners or the inability of the people making the consolidation to convey the necessary information to the other party, the owners cannot fully grasp the functioning process, causing grievances.

In the interviews, it is very important to inform the implementer about the current situation in line with their wishes for the parcelling plans to be prepared, and the information obtained from the citizens while making the arrangement is very important since they are the people who use it personally, and doing the work within this information while the distribution and parcelling is done means the work to be carried out efficiently. This can be revealed by experts and conscious people.

Land consolidation projects are given to private companies. Some companies rush the interviews without investing too much, and the irresponsible interviewing of other people, not the responsible engineer, who will do the project, causes the desired efficiency in the project to not be achieved.

Suspension processes are also important in land consolidation projects. The desired satisfaction and efficiency in the project cannot be achieved due to

reasons such as the landowners not following the suspension processes or not having map information, not being able to understand their new places from the incoming suspension and missing the objection processes.

This is because the owners whose parcel is on the edge of the forest use it by making a trench from the forest and cannot accept the parcel when its location changes.

Soil Survey and Grading Problem

Problems in soil grading and field changes due to index differences after grading are seen as DOP deductions.

For a fair land grading and fair land arrangement, an accurate soil survey must be done in the Consolidation area. Soil surveys previously developed for irrigation purposes are also used from time to time in areas where irrigation system is available.

Taking the weighted average of the 10-point parcel indices remaining in each class range in the classification according to the parcel index used to facilitate the transactions in land grading causes errors and injustices. Weighted average applications should be abandoned today, as computer and area measurement techniques are advancing.

The lack of coordination in the relevant institutions and organizations, for example, the difference between the company that carries out the irrigation project and the company that carries out the consolidation, and the fact that the projects are not carried out together cause the incompatibility of the newly planned roads and irrigation networks and thus the inability to provide adequate service. At the same time, the desire to complete land consolidation projects in a short time causes insufficient coordination between institutions. Time pressure manifests itself in preliminary studies, planning, soil surveys, land grading, designing field development services, conducting interviews and reorganizing, and it will be difficult to discuss with other institutions and organizations and to get their opinions. The short duration of the project and the haste may prevent the correct implementation of the project. Where the projects are large, this problem may become even greater

CONCLUSION AND RECOMMENDATIONS

As a result of the study, before consolidation work is carried out in the project application areas, it is necessary to determine the needs of the village, to increase the one-to-one interviews with the farmer, to eliminate the deficiencies in the institutions and organizations, and to determine and solve the problems experienced between the institutions by law. Since the farmers do not have enough information, the new planning is bad, the fear of planning in the hilly area and considering the land conditions, the selected area for consolidation is not a flatter and almost flat land, or there are areas with a wavy land structure and level difference by increasing the in-field development services. shows that their work is done with less efficiency. In addition, the relevant institution responsible for the project should attach importance to the work of the personnel and adopt it.

As a result, land consolidation efforts that reduce the number of enterprises in rural areas and solve the irrigation and transportation problems of the parcels are among the most important factors in rural development. Consolidation, which means the regulation of the economic activities of the rural areas by the public, should not be regarded as merely enlarging the lands by bringing them together, but it should not be forgotten that it is an important social and technical practice

REFERANSLAR

Çay, T. ve İnceyol, Y. (2000). Arazi Toplulaştırması Çalışmalarında Jeodezi ve Fotogrametri Mühendisliğinin Yeri. *Harita Bülteni*, Sayı:43.

Çevik, B. ve Tekinel, O. (1988). *Arazi toplulaştırması, sulama projelerinde arazi toplulaştırma seminer bildirileri*, Devlet Su İşleri, 45-68.

Muyombano, E., (2019). Livelihood and Food Security of Vulnerable People with Limited or No Land in Northern Rwanda: Analysis of a Land Use Consolidation Program cilt 11 Sayı 2 Ghana Journal of Geography

Karaman, S. ve Gökalp, Z. (2018). Land consolidation practices in Turkey. *Current Trends in Natural Sciences*, 7(14):76-80.

Ortaçay, Z. (2020). Arazi toplulaştırma çalışmasında çok amaçlı optimizasyon tabanlı dağıtım (Yüksek Lisans Tezi). Konya Teknik Üniversitesi, Lisansüstü Eğitim Enstitüsü, Konya.

Taşdemir, N. (2001). *Konya-İçeri Çumra'da tarla içi geliştirme hizmetleri ile birlikte uygulanan arazi toplulaştırmasının ekonomik analizi*. Trakya Toprak ve Su Kaynakları Sempozyumu.

Yılmaz N., Çiftçi N., "Arazi Toplulaştırması Üzerine Yapılmış Akademik Çalışmaların Analizi," Arazi Toplulaştırma Sempozyumu 15-16 Eylül, Konya. 2005.

Yoğunlu, A. (2013). Arazi toplulaştırma faaliyetleri, TRB1 bölgesi (Bingöl, Elazığ, Malatya, Tunceli). *Fırat Kalkınma Ajansı,* Elazığ.

(http://www.e-kutuphane.imo.org.tr Erişim tarih: 15.04.2020)

(https://www.resmigazete.gov.tr/).

Chapter 2

Length-Weight Relationships and Condition Factor of *Acanthobrama marmid* Heckel, 1843 in the Munzur River

Ebru İfakat ÖZCAN[1], Osman SERDAR[2]

[1] Doç. Dr.; Munzur Üniversitesi Su Ürünleri Fakültesi Temel Bilimler Bölümü.
ebruozer@munzur.edu.tr ORCID No: 0000-0003-2017-6647

[2] Doç. Dr.; Munzur Üniversitesi Su Ürünleri Fakültesi Temel Bilimler Bölümü.
oserdar@munzur.edu.tr ORCID No: 0000-0003-1744-8883

Abstract

In this study; some features were investigated such as length-weight, and condition factor of *Acanthobrama marmid* Heckel, 1843 were obtained between 2019-2021 from Munzur River. 54 (53.5%) were female and 47 (46.5%) were male; female:male ratio was calculated as 1.00/0.87. The total length and weight of all individuals of *A. marmid* ranged between 9.9-21.9 cm and 8.0-116.6 g and average length was found 14.25±0.20 cm in the Munzur River. It was observed that the most dominant length group was 13.0-14.9 cm. The length-weight relationship of *A. marmid* was found as $W = 0.0053L^{3.14}$ ($R^2 = 0.94$) in females, $W = 0.0071L^{3.02}$ ($R^2 = 0.93$) in males and $W = 0.0059L^{3.09}$ ($R^2 = 0.93$) in all individuals from Munzur River. The 95% confidence interval of b value calculated from all individuals obtained was calculated as 3.09-3.73. In addition, it was determined that the b value was not statistically different from 3 in females, males and all individuals (t-test; $p>0.05$). The growth of *A. marmid* was determined isometric (b=3) in the Munzur River. The condition factor of *A. marmid* was found between 0.57-1.11 in female and 0.57-0.95 in male from Munzur River.

Keywords: *Acanthobrama marmid*, length-weight relationship, condition factor, Munzur River

INTRODUCTION

Acanthobrama marmid Heckel, 1843 is known by the public as the wood fish, and the head and body of the species are flattened from the sides. The mouth is small and terminal and has no lips or whiskers. The free edges of the dorsal and anal fins are slightly indented. The caudal fin is deeply lobed and the ends of lobes are pointed. The body rises obliquely, starting from the nape of the neck to the front of the dorsal fin. It narrows significantly from the beginning of the anus. Its length is about 20 cm. Its general color is gray-yellow and its fins are pinkish. There are thin black dots on the scales in the area above and below the lateral line (Geldiay and Balık, 2007). Various studies have been conducted on *A. marmid* in different water resources before (Başusta and Çiçek, 2006; Çoban and Yüksel, 2013; Şahinöz et al., 2013; Gündüz, 2014; Alkan Uçkun and Gökçe, 2015; Başusta and Yeniyol, 2016; Serdar et al., 2017; Özcan, 2020).

Examining the population characteristics of fish species is very important in fisheries management and fisheries biology studies. Calculating length-weight relationship parameters in fish species allows estimating the weight of the fish from its length, calculating the condition index, and thus allowing comparison of the morphologies and life processes of populations in different habitats, indicating how important these parameters are (Petrakis and Stergiou, 1995). In addition, a and b values, which are the length-weight relationship parameters, allow comparison of the morphologies of populations spreading in different habitats and the life processes of fish species (Yılmaz et al., 2010). The condition factor in fish is one of the most important parameters related to the body shape of the fish. It is a parameter that shows the degree of fitness or relative fatness of a fish. Changes in condition factor primarily reflect sexual maturity status and nutritional level (Le Cren, 1951; Williams, 2000).

This study aimed to calculate the length-weight relationships and condition factor of the *Acanthobrama marmid* in the Munzur River. Thus, it is aimed to compare this species with future studies.

MATERIAL and METHODS

The Munzur River starts in many branches from the southern slopes of the hills in the middle part of the Munzur Mountains. These branches unite in the Ovacık depression area, which is the largest plain of the province. Munzur River joins the Pülümür River in the borders of Tunceli city center (Saler and Haykır, 2011). Uzunçayır Dam Lake is located, which was established to generate energy on the Munzur River (Saler et al., 2014; Bulut et al., 2021).

In this study, 101 *A.marmid* specimens were collected from Munzur River between 2019-2021 (Figure 1). The obtained fish were brought to the laboratory immediately and their total length was measured on a measuring board with ±1 mm; the weights were recorded by measuring with an electronic balance with ±1 g. The sexes of the fish were determined by opening their bellies and examining their gonads. Those with milky white and smooth surface gonads were evaluated as male, those with greenish yellow and granular surface gonads as female (Lagler et al., 1977).

Figure 1. Munzur River (URL-1 2023)

Average length and weight values for each sex were calculated. In our study, the formula $W=aL^b$ (Bagenal & Tesch, 1978) was used to calculate the length-weight relationships. In this formula, W= fish weight (g), L= fish total length (cm), a and b represent the relationship constants. For this species, the 95% confidence interval (95%CI) of the b value was also calculated (Zar, 1999).

Condition factor, which is an indicator of the nutritive capacity of the environment in which the fish live, was calculated with the following formula: Condition factor = $(W/L^3)*100$ (Le Cren, 1951).

RESULT and DISCUSSION

In the study example was used, a total of 101 *A. marmid*, 54 (53.5%) females and 47 (46.5%) males. The female:male ratio was calculated as 1.00/0.87 in *A. marmid* Özcan (2020) found the female/male ratio of *A. marmid* 1/0.758 in the Pülümür River.

The total length and weight of all individuals of *A. marmid* ranged between 9.9-21.9 cm and 8.0-116.6 g and average length was found 14.25±0.20 cm in the Munzur River. It was observed that the most dominant length group was the 13.0-14.9 cm (Figure 2). Length and weight ranges obtained from studies conducted in different regions on *A. marmid*; Başusta and Çiçek (2006), 9.2-28.6 cm and 17.31 g (mean) in Atatürk Dam Lake; Çoban et al., (2013), 10.7-19.8 cm (SL) in Uzunçayır Dam Lake; Çoban and Yüksel (2013), 8.8-27.8 cm and 6.2-182.0 g in Uzunçayır Dam Lake; Şahinöz et al., (2013), 9.0-22.20 cm and 12.30-138.40 g in Atatürk Dam Lake; Gündüz (2014), 9.0-25.7 cm and 8.5-160 g for female; 8.8-25.6 cm and 6.2-131 g for male in Uzunçayır Dam Lake; Alkan Uçkun and Gökçe (2015), 9.6-16.3 cm and 9.99-67.48 g in Karakaya Dam Lake; Başusta and Yeniyol (2016), 15-20.1 cm and 34-46 g in the Gerger region of Atatürk Dam Lake; Serdar et al., (2017), 6.1-11.7 cm and 2.4-20.5 g in the Karasu River; Özcan (2020) reported 7.8-21.1 cm and 5.6-121.21 g in the Pülümür River. Differences in length and weight values in studies conducted with the same species may be caused by sampling location and time, sampling method, fork length or total length values used in the study and many ecological factors (Suiçmez et al., 2011; Gündüz, 2014).

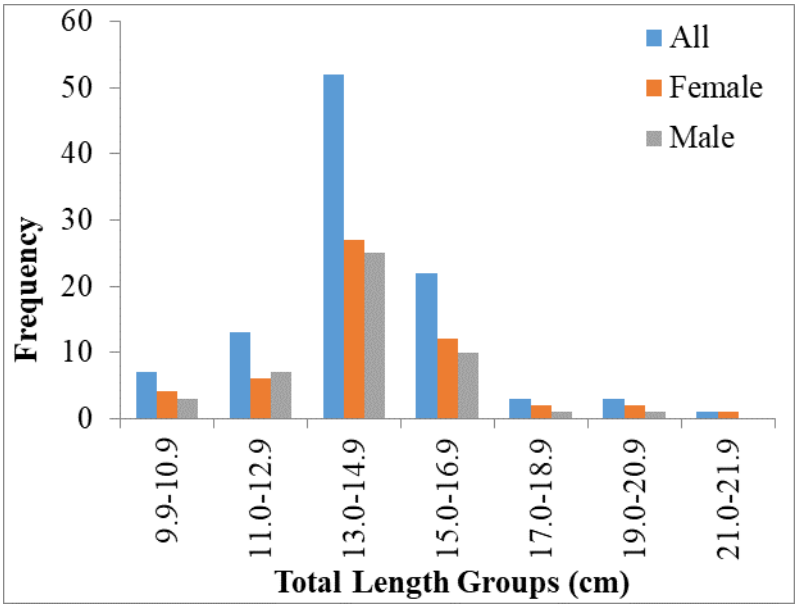
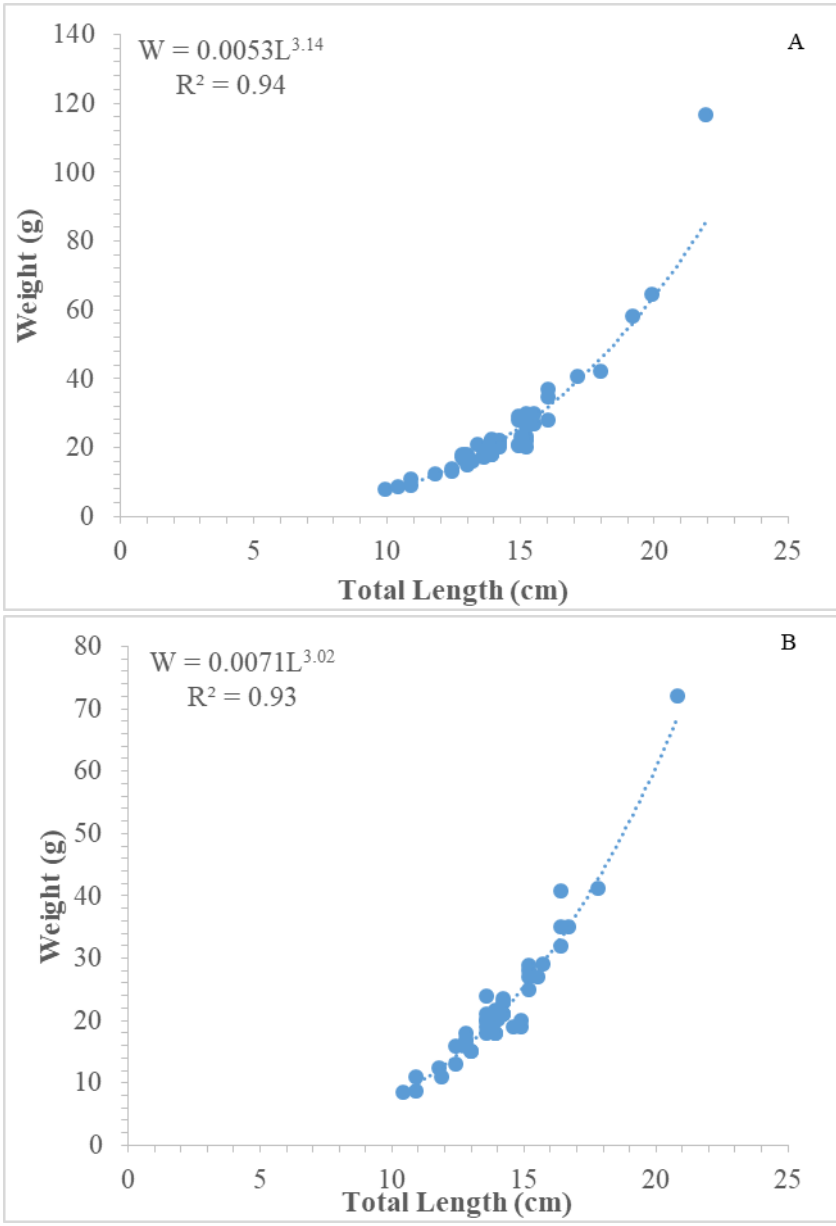


Figure 2. Total length-frequency distribution of *A. marmid* in female, male and all individuals in the Munzur River

Table 1. Length and weight descriptive statistics of *A. marmid* in Munzur River

Species	Sex	n	Total Length		Weight		Condition Factor	
			Mean±S.E	Min-Max	Mean±S.E	Min-Max	Mean±S.E	Min-Max
A.marmid	Female	54	14.36±0.27	9.9-21.9	24.79±1.89	8.0-116.6	0.77±0.011	0.57-1.11
	Male	47	14.12±0.26	10.4-20.8	22.43±1.50	8.6-72.14	0.76±0.010	0.57-0.95
	All	101	14.25±0.20	9.9-21.9	23.69±1.38	8.0-116.6	0.76±0.008	0.57-1.11

The length-weight relationship of *A. marmid* was found as $W = 0.0053L^{3.14}$ ($R^2 = 0.94$) in females, $W = 0.0071L^{3.02}$ ($R^2 = 0.93$) in males and $W = 0.0059L^{3.09}$ ($R^2 = 0.93$) in all individuals from Munzur River (Figure 3). The 95% confidence interval of the b value calculated from all individuals obtained was calculated as 3.09-3.73 (Table 2). In addition, it was determined that the b value was not statistically different from 3 in females, males and all individuals (t-test; $p>0.05$). The growth of *A. marmid* was determined isometric (b=3) in the Munzur River. Başusta and Çiçek (2006), determined the "b" value as 3.168 for all individuals in Atatürk Dam Lake; Gündüz (2014), 3.093 and 3.169 for females and males in Uzunçayır Dam Lake, respectively; Alkan Uçkun and Gökçe (2015), 2.678 and 2.631 for females and males in Karakaya Dam Lake, respectively; Serdar et al., (2017), 3.35 and 3.27 in females and males in the Karasu River, respectively; Özcan (2020) reported 3.248 and 3.252 for females and males in the Pülümür River, respectively. Length-weight relationship parameters in fish are not constant throughout the year and vary according to factors such as nutritional adequacy, growth rate, gonad development and reproductive period (Bagenal and Tesch, 1978).


A
W = 0.0053L3.14
R² = 0.94
Weight (g)
Total Length (cm)
0
20
40
60
80
100
120
140
0
5
10
15
20
25
B
W = 0.0071L3.02
R² = 0.93
Weight (g)
Total Length (cm)
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25

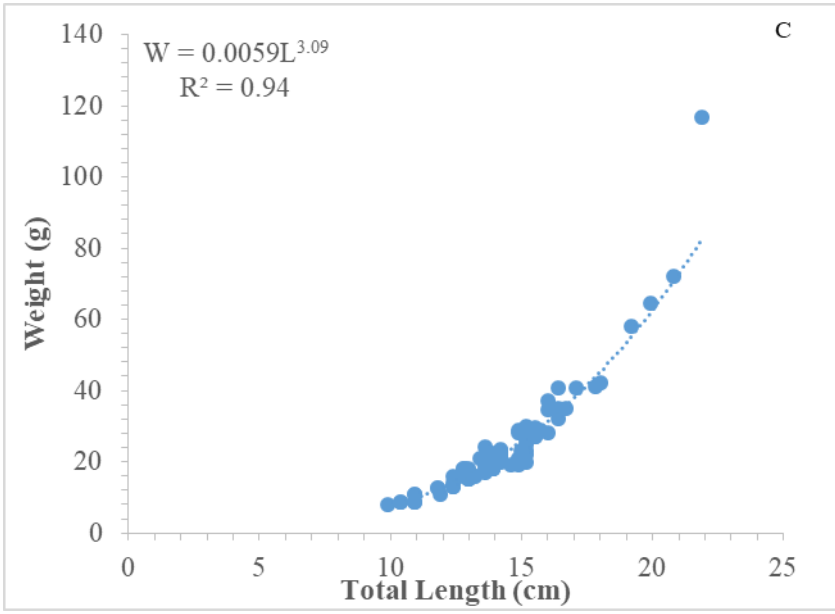


Figure 3. Length-weight relationship female (A), male (B) and all individuals (C) of *A. marmid* from Munzur River

Table 2. Length-weight relationship parameters of *A. marmid* in Munzur River

Species	Sex	a	b	%95 Confidence Interval	R^2
A.marmid	Female	0.0053	3.14	3.09-3.73	0.94
	Male	0.0071	3.02	3.09-3.55	0.93
	All	0.0059	3.09	3.09-3.73	0.94

The condition factor of *A. marmid* was found between 0.57-1.11 in female and 0.57-0.95 in male from Munzur River. Özcan (2020), the condition factor of *A. marmid* found between 0.548-1.653 in female and 0.567-1.670 in male from Pülümür River. Condition factor is a parameter related to the body shape of the fish; It provides information about the suitability of the environments in which the species lives in terms of its development, nutritional status, breeding times, population density and the effect of seasonal changes on growth (Weatherley, 1972).

In conclusion; because of the length-weight relationship in fish is not constant, it may vary depending on factors such as nutritional status, feeding rate, gonad development and reproductive period. In order for ecosystem management sustainable, continuous monitoring of natural stocks is also

extremely important in terms of fisheries biology and management. Therefore, this study will allow comparison of this species with species in different regions for stock management.

REFERENCES

Alkan Uçkun, A., & Gökçe, D. (2015). Assessing Age, Growth, and Reproduction of *Alburnus mossulensis* and *Acanthobrama marmid* (Cyprinidae) Populations in Karakaya Dam Lake (Turkey). Turkish Journal of Zoology, 39:1-14.

Bagenal, T.B., & Tesch, F.W. (1978). Age and growth. In: Methods for assessment of fish production in freshwaters. 3rd edn. T. Bagenal (Ed.). IBP Handbook No. 3. Blackwell Scientific Publications, Oxford, UK, pp. 101–136.

Başusta, N., & Çicek, E. (2006). Length-weight Relationships for Some Teleost Fishes Caught in Ataturk Dam Lake on Southeastern Anatolia, Turkey. Journal of Applied Ichthyology, 22: 297-280. https://doi:10.1111/j.1439-0426.2006.00778.x

Başusta, A., & Yeniyol, S. (2016). Atatürk Barajı Gerger Bölgesi Balık Faunasının Taksonomik Yönden İncelenmesi. Fırat Üniv. Fen Bilimleri Dergisi, 28(2):43-50.

Bulut, H., Sesli, A., & Tepe, R. (2021). Uzunçayır Baraj Gölü Güncel Zooplanktonunun Bazı Su Kalite Parametreleri ile Değerlendirilmesi. International Journal of Pure and Applied Sciences, 7 (3), 429-441. DOI: 10.29132/ijpas.938647

Çoban, M. Z., Gündüz, F., Yüksel, F., Demirol, F., Yıldırım, T., & Kurtoğlu, M. (2013). Uzunçayır Baraj Gölü (Tunceli) Balık Faunası. Aquaculture Studies, 2013 (2) , 0-0. DOI: 10.17693/yunusae.v2013i21905.235421

Çoban, M.Z., & Yüksel, F. (2013). Age and Growth Properties of *Acanthobrama marmid* Heckel, 1843 Population Inhabiting Uzuncayir Dam Lake (Tunceli/Turkey). Journal of Animal and Veterinary Advances 12(5):644-649.

Geldiay, R., & Balık, S. (2007). Türkiye Tatlı Su Balıkları. Ege Üniversitesi Su Ürünleri Fakültesi Yayın No: 46, Ege University Press, Bornova Izmir, p:532.

Gündüz, F. (2014). Determination of Biological Characteristics of *Acanthobrama marmid* Heckel, 1843 Population in the Uzunçayır Dam Lake (Tunceli). Yüksek Lisans Tezi. Kahramanmaraş Sütçü İmam Üniversitesi/Fen Bilimleri Enstitüsü/Su Ürünleri Anabilim Dalı, 61 s.

Lagler, K.F., Bardach, J.E., Miller, R.R., & Passino, D.R.M. (1977). *Ichtyology*. John Wiley and Sons, Newyork, 506 p.

Le Cren E.D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*), Journal of Animal Ecology, 20: 201-219.

Özcan, E.İ. (2020). Pülümür Nehri'nde Yaşayan *Acanthobrama marmid* Heckel, 1843 Populasyonunun Bazı Büyüme Özelliklerinin Belirlenmesi, Ecological Life Sciences (NWSAELS), 15(4):121-133, DOI: 10.12739/NWSA.2020.15.4.5A0139.

Petrakis, G., & Stergiou, K. I. (1995). Weight-length relationships for 33 fish species in Greek waters. Fisheries Research, 21, 465-469.

Saler, S., & Haykır, H. (2011). Zooplankton composition of Pulumur Stream (Tunceli-Turkey). Journal of Animal and Veterinary Advances, 10(11):1401-1403. DOI: 10.3923/javaa.2011.1401.1403

Saler, S., Haykır, H., & Baysal, N. (2014). Zooplankton of Uzunçayır Dam Lake (Tunceli-Turkey). Journal of FisheriesSciences.com, 8(1):1-7. (ShortCommunication). DOI: 10.3153/jfscom.2014001.

Serdar, O., Özcan, E.I., & Aydın, R. (2017). Length-Weight and Length-Length Relationships of *Alburnus mossulensis* and *Acanthobrama marmid* (Heckel, 1843) in the Karasu River (Turkey). Yunus Araştırma Bülteni, https://doi.org/10.17693/yunusae.vi.278434.

Suicmez, M., Yilmaz, S., & Seherli, T. (2011). Age and Growth Features of *Chondrostoma regium* (Heckel, 1843) from Almus Dam Lake, Turkey. Suleyman Demirel Univ. J. Sci., 6: 82-90.

Şahinöz, E., Doğu, Z., Yüksel, A.Y., & Sarı, H. M. (2013). Atatürk Baraj Gölü'nde Bulunan *Acanthobrama marmid* (Heckel, 1843) Balığının Bazı Büyüme Özelliklerinin ve Mortalite Oranlarının Belirlenmesi. Ziraat Mühendisliği, Ocak-Haziran 2013. Sayı: 360.

URL-1, (2023). https://www.google.com/maps/place/Munzur Irmağı, 09.06.2023

Weatherley, A.H. (1972). Growth and Ecology of Fish populations. Academic Press. London, 293 p.

Williams J.E., (2000). The Coefficient of Condition of Fish, pp. 1-2, In: Manual Of Fisheries Survey Methods II: With Periodic Updates (Ed.:Schneider J.C), Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor, p. 306.

Yılmaz, S., Polat, N., & Yazıcıoğlu, O. (2010). Samsun ili iç sularında yaşayan sazan (*Cyprinus carpio* L., 1758)'ın boy-ağırlık ve boy-boy ilişkileri. Karadeniz Fen Bilimleri Dergisi/The Black Sea Journal of Sciences, 1, 39-47.

Zar, J.H. (1999). Biostatistical Analysis, 4th edn. Upper Saddle River, New Jersey: Prentice Hall, 663p.

Chapter 3

Current Status and Future of Bread Wheat Landraces in Southeastern Anatolia Region

Enver KENDAL[1]

Mardin Artuklu University, Kızıltepe VHS, Plant and Animal Production, 21500, Kızıltepe, Mardin,
E mail:enver21_1@hotmail.com

ABSTRACT

Local plant resources are of vital importance to ensure continuity in production. Today, especially with the effect of global warming, as a result of the world's exposure to more heat, drought, floods, frost events from time to time, diseases are becoming more and more common. The occurrence of these natural events limits the yield and quality of existing cultural varieties. As a result, production decreases from time to time. Because cultural varieties usually show their real performance under optimum conditions. However, local varieties are more resistant to extreme natural conditions and can maintain their performance. For this reason, it is extremely important to identify, collect and use local varieties that are more resistant to adverse environmental conditions caused by global warming. For this purpose, in order to enrich the shrinking gene pool in bread wheat breeding, screenings were carried out in some provinces in the Southeast (Diyarbakır, Şanlıurfa, Mardin, Şırnak, Siirt) and Eastern Anatolia (Elazığ, Bingöl) Regions between 2012 and 2014 and total 80 bread wheat landraces were collected. These collected local populations were examined, and those with similar characteristics were eliminated and some studies were carried out on those with different characteristics. Populations that are resistant to adverse environmental conditions and have high quality and productivity were identified and transferred to the gene pool to be used in breeding studies.

Keywords: Bread, Local, Specialty, Southeastern Anatolia.

INTRODUCTION

wheat was cultivated around Karacadağ approximately 12 thousand years ago and that it grew efficiently and with high quality in the origin region called the "Fertile Crescent", which starts from the Zagros Mountains and extends through Turkey and Syria to Lebanon (Kırtok, 1997; Harlan 1995; Karagöz et al. 2010). Wheat, which is currently estimated to have 15 species and approximately 30 thousand cultivars, is basically defined in two groups as pasta (hard) and bread (soft). Durum wheat (*Triticum Durum* Desf.) is an indispensable raw material for the pasta, semolina and bulgur industry, and bread wheat (Triticum aestivum L.) for the flour and biscuit industry. Wheat ranks first among grains in the Southeastern Anatolia Region, as in different countries and regions (Kendal, 2013).

When the Southeastern Anatolia Region is evaluated in terms of wheat plant; It has been stated in studies conducted by many researchers that the cultivated varieties, local populations and wild type wheat used as their parents are in a central position (Ozberk et al., 2016). The development of wheat, the evolution process of wild wheat species and the selection within the Triticum genus, local wheats (diploid), and as a result of various breeding studies carried out on these local wheats, pasta (tetraloid) and bread wheat (hexaploid) were obtained and have survived to the present day in three groups (Degirmenci , 2017). The evolution and spread of wheat took place through genetic progress due to the adaptation of wheat to very different conditions and the development of cultural varieties. As a result of archaeological studies, they reported that wheat spread from the Southeastern Anatolia Region (Fertile Crescent Region) to the whole world and that einkorn local wheat, which is still grown in the Balkan countries and France, was cultivated in the Southeastern Anatolia Region for the first time in the world (Diamond 1997; Heun et al.1997). ; Nesbit and Samuel 1998; Lev-Yadun et al., 2000).

Local populations (village varieties) are groups of individuals that are phenotypically similar, suitable for local use, and have survived to the present day under the pressure of natural and artificial selection. As a result of successful breeding studies, the development of new cultivars, the increase in the use of agricultural inputs and the spread of mechanization, the cultivation areas of local wheat varieties have begun to decrease and have even been completely abandoned in some regions (Özberk et al., 2016). Studies conducted today report that the cultivation area of local wheat varieties is gradually decreasing (Karagöz 2014; Morgounov et al. 2016). In the Southeastern and Eastern Anatolia Regions, local wheat cultivation areas have faced extinction because they cannot compete with cultural varieties in terms of yield and profitability (Karagöz and Zencirci,

2005). Some local wheat varieties that are still planted in very small areas in these regions (Diyarbakır, Adıyaman, Elâzığ, Bingöl Mardin, Siirt, Şırnak) can be listed as follows: Ruto, Aşure, Sorik, Kızıl, Kırmızı (Kan et al. 2015; Kendal, 2020).

Nowadays, healthy nutrition is important; Changes are observed in people's nutrition and consumption habits, and the importance of local wheat is increasing. For this reason, the populations that still exist in some regions need to be collected and preserved. Our country's richness in biodiversity opens the door to hosting these populations and, as a very good opportunity, will contribute to the development of new varieties that carry local genes and are more resistant to ecological factors (Gökgöl, 1939; Özberk et al., 2005). Local wheats will be used to expand the shrinking gene pool. They can be used in direct hybridization as rootstocks to obtain commercial varieties, as well as in bridge hybrids against biotic and abiotic stress factors (Şehirali and Özgen 1987). However, regular seed production and characterization of these local wheats is very important. Although these wheats have been characterized in many studies (other than molecular methods) and some of their properties that may help breeding (disease resistance, color, micro and macronutrient contents in the grain) have been determined, they have not been utilized sufficiently in the breeding studies carried out in our country (Özberk et al. 2005; Koyuncu 2009, Kendal). et al., 2019; Kendal, 2020; Öner and Kendal, 2022).

Local wheat populations are genetic resources that are generally low tillering, prone to lodging due to their tallness, susceptible to rust and similar leaf diseases, and whose yields are limited even under improved environmental and soil conditions. However, the grain qualities of these population-shaped resources (largeness, etc.) and their special adaptation abilities to bad environmental conditions (barren and stony soils, low rainfall areas, etc.) are highly developed, especially due to their strong root structures. Many studies have shown that under changing environmental conditions with global warming, cultural varieties are not particularly resistant to drought and rust diseases, and that they cause some health diseases in humans due to the insufficient plant nutrients they contain (Jaradat, 2012; Kan et al. 2015; Kendall et al., 2019). For this reason, studies aimed at eliminating the deficiencies of cultivated varieties by transferring genes from local to cultivated varieties through some molecular studies have gained momentum. For this reason, the importance of local wheat populations is increasing (Kendal, 2020), and due to their social, cultural and historical importance, it is very important to find, characterize and protect local bread wheat populations due to some local dishes (flour, ashure, etc.) in some limited special areas in the Southeastern Anatolia Region.

THE CURRENT SITUATION

In this study (between 2012 and 2014), in the provinces of Diyarbakır, Adıyaman, Mardin, Siirt and Şırnak, Elazığ and Bingöl, located within the borders of the Southeastern and Eastern Anatolia Regions, geographically, especially where technology has not been sufficiently introduced and where sufficient scanning has not been carried out until now due to political events. In general, districts and villages located in mountainous areas, that is, areas where local bread wheat populations can be found, were scanned before harvest. Samples were taken from the local bread wheat detected in the surveyed areas, and after the examination of these samples, a total of 80 bread wheat populations were recorded and started to be used in the projects. GPS data and colloquial names of the areas where the samples were collected are given in Table 1.

Table 1. Geographic information on local populations collected from the region

Sıra No	Province	Hometown	Village	Altitude m)	GPS Koor.		N	E
					X	Y		
1	Diyarbakır	Eğil	Baysu	740	596788	4222746		
2	Diyarbakır	Yenişehir	Sivritepe	680	603601	4220808		
3	Diyarbakır	Eğil	Kaya	703	65102	4222698		
4	Diyarbakır	Eğil	Kaya	705	605097	4222712		
5	Diyarbakır	Eğil	Balaban	789	606206	4225495		
6	Diyarbakır	Eğil	Düzlük	795	609224	4228412		
7	Diyarbakır	Sur	B.akveyran	761	618688	4232942	38.14.1999	040.21.3708
8	Diyarbakır	Hani	Sergen	831	618786	4240535	38.18.3034	04.21.5150
9	Diyarbakır	Kulp	Yakıt	894	684655	4246869	38.21.0576	041.06.7924
10	Diyarbakır	Dicle	Bahçedere	801	589545	4241852	38.19.2189	040.01.4605
11	Diyarbakır	Ergani	Kartaş	973	558102.19	4237474	38.17.0078	39.39.8607
12	Diyarbakır	Çüngüş	Çınar	811	542115.75	4232003	38.14.1035	39.28.8738
13	Diyarbakır	Çermik	Kergentaş	812	550246.00	4226668	38.11.1922	34.34.4248
14	Adıyaman	Gerger	Aşağıdağlıca	1045	500979.00	4210611	38.02.5940	39.00.6698
15	Adıyaman	Gerger	Koşarlar	1069	492233.44	4209073	38.01.7600	38.54.6903
16	Adıyaman	Çelikhan	Mergi Mevkii	1285	429840.81	4207063	38.00.5129	38.12.0474
17	Adıyaman	Sincik	Çatbahçe	718	464940.59	4201953	37.57.8714	38.36.0522
18	Adıyaman	Sincik	Çatbahçe	740	465185.38	420584	37.58.2118	39.36.2179
19	Adıyaman	Sincik	Çatbahçe	772	465217.81	4203300	37.58.6000	38.36.2381
20	Adıyaman	Kahta	Akdoğan	840	474767	4192466	37.52.7609	38.42.7841
21	Adıyaman	Kahta	Tosun	950	474758	4193364	37.53.2447	38.42.7772
22	Adıyaman	Kahta	Bağbaşı	814	478029	4192400	37.52.7305	38.45.0100
23	Elazığ	Maden	Tekevler	1248	549663	4259243	38.28.8096	39.34.1620
24	Elazığ	Maden	Gezin	1256	546248	4260175	38.29.3234	39.31.8182
25	Elazığ	Sivrice	Bekçitepe	1156	521164	4260989	38.29.6335	39.15.1320
26	Elazığ	Merkez	Karşıdağ	865	528359	4272660	38.36.1187	39.19.5414
27	Elazığ	Kovancılar	Akmezra	992	569585	4282048	38.41.0585	39.48.0038
28	Elazığ	Palu	Uçdeğirmenler	1031	577880	4280393	38.40.1217	39.53.7136
29	Bingöl	Merkez	Çayazı	990	634063	4294028	38.47.0888	40.32.6119
30	Elazığ	Karakoçan	Bulgurcuk	1174	594348	4309784	38.55.9151	40.05.3114
31	Elazığ	Karakoçan	Yolçatı	1129	592012	4308392	38.55.4627	40.03.6837

32	Elazığ	Kovancılar	Tekevler	1050	571771	4283994	38.42.0777	39.49.5528
33	Elazığ	Merkez	Ortagah	1121	403408	4266888	38.32.8630	39.02.3467
34	Elazığ	Merkez	Temmur	1166	503926	4262391	38.30.5954	39.02.7029
35	Elazığ	Baskil	Merkez	1244	485075	4269414	38.34.3838	38.49.7202
36	Elazığ	Baskil	Kayabeyli	1304	4886377	4269704	38.34.5414	38.50.6164
37	Elazığ	Kovancılar						
38	Elazığ	Kovancılar						
39	Malatya	Arguvan						
40	Bitlis	Ahlat		670	610421	4200219	37.56.5755	40.15.4038
41	Şanlıurfa	Siverek	Özümtaş	762	524911.00	4180531.50	37:46.3067	039:16.9710
42	Şanlıurfa	Siverek	Mantarlı	668	513518.31	4150858.75	370:30.2736	0390:09.1771
43	Şanlıurfa	Siverek	Mantarlı	668	513518.31	4150858.75	370:30.2736	0390:09.1771
44	Şanlıurfa	Siverek	Aşağıtaşlı	728	526140.69	4150528.00	379.002.447	039:17.7448
45	Şanlıurfa	Siverek	Aşağıtaşlı	728	526140.69	4150528.00	379.002.447	039:17.7448
46	Şanlıurfa	Siverek	Yüceler	745	529096.25	4163497.75	370:37.0862	0390:19.7816
47	Mardin	Savur	Dereyanı	943	664542.88	4146608.75	370:27.1019	0400:51.6166
48	Mardin	Savur	Dereyanı	943	664542.88	4146608.75	370:27.1019	0400:51.6166
49	Mardin	Savur	Merkez	931	663389.70	4148880.25	370:28.1209	0400:50.8490
50	Mardin	Savur	merkez	925	473117.60	4157641.70	370:33.0410	0400:37.2040
51	Mardin	Midyat	Şenköy	971	693754.25	4148289.50	370:20.6718	0410:11.4458
52	Mardin	Ömerli	Anıttepe	1094	679879.00	4146845.75	370.26.8334	0410:01.6106
53	Mardin	Mazıdağı	Ömürlü	909	634001.75	4153125.50	370.30.9218	0400:30.9773
54	Mardin	Mazıdağı	Ömürlü	909	634001.75	4153125.50	370.30.9218	0400:30.9773
55	Mardin	Mazıdağı	Ömürlü	917	634.514.94	4152010.25	370:30.3153	0400.31.3223
56	Mardin	Mazıdağı	Kocakent	920	624723.50	4147168.00	37.27:8811	040:24.8497
57	Mardin	Derik	Alankuş	1041	617647.80	4142738.75	370:25.7329	0400:20.9780
58	Mardin	Derik	Alankuş	1041	617647.80	4142738.75	370:25.7329	0400:20.9780
59	Mardin	Midyat	Yemişli	950	708362.06	4135393.00	370:20.2959	0410:21.3969
60	Mardin	Midyat	Budaklı	911	708160.81	4136423.25	370:21.1478	0410:20.9861
61	Mardin	Midyat	Merkez	921	707595.06	4141429.25	370:23.7804	0410:20.7133
62	Batman	Gercüş	Yolağzı	986	708146.00	4154610.50	37:30.8998	041:21.3103
63	Batman	Gercüş	Yolağzı	986	708146.00	4154610.50	37:30.8998	041:21.3103
64	Siirt	Merkez	merkez	624	041:49.3349		370:57.2686	0410.49.3349
65	Siirt	Merkez	Tuzkuyusu	628	749524.25	4208746.00	370:59.5237	0400:50.4876
66	Siirt	Merkez	Tuzkuyusu	628	749524.25	4208746.00	370:59.5237	0400:50.4876
67	Siirt	Merkez	Eruh yolu	555	753958.94	4194625.04	370:51.8708	0410:53.2842
68	Siirt	Eruh	Ormanaltı	542	747895.05	4878340.50	370:43.1618	0410:48.5648
69	Siirt	Eruh	Çeltiksuyu	723	754523.31	4177849.50	37:42.7536	041:53.2472
70	Siirt	Eruh	Karadayılar	787			37:42.0753	041:55.1596
71	Siirt	Eruh	Erenkaya	1112	240147.83	4169709.25	370:38.2679	0420:03.3340
72	Siirt	Eruh	Erenkaya	1118	241140.56	4170064.50	370:38.4762	0420:03.9545
73	Siirt	Eruh	Dikboğaz	1388	244319.58	4175718.50	370:41.5831	0420:06.0117
74	Siirt	Eruh	Dikboğaz	1342	244144.04	4175940.50	370:41.6988	0420:05.8875
75	Siirt	Eruh	Bengü	1148	241629.31	4177221.25	370:42.3487	0420.04.1502
76	Şırnak	Güçlükonak	Yatağankaya	875	760055.31	415805.50	370:31.9695	0410:56.5848
77	Şırnak	Güçlükonak	Sağbol	792	756828.00	4153671.25	370:29.6571	0410:54.3044
78	Mardin	Dargeçit	merkez	896	738389.38	4158352.50	370:32.4826	0410:41.8944
79	Mardin	Dargeçit	Midyat Sınırı	978	727246.69	4155708.75	37:31.2010	041:34.1680
80	Mardin	Dargeçit	Midyat Sınırı	951	724918.13	4154284.00	37:30.4879	041.32.6801

The geographical structure of the scanned areas in the Southeastern and Eastern Anatolia Regions consists mostly of plains, partly valleys, slopes and a certain part of mountainous areas. Observations have shown that local bread wheat populations are mostly grown in mountainous, valley and hillside areas

consisting of barren soil. The main reasons why bread wheat populations are still preferred are listed as follows; Consumption habits of local bread wheat populations (flour and ashure), the ability of these populations to withstand drought conditions well, high asure and flour quality, sometimes resistance to late winter and spring frosts, high straw yield, grain size, not dropping grains, inability to reach certified seed, artificial There is no need to use fertilizer, the areas consist of small parcels, little use of technology, etc. The reasons are listed. In short, while it is preferred in some places, it is grown out of necessity in some places. Local populations that survive for a long time are very valuable genetic resources to meet the challenges of modern agriculture and it has been stated that they should be protected (Morgounov et al., 2016).

Current situation in Diyarbakır Province: Eğil, Ergani, Hazro and Silvan districts: Since the northern parts of these districts consist of mountainous areas, local breadfruit populations have been found here and there, and populations called Şergun, Ruto and Ashurelik are generally grown. It has been stated that in these regions, especially the Shergun local population is widely preferred due to drought, flour quality and high hay yield. In the observations made, it was determined that the share of local bread wheat populations in bread wheat was around 2-5%.

Hani, Dicle, Lice and Kulp districts: These districts consist of mountainous areas and very small, stony, forested and sloping pieces of land. Although farmers growing in these regions are open to innovation, local bread wheat populations are still grown for the reasons mentioned above. In these districts, the populations of areas where cultural varieties and local populations are grown together are quite mixed. However, it has been determined that populations are more homogeneous in areas where cultivation is still carried out using old methods. In these regions, local bread wheat populations called Şergun and Ashura are grown and it can be said that they have a share of approximately 15-20% in the total pasta wheat area.

Hani Hometown

Silvan ve Kulp Hometowns

Çermik and Çüngüş districts: Since both districts are extremely mountainous, rugged and have small wheat areas, technology cannot be used sufficiently. Therefore, planting, harvesting and threshing operations are carried out using old methods. Since wheat fields generally consist of both local populations and cultivars, local populations are generally mixed and rare areas where only local populations are planted are homogeneous. In these regions, local bread wheat populations called Ruto and Ashura are grown and it can be said that they have a share of 5-7% in the total bread wheat area.

Çermik Hometown-Kulp ilçesi

Current situation in Adıyaman Province:

Kahta District: Certified seeds are used in the plain villages close to the center. However, although very rare, local wheat populations can be found in mountainous villages. Since the harvesting of these local populations is done with a combine harvester, they are not homogeneous.

Çelikhan District: Wheat fields are very rare. During this survey, only Ashura wheat populations were found in the villages visited.

Sincik District: While certified seeds are preferred in the plains of this district, local wheat populations are preferred in mountainous, valley, sloping and high areas where wheat is still cultivated using old methods. Local bread wheat populations are dominated by Ashura and Kınık, and their share in total cultivation is around 5-10%.

Gerger district: Among the provinces and districts scanned, it is the only district where very rare certified varieties are grown and where predominantly homogeneous local durum wheat populations are still encountered. The geographical structure of the district is extremely mountainous, transportation is difficult, technological tools are almost non-existent, and agriculture is mostly done with old methods. Agricultural areas consist of extremely small pieces. Wheat growers use especially the seeds they obtain from their own production. According to the surveys made in this district, local bread wheat populations such as Kırmızı, Ashura and Ruto are predominantly grown and its share in the total wheat cultivation area can be said to be around 10%.

Current Situation in Elazığ Province:

Elazığ province is far from seed centers. The distribution of certified seeds by the Provincial Directorate of Agriculture for two years introduced farmers to certified seeds. However, local populations are still used in many places. Maden, Sivrice districts and Elazığ Center: In these places, the rate of certified seeds is high and bread landrace populations are not common. The use of certified seeds and cultivation are done consciously. However, the fact that cultural varieties are damaged by the cold weather in the region makes some farmers consciously direct them to local wheat populations.

Palu District: The use of certified seeds is extremely low in this district. Local populations are planted more frequently, especially since it consists of mountainous and sloping lands and has harsh winters. The local population of Ekmeklik is dominated by Ruto.

Kovancılar and Karakoçan Districts: Although partially certified seeds are used in these districts, the local breadfruit populations are very minority.

Arapgir District: The areas of this district are both plain and mountainous. Certified seed use is 60%. Local bread wheat populations can be found here and there. The reasons why local wheat populations are preferred are their flour yield, ashure quality, their resistance to cold and heat, and their tolerance under all conditions.

Local Bread Wheat Field in Elazığ Province

Current Situation in Bingöl Province

Wheat cultivation areas within the borders of Bingöl province are very few. Especially the plain located between the center and Genç district is the center of wheat fields. Although certified seeds are used occasionally within the borders of Bingöl province, seeds purchased randomly from the market are dominant. Local and homogeneous wheat populations are very rare. Ashura and Ruto local populations are found here.

Local Bread Wheat Field in Bingöl Province

Current Situation in Şanlıurfa Province:

The use of certified seeds in this province has reached almost 100%. That's why it's almost impossible to come across local populations. The fact that the lands are generally in the plains has caused the seeds of commercial varieties to penetrate more quickly. For this reason, local populations cannot be found.

Current Situation in Mardin Province:

Kızıltepe and Nusaybin districts of Mardin province were scanned, but local wheat populations were not found. The use of certified seeds is high in these districts. Generally, durum wheat varieties are grown. In Derik district, only 1-2 mixed local wheat samples were found. In addition, since the central borders of Mardin province and the borders of Yeşilli district are extremely mountainous, wheat cultivation has not been possible. Information about local wheat populations in the other districts in question is detailed below.

Midyat and Derik Districts: Since the borders of these districts are far from the regions where certified seeds are marketed and are mountainous, high local populations (Red, Ashura) are planted. While wheat is planted by seeder, distributor and manually, it is harvested by combine harvester, hanging machine and manually.

Local Bread Wheat Field in Mardin Province

Savur and Ömerli Districts: Since these districts are far from the regions where certified seeds are marketed and are mountainous, high local populations (Red, Ashura, etc.) are planted. Wheat is planted by seeder, distributor and manually, and it is harvested by combine harvester, hanging machine and hand. Wheat is cultivated in narrow areas, especially to meet household needs, and therefore it is still possible to find local populations.

Current Situation in Şırnak Province

Şırnak province consists of two different areas. During the surveys, while certified varieties were planted in Silopi, Cizre and İdil plains on one side of the Tigris River, no local wheat populations were found. However, dense local wheat populations (Red, Ruto, etc.) were found in Güçlükonak district on the other side.

Local Bread Wheat Field in Şırnak Province

Current Situation in Siirt Province

The borders of Siirt province are divided into two parts in terms of the wheat varieties grown. Chapter 1 includes the districts of Kurtalan, Baykan, Tillo, Pervari and Şirvan, where certified seeds are used in high amounts despite being located in mountainous areas. Despite intensive screening, very few local wheat populations have been found. Bread wheat varieties such as Nurkent and Ceyhan 99 are planted intensively in these districts. Part 2 covers the central borders of Siirt province and the borders of Eruh district. It is very easy to come across local wheat populations (Ruto, Ashura, etc.) in these regions, especially in Eruh district. It is still possible to come across local wheat populations because it consists of steep mountains and is far from certified seed centers (Kurtalan).

Local Bread Wheat Field in Siirt Province (called as Ruto)

Reasons for the Low Use of Certified Seeds in Some Places in the Southeastern and Eastern Anatolia Regions

1. Geographical structure of the region
2. Political Events
3. Habits from family
4. Being away from certified seed areas
5. Some outstanding characteristics of local populations
6. Lack of knowledge of the superior features of certified seeds
7. Cultivated varieties are sensitive to extreme conditions
8. Their quality is low
9. Low hay yield

Reasons for Preferring Local Populations in Southeastern and Eastern Anatolia Region

1. High adaptability to extreme conditions (drought, barren, frost damage)
2. High quality of bread flour and ashure
3. They do not have enough information about certified seeds.
4. The areas are mountainous and the parts are small
5. High hay yield
6. Being content and giving high efficiency in all conditions
7. Habits inherited from the family

How Local Populations Can Sustain

1. Purification and protection of these local populations
2. Propagation of seeds
3. Supporting their seeds and providing high support
4. Complementing the deficiencies (sometimes low productivity, lodging) with new breeding techniques
5. Explaining the importance of local wheat populations in detail to all producers
6. In addition, explaining the cultivation package well (soil cultivation, amount of seeds to be sown per decare, planting depth, fertilization, irrigation, sowing time, harvest time) will increase the cultivation of local populations.

REFERANCES

Y. Kırtok, General field crops. Cool and Warm Climate Cereals. Adana: Çukurova University Faculty of Agriculture Textbook, 1997.

E. Kendal, "Genotype x in some durum wheat varieties"The effect of environmental interaction on quality and yield characteristics," Doctoral Thesis, Mustafa Kemal University, Institute of Science, Field Crops Department, Antakya, Hatay, 2013.

Kendal, E. (2020). Determination of Inter-Trait Relationships in Diyarbakır Ecological Conditions of Pure Lines Selected from Local Bread Wheat Populations. Kahramanmaraş Sütçü İmam University Journal of Agriculture and Nature, 23(4), 1021-1029.

Karagöz A, Zencirci N 2005. Variation in Wheat (Triticum spp.) Landraces from Different Altitudes of Three Regions of Turkey. Genetic Resources and Crop Evolution, 52(6): 775-785.

I. Özberk, F. Özberk, Y. Coşkun, "Özberk Urfa-2005 Yield performances and stability of durum wheat varieties". Harran U. Faculty of Agriculture Journal, vol. 9, no. 3, pp.29-34, 2005.

Jaradat, A.A., (2012). Wheat Landraces: Genetic Resources for Sustenance and Sustainability. USDA-ARS, 803 Iowa Ave., Morris, MN 56267 USA. http://www.ars.usda.gov/SP2UserFiles/Place/36450000/products-wheat/AAJWheat%20L andraces.pdf

Gökgöl, M. (1939). Turkish wheat. Istanbul.

Barutçular C., Koç M. and Genç İ., 1993. The Course of Flag Leaf Stoma Resistance in Some Local and Improved Durum Wheat Varieties during the Grain Filling Period. Durum Wheat and Products Symposium, 30 November - 3 December, Ankara, 467-485.

Değirmenci, G. (2017). Determination of yield, quality and antioxidant activity characteristics of some durum wheat (Triticum Durum Desf.) varieties (Master's thesis, Adnan Menderes University, Institute of Science and Technology).

Diamond J., 1997. Location, Location, Location: The First Farmers. Science, 278: 1243-1244

Harlan, J. R., De Wet, J.M.J., 1971. Toward a Rational Classification of Cultivated Plants. taxon 20(4): 509–517. doi:10.2307/1218252

Heun M., Schafer-Pregl R., Klawan D., Castagna R., Accerbi M., Borghi B. and Salamini F., 1997. Site of Einkorn Wheat Domestication Identified by DNA Fingerprinting. Science, 278: 1321-1314.

Kan M., Küçükçongar M., Keser M., Morgounov A., Muminjanov H., Özdemir F. and Qualset C., 2015. Wheat Landraces in Farmers' Fields in Turkey: National Survey, Collection and Conservation, 2009-2014, FAO publication, 178 p.

Karagöz A., 2014. Wheat landraces of Turkey. Emirates Journal of Food and Agriculture, 26(2): 149-156.

Karagöz A., 2014. Wheat landraces of Turkey. Emirates Journal of Food and Agriculture, 26(2): 149-156.

Karagöz A., Zencirci N., Tan A., Taşkın T., Köksel H., Sürek M., Toker C. and Özbek K., 2010. Conservation and Use of Plant Genetic Resources. Turkish Agricultural Engineering VII. Technical Congress. 11-15 January 2010. Proceedings – I: 155-177.

Kendal, E., Doğan, Y., Oral, E., & Koyuncu, M. (2019). Investigating the quality of wheat landraces and determination of parents to use in breeding programs. Applied ecology and environmental research, 17(3), 6031-6049.

Koyuncu M., 2009. Screening of Local Durum Wheat Varieties in Terms of Important Parameters Affecting the Quality of Durum Wheat. YL. Thesis. Gazi Osman Pasha Univ. Science. Inst. Food Eng. USA. Tokat 49 p.

Lev-Yadun A., Gopher A. and Abbo S., 2000. The Cradle of Agriculture. Science, 288: 1602- 1603.

Morgounov A., Keser M., Kan M., Küçükçongar M., Özdemir F., Gummadov N., Muminjanov H., Zuev E. and Qualset C. O., 2016. Wheat Landraces Currently Grown in Turkey: Distribution, Diversity, and Use . Crop Sci. 56: 3112-3124. doi:10.2135/cropsci2016.03.0192.

Nesbit M. and Samuel L., 1998. Wheat Domestication, Archeobotanical Evidence. Science. 279:1433.

Özberk I. and Özberk F., 2016. Use of Wheat Genetic Resources in Breeding. Türktob magazine April-June 2016. Year: 5, 18: 24-33.

Özberk İ., Atay S., Altay F., Cabi E., Özkan H. and Atlı A., 2016. Turkish wheat atlas. WWF. Natural Life Conservation Foundation, September 2016, Istanbul.

Özberk İ., Atay S., Altay F., Cabi E., Özkan H. and Atlı A., 2016b. Türkiye wheat atlas. WWF. Natural Life Conservation Foundation, September 2016, Istanbul.

Özberk İ., Özberk F., Atlı A., Cetin L., Aydemir T., Keklikci Z., Önal M.A. and Braun H.J., 2005. Durum Wheat in Turkey; Yesterday, Today and Tomorrow. Status Wheat Breeding: Current Aproaches and Future Strategies. (Ed) Royo, C., Nachit, M.N., Difonzo, N., Araus, J.L., Pfeiffer, W.H. and Slafer, G.A. Chapter: 33. The Howard Press Inc., USA. 1049 p.

Şehirali S. and Özgen M., 1987. Plant genetic resources. Ankara Univ. Faculty of Agriculture Publications No: 1020. Textbook: 294, Ankara.

Chapter 4

Olive Leaves grown in Aydın, Türkiye: Total Phenolic and Flavonoid Contents and Antioxidant Activity

Zuhal ŞAHİN[1], Fatih SÖNMEZ [2], Davut AVCI [3]

[1] Lect. Dr.; Sakarya University of Applied Sciences, Pamukova Vocational School.
zuhalsahin@subu.edu.tr ORCID No: 0000-0001-9856-8064
[2] Prof. Dr.; Sakarya University of Applied Sciences, Pamukova Vocational School.
fsonmez@subu.edu.tr ORCID No: 0000-0001-7486-6374
[3] Prof. Dr.; Sakarya University, Faculty of Sciences, Department of Physics.
davci@sakarya.edu.tr ORCID No: 0000-0002-9011-6191

ABSTRACT

The leaves of *Olea europaea* L. are a source of bioactive compounds such as phenolic substances and flavonoids, which are very useful for both human health and technological purposes and in many industries. Polyphenols are food components that are effective in the formation of taste, color, as well as being a purity control criterion in foods. In addition, they have an important place on human health as they have antimicrobial, antioxidative and enzyme inhibition effects. In this chapter, 'Domat', 'Çekişte', 'Memecik', 'Kalamata', 'Gemlik', 'Manzanilla', 'Yamalak sarısı' varieties of olive leaves, grown in Nazilli, Aydın, Turkey, are evaluated regarding total phenolic content (TPC), total flavonoid content (TFC) and antioxidant activity. Among them, 'Domat' leaves extract has the highest total phenolic content and total flavonoid content (73.55±0.35 mg GAE g^{-1} dw and 81.90±2.22 mg catechin g^{-1} dw, respectively). Moreover, 'Domat' leaf exhibit an effective result in DPPH activity (IC_{50} = 17.28±0.65 µg mL^{-1}) as antioxidant capacity.

Keywords: Olive leaf; Total phenolic content; Total flavonoid content; DPPH and ABTS activity

INTRODUCTION

Free radicals have reactive properties. They react with a large number of biomolecules to form different compounds (Valko et al., 2007:44). Radical reactions occupy a very important position in biology, medicine and industrial process. an antioxidant can be defined as a substance that prevents reactions with oxygen or peroxides and resists oxidation. Many of the antioxidants are used as preservatives in various products. Antioxidants have a very wide area in the food industry (Huang et al., 2005:1841). The most important factor determining the place of antioxidants on human health is their structure-activity relationships, solubility, chemical structures and obtaining from natural sources (Kaur and Kapoor, 2001:703). Just as antioxidants can be produced by body cells, they can also be taken from outside with food. The most important natural antioxidants found in foods can be listed as vitamins (vitamins C, E and A), carotenoids, flavonoids and polyphenols. One of the most important health effects of these natural antioxidants is to protect the human body from harmful free radicals (Rice-Evans et al., 1997:152).

Polyphenols are food components that are effective in the formation of taste, color, as well as being a purity control criterion in foods. In addition, they have an important place on human health as they have antimicrobial, antioxidative and enzyme inhibition effects (Cimen et al., 2020:190). Flavonoids are polyphenolic compounds that are the main source of yellow, blue and red pigments in plants. The antioxidant capacities of flavonoids differ depending on their structure (Cao et al., 1997:749). These compounds have a wide range of uses (medicine, food, leather, metallurgy, textile, agriculture, etc.). Apart from its antioxidant properties, it also has antitumor, antiviral, antithrombotic, anti-inflammatory, antiallergic, and protection effects from coronary heart diseases (Tapas et al., 2008:1089).

Olive tree (*Olea europaea L.*), which stands out with its economic and social importance in Mediterranean countries, has been accepted as one of the species with high antioxidant activity due to the rich phenolic component content of its oil, fruit and leaves (Jemai et al., 2009:8798). Bioactive compounds of olive leaves include secoiridoids (oleuropein, ligstroside, dimethyloleuropein and oleoside), flavonoids (apigenin, kaempferol, luteolin), phenolic compounds (caffeic acid, tyrosol, hydroxytyrosol), carotenoids, tocopherols and chlorophyll (Markhali et al., 2020:1177; Tarchoune et al., 2019:545). Olive leaves are important for human health and are used by the public in the treatment of various diseases (Gürbüz and Ogüt, 2018:242). In folk medicine of olive leaf, it is used in the treatment of diseases such as stomach and intestinal diseases, mouth cleaner, diarrhea, urinary tract infections, hypertension and bronchial asthma

(Uylaser and Yıldız, 2014:1092). Furthermore, olive leaf has antimicrobial, antihypertensive, anti-inflammatory, hypoglycemic and hypolipidemic effects as well as antioxidant properties (Benavente-Garcia et al., 2000:457; Bayram et al., 2020:337; Gürbüz and Ogüt, 2018:242; Mmopele et al., 2018:886).

In this chapter, the extraction, total phenolic contents (TPC), total flavonoid contents (TFC) and antioxidant activity assays of seven olive leaves 'Domat', 'Çekişte', 'Memecik', 'Kalamata', 'Gemlik', 'Manzanilla', 'Yamalak sarısı') varieties grown in Nazilli, Aydın are presented.

EXTRACTION, TPC, TFC, DPPH AND ABTS ASSAYS

Oil Leaf Extraction

Olive leaves are separated from vegetable oils before extraction. Accordingly, olive leaves sample (10 g) are extracted with n-hexane (250 mL) for 6-10 h in a Soxhlet apparatus. After then, the same olive leaves are air-dried and samples are extracted with methanol (Benzarti et al., 2015:518). The extracts are filtered and evaporated to dryness at 40 °C in a rotary evaporator. The obtained olive leaf extracts can be stored at 4 ºC for biological assays (Figure 1).

Figure 1: Graphical Representation of Extraction Assays

Total Phenolic Content Assay

Total phenolic content can be determined according to Sonmez et al. (Sonmez and Sahin, 2023:745) methods. This method consists of following steps: 100 µl sample is mixed with diluted Folin-Ciocalteu reagent. After 3 minutes at 25 °C, 20% sodium carbonate solution is added. The mixture is incubated in the dark for 60 minutes. Measurements are determined at 765 nm using a UV-vis spectrophotometer. Gallic acid (GAE) is generally used as a standard (Figure 2). The total amount of phenolic substance is calculated as mg GAE g^{-1} dry sample.

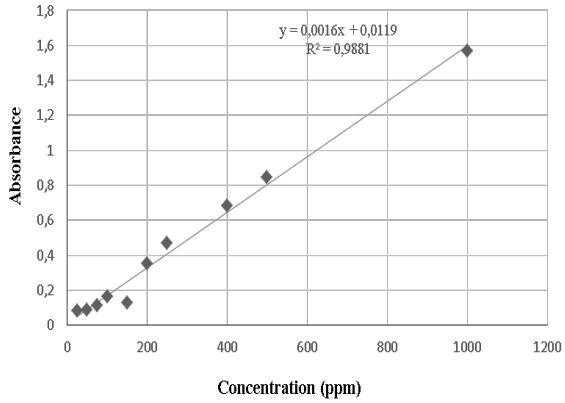


Figure 2: The Calibration Curve of Gallic Acid

Total Flavonoid Content Assay

The flavonoid contents of olive leaf extracts can be determined by the Wannes et al. (2010:1362) methods. This method consists of following steps: 1 ml of the extract is taken and diluted with distilled water. 0.3 ml of $NaNO_2$ (%5) is added to this extract solution and it is incubated for 5 minutes. Then this incubation proses is repeated by adding $AlCl_3.6H_2O$. After that 2 ml of NaOH solution (1 M) is added and absorbance values are measured at 510 nm wavelength in a UV-vis spectrophotometer. Flavonoid amounts are expressed as mg catechin g^{-1} dry sample from the calibration curve drawn with catechin (Figure 3).

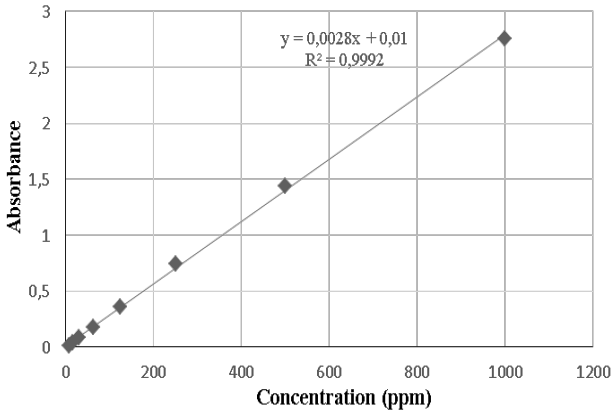


Figure 3: The Calibration Curve of Catechin

DPPH assay

A synthetic 2,2-diphenyl-1-picrylhydrazil (DPPH), a stable and long-lived nitrogen radical, is used for this radical scavenging capacity method. In the DPPH

method, the antioxidant completes the reaction by transferring protons to the DPPH$^{\bullet}$ free radical (Figure 4) (Huang et al., 2005:1841).

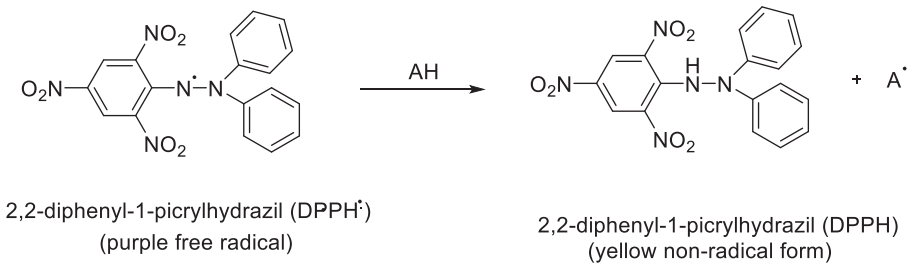


Figure 4: The Reaction between DPPH and Antioxidant

DPPH radical scavenging activities of olive leaf extract can be measured according to Cadi et al. (2020:6299) methods. This method consists of following steps: Olive leaves extracts are prepared in methanol at different concentrations. 0.2 mL of these prepared solutions are mixed with 3 mL of 0.05 mM DPPH in 70% MeOH solution in a tube. After mixing well, it is incubated for 30 minutes at room temperature. Absorbance values are measured at 517 nm. The DPPH activity is calculated according to following equation.

$$\text{DPPH activity \%} = [(Abs_{control} - Abs_{sample}) / Abs_{control}] * 100 \quad (1)$$

IC_{50} values are calculated by from the graph of %inhibition against the extract concentration.

ABTS assay

2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) is oxidized by peroxyl or other oxidants. At the end of oxidation, ABTS$^{\bullet+}$ radical cation is formed. The molecular structures of ABTS and ABTS$^{\bullet+}$ radical cation are given in Figure 5.

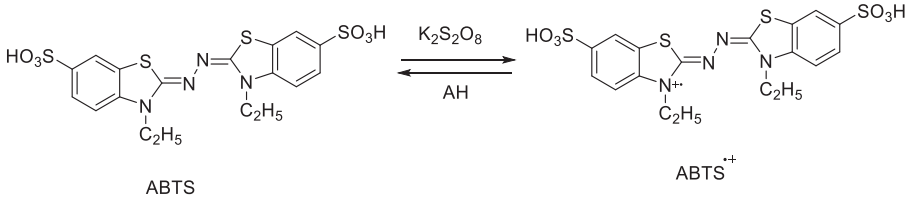


Figure 5: The Structures of ABTS and ABTS$^{\bullet+}$ Radical Cation

$ABTS^{\bullet+}$ radical cation has a very dark blue-green color. In the antioxidant capacity measurement, the reduction in color as a result of the reaction of the sample with the $ABTS^{\bullet+}$ radical cation is determined (Prior et al., 2005:4290). ABTS scavenging activities of the extracts can be measured according to Sonmez et al. (2019:829) method. This method consists of following steps: The solution of ABTS radical is produced by dissolving 7 mM ABTS and 3.3 mg $K_2S_2O_3$ in distilled water. ABTS solution is incubated at room temperature. The absorbance of the solution is adjusted to 0.70 ± 0.02 in the UV-vis spectrophotometer. Olive leaves prepared at different concentrations in methanol are used for analysis. The absorbance at 734 nm is measured 6 minutes after the sample and $ABTS^{\bullet+}$ are mixed. The % inhibition value is calculated by using the absorbance change. The inhibition-concentration plot of each extract is obtained and the results are expressed as IC_{50}.

RESULTS

The TPC, TFC, DPPH and ABTS activity values of the olive leaf extracts, investigated in this chapter, are given in Table 1. The graphic representation of total phenolic contents, total flavonoid contents, ABTS, and DPPH activities of olive leaf extracts are also given in Figure 6.

Table 1: Total Phenolic Content (TPC), Total Flavonoid Content (TFC), IC_{50} Values of DPPH and ABTS Activity of Olive Leaf Extracts

Olive leaf samples	**TPC (mg GAE/g dw)**	**TFC (mg catechin/ g dw)**	**DPPH assay (IC_{50}, µg mL^{-1})**	**ABTS assay (IC_{50}, µg mL^{-1})**
Domat	73.55±0.35	81.90±2.22	17.28±0.65	43.28±3.11
Çekişte	54.76±4.92	61.09±1.27	31.35±1.34	26.15±0.11
Memecik	58.69±3.06	50.40±0.20	18.95±0.24	25.17±1.36
Kalamata	66.88±0.04	62.65±1.69	22.69±0.02	23.97±0.31
Gemlik	65.94±5.38	57.00±0.81	29.75±1.94	19.95±0.78
Manzanilla	64.49±3.41	44.44±1.95	15.59±2.96	25.01±0.65
Yamalak sarısı	69.63±5.81	71.62±1.58	26.22±0.17	17.84±0.43
Ascorbic acid	-	-	2.36±0.97	29.23±0.77

Results are expressed as means ± SD (standard deviation) (n=3).

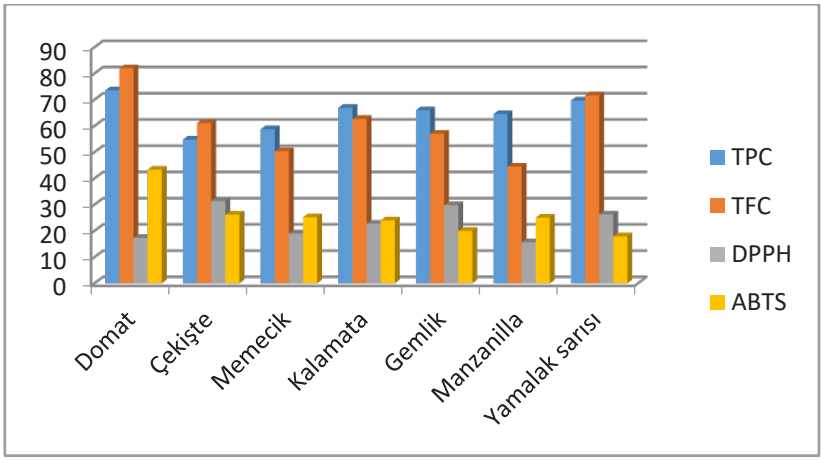


Figure 6: Graphical Representation of TPC, TFC, DPPH and ABTS Activities for Olive Leaf Extracts

According to TPC results, 'Domat' leaf and 'Yamalak sarısı' leaf extracts have the highest phenolic content (73.55±0.35, 69.63±5.81 mg GAE g^{-1} dw, respectively), while 'Çekişte' leaf exract has the lowest phenolic content (54.76±4.92 mg GAE g^{-1} dw). Kiritsakis et al. (2010:369) reported the total phenolic contents of 'Megaritiki', 'Calamon' and 'Koroneiki' olive leaf varieties as 6.094, 5.579 and 6.196 mg kg^{-1}, respectively. The total phenolic contents of olive leaves varieties, grown in Nazilli and presented in this chapter, were determined to be higher than these three olive leaf extracts.

'Domat' leaf extract has the highest flavonoid content (81.90±2.22 mg catechin g^{-1} dw), while 'Manzanilla' leaf extract has the lowest content (44.44±1.95 mg catechin g^{-1} dw). The flavonoid contents of some olive leaves collected in different months were determined as 9.2 to 180.42 mg catechin $100g^{-1}$ dw by Brahmi et al. (2012:146). The flavonoid contents of all olive leaf extracts presented in this chapter were much higher than the results obtained by Brahmi et al.

IC_{50} values of olive leaf extracts for DPPH were found to range from 15.59±2.96 µg mL^{-1} to 31.35±1.34 µg mL^{-1}. Among them, the extract of 'Manzanilla' leaf showed the highest DPPH activity with the IC_{50} value of 15.59±2.96 µg mL^{-1}. The antioxidant activities of olive leaf and other components were investigated by Hayes et al. (2011:948) and the IC_{50} value of DPPH activity of olive leaf extract was determined as 34.58 µg mL^{-1}. DPPH activity of the obtained seven different olive leaf extracts gave much better results. Additionally, their IC_{50} values for ABTS activity were found to range from 17.84±0.43 µg mL^{-}

^{1} to 43.28±3.11 µg mL^{-1}. The 'Yamalak sarısı' leaf extract showed the strongest ABTS activity (IC_{50}=17.84±0.43 µg mL^{-1}). The extracts of 'Çekişte', 'Memecik', 'Kalamata', 'Gemlik', 'Manzanilla' and 'Yamalak sarısı' leaves showed higher ABTS activity than ascorbic acid (IC_{50}=29.23±0.77 µg mL^{-1}).

CONCLUSIONS

In this chapter, seven olive varieties ('Domat', 'Çekişte', 'Memecik', 'Kalamata', 'Gemlik', 'Manzanilla', 'Yamalak sarısı'), grown in Nazilli, Aydın, Türkiye, were investigated regarding the total phenolic and flavonoid contents and DPPH and ABTS activities as antioxidant properties. The results showed that these olive leaf extracts had very high phenolic and flavonoid contents. Among them, 'Domat' variety have the highest phenolic content (73.55±0.35 mg GAE g^{-1} dw) and flavonoid content (81.90±2.22 mg catechin g^{-1} dw). Furthermore, this variety exhibited strong DPPH activity with the IC_{50} value of 17.28±0.65 µg mL^{-1}.

Olive leaves are not given much importance by growers and are not widely used as industrial products. This research predicts that olive leaf extracts may be used as preservative additives in various products due to their high phenolic content and antioxidant properties.

REFERENCES

Bayram, M., Topuz, S. and Kaya, C. (2020). Antioxidant, antimicrobial activity of olive leaf extract and oleuropein, their possibilities usage in foods. Turkish Journal of Agriculture-Food Science and Technology, 8(2), 337-347.

Benavente-Garcia, O., Castillo, J., Lorente, J. et al. (2020). Antioxidant activity of phenolics extracted from *Olea europaea* L. leaves. Food Chemistry, 68(4), 457-462.

Benzarti, S., Hamdi, H., Lahmayer, I. et al. (2015). Total phenolic compounds and antioxidant potential of quince (Cydonia oblonga Miller) leaf methanol extract. International Journal of Innovation and Applied Studies, 13(3), 518-526.

Brahmi, F., Mechr, B., Dabbou, S. et al. (2012). The efficacy of phenolics compounds with different polarities as antioxidants from olive leaves depending on seasonal variations. Industrial Crops and Products, 38, 146-152.

Cadi, H. E., Cadi, A. E., Kounnoun, A. et al. (2020). Wild strawberry (Arbutus unedo): Phytochemical screening and antioxidant properties of fruits collected in northern Morocco. Arabian Journal of Chemistry, 13(8), 6299–6311.

Cao, G., Sofic, E. and Prior, R. L. (1997). Antioxidant and prooxidant behaviour of flavonoids: structure-activity relationships. Free Radical Biology and Medicine, 22, 749-760.

Cimen, F., Polat, H. and Ekici, L. (2020). Regulatory impact of polyphenols on intestinal microbiota composition and neuroprotective effects of these compounds. Akademik Gıda, 18(2), 190-208.

Gürbüz, M. and Ogüt, S. (2018). Potential health benefits of olive leaf. Türkiye Klinikleri Journal of Health Sciences, 3(3), 242-253.

Hayes, J. E., Allen, P., Brunton, N. et al. (2011). Phenolic composition and in vitro antioxidant capacity of four commercial phytochemical products: Olive leaf extract (Olea europaea L.), lutein, sesamol and ellagic acid. Food Chemistry, 126, 948-955.

Huang, D., Ou, B. and Prior, R.L. (2005). The chemistry behind antioxidant capacity assays. Journal of Agricultural and Food Chemistry, 53, 1841-1856.

Jemai, H., Feki, A. E. L. and Sayadi, S. (2009). Antidiabetic and antioxidant effects of hydroxytyrosol and oleuropein from olive leaves in alloxan-diabetic rats. Journal of Agricultural and Food Chemistry, 57(19), 8798–8804.

Kaur, C. and Kapoor, H. C. (2001). Antioxidants in fruits and vegetables–the millennium's health. International Journal of Food Science and Technology, 36(7), 703–725.

Kiritsakis, K., Kontominas, M. G., Kontogiorgis, C. et al. (2010). Composition and antioxidant activity of olive leaf extracts from greek olive cultivars. Journal of the American Oil Chemists' Society, 87, 369-376.

Markhali, F. S., Teixeira, J. A. and Rocha, C. M. R. (2020). Olive tree leaves-a source of valuable active compounds. Processes, 8(9), 1177.

Mmopele, K., Combrinck, S., Hamman, J. et al. (2018). Potential herb-drug pharmacokinetic interactions between African wild olive leaf extract and selected antihypertensive drugs. Planta Medica, 84(12/13), 886–894.

Prior, R. L., Wu, X. and Schaich, K. (2005). Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements. Journal of Agricultural and Food Chemistry, 53(10), 4290-4302.

Rice-Evans, C. A., Miller, N. J. and Paganga, G. (1997). Antioxidant properties of phenolic compounds. Trends in Plant Science, 2, 152-159.

Sonmez, F. and Sahin, Z. (2023). comparative study of total phenolic content, antioxidant activities, and polyphenol oxidase enzyme inhibition of quince leaf, peel, and seed extracts. Erwerbs-Obstbau, 65, 745-750.

Sonmez, F., Gunesli, Z., Kurt, B. Z. et al. (2019). Synthesis, antioxidant activity and SAR study of novel spiro-isatin-based Schiff bases. Molecular Diversity, 23, 829-844.

Tapas, A. R., Sakarkar, D. M. and Kakde, R. B. (2008). Flavonoids as nutraceuticals: A review. Tropical Journal of Pharmaceutical Research, 7(3), 1089-1099.

Tarchoune, I., Sgherri, C., Eddouzi, J. et al. (2019). Olive leaf addition increases olive oil nutraceutical properties. Molecules, 24(3), 545.

Uylaser, V. and Yıldız, G. (2014). The historical development and nutritional importance of olive and olive oil constituted an important part of the mediterranean diet. Critical Reviews in Food Science and Nutrition, 54(8), 1092-1101.

Valko, M., Leibfritz, D. and Moncola, J. (2007). Free radicals and antioxidants in normal physiological functions and human disease. The International Journal of Biochemistry and Cell Biology, 39, 44-84.

Wannes, W. A., Mhamdi, B., Sriti, J. et al. (2010). Antioxidant activities of the essential oils and methanol extracts from myrtle (myrtus communis var. italica l.) leaf, stem and flower. Food and Chemical Toxicology, 48(5), 1362-1370.

Chapter 5

Earthworms and Their Contribution to Sustainable Soil Health

Fevziye Şüheda HEPŞEN TÜRKAY[1]

[1] Asist. Prof. Dr.; Kırşehir Ahi Evran Unıversity Agriculture Faculty Department of Soil Science and Plant Nutrition suheda.turkay@ahievran.edu.tr ORCID No: 0000-0002-9413-264X

ABSTRACT

Although the functions of earthworms began to attract scientific interest in the 1880s, studies were limited to natural history, biogeography, and classification. Later on, the ecology, behavior and functions of earthworms began to be studied in terms of soil fertility, plant growth, environmental protection and the relationship between soil and earthworms. These studies have been followed by studies on the usability of earthworms in areas such as waste management, detoxification, biomining and medicine. However, in recent years, the functions of earthworms in soil are better categorized in terms of environmental, agricultural and resource use sustainability. Earthworms have very important functions in soil such as increasing soil fertility, improving aggregation and soil structure, as biomonitors and bioaccumulators in soil pollution, as well as significant potential benefits in organic waste management, land reclamation and agriculture. In addition to its contributions to the environment and agriculture, one of the most important biological properties of earthworms is the cytosomal fluid secreted under the skin for locomotion, reproduction, disinfection, and regeneration, which is used in the cosmetics and pharmaceutical industries. It is used in traditional medicine in the Far East and is now used in the pharmaceutical and cosmetic industries in America and Europe. Since earthworm biomass is a good source of animal protein, it is added to fish and poultry feed rations. In addition, working on robot worms that simulate the muscular systems of earthworms in the development of the movements of humanoid robots is another field in which they are involved in science. Among all these, the most important contribution of earthworms is that they are indispensable for the protection and maintenance of ecological balance in the soil. However, earthworms are being destroyed by humans due to the destruction of forests and the opening of new agricultural lands, the use of agricultural chemicals, and the degradation of natural habitats for urbanization. In this study, the ecology of earthworms, their new regulated classification, their contribution to soil health and soil fertility are explained by expanding the basic information mentioned above. In addition, this article is presented to serve as a reference for further studies on the subject.

Keywords: earthworms, soil biology, soil fertility, soil health, waste management

INTRODUCTION

The composition of a healthy soil consists of 93% mineral coverage and voids volume and 7% bioorganic fraction. The bioorganic part consists of 85% humus, 10% plant roots and 5% edaphone. The edaphone is composed of 40% fungi and algae, 40% bacteria and actinomycetes, 12% earthworms, 5% macro fauna and 3% micro-meso fauna. The first description of earthworms was Linné's taxonomic description of "*Lumbricus terrestris*" in 1758 (Sumner, 2000). Scientific studies focused on natural history, biogeography and classification until the 1980s. Later on, the ecology, behavior and functions of earthworms started to be studied. With the increasing awareness of this issue, scientific studies on the relationship between soil and earthworms such as the functions of earthworms in soil, soil fertility and plant development, environmental protection, effects on organic waste management have intensified and continue. However, in recent years, the functions of earthworms in soil are better categorized in line with the principle of sustainability in terms of environmental, agricultural and resource use.

Earthworms should be categorized into two categories: (i) the vital activities of earthworms living in soil and their direct effects on soil and (ii) the functions of earthworms living in organic waste piles in organic waste management. In this study, earthworms and their effects on soil properties were mainly evaluated.

The contribution of earthworms to soil health and fertility is realized in 3 main ways: physical, chemical and biological.

- Biologically, their effects on the genus, species and numerical distribution of soil microorganisms and their effects on microbial biomass and soil enzymes.
- Chemically, through their effects on the breakdown of soil organic matter and the availability of nutrients in the soil,
- In physical terms, their effects on soil aeration through the channels and canals they open in the soil, increasing the water holding capacity, ensuring the movement of nutrients along the soil profile as a result of their feces and other activities, and improving the soil structure by forming stable aggregates with their feces.

In this study, the importance of earthworms in sustainable soil health, biology, classification, ecology, and effects of earthworms on soil properties are presented under the main topics.

1. Classification and Biology of Earthworms

1.1. Taxonomic Classification of Earthworms

According to Sumner (2000), earthworms belong to the family *Lumbricidae* of the class *Clitellata* of the branch *Annelida*, which is known as ringworms, is distributed all over the world and includes 36 families. However, it has been reported that there are aquatic, semi-aquatic and terrestrial forms of *Clitellata* and 7254 species belonging to 43 terrestrial families and 739 genera, both terrestrial and aquatic. However, with the studies carried out in the last 20 years, taxonomic categories have been revised in the classification of earthworms.

Based on ITIS (2022), the families belonging to the revised current classification of *Clitellata* are listed in Table 1. As per the new classification, earthworms are 5326 species in 20 families (ITIS, 2022). It is known that there are more than 60 species belonging to earthworm families in Turkey. Since Turkey is very rich in species and harbors endemic species, Anatolia forms a special fauna bridge between the Caucasus and the Balkan Peninsula in terms of Lumbricids (Mısıroğlu, 2001).

Table 1. Families of earthworms and the number of earthworm species within these families (ITIS, 2022)

TAXA	*NAME*	Number of earthworm species in the taxon
Kingdom	*Animalia*	
Subkingdom	*Bilateria*	
Infrakingdom	*Protostomia*	
Superphylum	*Lophozoa*	
Phylum	*Annelida*	
Class	*Clitellata*	
Superorder	*Metagynophora*	
Order	*Moniligastrida*	
Family	*Moniligastridae*	213
Order	*Opisthopora*	
Suborder	*Alluroidina*	
Superfamily	*Alluroidoidea*	
Family	*Alluroididae*	3
Family	*Syngenodrilidae*	2
Suborder	*Crassiclitellata*	
Family	*Tumakidae*	1
Family	*Sparganophilidae*	15
Family	*Microchaetidae*	61
Family	*Kynotidae*	15
Family	*Komarekionidae*	1
Family	*Glossoscolecidae*	154
Family	*Eudrilidae*	362
Family	*Biwadrilidae*	1
Family	*Almidae*	54
Superfamily	*Megascolecoidea*	
Family	*Acanthodrilidae*	1292
Family	*Megascolecidae*	2221
Family	*Ocnerodrilidae*	189
Superfamily	*Lumbricoidea*	
Family	*Ailoscolecidae*	2
Family	*Criodrilidae*	1
Family	*Hormogastridae*	28
Family	*Lumbricidae*	710
Family	*Lutodrilidae*	1
	Total:	5326

1.2. Biology of Earthworms

Earthworms are segmented and cylindrical organisms, ranging from a few mm to 3 m in length (Figure 1). An adult earthworm usually consists of 100-250 segments. Their bodies have a girdle-like clitellum, called “clitellae” in Latin, which is formed by the bulging of the upper skin on one or more segments

around the sexual orifices during sexual maturation. The clitellum performs functions such as mating, fertilization, cocoon formation, storage and protection of eggs. (Villee, 1984; Paoletti, 1999; Thorp et al., 2016; Hill et al., 2018).

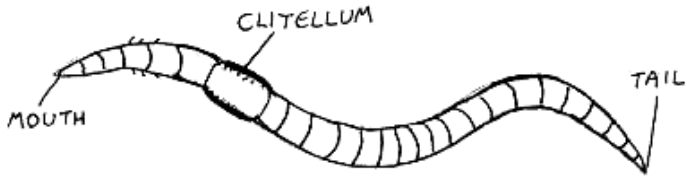


Figure 1. The anatomy of the earthworm in a simplified diagram (Thomas, 2006)

Their body structure is simply in the form of 2 intertwined tubes, with the inner tube consisting of the digestive tract. The body surface is covered with a layer called cuticle. Beneath this is a monolayer of epidermis and a layer of longitudinal and transverse musculature. The body segments are separated from each other by the septum and their movement is provided by the skin-muscle sheath system. The body cavities, which provide the dynamics and hydrostatics for locomotion, are filled with a fluid, the cytosome, which acts as a hydraulic skeleton. Worms have a specialized respiratory system. They respire by absorbing and transporting oxygen from the blood through the moist skin to the closed vascular system that runs in capillaries beneath the epidermis (Sumner, 2000).

Skin-breathing worms require a consistently moist environment and a moist epidermis. However, when their environment is submerged in water and they dry out, they die. Some segments on the midline of the dorsum have dorsal pores that allow the skin to moisturize by expelling cytosomal fluid in case of desiccation (Mısıroğlu, 2001).

The mouth opening is in the first segment, the intestine lies straight and has a dorsal recess that increases the absorption surface. The greenish cells around the intestine act as a liver. The last intestine is very short, and the mineral part of the ingested food is excreted through the anus. Their main food is decayed plant organic matter and microscopic organisms. They excrete an average of 60% of their body weight in feces per day. The fact that they have a closed circulatory system is a rare feature in invertebrates. There are two main veins and side veins connecting them. The front 5 of the side veins are contractile and act as a heart. They have primitive kidneys called “nephridium”, and each segment has a pair. Their nervous system is highly developed, with a brain at the anterior

end and nerve nodes called "gangligons" in each segment (Harris, 1992, Mısıroğlu, 2001). Figure 1 shows a view of the internal organs of the earthworm.

Nerve cells are sensitive to heat, light, and vibrations but not to sound (Darwin, 1883; Mısıroğlu, 2001). Each segment, except the head and the last segment, has hair-like structures called setae, which are in pairs. These structures provide the movement of the earthworm and can extend and retract (Sisli et al., 1977). Earthworms eat the wastes, plant residues and soil on the soil surface and pass them through their digestive system (Heynes and Fraser, 1998). The contents of the digestive tract are fluid and consist of amino acids, sugars and small organic molecules from organic waste. Smaller molecules are absorbed through the outer membrane and used for cell composition and energy production.

Earthworms are hermaphrodites. Each individual carries male and female reproductive organs but cannot fertilize themselves. Each individual mates with another individual for fertilization, exchanging sperm and fertilization is mutual (Figure2).

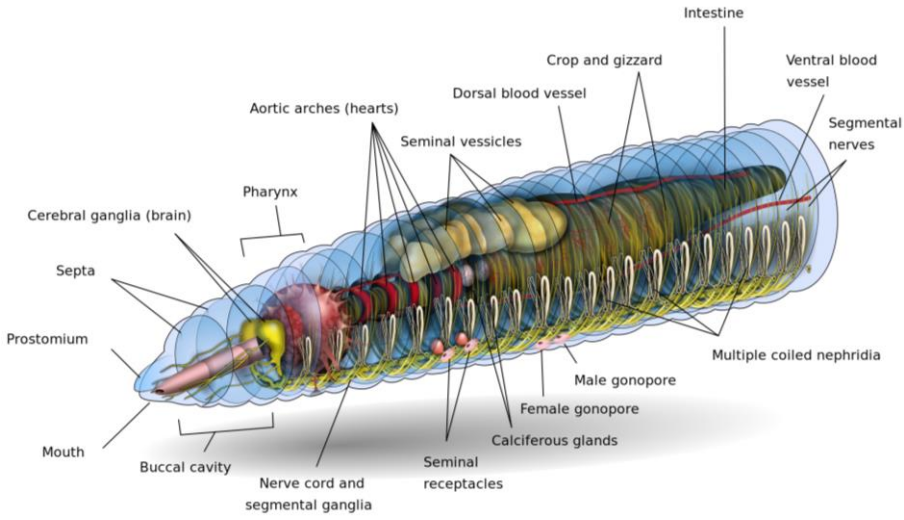


Figure 2. View of the internal organs of *Lumbricus* (KDS4444, 2016)

.

Figure 2. Mating earthworms (Jackhynes, 2006).

Sometime after mating, a cocoon ring forms around the clitellum, with substances secreted from it. This ring slides along the body and contains the eggs as they pass through the female opening and the sperm as they pass through the male opening. It is then released from the anterior end in a sheath by the "grandular clitellum". The released ring closes at the ends to form a lemon and is called the "cocoon". Fertilization takes place inside the cocoon. In adult individuals, this sheath becomes characteristically prominent and darker only in the anterior few segments (Harris, 1992; Sumner, 2000; Mısıroğlu, 2001). Each cocoon contains 3-7 eggs, one or more of which may mature, depending on the species. The young hatch after about 3 weeks depending on environmental conditions, if soil moisture and temperature are suitable (Figure 4). Unlike warm-blooded animals, the reproductive process of cold-blooded animals is highly dependent on ecological conditions.

Figure 4. Cocoons of the earthworm species *Eisenia fetida.*

Earthworms have been kept alive for 10 years under laboratory conditions and some large species (such as *Lumbricus terrestris*) for 30 years, but in nature their life span is usually limited to 1 year. They have a high regenerative ability. Although flatworms do not die even when their bodies are cut into several pieces, earthworms do not regenerate. In earthworms, if the severed body is not too close to the head or clitellum, the side with the head can survive.

2. Ecology of Earthworms

Earthworms inhabit all areas where water and temperature are suitable, except desert and polar conditions. They show a wide range of morphological, physiological and behavioral adaptations to environmental conditions. Many species can enter a state of temporary dormancy during periods of unfavorable conditions or produce protective covers from which they can emerge when conditions are favorable. The number of earthworms in nature depends on a variety of factors such as climate, edaphic conditions, ecosystem type and the degree to which the habitat has been modified (e.g. agriculture) (Sumner, 2000).

Figure 3. Mating and fertilized clitellum in *Eisenia* worm.

2.1. Factors Affecting the Activity of Earthworms

Environmental factors affecting the basic vital activities of earthworms such as feeding, development and reproduction are temperature, humidity, ventilation and climate (Edward, 1983; Curry, 1988; Schrader and Zhang, 1997; Martin et al. 1999; Mısıroğlu, 2001).

2.1.1. Temperature

Earthworms can protect themselves by moving to the lower soil layers as the soil temperature drops. Although the earthworm class has species that can live in extreme ecological conditions, the optimum temperature for optimum development and activity ranges between 15-27 °C. However, earthworms can

be found in all areas except desert and polar conditions. Although they are highly adaptable, temperature and humidity conditions are of vital importance.

2.1.2. Humidity

Earthworms need optimum moisture for their vital activity. Earthworm burrows should not be too damp and should contain moisture at approximately field capacity. If the galleries remain permanently under water-saturated conditions, earthworms will leave their burrows and move to other areas if conditions are favorable. Otherwise, even though they are classified as aquatic, they cannot live in submerged environments. Worms or their burrows should not be exposed to direct sunlight.

2.1.3. Ventilation

Unlike other macro-organisms, earthworms can thrive in low oxygen and high CO_2 levels. If the soil water contains dissolved oxygen, they can survive by being submerged in water, provided that it is not continuous and uninterrupted. On the other hand, if earthworm burrows are submerged under water for a long period of time, a high population of anaerobic bacteria develops in the environment and since these species provide their oxygen needs from dissolved oxygen in the water, the oxygen in the environment is depleted and the worms die if they cannot get out of the burrow.

2.1.4. pH

Earthworms can live in a very wide pH range, between 4.2-8.0. Although the optimum pH requirements of earthworms vary between 5-7, the optimum pH for earthworm burrows is neutral (pH 7.0). As earthworms carry out their vital activities, they change the pH value of the gallery environment and primarily the pH value of the material forming the gallery walls towards neutral. This change, which is very important for soil microbiota and soil chemical reactions, has a significant and positive effect on soil ecology.

2.1.5. Climate

Earthworms are more abundant in the damp spring and autumn months, descending to the lower soil layers in cold and dry weather. During these periods, they form a ball by wrapping themselves around themselves in the rooms they create deep in the soil. This depth can reach up to 3 m in some species. Earthworms belong to a very large branch and have 20 different families. Therefore, their behavior can vary within wide limits according to the climate.

2.1.6. Light

Distinct from the relationship between temperature and humidity and light, earthworms are sensitive to light conditions. Light is an important abiotic factor affecting earthworm activity. Although there is not much current research on this subject in the scientific literature, it is a research topic that has recently attracted the attention of scientists and has revealed information that can form the basis for different fields (Geier et all.2021; Owa et al., 2008; Hamman et al., 2003). Animals perceive light because they have eyes that contain light receptors. Earthworms do not have eyes but have light receptors called photoreceptors in their skin. Worm photoreceptors are located on nerve fibers in the skin. These nerve fibers are connected to special nerves called ganglia, which connect to the worm version of the brain. The brain, called the ganglion, helps trigger chemical reactions to control the worm's entire body. Worms soon wither and die when exposed to heat and sunlight. To survive, they need to stay underground in moist soil. If any part of the worm is exposed to light while tunneling, the worm is stimulated via photoreceptors and can react quickly to return to a safer place. Worm photoreceptors can detect the intensity of different colored lights. Worms move away from white or blue light but do not react to red light (Morgan et al., 1965; Wilson et al., 2014).

2.2. Distribution of Earthworms in Soil

Under favorable conditions, earthworm density and biomass are significantly affected by the organic carbon or organic matter content of the soil (Paoletti, 1999). Earthworms are found in numbers in the range of 100-400 per 1 m^2 in tropical forests and areas under tillage agriculture (Edwards, 1983). In general, in moist and organic matter-rich soils, the number of earthworms in the plough depth of 1 ha of agricultural soil can reach several million, but it can also drop to a few hundred. These values correspond to 200-1000 kg/ha in terms of earthworm biomass.

2.3. Ecological Classes of Earthworms

In their natural environment earthworms are generally heterogeneously distributed. The life stages or basic ecological functions of earthworms vary according to their environment and nutritional status. The main ecological classes are classified into 5 groups according to their ability to live at different depths in the soil: epigeic, endogeic, anecic, coprophagic, and arboricolous, These species are important for soil and soil fertility. Among these categories, epigeic, anecic and endogeic species are more frequently used in soil evaluation than coprophagic and arboricolous species (Sumner, 2000; Paoletti, 1999;

Mısıroğlu, 2001). For example, although *Eisenia fetida*, one of the species commonly used in organic waste transformation and vermicompost production, is a coprophagic species because it lives in barnyard manure, it is classified as an epigeic species in many sources because it can naturally colonize both barnyard manure piles and decomposed organic waste piles (Namlı et al. 2010; Turgay et al., 2011).

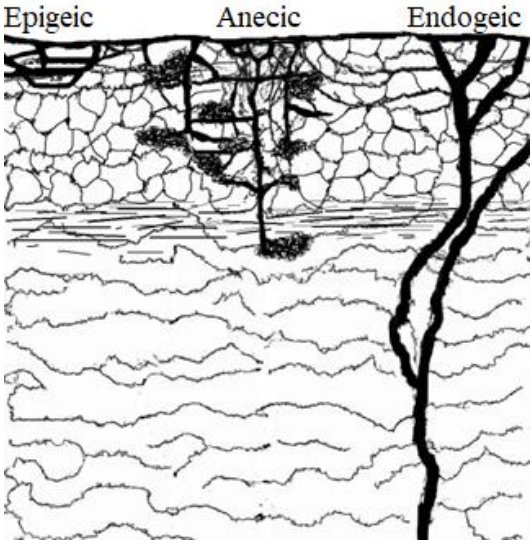


Figure 4. The appearance of different types of galleries of different earthworm species in the soil and their ecological class accordingly.

Ecological groups of earthworms are associated with earthworm functions by soil biology researchers, but there are also recent studies that suggest that ecological groups do not necessarily represent functional groups (Bottinelli and Capowiez, 2021).

2.3.1. Epigeic species

These species live above the mineral horizon layer of soils, below the debris layer, close to the surface and feed on organic matter on the surface. Epigeic earthworms are small-bodied and range from 1-7 cm in length. Some are bright red in color, but most have a reddish-brown skin pigmentation. Their pigmentation is darker on their backs and lighter on their tails and abdomen. This can provide extra protection against ultraviolet rays. Epigeics share essentially the same anatomy and reproductive methods as endogenous and anecic species. They are pigmented worms with a red-brown pigment in their skin, which tends to be darker on the back and head, so their belly color is

usually beiger. Scientists think that this pigmentation may provide protection against predators and UV rays, to which they are very sensitive.

Epigeics are adapted to live in humid conditions and at variable temperatures at the soil surface. Earthworms found in compost heaps are epigeic and are unlikely to survive in an environment with low amounts of organic matter. Epigeics live on every continent except Antarctica. But all earthworms are invasive species in the temperate and boreal forests of North America. Endogeic species can become epigeic under favorable weather conditions, but in dry weather they retreat below the soil. Other epigeics migrate to soften the soil or hibernate. Some classify earthworms with both of these "migratory" type behaviors as epi-endogeic (Singh et al., 2016; Edwards, 2019).

2.3.2. Anecic species

These species open deep galleries in the soil and feed on organic matter on the surface. These species are larger than other epigeic and endogeic species. Anecic species are more common in agricultural areas and meadow-pasture soils than in forested areas. These species build their nests at depths of 150-180 cm in a large, erect and unbranched burrow, they surface to the soil surface for feeding, and they perform waste management by collecting organic waste in the mouth of their burrows. Unlike other ecological species, they also deposit their feces in the mouth of the nest. This creates the appearance of a small anthill. Although larger than others, they have the reddish-brown strong pigmentation seen in epigeic species. The best known anecic species is *Lumbricus terrestris*. They can have a great impact on the forest floor, especially if they colonize forest soils. There is also one individual in each nest, and they are widely used in fisheries (Hoeffner et al., 2022).

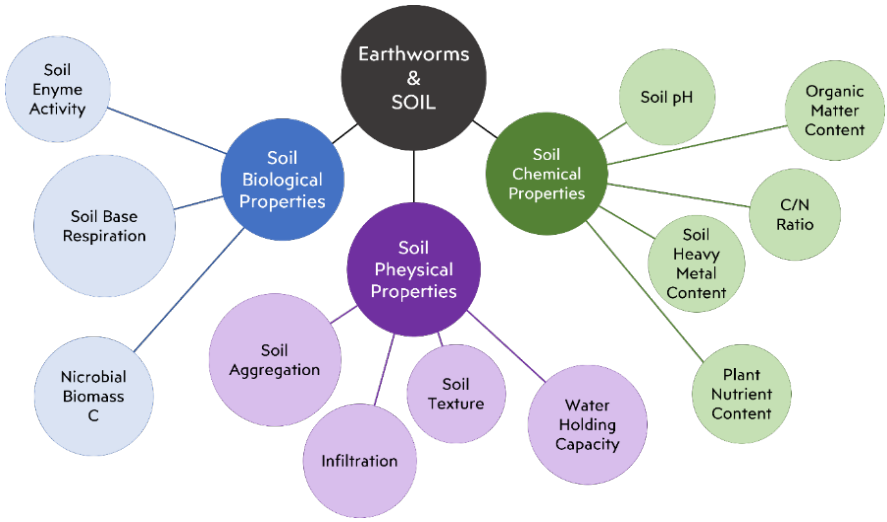
2.3.3. Endogeic species

These species live in the mineral horizons of the soil and feed on organic materials that reach these soil layers under the influence of factors such as rainfall and irrigation. Among endogeic species, there are many species that can live up to 3.5-4.0 meters deep in the soil. They do not build continuous and regular nests, they build random nests in the places they visit and where the nutrients they eat are found (Lee, 1985; Edwards, 1996). Therefore, they cannot manage waste.

A typical agricultural soil may contain 1-5 different endogeic species and one anecic species. Earthworms are referred to as oligohumic, mesohumic, polyhumic depending on the richness in organic matter of the materials they use as substrate (Lee, 1985). The activities of earthworms, which are functionally

classified as epigeic, anecic and endogeic, cause significant effects on the geobiochemical properties of soils. Earthworms transport soil organic matter to subsoil depths and mix organic compounds with mineral fractions (Lee, 1985; Edwards et al. 1990). Different earthworm species can coexist in healthy agricultural soils and Lee (1991, 1995) emphasizes that ideal agricultural soils should have a combination of what he calls "target earthworm communities".

3. Effects of Earthworms on Soil Properties



3.1. Effects of Earthworms on Physical Properties of Soils

Earthworms have positive effects on soil physical properties such as the formation of stable aggregates and consequently improving soil structure, increasing infiltration and water retention capacities of soils.

3.1.1. Effects on aggregation

Earthworm droppings are evaluated in terms of their effect on the physical properties of soils in two ways: the effect of fresh and dry droppings. Earthworm droppings are more saturated when fresh and more stable in the soil when dry (Edwards, 1995). The amount of organic matter in the feces, the wetting and drying cycle of the feces, hyphae and mycelia of fungi in the feces, residues and products of other microorganisms have an effect on increasing aggregation in the soil. Feces of earthworms are mostly collected in the upper soil layers (0-20 cm) and as a result, the effects of feces such as the formation of

water-resistant aggregates are more pronounced in the upper soil layers (Marinissen et al. 1994; Shipitalo and Protz, 1998).

The general characteristics of earthworm feces vary between earthworm species and soil type. There are also differences between ecological groups of earthworms in the organic matter content of the feces and the associated chemical and biological properties. Soils with earthworms have larger aggregation and larger earthworms form larger aggregates. Aggregates formed in the area where earthworms are present are much more durable than others. Soils with many earthworms have granular, porous and more durable soil structure. Earthworm droppings are the most important fraction in increasing the stability and size of soil aggregates. In the soil environment, dry feces form more durable aggregates than fresh feces. Generally, C/N ratios of earthworm droppings are narrower than soils and the narrower the C/N ratio, the higher the aggregate stability (Schrader et al., 1977; Garvin et al., 2000).

The effect of earthworms on soil aggregation (Lee et al., 1995) is that the microorganism activity in the environment, which is the main element that provides aggregation as a result of the combination of earthworm excrement and soil, increases and carbohydrate accumulation occurs compared to the initial soil. In addition, the soil in which the earthworm burrow is located contains more durable aggregates than the soil around the burrow because of its high content of carbonaceous compounds. The aggregation provided by dry earthworm droppings is mainly due to the hyphae and mycelial development of fungi, whereas the aggregation of fresh droppings is mainly due to microbial polysaccharides and plant cell debris. Although fresh droppings have lower durability than dry droppings because they are more saturated, they have the effect of increasing aggregation and durability compared to worm-free soils.

The chemical composition of organic wastes in the composition of earthworm droppings plays a decisive role in determining the effect of that droppings on the soil and its durability. Hyphae and mycelia of fungi in earthworm droppings, which are a good substrate for microorganisms, are decisive both in the formation of durable soil aggregates and in the resistance of droppings to environmental influences (Degens, 1997). Studies have shown that the addition of organic matter increased water-resistant aggregate stability in soil inoculated with earthworms (*Pontoscolex corethrurus*) more than in soil inoculated with organic matter without earthworms. However, there are studies showing that aggregation increases as a result of earthworm activity even without the addition of organic matter to soils (Hallaire et al. (2000).

3.1.2. Effects on infiltration

The feces of earthworms and the factors affecting the durability of feces (such as wetting-drying, fungal hyphae) also have important effects on the infiltration of water from the soil. The burrows and galleries of earthworms are similar to the body type of earthworms and their diameters generally vary between 1-10 mm. Cavities of this size are usually the largest of the soil pores (Lee, 1985; Tamlin et al. 1995). The soil eaten by earthworms, the galleries they open and the feces they leave in the environment form macropores in the soil like a nest-centered network. This situation facilitates the movement of water in the soil. Sometimes, at some depths, the feces they leave in these galleries can temporarily prevent the movement of water (Sumner, 2000).

Since anecic earthworm species open vertical galleries in the soil at soil depths of 1 m or less, the soils surrounding the burrows of earthworms are more compacted. Aggregation is also achieved in these areas (Lee, 1985; Tamlin et al., 1995). This situation varies according to the type of earthworm and soil properties and has a significant effect on water infiltration (Mısıroğlu, 2001).

Soils contain a volume of voids to allow aeration and water infiltration. Soil porosity may vary depending on factors such as texture, organic matter content and tillage (Demir, 2019; Bayraklı, B., 2023). The porosity that is naturally present in any soil environment is observed in the immediate vicinity of the gallery when earthworms pass through that environment and a decrease in porosity is observed. The amount of compaction varies according to the type of earthworm. While the inner wall of the gallery combines with the skin fluid of the earthworm to form a more durable structure, compaction decreases outward from the gallery wall (Jegou et al., 2000).

Figure 5. View of the galleries opened by earthworms in the soil. B.p., Gallery outer boundary line; B.w., Gallery wall

Significant increases in the movement of water in the soil through the galleries opened as a result of earthworm activity in the soil (Lee, 1985; Tamlin et al. 1995) and its effect on increasing infiltration also reduces water erosion.

3.1.3. Effects on water holding capacity

Since earthworms also feed on soils and soil organic material, their feces contain organic material that undergoes rapid humification in the digestive tract. Therefore, the humified organic material enriches earthworm excreta with polysaccharides and mucilagel substances. In addition to the increase in humus in the medium, this leads to an increase in the water holding capacity of soils (Tiwari et al., 2022; Kumar, 2005).

3.1.4. Effects on soil texture

Depending on the species, earthworms consume on average several times their own weight of soil in a day and transform it in their digestive system,

causing changes in soil texture. In general, the composition of the excreta resulting from earthworm activity is higher in clay and lower in sand compared to soil. It is thought that this may be due to the earthworms mixing the soil and crumbling the large mineral fraction during digestion. According to scientific data, it was determined that the percentage of clay in the feces released as a result of the activities of two different earthworm species in loamy and clayey soils increased, while the percentage of sand decreased (Schrader and Zhang, 1997).

3.1.5. Effects on organic matter content

Earthworm activity in soils causes soil organic matter to contain a high proportion of carbohydrates (Degens, 1997). Although the C/N ratio of soil organic matter is high, with earthworm activity, the carbohydrates that make up the organic matter are transformed into simple monosaccharides or disaccharides. Therefore, the breakdown of these carbohydrates in the soil is faster than other organic compounds. Since the activity of earthworms usually takes place within the soil, the total amount of organic matter at the soil surface (0-15 cm) often does not change greatly, but organic compounds are distributed within the soil (Scullion and Malik, 2000). This creates aggregate stability in the upper soil layers due to the activity of organic matter and microorganisms, as well as aggregation in the lower soil layers caused by earthworms. Heterotrophic microorganism activity increases on the soil surface due to organic matter and earthworm activity; however, although earthworm activity is more intense in the lower soil layers, there is a significant decrease in aggregation due to the decrease in microbial activity (Scullion and Malik, 2000).

Due to the changes made by earthworms in the composition of soil organic matter, there are also significant changes in the mineralization and mineralization rate of organic carbonaceous compounds. In short, earthworms direct C mineralization (Lee et al. 1991; Edwards et al. 1996). The rate of formation and breakdown of organic carbonaceous compounds as a result of earthworm action is closely related to soil type, earthworm species and ecology. For example, epigeic species feed on organic matter in the A and O horizons on the soil surface and contribute significantly to the mineralization of organic matter, while anecic species carry organic and mineral particles from the subsoil depths to the soil surface. As a result of the combined activity of epigeic and anecic species in the soil, soil organic matter causes the A horizon on the soil surface to be covered by humus, forming a thin layer on the surface in the form of mineral-humus complexes (Sumner, 2000).

3.1.6. Effects of soils on plant nutrient content

As a result of earthworm activity in soils, microbiological activity is greatly increased with the improvement of soil aeration conditions, infiltration and good aggregation. In particular, the transformation of organic material into simple organic carbonaceous compounds by passing through the digestive system of the earthworm accelerates microbial activity. Useful nutrients are also released with high microbial activity. In addition, the soils around the galleries opened by feces and earthworms in the soil are rich in nutrients in the form of available nutrients. This is due to the fact that the soil along with the organic materials changes its form during the passage through the digestive system of the earthworm and the earthworms create favorable conditions for the conversion of the available nutrients in the soil into the available form (Kızılkaya and Hepşen, 2004; Materechera, 2002; Zhang et al., 2000).

3.1.7. Effect on soil reaction (pH)

The presence of earthworms in the soil causes partial changes in soil reaction. The effect of earthworms on pH is mostly related to the composition of feces and excreta. Earthworm droppings show a more alkaline reaction than soils. This is due to the presence of more basic cations (Ca^{+2}, Mg^{+2}, K^{+}) in the feces than in the soil. Earthworms are known to be texturally and mineral selective in their consumption of soil mineral components. Studies show that earthworms have higher amounts of $CaCO_3$ in their feces than in the soils they live in.

3.1.8. Effects on heavy metal content of soils

Bioaccumulation abilities of earthworms affect the heavy metal content of the environment they live in (Li et al., 2010; Wang et al., 2018). Especially in areas with heavy metal contents that have reached toxic levels, earthworms can reduce the heavy metal contents of the environment by accumulating heavy metals in their own tissues within their own living limits. For this purpose, earthworms are added to soils contaminated with heavy metals at toxic levels such as agricultural lands or closed mining areas. In studies, it has been determined that earthworms reduce the content of the environment to non-toxic levels and bioaccumulate toxic heavy metal amounts in their bodies in environments containing toxic levels of heavy metals (Kızılkaya 2004, 2005; Kızılkaya and Türkay, 2014; Turgay et al., 2011; Hepşen and Kızılkaya, 2007; Kızılkaya et al., 2009).

It seems to be a handicap that heavy metals return to the environment when earthworms, which are found in heavy metal contaminated areas and have

accumulated pollutants in their tissues, die in the same environment. However, in bioaccumulation studies, low voltages are used to bring the worms to the surface, collect them and remove them from the environment. Even if the worms removed from the environment are left in non-agricultural areas or destroyed, the pollutants return to nature. In new scientific studies with an environmentally friendly and recycling perspective, the recovery of heavy metals collected by bioaccumulation from tissues by biomanufacturing is being investigated.

3.2. Effects on Biological Properties of Soils

Earthworms mix organic matter and soil in the soil. Because of the high nutrient content of this mixture and their feces, and because these are organic carbonaceous compounds (mono- and disaccharides, various mucilagel substances, etc.) that are easier to break down, soils with feces and earthworm activity (galleries or burrows) contain high levels of microbial activity (Lee et al. 1991). In the assessment of microbial activity of soils, intracellular and extracellular enzyme activities, respiration or respiration rates and microbial biomass are used as parameters instead of total microorganism counts.

3.2.1. Effects on enzyme activity

Oxidoreductase group enzymes such as dehydrogenase, which belong to the intracellular group of soil enzymes, and hydrolases such as urease and phosphatase, which belong to the extracellular enzyme group, are more abundant in soils where earthworms are concentrated and in earthworm droppings. This is due to the higher concentration of materials (such as urea for urease) that are substrate sources for the enzymes. Studies have shown that earthworm feces have high levels of enzyme activity. However, the activity of some enzymes can also be found at lower levels in worm feces. This is due to the change in the pH of the feces away from the pH at which the enzyme in question shows optimum activity. For example, while the optimum pH for arylsulfatase enzyme is 5.5-6.0, arylsulfatase activity may decrease due to the higher pH of feces compared to soil. Similar situation can be seen in acid phosphatase activity. In the studies, it was determined that the levels of enzyme activity in earthworm feces were higher than the soils around the galleries they opened in the soil and the outer soils surrounding them, although it varied depending on the species of earthworms. The addition of organic matter to soils increases enzyme activity levels, but when earthworm activity is added to the same medium, enzyme activity levels in feces and soil are higher (Jégou et al., 2000; Zhang et al. 2000).

3.2.2. Effects on CO_2 production

Carbon dioxide production of soils is based on the principle that microorganisms use oxygen in the environment to produce carbon dioxide and the carbon dioxide produced is determined under laboratory conditions and is also called soil respiration. Since there is often a linear relationship between the carbon dioxide production of soils and the total number of microorganisms, carbon dioxide production is determined instead of determining the total number of microorganisms. Soils with the addition of earthworms or with a higher concentration of earthworms have a higher carbon dioxide production potential. Hendriksen (1997) investigated the effects of the addition of different numbers of earthworms (*L. festivus* and *L. rubellus*) to a sandy loam soil (organic matter 5%, pH 7.4) on the 48-hour carbon dioxide production of soils.

Although carbon dioxide production is used to evaluate the total number of microorganisms, the increase in the total number of microorganisms is not always a measure of productivity. Because it is not possible to determine whether the increased microorganism group belongs to the saprophytic microorganism group that feeds on dead plant or animal tissues only by measuring the amount of respiration. For this purpose, heterotrophic carbon dioxide production is determined by adding glucose or cellulose, the simplest carbohydrate, to soils. In this way, high heterotrophic carbon dioxide production due to increased organic compounds and nutrients in soils with high earthworm feces or activity is also determined. In studies investigating the carbon dioxide production capacity of earthworm droppings, it was determined that the carbon dioxide production amounts of both glucose added and non-glucose added samples were higher than the soil in which the droppings were present (Zhang et al., 2000; Kızılkaya and Hepşen, 2007).

3.2.3. Effects on microbial biomass

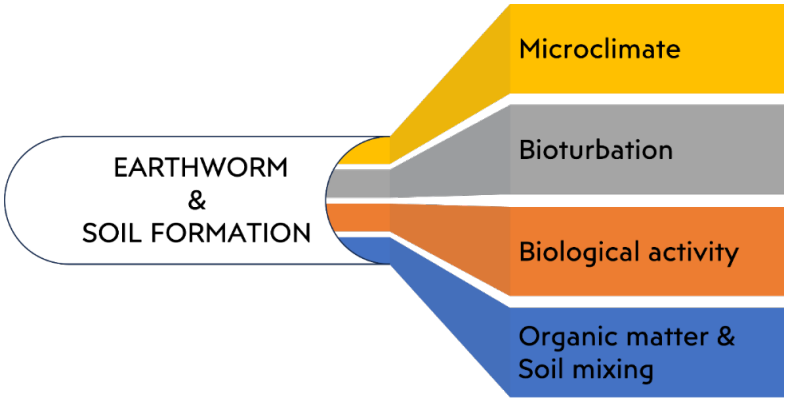
The total weight of microorganisms in each gram of soil is called the microbial biomass of that soil. As a result of the increase in the total number of microorganisms, the microbial biomass increases in most cases, but this is not always the case. Because, although there are approximately 108-109 total bacteria in 1 g of agricultural soil (depending on climate and soil properties), their biomass varies between 300-3000 kg/ha. On the other hand, the number of fungi in 1g of agricultural soil is approximately 105-106 and their biomass is between 500-5000 kg/ha. This situation varies according to the filamentous structure of microorganisms. In addition, just like carbon dioxide production, an increase in total microbial biomass does not always lead to an increase in productivity. Therefore, when microbial biomass is used as a parameter for

productivity, the biomass of heterotrophic microorganisms should be determined.

Microorganisms are the secondary nutrients of earthworms other than soil organic matter. Therefore, as microorganisms pass through the earthworm intestine, their numbers and total biomass decrease, but after a short period of time, they return to their previous levels in the feces and even reach higher levels (Zhang et al. 2000). The level of microbial biomass determined especially in new or fresh feces, which are a few days old, increases with increasing fecal age. This is due to the fact that microorganisms with a very short generation time consume easily degradable organic compounds in the feces to form new individuals. Among the groups of microorganisms passing through the intestine of worms, fungi show a more resistant structure than other microorganisms through their spores (Edwards and Fletcher, 1988; Hendriksen, 1990). For this reason, fungal biomass constitutes a large part of the total biomass in fresh feces. As the age of earthworm feces increases, microbial biomass-C levels also increase (Haynes and Fraser, 1998).

Soil and organic materials are crumbled and mixed as they pass through the digestive tract of earthworms (Lavelle et al., 1996). As a result, organic materials are dissolved and adsorbed in the feces. Feces contain less organic C of plant origin than aggregates or organic materials that have not been eaten by earthworms, and the total organic C content is higher. The vast majority (30-70%) of the organic C in feces is microbial biomass C and a small proportion (10-30%) is available C. The levels of microbial biomass C in earthworm droppings are higher than in the soil in which the earthworm is present. As a result of the processes carried out by applying earthworm droppings to soils, high levels of microbial biomass are added to the soils (Haynes and Fraser, 1998; Hepşen and Kızılkaya, 2009).

4. The Role of Earthworms in Soil Formation



Climate and living organisms are factors that directly affect soil formation. Earthworms play an important role in the effects of these two factors on soil formation. This effect has been the basis of our studies since the first studies in which the relationships between soil formation and earthworm activity were recognized and investigated.

Anecic earthworms, which have an important contribution to soil formation, create a microclimate in their burrows deep in the soil where they live. It is known that not only in steppes but also in wide plains in the process of soil formation, earthworm galleries in the soil profile increase bioturbation (Dokuchayev, 1883). Anecic earthworms are known to manage organic waste in the soil profile. Anecic earthworms go to the soil surface to feed and when they return to the gallery, they carry their feces back to the soil surface. Therefore, they move organic matter, which is also a substrate source for microorganisms, along the soil profile and increase biological activity (Bouché, 1977).

Anecic earthworms open their galleries perpendicularly from the soil surface to the depths. For this reason, there is a fall of organic materials from the surface to the soil depths, except for feeding. Anecic earthworms carry or store these organic materials that fill their burrows, sometimes to the surface and sometimes further away from their burrows along the horizontal or vertical profile. These unexpected accumulation points of organic matter caused by earthworms deep in soil profiles are called "crotovina". Recent studies have also shown that earthworms play a crucial role in the formation of chernozem (mollisols) soils, which make up 7% of the world's land surface and are of great agricultural importance (Dreibrodt et al., 2022). In addition, some researchers have reported that the bioturbation caused by earthworms is extremely important for archaeological and ecological studies (Prieto et al., 2009; Pietsch, 2013).

5. Environmental Impacts of Earthworms

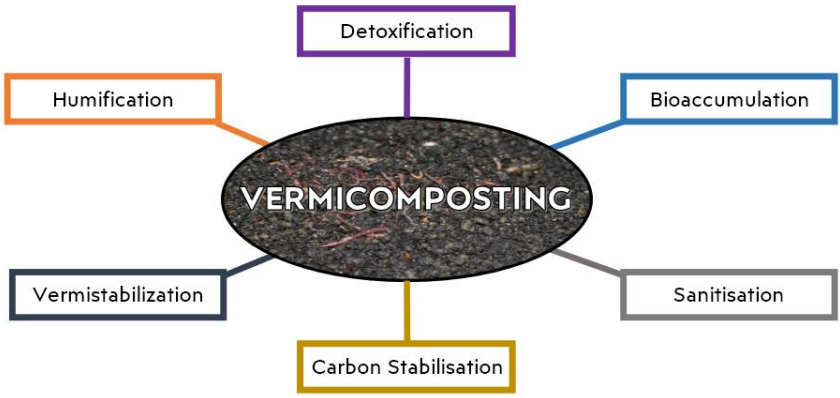
Nowadays, huge amounts of organic waste are generated from domestic, agricultural and industrial sources. The utilization of organic wastes and residues is one of the most important environmental problems. Organic wastes are tried to be utilized by various methods such as composting, biogas production and recycling.

According to the ecological classes of earthworms, some species of the epigeic class feed on organic wastes at high rates. They can be naturally colonized in piles of organic material, or they can be found in environments rich in organic matter, close to the surface, with high oxygenation and high humidity. Among these species, some species stand out in terms of adaptability,

reproductive rate and eating capacity. It is known that earthworms humify the organic matter they consume while passing it through their digestive system. In addition to mechanical breakdown, decomposition takes place by means of enzymes in the worm body and microorganisms living in the worm digestive system (Edwards et al., 2011).

Figure 6. *Eisenia fetida* species earthworms in vermicomposting pile

These species, which can naturally colonize in organic materials, are inoculated into piles of organic residues, and used in the transformation of organic materials. This process is called vermicomposting. Since all vital activities of earthworms in this method depend on ecological conditions, in order to obtain the highest conversion rate and the highest quality output, studies such as converting organic material into worm food (such as content, ratio, particle size), adjusting pile ecological conditions (such as pile internal temperature, moisture percentage, oxygenation), optimizing worm reproduction rate are called vermicomposting technologies (Namlı et al, 2010)



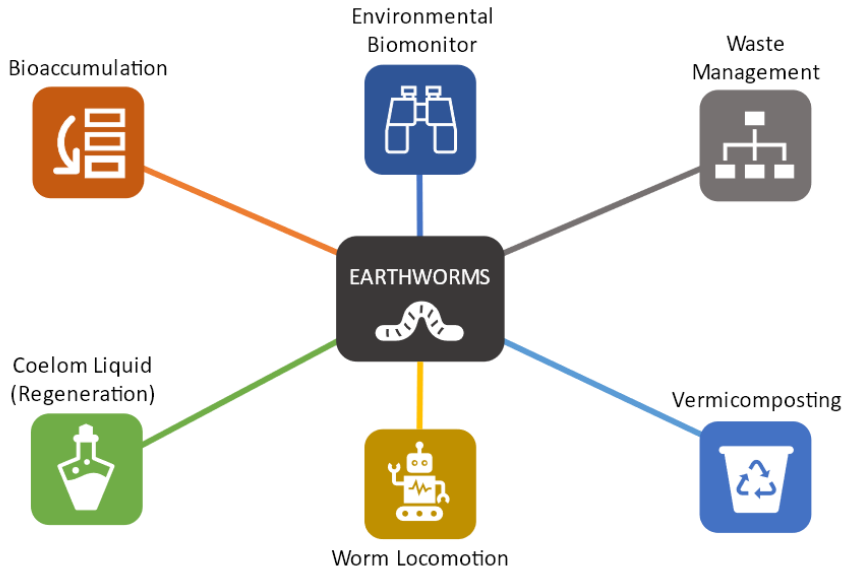
Vermicomposting is included in the general definition of composting but is not classified as traditional thermophilic composting or anaerobic cold composting. In vermicomposting, the composting process takes place within the worm by the microorganisms that the worm possesses. Since the diversity and population of aerobic microorganisms are very high in the environment of worms, the transformation of organic matter in the environment works bidirectionally. While these microorganisms decompose some of the organic matter, they also make some of it more easily consumable by earthworms. At the end of vermicomposting by earthworms and microorganisms, vermicast and a small amount of material that has not yet completed decomposition together constitute the vermicompost product. As an organic material, vermicast is of higher quality than the product consumed by the worm. This superiority of vermicompost is due to the very high microbial activity it contains. In addition, it is much richer in nutrients and plant growth regulators, has a narrow C/N ratio, neutral, salt-free and fine material (Türkay, 2023; Rakıcıoğlu and Kızılkaya, 2021).

When the vermicomposting process is compared with other composting techniques, the most humid process is that composting takes place in a mesophilic environment. This is advantageous as it allows the beneficial microorganism groups involved in the transformation of organic materials to live. Although the humification process of the material depends on the number of worms as well as the time it takes to pass through the worm digestive system, it is incomparably faster than other methods. Toxic elements that may originate from the raw material are eliminated by the detoxification ability of the worms, heavy metals above the limit value are stored in the bodies of the worms by bioaccumulation and heavy metal levels in the environment decrease rapidly. Pathogenic microorganisms carried into the environment along with the raw

material are digested by microorganisms in the worm digestive system and a non-thermophilic sanitization takes place. This allows even organic wastes containing highly toxic elements and pathogens to be transformed by earthworms. In addition, vermicompost provide plant protection against plant diseases and pests in soil and foliar applications (Kızılkaya and Hepşen Türkay, 2014).

Vermicompost fluid, which is involved in the mobility, reproduction, body hygiene and regeneration of earthworms, is a bright dark yellow liquid in the space between the mesoderm and endoderm. Worms rapidly secrete this fluid from the injured area, especially in case of injuries, and rapidly sterilize and repair the area. Although the coelom fluid is the subject of a separate study, it is one of the products of worms. Today, there are patented and commercially produced products of worms in the cosmetics industry and in the health sector. In agricultural terms, coelom liquid is used for plant protection purposes.

Figure 7. Taking the coelomic fluid secreted by earthworms with a syringe



Organic wastes that cause environmental problems are transformed into usable organic soil conditioners in an environmentally friendly way. The resulting high-quality product provides an alternative to the use of chemical fertilizers and an opportunity for sustainable soil health improvement and reliable food production.

CONCLUSION

The biology of earthworms, their vital activities, their functions in nature, and the benefits of their vital activities on sustainable soil health and soil fertility are presented in this study. In general, earthworms open galleries in the soil during their natural life, just like a volunteer gardener. Thus, they increase infiltration, ensure aggregation, regulate the distribution of organic matter by mixing the soil, increase the usefulness of nutrients and increase the microbial activity of the soil. As a result of all these functions, they provide significant increases in crop production. In addition to these contributions of earthworms to sustainable soil health:

- Some earthworm species, such as *Lumbricus terrestris* and others, have been used as important pollution biomonitors in recent years.
- In addition to being biomonitors, earthworms are known to bioaccumulate and store toxic elements in their bodies.

- Earthworms are known to detoxify with their ability to eliminate toxic substances through their digestive systems and microorganism groups living in their intestines.
- They also digest soil, plant, and animal pathogens with the mechanism in their digestive system. Therefore, they have a biological sanitization ability. With these properties, they decrease the number of pathogens in the environment while increasing the number of beneficial microorganisms.
- The highly regenerative cytosomal fluid of earthworms, which is used in traditional medicine in Far Eastern cultures, is still used today in the production of ointments and creams.
- The worms' naive but durable and persistent musculature and locomotor systems in the evolutionary process shed light on the development of humanoid robotic locomotion. The movements of robot worms are being researched.

Earthworms are indispensable for the protection and maintenance of ecological balance in the soil. However, earthworms are being destroyed by humans due to deforestation and the opening of new agricultural lands, the use of agricultural chemicals, the degradation of natural habitats for urbanization, and the effects of earthworms on soil health are often ignored. There is a need for more multi-disciplinary and multidisciplinary studies on the effects and possible contributions of earthworms to sustainable life.

REFERENCES

Bayraklı, B., & Gülser, C. (2023). Changes in some physical properties of the soils tread with wheat straw and rice husk under the rotation of white-head cabbage, tomato and wheat. *Soil Studies, 12*, 030-039. http://doi.org/10.21657/soilst.1328706

Bottinelli, N., & Capowiez, Y. (2021). Earthworm ecological categories are not functional groups. *Biol Fertil Soils, 57*, 329–331. https://doi.org/10.1007/s00374-020-01517-1

Bouché, M.B. (1977). Soil organisms as components of ecosystems. In U. Lohm & T. Persson (Eds.), *Ecol. Bull. 25* (pp. 122-132). Stockholm.

Chiarawatchai, N. (2010). Implementation of earthworm-assisted constructed wetlands to treat wastewater and possibility of using alternative plants in constructed wetlands. Technische Universität Hamburg.

Curry, J.P. (1998). Factors affecting earthworm abundance in soils. In C.A. Edwards (Ed.), *Earthworm ecology* (pp. 37-64). CRC Press.

Darwin, C. (1892). *The Formation of Vegetable Mould, Through the Action of Worms, with Observations on Their Habits* (12th ed., Vol. 37, Works of Darwin). J. Murray. (Original work held at Chicago Üniversitesi; Digitized 15 Eyl 2010).

Degens, B. (1997). The contribution of carbohydrate C and earthworm activity to the water-stable aggregation of a sandy soil. *Austral Journal of Soil Research, 35*, 61-71.

Demir, Z. (2019). Effects of vermicompost on soil physicochemical properties and lettuce (Lactuca sativa Var. Crispa) yield in greenhouse under different soil water regimes. *Communications in Soil Science and Plant Analysis, 50*(17), 2151-2168.

Dokuchaev, V. V. (1883). Russkiy chernozem [Russian chernozem]. *St. Petersburg*.

Dreibrodt, S., Hofmann, R., Dal Corso, M., Bork, H., Duttmann, R., Martini, S., Saggau, P., Schwark, L., Shatilo, L., Videiko, M., Nadeau, M., Grootes, P.M., Kirleis, W., & Müller, J. (2022). Earthworms, Darwin and prehistoric agriculture-Chernozem genesis reconsidered. *Geoderma, 409*, 115607. https://doi.org/10.1016/j.geoderma.2021.115607

Edwards, C.A. (1983). Earthworm ecology in cultivated systems. In J.E. Satchell (Ed.), *Earthworm ecology: From Darwin to vermiculture* (p. 123-137). Chapman and Hill.

Edwards, C.A., Bohlen, P.J., Linden, D.R., & Subler, S. (1995). Earthworms in agroecosystems. In P.F. Hendrix (Ed.), *Earthworm ecology and biogeography* (pp. 185-206). Levis.

Edwards, C.A., & Fletcher, K.E. (1988). Interactions between earthworms and microorganisms in organic matter breakdown. *Agriculture, Ecosystems and Environment, 24*, 235-247.

Edwards, W.M., Shipitalo, M.J., Ovens, L.B., & Nortons, L.D. (1990). Effect of Lumbricus terrestris on hydrology of continuous no-till corn fields. *Geoderma, 46*, 73-84.

Wikimedia Commons. (2021, February 1). Mating earthworms.jpg. https://commons.wikimedia.org/w/index.php?title=File:Mating_earthworms.jpg&oldid=529752025

Edwards, C. A. (2019). Natural Resources Conservation Service. *Home | NRCS Soils*. https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/biology/?cid=nrcs142p2_053863

Garvin, M., Martinez, F., Jesus, J., Gutierrez, M., Ruiz, P., & Cosin, D. (2001). Effect of Hormogaster erisae (Oligochaeta:Hormogastridae) on the stability of soil aggregates. *European Journal of Soil Biology, 37*, 273-276.

Geier, B., Oetjen, J., Ruthensteiner, B., Polikarpov, M., & Gruber-Vodicka, H., & Liebeke, M. (2021). Connecting structure and function from organisms to molecules in small-animal symbioses through chemo-histo-tomography. *Proceedings of the National Academy of Sciences, 118*, e2023773118. https://doi.org/10.1073/pnas.2023773118

Hallaire, V., Curmi, P., Duboisset, A., Lavelle, P., & Pashanasi, B. (2000). Soil structure changes induced by the tropical earthworm Pantoscolex corethurus and organic inputs in a Peruvian ultisol. *European Journal of Soil Biology, 37*, 251-254.

Hamman, A., Momo, A. R., Duhour, A., Falco, A., Sagario, M. C., & Cuadrado, E. (2003). Effect of UV Radiation on Eisenia fetida populations. *PedoboOwa et al. 035 ologia, 47*, 842-845.

Harris, L. (1992). *Concept in Zoology*. Harper Collins Publishers. pp. 619-624.

Hendriksen, N.B. (1990). Leaf litter selection by detritivore and geophagous earthworms. *Biology and Fertility of Soils, 10*, 17-21.

Hendriksen, N.B. (1997). Earthworm effects on respiratory activity in a dung-soil system. *Soil Biology and Biochemistry, 29*, 347-351.

Heynes, R., & Fraser, P. (1998). A comparison of aggregate stability and biological activity of the earthworms Lumbricus terrestris and Aporrectodea giardi and consequences on C transfer in soil. *European Journal of Soil Biology, 36*, 27-34.

Hickman, C.P., Roberts, L.S., & Hickman, F.M. (1988). *Integrated Principles of Zoology* (8th ed.). Times Mirror/Mosby College Publishing. pp. 304-309.

Hill, S. D., Saglam, N., & Shain, D. H. (2018). Reproduction in the Annelida. In M. K. Skinner (Ed.), *Encyclopedia of Reproduction (Second Edition)* (pp. 526-532). Academic Press. https://doi.org/10.1016/B978-0-12-809633-8.20648-1.

Hoeffner, K., Butt, K. R., Monard, C., Frazão, J., Pérès, G., & Cluzeau, D. (2022). Two distinct ecological behaviours within anecic earthworm species in temperate climates. *European Journal of Soil Biology, 113*, 103446. https://doi.org/10.1016/j.ejsobi.2022.103446.

Integrated Taxonomic Information System (ITIS). (n.d.). *On-line database*. www.itis.gov. https://doi.org/10.5066/F7KH0KBK

Jackhynes. (2006). Earthworms mating [Photograph]. Wikimedia Commons. https://upload.wikimedia.org/wikipedia/commons/f/f6/Mating_earthworms.jpg

Jégou, D., Cluzeau, D., Hallaire, V., Balesdent, J., & Tréhen, P. (2000). Burrowing activity of the earthworms Lumbricus terrestris and Aporrectodea giardi and consequences on C transfers in soil. *European Journal of Soil Biology, 36*, 27-34. https://doi.org/10.1016/S1164-5563(00)01046-3

Jegou, D., Schrader, S., Diestel, H., & Cluzeau, D. (2001). Morphological, physical and biochemical characteristics of burrow walls formed by earthworms. *Applied Soil Ecology, 17*, 165-174. https://doi.org/10.1016/S0929-1393(00)00136-0

KDS4444. (2016). The head of an earthworm, Lumbricus terrestris [Image]. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Earthworm_head.svg

Kızılkaya, R., & Hepşen, F. S. (2004). Effect of biosolid amendment on enzyme activities in earthworm (Lumbricus terrestris) casts. *Journal of Plant Nutrition and Soil Science, 167*(2), 202-208.

Kızılkaya, R., & Hepşen, Ş. (2007). Microbiological properties in earthworm cast and surrounding soil amended with various organic wastes. *Communications in Soil Science and Plant Analysis, 38*(19-20), 2861-2876.

Kızılkaya, R., & Türkay, F.Ş.H. (2014). Vermicomposting of anaerobically digested sewage sludge with hazelnut husk and cow manure by earthworm Eisenia foetida. *Compost Science & Utilization, 22*(2), 68-82.

Kizilkaya, R., Hepsen Turkay, F.S., Turkmen, C., & Durmus, M. (2012). Vermicompost effects on wheat yield and nutrient contents in soil and plant. *Archives of Agronomy and Soil Science, 58*, S175-S179.

Kumar, A. (2005). *Verms and Vermitechnology*. APH Publishing Corporation.

Lee, K.E. (1985). *Earthworms; their ecology and relationships with soil and land use*. Academic Press.

Lee, K.E., & Foster, R.C. (1991). Soil fauna and soil structure. *Australian Journal of Soil Research, 29*, 745-775.

Lee, K.E., & Smettem, K.R.C. (1995). Identification and manipulating of soil biopores for the management of subsoil problems. In N.S. Jayawardane & B.A. Stewart (Eds.), *Advances in Soil Science*. Levis Publishers.

Li, L., Xu, Z., Wu, J., & Tian, G. (2010). Bioaccumulation of heavy metals in the earthworm Eisenia fetida in relation to bioavailable metal concentrations in pig manure. *Biores. Technol., 101*, 3430-3436.

Materechera, S. (2000). Nutrient availability and maize growth in a soil amendment with earthworm casts from a South African indigenous species. *Bioresource Tecnology, 84*, 197-201.

Mısıroğlu, İ.M. (2001). Toprak Solucanları. *Bilim ve Teknik Dergisi. TÜBİTAK, 408*, 78-80.

Morgan, R., Ratner, S., & Denny, M. (1965). Response of earthworms to light as measured by the GSR. *Psychonomic Science, 3*, 27-28. https://doi.org/10.3758/BF03343000

Namlı, A., Kizilkaya, R., Turgay, O., & Camci Cetin, S. (2010). Effects of Earthworms on the Availability and Removal of Heavy Metals in Soil. https://doi.org/10.1007/978-3-642-02436-8_17

Owa, S., Peters, S., & Dedeke, G.A. (2008). Effects of light colour and oscillator frequency on earthworm bioactivity. *African Journal of Agricultural Research, 3*(1), 029-036.

Paoletti, M. (1999). The role of earthworms for assessment of sustainability and as bioindicators. *Agriculture, Ecosystems and Environment, 74*, 137-155.

Pietsch, D. (2013). Krotovinas-soil archives of steppe landscape history. *Catena, 104*, 257–264. https://doi.org/10.1016/j.catena.2012.12.003

Prieto, J., Böhme, M., Maurer, H., Heissig, K., Abdul Aziz, H. (2009). Biostratigraphy and sedimentology of the fluviatile untere Serie (Early and Middle Miocene) in the central part of the North Alpine Foreland basin: implications for paleoenvironment and climate. *International Journal of Earth Science, 98*, 1767–1791.

Rakıcıoğlu, S., & Kızılkaya, R. (2021). Çay fabrikasyon atığının windrow yöntemine göre kompostlanması. *Toprak Bilimi ve Bitki Besleme Dergisi, 9*(2), 62-68. https://doi.org/10.33409/tbbbd.998698

Schrader, S., & Zhang, H. (1997). Earthworm casting: stabilization or destabilization of soil structure? *Soil Biology and Biochemistry, 29*, 469-475.

Scullion, J., & Malik, A. (2000). Earthworm activity affecting organic matter, aggregation and microbial activity in soils restored after opencast mining for coal. *Soil Biology and Biochemistry, 32*, 119-126.

Singh, A., Tiwari, R., Sharma, A., Adak, A., Singh, S., Prasanna, R., Saxena, A.K., Nain, L., & Singh, R.V. (2016). Taxonomic and functional diversity of the culturable microbiomes of epigeic earthworms and their prospects in agriculture. *Journal of Basic Microbiology, 56*(9), 1009-1020. https://onlinelibrary.wiley.com/doi/full/10.1002/jobm.201500779

Sumner, M. (2000). *Handbook of Soil Science*. CRC Press.

Şişli, M.N., Bozcuk, A.N., Bozcuk, A.S., & Boşgelmez, A. (1979). *Genel Biyoloji 1. Basım*. M.E.B. Basımevi.

Tamlin, A.D., Shipitalo, M.J., Edwards, W.M., & Protz, R. (1995). Earthworms and their influence on soil structure and inflitration. In P.F. Hendrix (Ed.), *Earthworm Ecology and Biogeography in North America*. Levis Publishers.

Thomas, J. (2006). Simple diagram showing the location of the head, tail, and clitellum on an earthworm [Image]. Wikimedia Commons. https://upload.wikimedia.org/wikipedia/commons/9/97/Wormanatomy_simplified.png

Thorp, J.H., & Lovell, L.L. (2016). Keys to Nearctic Fauna. In J.H. Thorp & D.C. Rogers (Eds.), *Thorp and Covich's Freshwater Invertebrates (Fourth Edition)* (pp. 223-263). Academic Press. https://doi.org/10.1016/B978-0-12-385028-7.00012-3

Tiwari, N., Yadav, S., Lone, A., & Thakur, S. (2022). Earthworms: A Contrivance to Ameliorate Water Infiltration Rates and Water Holding Capacity in Agroecosystem.

Turgay, O. C., Kizilkaya, R., Karaca, A., & Cetin, S. C. (2011). Detoxification of heavy metals using earthworms. In *Detoxification of Heavy Metals* (pp. 407-421). Springer, Berlin, Heidelberg.

Türkay, İ., & Öztürk, L. (2023). The form, dose, and method of application of vermicompost differentiate the phenylpropene biosynthesis in the peltate glandular trichomes of methylchavicol chemotype of Ocimum basilicum

L. *Industrial Crops and Products, 198*, 116688. https://doi.org/10.1016/j.indcrop.2023.116688

Villee, C.A., Walker, W.F., & Barnes, R.D. (1984). *General Zoology* (6th ed.). CBS College Publishing Sounders College Publishing Holt, Rinehart and Winsten The Dryden Press.

Wang, K., Qiao, Y., Zhang, H., Yue, S., Li, H., Ji, X., & Liu, L. (2018). Bioaccumulation of heavy metals in earthworms from field contaminated soil in a subtropical area of China. *Ecotoxicology and Environmental Safety, 148*, 876-883.

Wilson, W.J., Ferrara, N., Blaker, A., & Giddings, C. (2014). Escape and avoidance learning in the earthworm Eisenia hortensis. *PeerJ, 2*, e250. https://doi.org/10.7717/peerj.250

Zhang, B., Li, G., Shen, T., Wang, J., & Sun, Z. (2000). Changes in microbial biomass C, N and P and enzyme activities in soil incubated with the earthworms Metaphire guilelmi or Eisenia fetida. *Soil Biology and Biochemistry, 32*, 2055-2062.

Chapter 6

Determination of Physiography's And Relationships with Surrounding Lands of Organic Farming Areas by Remote Sensing

Serden EROL, Sevda ALTUNBAŞ,
Bayram Çağdaş DEMİREL

ABSTRACT

Due to the crowded world population, increasing food needs, and decreasing agricultural areas, existing agricultural areas are being used quite intensively. As a result of these intensive uses, organic farming practices have become widespread as people prefer to reach healthy food and practices that harm nature less. Organic farming is a production model that supports chemical use at zero or minimum, targets quality and healthy products, provides control from the flowering of the product to its packaging, and tries to keep environmental factors under control. In this study, the status of agricultural activities in the highland and coastal areas of Antalya province, its physiography and its relationship with the surrounding lands were examined. It has been determined that there are 5 different physiography units in the districts of Antalya province Elmalı and Finike, which are selected as the field of study. It was determined that 77.60% of the 596,074 da certified organic agricultural land in Elmalı district is located on flat to almost flat lake bottom lands, 15.70% is located on flat to almost flat slightly undulating flood plain lands, and 6.70% is located on lake bottom flat lands with eroded undulating topography. It was determined that 69.80% of the 286,619 da organic farming land in Finike district was on very steep slope slope land, 17.65% was on medium slope slope land, 6.75% was on narrow surface stream terraces, 5.10% was on steep slope slope land and 0.70% was on skirt land. The relationship of the examined areas with the surrounding lands was interpreted, technical deficiencies not included in the legislation were evaluated and solutions were proposed.

1. Introduction

Food is one of the most basic needs of humanity. Especially in the last quarter century, in order to meet the demands of the increasing human population, more products are tried to be obtained from the unit area. As a result of these efforts, existing agricultural lands are used more intensively. These intensively farmed lands become inefficient, salinised or contaminated by chemical wastes over time. For inefficient soils, the plant nutrients lost by the soil before and during the production season are tried to be returned to the soil with chemical fertilisers. As a result of misuse due to deficiencies arising from this, agricultural lands can be destroyed. The application of not only chemical fertilisers but also chemical pesticides in increasing doses every year has negative effects on both the plant and the human beings consuming this plant.

Especially in the last quarter of the last century, the increase in diseases and environmental pollution and the decrease in natural resources have led to the desire of human beings to consume clean food or organic food. This desire has brought along the demands to consume the purchased food without being damaged in the process until it reaches the table and without losing its nutritional value. In other words, the need to protect consumer and environmental health has become an important factor not only in plant production but also in the stages of agricultural products until they reach the consumer. Thus, organic farming practices have become widespread as an alternative to conventional agriculture.

Organic farming is a holistic management system that supports the sustainability of the agricultural ecosystem and recommends necessary corrections (FAO/WHO, 1999). The aim is to ensure the sustainability of vital resources such as soil, air and water without harming them by preserving the natural balance. In many developing countries, organic agriculture is adopted as a method of improving household food security or reducing input costs (FAO, 2022). Although farmers pioneered the organic farming movement in Europe, European private organic farming companies played an active role in the adoption of organic farming in Turkey (Demiryürek, 2011). Organic farming activities, which started in 1984-1985, were realised within the framework of the rules of the International Federation of Organic Agriculture Movements (IFOAM) established in Germany in 1972. The first legal regulation in Turkey came into force in 1994 with the 'Regulation on the Production of Plant and Animal Products by Ecological Methods'. The last organic agriculture regulation in force today is the 'Regulation on the Principles and Implementation of Organic Agriculture'.

Organic agriculture has become a new sector in recent years due to reasons such as the awareness of sustainable agriculture in our country, changing

consumer habits, and preference for practices that are less harmful to the environment. According to 2019 data from the General Directorate of Crop Production (BÜGEM), 655,930 tonnes of vegetable production was achieved as a result of organic farming activities carried out by 20,763 registered farmers in our country. The areas where organic agriculture is practised and the types of products grown have increased over the years and have taken an important place in agricultural production. In 1990, when organic agriculture was not widespread in our country, the cultivated area was 1.037 ha and the variety of organic products grown was 8, while in 2019, when organic agriculture became widespread, the cultivated area increased to 505.551 ha and the variety of products increased to 247 (BÜGEM, 2019).

Kuşçu et al. (2009) stated that organic agricultural production, which has been carried out in Vakıflı village of Samandağ district of Hatay province in the Mediterranean Region since 2000, can also be carried out throughout the district. It is reported that the ecology and soil structure of the district is suitable for organic agriculture and that organic agriculture can be carried out in all soils of the district with the transition process to be implemented.

Yıldırım et al. (2013) stated that the Eastern Black Sea Region is one of the regions where the use of chemical inputs for agricultural purposes and industrialisation, which pose a threat in terms of environmental pollution, are the least. For this reason, they emphasised that it has an important potential for organic agriculture.

With the development of technology, many parameters that are important for crop production and land management can be analysed and interpreted by using remote sensing (RS) and geographic information systems (GIS) in conventional and organic agricultural lands (Bolca et al. 2003; Başayiğit et al. 2008; Peşkircioğlu et al. 2008).

In the study conducted by Demirel and Şenol (2019) using Quickbird satellite images, detailed mapping was carried out for settlement areas with rapid growth potential. In this detailed survey mapping study, Land Capability Classification Map, Classification Map according to the Soil Conservation and Land Use Law No. 5403 and Potential Use Map were created.

Gözükara (2019) examined the temporal and spatial change of the Burdur Lake Basin between 1975-2019 in his study in and around Burdur Lake, which continues to actively recede, and determined that the structures formed on the old lake bottom are not suitable for agriculture.

Organic farming activities in many regions of our country are carried out in different physiographies on different lands. The different characteristics of each physiography and soil and the land utilisation without determining these

characteristics sometimes make it impossible for organic agriculture production to be sustainable. Not only market problems, but also yield and quality losses due to the wrong selection of production areas cause farmers to give up organic agriculture and turn back to conventional agriculture.

For organic agriculture, which is a special type of production, it is necessary to determine the land and soil characteristics in detail and to open the land and soils to production with the most appropriate plant selection within their capabilities. Determination of land characteristics is known as a costly and time-consuming study. However, thanks to the new technologies developed, especially with the UA technology using aerial photographs and satellite images, lands can be classified and mapped in a short time and more economically.

In this framework, by using UA and GIS, it is possible to obtain fast, economical and highly accurate data on parameters such as location, climate, certain soil properties, yield estimation, topography, water resources, status with neighbouring lands and proximity to roads.

As a result, the sources of food, which is the basis of human nutrition, are plant and animal production. Soil, which is indispensable in both forms of production and is also considered as a basic element of the concept of land, can be formed under the influence of parent material, climate, living organisms, topography and time. As these factors change, many different soils are distributed in different physiographies. Physiographic features are of great importance especially in agricultural utilisation. In other words, the degree of influence of other factors (parent material, climate, time, organisms) that serve soil formation is directly related to physiographic structure. Therefore, physiography should be determined firstly in the planning studies to be carried out on the land. Because understanding a complex system such as soil can only be possible by associating it with its environment.

In this study, the areas of organic agriculture in selected regions (Elmalı and Finike districts) in Antalya province were mapped using UA technology and the compatibility of soil-land-plant selection in selected products was evaluated by emphasising the importance of the physiography factor, which is not included in the legislation.

2. Materials and Methods

2.1. Material

The study area is Elmalı and Finike districts in the west of Antalya province. Elmalı district is located between 29° 50'- 30° 11' east longitude and 36° 31'- 36° 54' north latitude. It is located in the northwest of Antalya province and its distance to the city centre is approximately 100 km. Finike district is located at

30° 09' east longitude and 36° 18' north latitude (Figure 1). The climate of Elmalı district belongs to the Mediterranean Intermediate transition climate type between the Mediterranean climate and the Central Anatolian climate (Atalay, 2012; Koday and Aydın, 2019). Semi-arid Mediterranean sub-Mediterranean climate type is observed in and around the Elmalı plain, and semi-humid Mediterranean sub-Mediterranean mountain climate is observed in the higher parts. (Atalay, 2020). Finike district is a typical Mediterranean climate in terms of climate. As characteristic of the Mediterranean climate, winters are mild and rainy, summers are hot and dry.

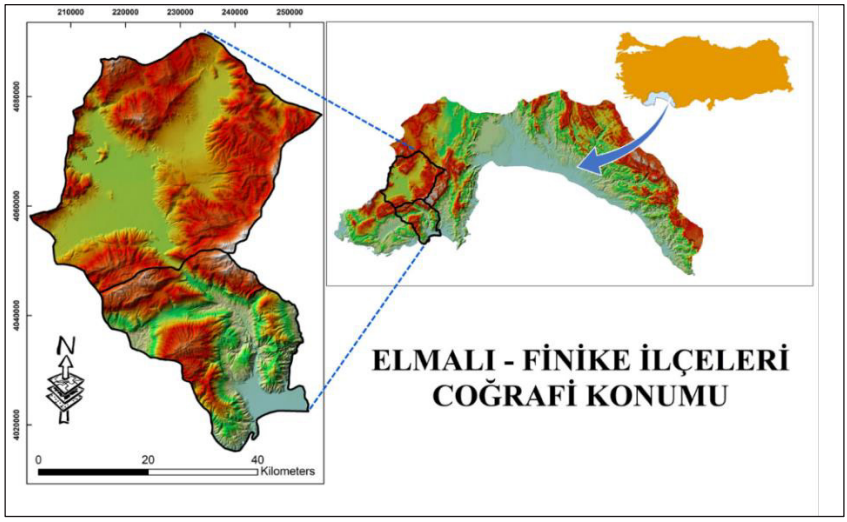


Figure 1. Geographical location of Elmalı and Finike districts

Geology and geomorphology of the study areas

Elmalı district has passed through many geological periods until it took its present shape. In the Elmalı Basin, which collapsed in the Plio-Quaternary period, alluvial fans and cones were deposited at the foot of the mountains and fine-sized alluvium was deposited in the lower part of the basin. Thus, there are three main lithological units; Mesozoic limestones in the higher parts of the area, Eocene clayey limestones in the eastern part and Plio-Quaternary alluvium in the basin. In Elmalı district, limestones cover the largest part in terms of area (Atalay, 2017).

While most of the rocks in the Finike region consist of Quaternary alluvials, Miocene aged sandstones, conglomerates, claystones, Eocene aged neritic limestones, Cretaceous aged neritic limestones are also observed (Şenel 1981). The biggest factor in the Finike plain taking its present shape is the rivers. It was

formed by the rivers coming from high regions reaching the Finike Plain where the slope is very low and storing the materials they carry in different sizes. One of the rivers effective in the formation of the Finike Plain is Akçay Stream. The waters stored in the region through the sinkhole formations in and around Lake Avlan come to the surface from different sources in the lower parts of the Avlan waist. Akçay Stream, which originates from Akçay Valley and flows into the sea, contributed to the alluvial filling of the Finike Plain thanks to the materials it carries.

Soils of the study areas

The soil types in Elmalı district are as follows: 31,5% (40326 ha) Red Mediterranean soils, 21,5% (25795 ha) Red Brown Mediterranean soils, 15,3% (19651 ha) Chestnut coloured soils, 15, 1% (19332 ha) is Alluvial soils, 9,9% (12621 ha) is Brown Forest soils, 5,5% (7050 ha) is Colluvial soils, 1,1% (1406 ha) is organic soils and 0,1% is Hydromorphic Alluvial soils (Anonymous, 1993).

There are alluvial soils formed by the storage of the materials carried by Akçay and Alakır rivers in the soils of Finike district. There are also colluvial soils in the foothill areas of mountainous areas in the district. Brown Forest Soils are encountered in the regions where the vegetation is dense.

Organic agricultural lands in the study area

The organic agricultural lands to be used in the study are 'Certified Agricultural Lands' certified by the Ministry of Agriculture and Forestry. The lands belonging to the 'Organic Agricultural Land' certificate of 2020 for Elmalı district and 2016 for Finike district were used.

2.2. Methods

In this study, which was carried out by making use of Remote Sensing and Geographical Information Systems technologies, 1/25000 scale Topographic Maps, 1/25000 and 1/100000 scale Geological Maps, Aerial Photographs of different dates, some of which are stereo, and several Satellite Images of different dates were used as basic cartographic materials for the determination of geomorphological differences and physiographic units and for the differentiation of different soils.

The Methodology part of the research was completed in 2 main stages: office and field. The cartographic materials (satellite images, digital elevation model (DEM) data, aerial photographs) collected in the first stage were processed in ArcGIS 10.2 programme, the high-resolution images obtained were overlaid on top of each other to obtain 3D images and physiographic analyses were

performed. The parcels where organic agriculture was carried out in Elmalı and Finike districts were processed on the maps, the physiographies of these areas were determined and the lands were evaluated according to their physiographic characteristics. In this context, the physiographic units in the study area were distinguished according to the principles of "Schematic Legend and Handbook of Land Physiographic Units" prepared by Kurucu et al. (2015) and published by the General Directorate of Agricultural Reform.

3. Results and Discussion

In this study, a detailed physiography research was carried out on the parcels located in Elmalı and Finike districts of Antalya province and registered by the Ministry of Agriculture and Forestry for organic farming. Organic agricultural lands were mapped using UA and GIS technologies with the help of available cartographic data and the suitability of the selected areas for organic agriculture was evaluated by considering their suitability for physiography. The 2016 and 2020 data of the registered organic agricultural lands in the study area were analysed. As a result of the processing and interpretation of digital elevation data (DEM), spatial and spatial data of organic farming areas, satellite images, a total of 8 different physiographic units were identified within the study areas (Elmalı and Finike).

All of the organic agricultural lands in the Elmalı district consist of soils developed on fluvial deposits formed by the lacustrine materials in the old lake bottom physiography and the deposits of the side streams coming from the environment. While Avlan Lake, a tectonic depression lake, was one of the most important wetlands of the lake's region; it was dried and distributed to the local people in the 1980s in order to gain agricultural land. As it is known, the lands opened to agriculture by drying are generally considered to be quite inefficient in terms of agricultural potential. This is because the materials that emerge to the terrestrial environment are not called soil but main material. These materials, which come to the terrestrial environment, then start to be exposed to soil formation processes and this process is quite a long period of time.

In Elmalı district, an area of 596,074 da where organic farming activities are carried out was identified. When the physiography of the study area was classified in detail; it was determined that the areas where organic agriculture activities are carried out are divided into 2 different physiographic units on the old (Neogene-sub-quartz) lake bottom. These physiographic units are flood plains which are close to flat and slightly undulating flood plains and lands with eroded-wavy topography (Figure 2). The geomorphological force that forms the flood

plain physiography is the Akçay river, which has its headwaters in Gömbe and ends in the Avlan Lake lands in the south of the Elmalı Plain.

When the registered organic farming areas in Elmalı region were analysed; it was determined that 462,551 da (77.6%) consisted of flat to almost flat lake bottom plains, 93,59 da (15.7%) consisted of flat to slightly undulating flood plains and 39,927 da (6.7%) consisted of eroded to undulating topography on lake bottom plains.

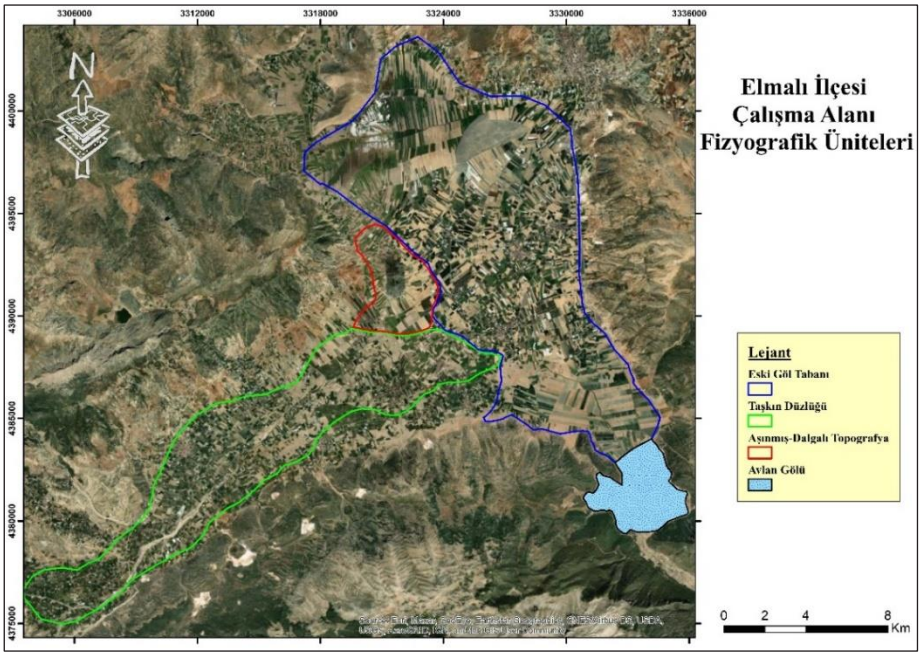


Figure 2. Physiographic units of Elmalı district study area

It has been determined that the registered organic farmland in Finike district has spread over a wide area and these are basically in 3 different physiographs on alluvial lands and at the foot of high lands (Figure 3). These physiographic units: It is detected as a flat-wave skirt terrain, narrow-surface stream terraces, linear mid-sloping slope, linear steep slope and linear very steep slope.

According to the data obtained from the Ministry of Agriculture and Forestry, it was determined that organic farming activities started in Finike district in the 2000s, and according to 2016 data, pomegranate and orange cultivation was carried out in an area of 286,619 da. However, according to 2020 data, it was determined that there is no agricultural production area with organic agriculture certificate in Finike district.

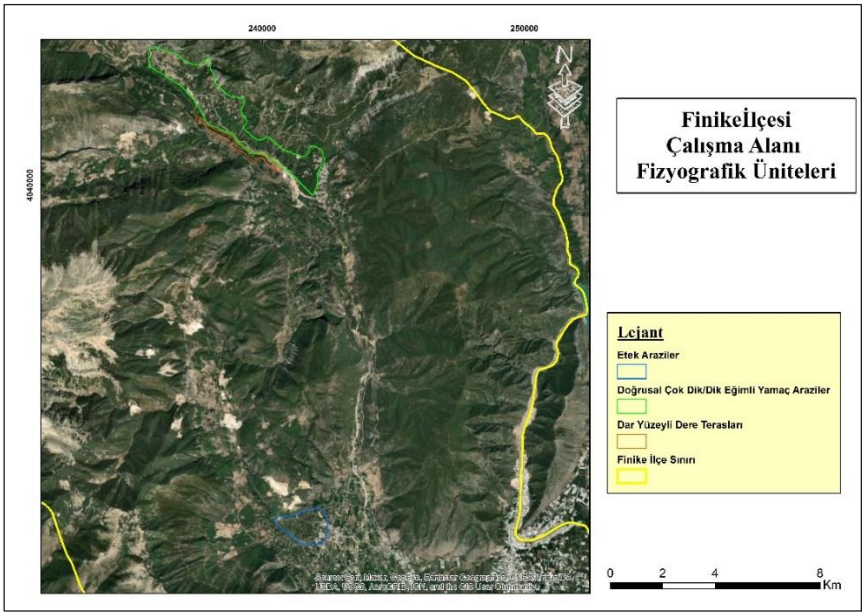


Figure 3. Physiographic units of the study area of Finike district

According to the data of 2016, organic farming activities were carried out in the area in 286,619. Within these areas; Linear very steep slope land in 200,083, linear mid-sloping slope land in 50,607, narrow surface stream terraces in 19,375, Linear steep slopes in 14,617 and area in 1,937 are designated as skirt terrain.

According to the organic agricultural production data of Finike district in 2016; It was determined that 286.19 organic farming area was produced in 241.55, (84.28%) pomegranate and 45.064 (15.72%) orange.

When the organic farming areas in the study area are examined, the proximity of the lands to city structures, other agricultural lands and roads draws attention (Figures 4 and 5). (Figure 4. and 5.) Due to the rapidly increasing urbanisation, motorway transport and traffic caused by the increase in the number of vehicles per capita, the risk of heavy metal pollution in the soil of these lands in the future. This heavy metal pollution poses a risk for all living organisms in the food chain.

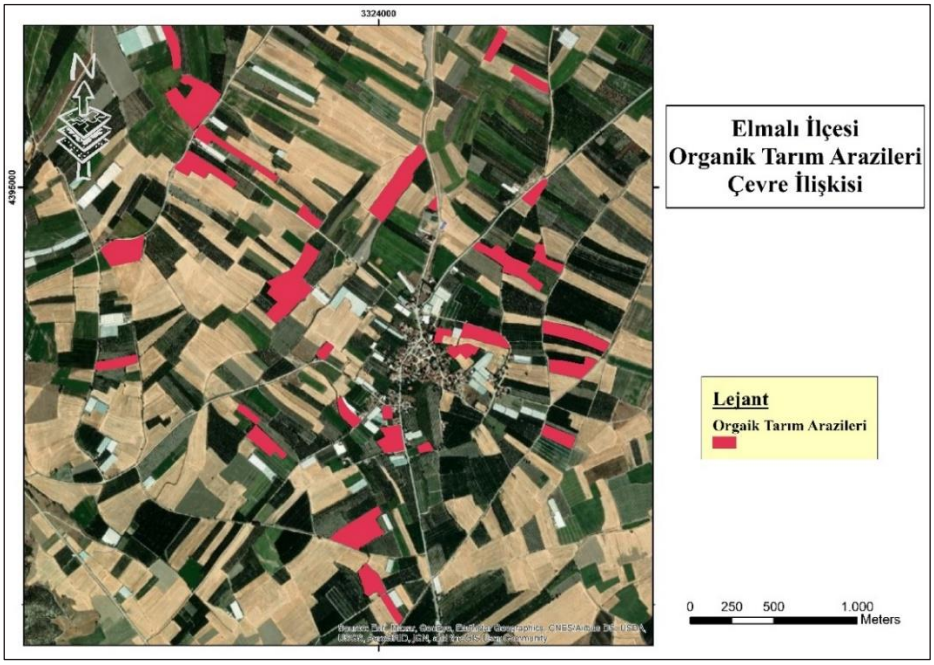


Figure 4. Elmalı district organic farming lands environment relation

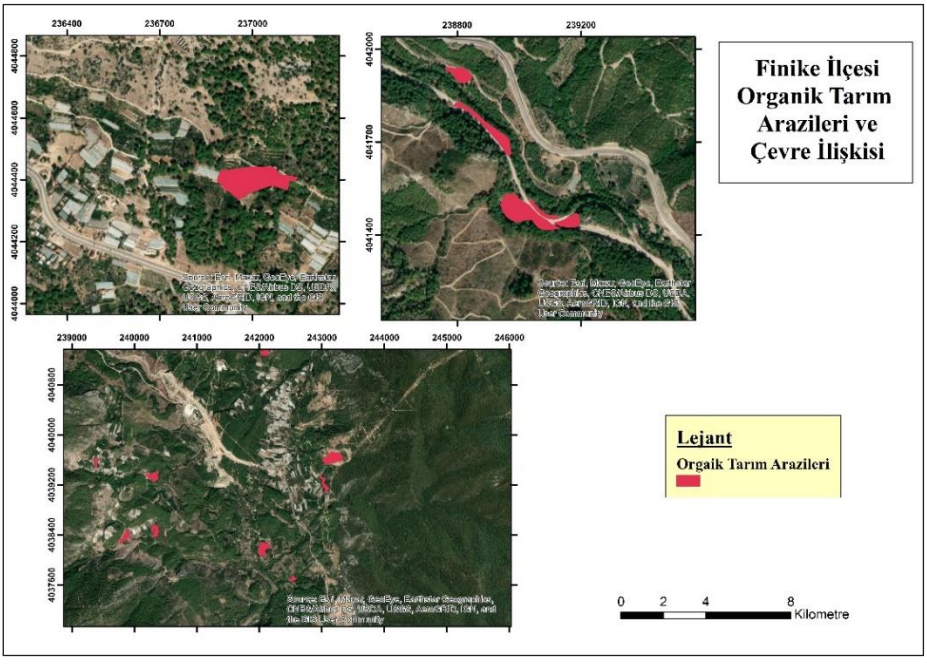


Figure 5. Finike district organic farming lands environment relation

On the other hand, chemical processes such as spraying and fertilisation in conventional agricultural lands, which are very close to organic agricultural areas, may be carried to organic agricultural areas by winds and insects and may cause problems such as chemical fertiliser contamination risk and pesticide residues for organic cultivated products. In addition, when these areas where organic agriculture activities are carried out are analysed on a basin basis, it is noteworthy that highland greenhouse activities are increasing day by day, especially in Elmalı district. It is inevitable that the chemicals used in these areas will affect the quality of organic agriculture production. In this regard, land surveys and use planning are very important.

4. Conclusion

Intensive agricultural practices have not always been friendly to the environment and human health. Some negative effects of chemical fertilisers and pesticides on human health have emerged, and people concerned about food safety have changed their eating habits. Organic agriculture has become widespread due to consumers' desire for foodstuffs containing zero or minimum level of chemicals.

In this study, using remote sensing and geographical information systems, two districts of Antalya province were selected to represent the coastal and highland parts of the province and the status of organic agricultural lands was analysed. In this study, the physiographic characteristics of the certified organic agricultural lands operating in Finike district in the coastal region and Elmalı district in the highland region and their relations with the surrounding lands were interpreted. In the study areas, which are very favourable for plant production in terms of climate and geographical conditions, it has been determined that organic agricultural lands occupy less space than expected. When we examined the areas operating as organic farming areas, it was seen that greenhouse farming and traditional agricultural activities were intensively carried out in the immediate vicinity.

When we examined the physiography of the Elmalı region, it was determined that organic agricultural areas were intensive in the former lake bottom lands. It is known that these areas are distributed in the lowest point of Lake Avlan, in other words, in the last part of Lake Avlan that reaches the terrestrial environment, that there are various soil problems in these areas, and accordingly, soil formation is weaker than other areas in the basin. It is concluded that this situation is a factor limiting the production of land and soil conditions in organic agriculture production in the region.

When the physiography of Finike region was analysed, it was found that, unlike Elmalı district, most of the organic farming areas are located on steep and very steep slope slopes. It has been concluded that the cultivation activities to be carried out in these areas have problems both in terms of economic and labor.

When the organic products cultivated are analysed in terms of variety, it is seen that the organic agriculture pattern in both regions is horticultural crops, especially fruit growing. This plant production pattern has developed over time in accordance with the ecological, economic and social structure of the region. Some of the conventional production has also switched to organic production in these regions.

Due to the physiographical location of the organic agricultural lands, it has been determined that attention should be paid to the accumulation of heavy metals and especially copper (Cu) accumulation in these organic agricultural lands as a result of reasons such as the mixing of heavy metals applied in conventional agriculture into groundwater and the transfer of chemicals used in high areas to low areas due to the effect of slope. The proximity of organic agricultural lands to urban structures, roads and areas where traditional agriculture is practised draws attention. It has been concluded that various chemicals, diseases and pests are transported from these lands close to each other by environmental and climatic effects (wind, precipitation, etc.) and this situation damages organic production in ecological and economic terms. In this context, when the laws and regulations related to organic agriculture were examined, it was seen that there was no spatial or physiographic article that would pose a threat to organic agriculture. It is concluded that this situation is important, and a new article should be added to the regulation on this subject.

It is thought that both producers and consumers are not fully informed about organic agriculture and its activities, and new policies and trainings should be developed in order for these activities to reach the desired levels. In addition, people should be instilled with the awareness that organic products not only have positive effects on health, but also provide many contributions to natural life and economy. As a result of the interviews with the producers who had been engaged in organic farming activities in the region in the past years, but then gave up, it was concluded that the reasons for giving up organic farming were the high labour and input costs compared to conventional agriculture, whereas the cost increased even more with the decrease in yield per unit area. As a matter of fact, the development of organic agriculture especially in the Finike region has been in this direction, and the Finike farmer gave up organic agriculture production, which he started in 2016, in 2020 and returned to conventional agriculture. In this

regard, producers expect the state to provide insurance to organic agriculture producers and to provide the necessary incentives/grants.

Finally, when the organic agricultural activities carried out in the regions in the study area were examined, it was determined that production was carried out in small and scattered parcels. It has been concluded that these lands should be planned and used based on the principles of organic agriculture, away from other agricultural lands and environmental factors, in areas of aggregation and / or large basins, encouraged and supported by the state, and awareness of producers and consumers should be raised.

References

Anonim, 1993. Antalya İli Arazi Varlığı T.C. Tarım ve Orman Bakanlığı Köy Hizmetleri Genel Müdürlüğü Yayınları, Ankara, 190ss

Atalay, İ., 2017. Türkiye Jeomorfolojisi. Meta Basım, İzmir. 636 s

Atalay, İ., 2020. İklim Sınıflandırmaları, Klimatoloji Şube Müdürlüğü, Meteoroloji Genel Müdürlüğü.

Başayiğit, L., Şenol, H. 2008. Meyve yetiştirme potansiyeli yüksek alanların Coğrafi Bilgi Sistemleri ortamında belirlenebilirliği ve uzaktan algılama metodu ile kontrolü. SDÜ Ziraat Fakültesi Dergisi, 3(1) 1-8 s.

Bolca, M., Altınbaş, Ü., Kurucu, Y. 2003. Arazi Fizyografyası İle Toprak Taksonomik Birimleri

BÜGEM, 2019. Organik Tarımda Genel Bitkisel Üretim Verileri

Demirel, B. Ç., ve Şenol, S. (2019). Hızlı büyüme potansiyeline sahip yerleşim alanlarının detaylı toprak etütleri ve arazi değerlendirmeleri: Mustafalar köyü örneği, Adana. Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi, 29(4), 711-721.

Demiryürek K. 2011. Organik Tarım Kavramı ve Organik Tarımın Dünya ve Türkiye'deki Durumu, Gaziosmanpaşa Üniversitesi, Ziraat Fakültesi Dergisi, 2011, s. 27-36

FAO (2022) Organic Agriculture. https://www.fao.org/organicag/oa-faq/oa-faq1/en/ Accessed 16 February, 2022

FAO/WHO (1999) Codex Alimentarius Commission, Fifteenth Session, Rome https://www.fao.org/3/X0075e/X0075e.htm

Koday, Z., Aydın, T., 2019. İdari Coğrafya Özellikleri Açısından Elmalı (Antalya) İlçesi, Atatürk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, Mart 2019 23(1): 67-92

Kurucu Y., Sarı, M., Delibacak, S., Arcak, Ç., Duran, A. R., Esetlili, T., Özen, F., 2015. Toprak Haritalama Amaçlı Foto Yorumlama Çalışmaları için Arazi Fizyografik Birimleri Şematik Lejantı ve El Kitabı, Tarım Arazileri Değerlendirme Dairesi Başkanlığı.

Kuşçu, V., Tunçel, H., 2009. Samandağı'nın (Hatay) Organik Tarım Potansiyeli, Fırat Üniversitesi Sosyal Bilimler Dergisi- Fırat University Journal of Social Science, 19 (2) 43-59 s.

Peşkircioğlu, M., Torunlar, H., Alsancak Sırlı, B., Özaydın, K.A., Mermer, A., Şahin, M., Tuğaç, M.G., Aydoğmuş, O., Emekliler, Y., Yıldırım, Y.E., Kodal, S., 2013.Türkiye'de çeltik (oryza sativa L.) yetiştirmeye uygun potansiyel alanların CBS teknikleri ile belirlenmesi. Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi, 22(1): 20-25 s.

Şenel, M., Serdaroğlu, M., Kengil, R., Ünverdi, M. ve Gözler, M.Z. 1981. Teke Toroslarının güneydoğusunun jeolojisi. MTA Dergisi, (128): 35-37 s.

Yıldırım M., Bayram B., Yolcu H., Kalkışım Ö., Aksakal V., Kantar F. 2013. Organik Vadi Olma Yolunda "Doğu Karadeniz Bölgesi". Türk Bilimsel Derlemeler Dergisi 6 (1): 113-117 s.

Chapter 7

Hazelnut Cultivation and Hazelnut Studies Trends in the World and Türkiye

Serkan UZUN[1]

[1] *Asst. Prof. Dr.; Düzce University, Çilimli Vocational School, Department of Plant and Animal Production. serkan.uzun28@hotmail.com ORCID No: 0000-0002-3857-6561*

ABSTRACT

Hazelnuts, which belong to the genus *Corylus*, are a type of nut distributed in various regions of the northern hemisphere with temperate climates. Hazelnut can be consumed raw or roasted and are used in various consumption styles, including the chocolate and confectionery industries, which contribute to their popularity worldwide. According to FAO data for 2021, global hazelnut production covers an area of 1 039 147 hectares, with a total production of 1 077 117 tons. Türkiye leads both in hazelnut production area and quantity, followed by Italy and Azerbaijan in terms of production area, and Italy and the USA in terms of production quantity. Hazelnuts are a valuable agricultural product for Türkiye, with a significant share in exports. In 2022, according to KIB data, Türkiye earned $1 748 835 811 from hazelnut exports, with Germany and Italy being the top export destinations. The increase in hazelnut production over the years has drawn the attention of researchers, resulting in numerous studies on various aspects of this type of fruit. In studies indexed in the Web of Science (WOS) database, it is evident that the first study on hazelnuts was published in 1982, and the number of studies has shown a consistent upward trend. These published studies cover a wide range of research topics, including Food Science Technology, Chemistry, Agriculture, and Engineering. Furthermore, these studies have been conducted in many different countries, with a particular focus on Türkiye, Italy, Spain, and the USA.

Keywords: *Corylus avellana*, hazelnut production, hazelnut research

INTRODUCTION

The hazelnut, *Corylus* L., is a member of the subfamily Coryloideae of the Betulaceae family, order Fagales (Bassil et al., 2013). Within the genus *Corylus*, there are 9-25 species of hazelnuts, which come in both shrub and tree forms (Islam, 2019). In the Northern Hemisphere, 11 species of *Corylus* are commonly found. Two of these species, *Corylus avellana* and *Corylus colurna,* are endemic to Europe and Asia Minor. These species are among the most commercially valuable ones (Özçağıran et al., 2014; Köksal, 2018; Karakaya, 2021). Additionally, there are distinct species specific to North America, the Himalayas, and Asia (Whitcher and Wen, 2001; Bassil et al., 2013).

Hazelnuts (*Corylus avellana* L.) are widely distributed across several regions in the Northern Hemisphere, primarily in temperate zones (Kılıç and Alkan, 2006; Uzun, 2021). The European hazelnut's geographic range stretches from the Mediterranean shores of North Africa in the south to the British Isles and the Scandinavian peninsula in the north. It also extends eastward to the Ural Mountains in Russia, the Caucasus Mountains, Iran, and Lebanon (Kasapligil, 1972; Bocacci and Botta, 2009).

Hazelnut production still relies on historic varieties that were chosen from the native, natural flora in the traditional agricultural areas around the Mediterranean Basin, particularly in Türkiye, Italy, and Spain. Significant cultivars include Tombul, Fosa, and Palaz in Türkiye; Negret in Spain; and Tonda Gentile delle Langhe, Tonda di Giffoni, and Tonda Romana in Italy. Especially their compliance with the processing criteria of the confectionery industry has been effective in bringing these varieties to the forefront (Botta et al., 2019).

Hazelnuts are a type of fruit beloved by people worldwide for their flavor and diverse usage possibilities, and they are in high demand in global markets. Hazelnuts, rich in phenolics, fat and fatty acids, protein, carbohydrates, dietary fiber, vitamins, and minerals have beneficial effects on human health (Alasalvar et al., 2010; Karakaya et al., 2023) and are also an important source of energy (Sımsek and Aykut, 2007). Hazelnut can be consumed both in their natural form and when roasted. Moreover, they are utilized as additives in a wide range of products, including chocolate, confectionery, baked goods, and cooking oil (Shahidi et al., 2007; Yaman et al., 2023).

HAZELNUT PRODUCTION IN THE WORLD

Hazelnuts have different consumption possibilities and are produced in many countries worldwide. While the products produced meet local needs in some countries, it is known that some countries earn significant income from this product. According to The Food and Agriculture Organization (FAO), data on hazelnut

production areas between 2017 and 2021 are presented in Table 1. Accordingly, it is seen that hazelnut production areas are expanding from year to year. Hazelnut production, made in an area of 939 811 ha in 2017, increased to 1 039 147 ha in 2021, an increase of 10.7%. In the same period, Türkiye's production areas had a 4.56% expansion. Türkiye has the largest areas in terms of hazelnut production. As of 2021, production is carried out in an area of 738 920 hectares. Then come Italy (82 590 ha), Azerbaijan (48 968 ha), Georgia (25 550 ha), Iran (25 587 ha), and USA (24 686 ha), respectively (Figure 1, Table 1).

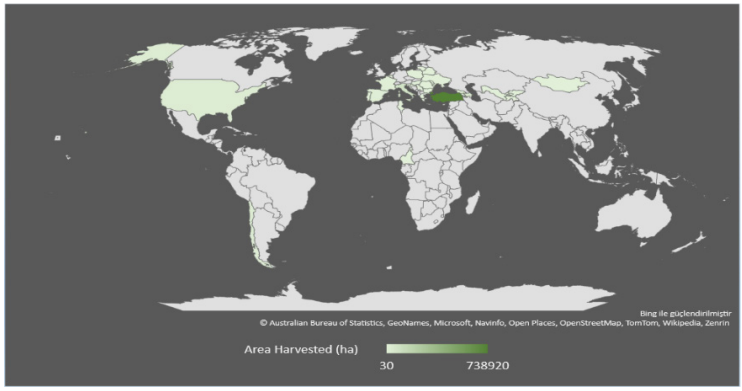


Figure 1: World hazelnut area harvested in 2021 (FAO, 2023)

Table 1: World hazelnut area harvested in 2017-2021 (ha)

Country	2017	2018	2019	2020	2021
Türkiye	706 667	728 381	734 409	734 538	738 920
Italy	73 772	78 590	79 350	80 280	82 590
Azerbaijan	35 782	39 021	43 381	44 502	48 968
Georgia	11 721	9 354	13 306	18 146	25 550
Iran	25 234	26 131	25 131	25 499	25 587
USA	16 190	17 810	20 235	24 281	24 686
Chile	13 110	13 104	24 437	24 430	24 456
Spain	12 806	13 510	13 020	13 070	13 110
China	11 838	12 460	12 527	12 627	12 538
Kyrgyzstan	6 367	6 534	6 435	6 445	6 471
France	6 232	6 680	5 190	5 540	7 510
Croatia	3 840	4 810	5 530	6 540	6 710
Serbia	3 218	4 363	4 479	4 922	5 083
Poland	3 740	3 720	3 750	5 400	5 400
Uzbekistan	3 000	3 000	3 000	3 000	3 000
Others	6 294	6 786	7 969	7 703	8 568
World (Total)	939 811	974 254	1 002 149	1 016 923	1 039 147

Source: FAO, 2023

Data based on FAO world hazelnut production values between 2017 and 2021 are presented in Table 2. Accordingly, a total of 5 140 998 t of hazelnuts were produced in the world between 2017 and 2021. There was a 7.54% increase in hazelnut production, which was 1 001 627 t in 2017, by 2021. Although hazelnut is a type of nut that experiences yield fluctuations from year to year and increases and decreases in production amount, it can be stated that the total world production is generally at a similar level in 2017-2021. Only a significant decrease in production in 2018 is noteworthy during this period. This decrease can be associated with the decrease in Türkiye's production amount in the same year (Table 2).

When the 5-year production data between 2017-2021 is examined, Türkiye is the leading producer country that meets 65% of the total world hazelnut production. It is seen that a total of 3 315 046 t of hazelnuts were produced in the country during these five years. This is followed by Italy (587 741 t), Azerbaijan (268 486 t), USA (242 490 t), Chile (149 421), and Georgia (141 100 t). When the data for 2021 is examined, 684 000 t of hazelnuts are produced in Türkiye, followed by Italy (84 670 t), USA (70 310 t), Azerbaijan (67 630 t), Georgia (46 000 t) and Chile (35 291 t), respectively (Table 2).

Table 2: World hazelnut production in 2017-2021 (t)

Country	2017	2018	2019	2020	2021	Total
Türkiye	675 000	515 000	776 046	665 000	684 000	3 315 046
Italy	131 281	132 700	98 530	140 560	84 670	587 741
Azerbaijan	45 530	52 067	53 793	49 465	67 630	268 486
USA	29 030	46 270	40 820	56 060	70 310	242 490
Chile	16 800	20 330	40 000	37 000	35 291	149 421
Georgia	21 400	17 000	24 000	32 700	46 000	141 100
China	24 519	24 509	24 312	24 447	24 423	122 210
Iran	12 790	13 688	13 745	13 407	13 613	67 243
France	11 111	15 660	11 660	9 690	12 340	60 461
Spain	10 487	8 030	12 370	5 450	7 780	44 117
Poland	4 635	6 640	5 440	7 700	7 600	32 015
Serbia	4 196	5 428	4 949	6 689	6 242	27 504
Kyrgyzstan	4 218	4 295	4 245	4 253	4 264	21 275
Uzbekistan	3 685	3 728	3 638	3 684	3 683	18 418
Croatia	1 534	1 740	1 960	3 040	1 880	10 154
Others	5 410	6 327	6 035	8 154	7 390	33 317
World (Total)	1 001 627	873 412	1 121 543	1 067 299	1 077 117	5 140 998

Source: FAO, 2023

HAZELNUT PRODUCTION IN TÜRKİYE

Hazelnut is an important agricultural product globally, and Türkiye is the primary producer of hazelnuts. According to Turkish Statistical Institute (TUIK), data on Türkiye's hazelnut production areas at the provincial level between 2018-2022 are presented in Table 3. When the production areas at the regional level are examined, it is seen that as of 2022, the highest production is made in the Eastern Black Sea region on an area of 4 209 240 da, followed by the Western Black Sea (1 671 872 da) and Eastern Marmara (1 528 784 da), respectively. The hazelnut production area in Türkiye, which was 7 283 808 da in 2018, reached 7 440 473 da by 2022, showing an increase of 2.16%. Accordingly, it shows that in Türkiye, which has large production areas, efforts are still being made to increase production areas yearly. As of 2022, it is seen that Ordu province has the largest production area with 2 272 158 da. After Ordu province, Samsun (1 206 479 da), Giresun (1 177 290 da), Sakarya (789 135 da), Trabzon (651 799 da), and Düzce (632 030 da) come respectively (Table 3).

Table 3: Türkiye hazelnut area harvested in 2018-2022 at the provincial level (da)

Country	2018	2019	2020	2021	2022
Ordu	2 271 076	2 273 114	2 272 188	2 272 258	2 272 158
Samsun	1 145 240	1 164 384	1 165 739	1 168 039	1 206 479
Giresun	1 171 903	1 177 780	1 178 010	1 176 390	1 177 290
Sakarya	734 424	743 486	750 992	794 552	789 135
Trabzon	655 074	655 353	655 972	652 224	651 799
Düzce	631 640	631 650	632 200	632 030	632 030
Zonguldak	239 946	257 695	259 058	264 632	264 329
Kocaeli	79 801	81 797	82 500	82 794	88 301
Artvin	88 069	89 790	82 110	82 428	82 482
Kastamonu	83 881	82 440	82 583	77 511	77 467
Bartın	61 815	62 005	62 430	63 780	76 600
Tokat	28 220	28 220	29 020	29 020	29 040
İstanbul	21 867	21 867	21 867	21 867	21 869
Sinop	17 209	17 214	17 224	17 424	17 444
Rize	23 389	23 689	18 375	18 375	17 271
Others	30 254	33 603	35 109	35 877	36 779
Türkiye (Total)	7 283 808	7 344 087	7 345 377	7 389 201	7 440 473

Source: TUIK, 2023

According to TUIK data, Türkiye 's hazelnut production amount for 2018-2022 is presented in Table 4. Considering the country's production values between 2018 and 2022, the amount of product has decreased and increased from

year to year. Despite these yield fluctuations, a total of 3 405 046 tons of hazelnuts have been produced in the country in the last five years. It is seen that the production amount in the country, which was 515 000 tons in 2018, reached 765 000 tons by 2022. Hazelnut production in 2022 attracts attention by reaching the highest level in the last five years. With this increase, a 48.27% increase in hazelnut production was achieved. It seems that Ordu province, which is the place where the highest hazelnut production is made in the country, has a significant impact on this increase. Hazelnut production in Ordu province reached 239 935 tons in 2022, showing an increase of 43.44% compared to the previous year. This situation reveals that Ordu province is significant in Türkiye's hazelnut production in terms of production areas and production amounts. In fact, in the last 5-year period, the hazelnut production in Ordu province reached 1 002 185 tons. Then, Samsun (556 255 t), Sakarya (466 462 t), Giresun (391 121 t), and Düzce (354 444 t) are important provinces with high production values, respectively (Table 4). In addition, in TUIK 2022 data, it is seen that many plants are not in productive age in many provinces such as Trabzon (1091050 pcs), Sakarya (2097517 pcs), Zonguldak (241 820 pcs), Kastamonu (414 290 pcs), and Giresun (276 445 pcs), especially in Samsun (7 949 570 pcs). It is predicted that production amounts may increase further in the coming years as these plants reach the productive age.

Table 4: Türkiye hazelnut production in 2018-2022 at the provincial level (t)

Country	2018	2019	2020	2021	2022	Total
Ordu	180 397	217 226	197 230	167 397	239 935	1 002 185
Samsun	66 363	137 841	123 555	116 795	111 701	556 255
Sakarya	78 300	102 123	91 397	96 173	98 469	466 462
Giresun	46 395	84 766	84 167	83 488	92 305	391 121
Düzce	52 686	85 688	57 330	75 688	83 052	354 444
Trabzon	34 271	53 946	40 315	44 041	52 461	225 034
Zonguldak	18 533	45 025	23 113	53 033	33 762	173 466
Kocaeli	12 509	13 395	14 113	12 230	14 165	66 412
Kastamonu	6 226	7 918	9 658	7 057	6 922	37 781
Bartın	3 072	6 046	5 868	6 046	12 987	34 019
Artvin	5 789	5 297	3 744	5 185	5 174	25 189
İstanbul	2 622	4 942	4 322	4 442	3 185	19 513
Tokat	2 342	2 627	3 293	3 387	3 396	15 045
Rize	1 710	2 910	1 404	2 672	1 296	9 992
Bolu	1 108	1 333	1 245	2 397	1 693	7 776
Others	2 677	4 963	4 246	3 969	4 497	20 352
Türkiye (Total)	515 000	776 046	665 000	684 000	765 000	3 405 046

Source: TUIK, 2023

TÜRKİYE HAZELNUT EXPORT

According to the Black Sea Exporters' Association (KİB) data, Türkiye's hazelnut export amounts for 2018-2022 are presented in Figure 2, and export revenues are shown in Figure 3. Considering these values, Türkiye exported 1 545 881 tons of hazelnuts in 5 years and obtained a total export income of 9 618 204 696 $. This clearly shows that hazelnuts have an important place among agricultural products in the country's economy. It is seen that the amount of products exported varies between years. This situation can be partly explained by the product fluctuations in the country's hazelnut production. Hazelnut exports, 279 251 tons in 2018, increased to 321 564 tons by 2022. However, it is seen that the highest export amount of the last five years was realized in 2021. In 2021, Türkiye exported 344 370 tons of hazelnuts (Figure 2). This situation also shows similarities in terms of export income. It is seen that the country's highest export income in the last 5-year period was again realized in 2021. In 2021, 2 260 105 304 $ income was obtained. It is seen that the export income, which was 1 635 235 672 $ in 2018, 1 748 835 811 $ by 2022, is an increase of 7.48% (Figure 2).

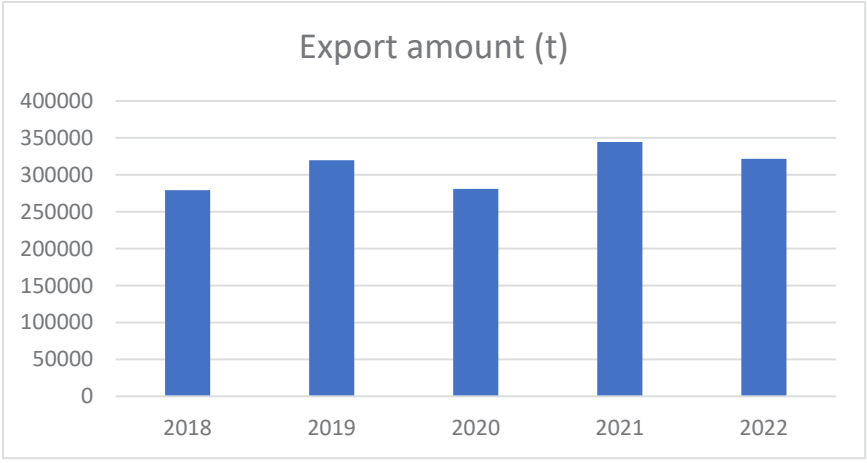


Figure 2: Türkiye Hazelnut Export Amount (tons) (KİB, 2023)

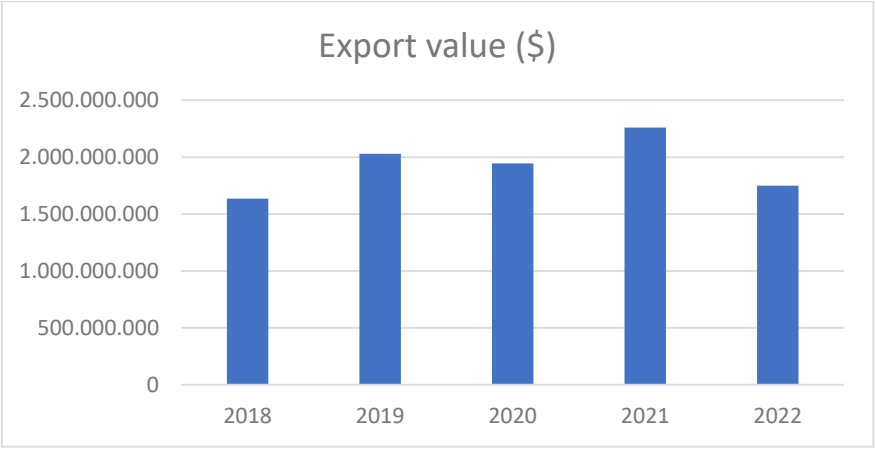


Figure 3: Türkiye Hazelnut Export Revenue ($) (KİB, 2023)

The data announced by KIB shows that the country Türkiye exports the most hazelnuts to Germany. In 2022, 89 103 tons of hazelnuts were exported to Germany, generating an income of $489 626 473. Following Germany comes Italy, which exported 62 627 tons of hazelnuts and earned $342 531 206 in income, and France, which earned $109 514 724 in income by exporting 20 042 tons. Accordingly, the share of these countries, which are among the top 3 countries to which Türkiye exports hazelnuts, in exports is 53.46%. Apart from these, Poland, Netherlands, Switzerland, Austria, Spain, China, Belgium, Brazil, Canada and the United Kingdom can be shown as other important export destinations (KİB, 2023).

HAZELNUT STUDIES IN THE WORLD

Trends in hazelnut cultivation and current studies in hazelnut research are of great interest to the hazelnut industry and agricultural researchers. This section provides an overview of hazelnut studies in the Web of Science (WOS) database. Hazelnut studies were classified according to the Web of Science (WOS) database. A search was made with the topic “hazelnut” in the database search engine. The search yielded 5.344 results. Document type: Article was selected from the results, and review articles were excluded. Accordingly, the remaining 4 150 articles were included in this review.

The first study on hazelnuts in the WOS database was published in 1982. A total of 50 scientific studies were published between 1982 and 1991. The studies carried out in this 10-year period correspond to 1.2% of the total number of publications. It can be said that studies on hazelnuts generally tend to increase from year to year. In the second 10-year period, 317 studies on hazelnuts were

published, a 6.34-fold increase. In 2002-2011, 1097 studies were published, and 2686 studies were published in 2012-2023. Especially since 2012, researchers have increased their studies on this nut species. 2021 attracted attention as the year in which the most studies on hazelnuts were published. While a total of 323 scientific studies were published in 2021, this number corresponds to 7.78% of the total number of studies (Figure 4, Figure 5).

When the research areas of the studies were examined, Food Science Technology ranked first, covering the subjects of 1270 studies. This is followed by Chemistry with 881 studies and Agriculture with 727 studies. These three study topics include 69.35% of the hazelnut studies in the WOS database. It can also be said that research topics such as Engineering, Allergy, Plant Sciences, Environmental Sciences, Nutrition dietetics, and Immunology are frequently included in the studies. Notably, 2086 studies in the "Other" category include different research topics. This shows that hazelnut is a type of nut that has many uses and that researchers are conducting detailed research on this type of fruit (Figure 6).

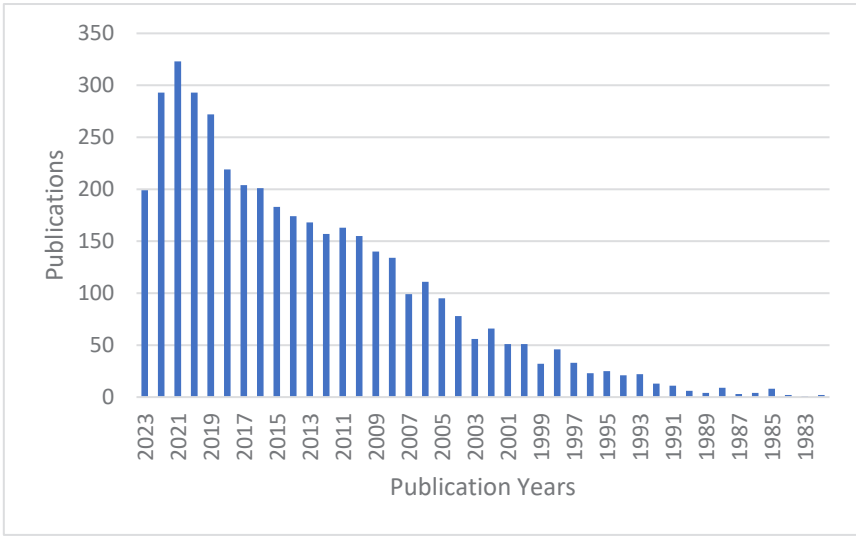


Figure 4: Hazelnut studies indexed in the WOS database by year

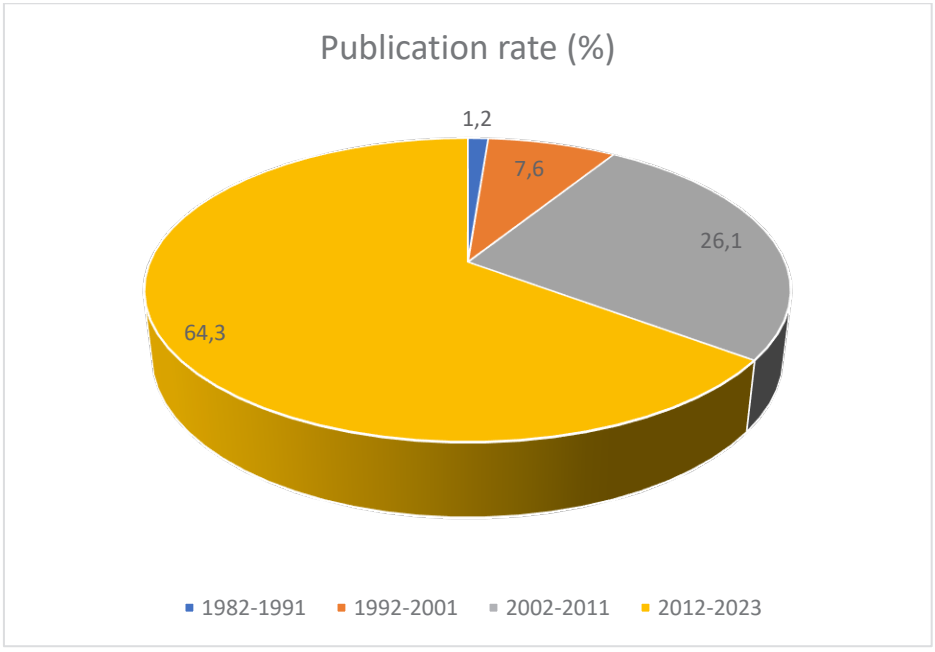


Figure 5: Distribution of studies on hazelnuts from the WOS database by years

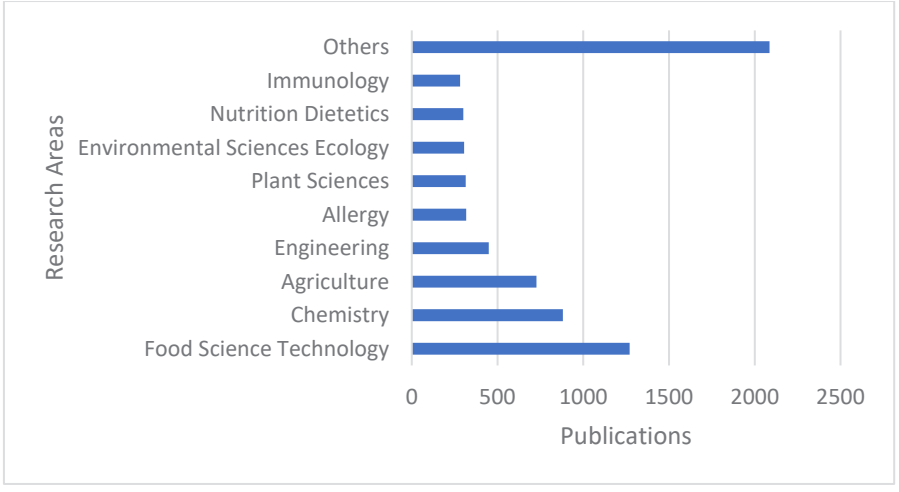


Figure 6: Research areas of studies on hazelnuts in the WOS database

When hazelnut studies were classified by country in the WOS database, it was seen that hazelnut-related studies were carried out in a total of 102 different countries. This situation should be seen as an indicator of the importance given to hazelnuts worldwide. In the studies conducted, Türkiye ranks first with 1188

studies. This situation shows that in the country with the largest hazelnut production areas and highest production amounts in the world, researchers are working on many issues, such as the development of hazelnuts, increasing production amounts and researching consumption opportunities and their effects on human health. After Türkiye, countries such as Italy, USA, Spain, and Germany attract attention as countries that focus on studies on hazelnuts (Figure 7).

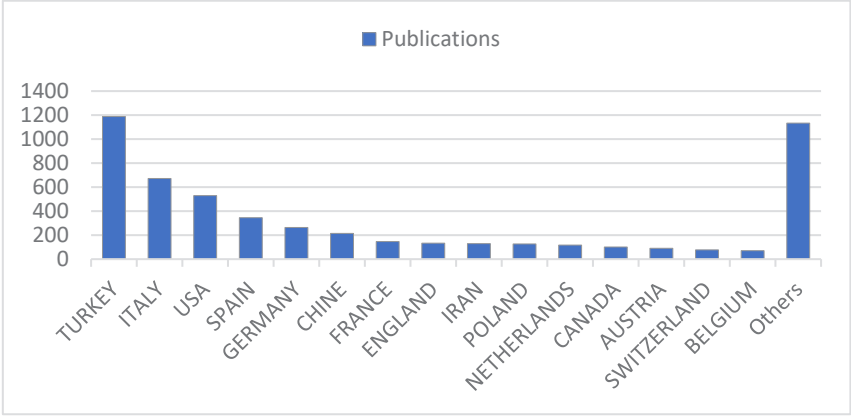


Figure 7: Distribution of studies on hazelnuts in the WOS database by country/regions

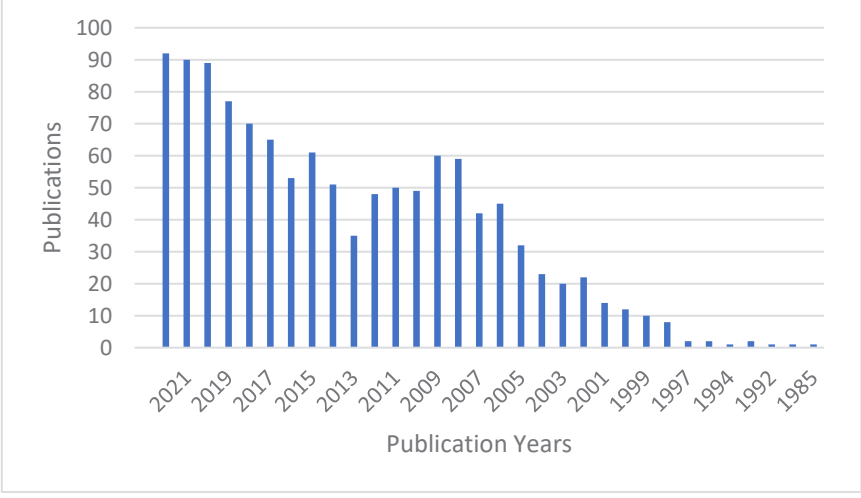


Figure 8: Hazelnut studies indexed of Türkiye in the WOS database by year

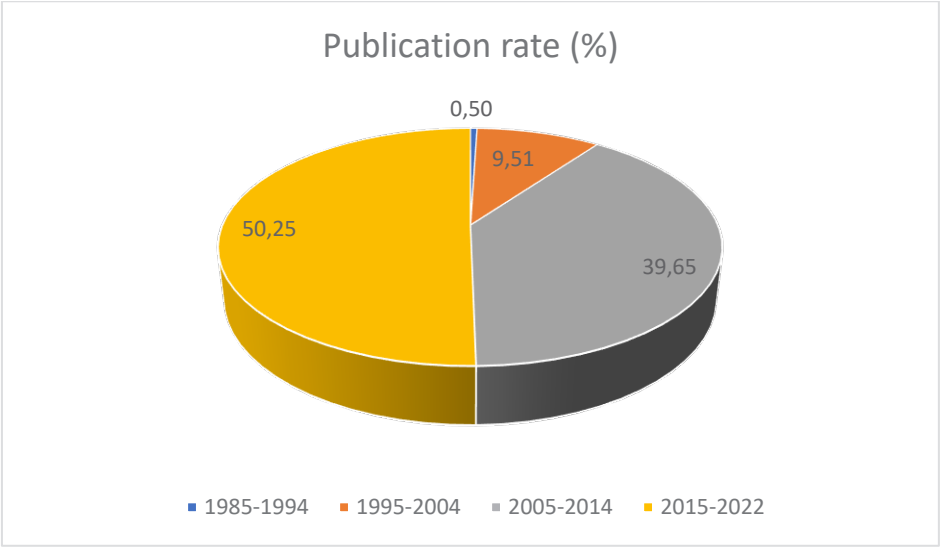


Figure 9: Distribution of studies on hazelnuts in Türkiye from the WOS database by years

It is seen that the first study indexed in the WOS database among the studies conducted in Türkiye was published in 1985. After this study, no studies were published in WOS for five years until 1991. Although it has been observed that hazelnut studies have started to be indexed in the WOS database since 1991, there has been an increase in the number of these studies over the years. It can be said that the number of studies increased significantly compared to previous periods, especially in 2005-2014. While 10% of the total number of studies were published in the 20 years between 1985-2004, 39.65% were published between 2005-2014. However, it can be stated that Türkiye has reached its highest number of publications in the last 7-year period covering the years 2015-2022. This process, which started with 61 studies published in 2015, increased to 53 in 2016, 65 in 2017, 70 in 2018, 77 in 2019, 89 in 2020, and 90 in 2021. The 92 studies published in 2022 constituted the highest number of publications of all periods in Türkiye (Figure 8, Figure 9).

When the research areas of the studies conducted in Türkiye were examined, Food Science Technology ranked first, including the research topics of 329 studies. This is followed by Engineering with 243 studies and Agriculture with 215 studies. These three study topics include 66.24% of Türkiye's total hazelnut studies in the WOS database. It can also be said that research topics such as Chemistry, Energy Fuels, Environmental Sciences, Biotechnology Applied Microbiology, Nutrition dietetics, Materials Science and Plant Sciences are

frequently included in the studies. It also includes different research topics in 68 studies in the "Other" category (Figure 10).

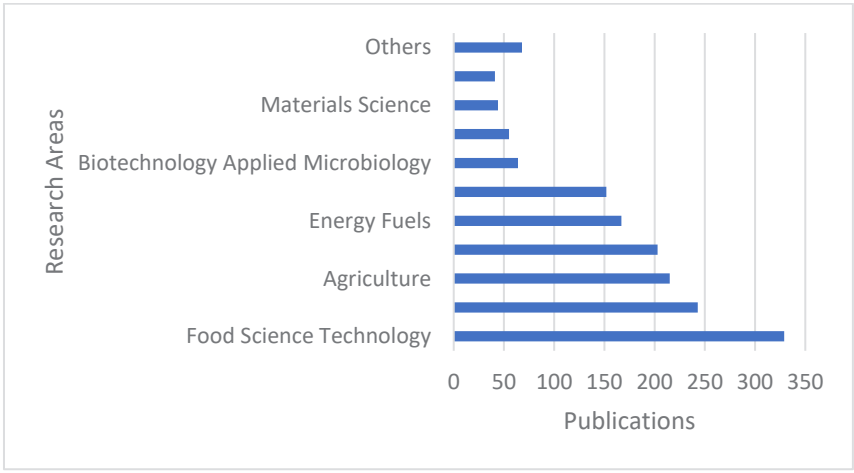


Figure 10: Research areas of studies on hazelnuts in Türkiye in the WOS database

As a result, considering the production areas and production amounts, it can be stated that hazelnut is a valuable agricultural product that is in demand all over the world. It can be seen from the studies that many different aspects of hazelnuts have been addressed by researchers. Studies will continue to guide the development of hazelnut cultivation techniques, a better understanding of the information about its nutritional content, and the discovery of different consumption and evaluation methods. Therefore, it should be considered important for hazelnut researchers to continue their comprehensive studies on hazelnut-related issues, taking into account the changing world conditions.

REFERENCES

Alasalvar, C., Pelvan, E., & Topal, B. (2010). Effects of roasting on oil and fatty acid composition of Turkish hazelnut varieties (*Corylus avellana* L.). *International journal of food sciences and nutrition*, *61*(6), 630-642.

Bassil, N., Boccacci, P., Botta, R., Postman, J., & Mehlenbacher, S. (2013). Nuclear and chloroplast microsatellite markers to assess genetic diversity and evolution in hazelnut species, hybrids and cultivars. *Genetic Resources and Crop Evolution*, *60*, 543-568.

Boccacci, P., & Botta, R. (2009). Investigating the origin of hazelnut (Corylus avellana L.) cultivars using chloroplast microsatellites. *Genetic Resources and Crop Evolution*, *56*, 851-859.

Botta, R., Molnar, T.J., Erdogan, V., Valentini, N., Torello Marinoni, D., & Mehlenbacher, S.A. (2019). Hazelnut (*Corylus* spp.) Breeding. In: Al-Khayri, J., Jain, S., Johnson, D. (eds) Advances in Plant Breeding Strategies: Nut and Beverage Crops. Springer, Cham. https://doi.org/10.1007/978-3-030-23112-5_6

FAO, (2023). The Food and Agriculture Organization (FAO), Crop production statistics. https://www.fao.org/faostat/en/#home (Access Date: 20.09.2023).

İslam, A. (2019). Fındık ıslahında gelişmeler. *Akademik Ziraat Dergisi*, *8*(Özel Sayı), 167-174.

Karakaya, O. (2021). Fatsa'da yetiştirilen palaz ve çakıldak fındık çeşitlerinde klon seleksiyonu. (Doktora Tezi). Fen Bilimleri Enstitüsü, Bahçe Bitkileri Anabilim Dalı, Ordu Üniversitesi

Karakaya, O., Yaman, İ., Kırkaya, H., Uzun, S., Kaya, T., & Balta, M.F. (2023). Effect of Cluster Drop Intensity on Nut Traits, Biochemical Properties, and Fatty Acids Composition in the 'Çakıldak' Hazelnut Cultivar. *Erwerbs-Obstbau*, 65,785–793. https://doi.org/10.1007/s10341022-00774-8

Kasapligil B. (1972). A bibliography on *Corylus* (Betulaceae) with annotations. Annu Rpt Northern Nut Growers Assn 63:107–162

KİB, (2023). Ülkelere göre ihracat istatistikleri. https://kib.org.tr/tr/ihracat-istatistikler-findik-istatistikleri-ulkelere-gore-ihracat-istatistikleri-1.html. (Access Date: 15.09.2023).

Kiliç, O. & Alkan, I. (2006). The developments in the world hazelnut production and export, the role of Turkey. *Journal of Applied Sciences*, 6(7), 1612-1616.

Köksal, İ. (2018). Türk Fındık Çeşitleri. Fındık Tanıtım Grubu Yayınları, Ankara, Türkiye, 136s.

Özçağıran, R., Ünal, A., Özeker, E. & İsfendiyaroğlu, M. (2014). Ilıman İklim Meyve Türleri. Cilt III, Ege Üniversitesi Yayınları Ziraat Fakültesi Yayınları, İzmir, Türkiye, 566.

Shahidi, F., Alasalvar, C., & Liyana-Pathirana, C.M. (2007). Antioxidant phytochemicals in hazelnut kernel (*Corylus avellana* L.) and hazelnut byproducts. *Journal of Agricultural and Food Chemistry*, 55(4), 1212-1220.

Simsek, A., & Aykut, O. (2007) Evaluation of the microelement profile of Turkish hazelnut (*Corylus avellana* L.) varieties for human nutrition and health, International Journal of Food Sciences and Nutrition, 58:8, 677-688, DOI: 10.1080/09637480701403202

TUIK, (2023). Turkish Statistical Institute (TUIK), Crop production statistics. https://biruni.tuik.gov.tr/medas/?locale=tr. (Access Date: 25.09.2023)

Uzun, S. (2021). Fatsa'da Yetiştirilen 'Tombul've 'Karafındık' Fındık Çeşitlerinde Klon Seleksiyonu. (Doktora Tezi). Fen Bilimleri Enstitüsü, Bahçe Bitkileri Anabilim Dalı, Ordu Üniversitesi

Whitcher, I. N., & Wen, J. (2001). Phylogeny and biogeography of *Corylus* (Betulaceae): inference from ITS sequences. Systematic Botany 26, 283–298.

Yaman, M., Balta, M. F., Karakaya, O., Kaya, T., Necas, T., Yildiz, E., & Dirim, E. (2023). Assessment of Fatty Acid Composition, Bioactive Compounds, and Mineral Composition in Hazelnut Genetic Resources: Implications for Nutritional Value and Breeding Programs. *Horticulturae*, *9*(9), 1008. MDPI AG. Retrieved from http://dx.doi.org/10.3390/horticulturae9091008

Chapter 8

Formation and Microscopic Examination of Roots in Grapevine Cuttings

Zeliha GÖKBAYRAK[1], Fatih Cem KUZUCU[2], Hakan ENGİN[3]

[1] Çanakkale Onsekiz Mart University, Department of Horticulture, Çanakkale. zgokbayrak@comu.edu.tr ORCID No: 0000-0002-0012-9782
[2] Çanakkale Onsekiz Mart University, Department of Horticulture, Çanakkale. fatihcem@comu.edu.tr, Orcid ID: 0000-0003-0497-4331
[3] Çanakkale Onsekiz Mart University, Department of Horticulture, Çanakkale. hakanengin@comu.edu.tr, Orcid ID: 0000-0001-6897-8708

ABSTRACT

Propagation of plants is one of the main activities of human beings and studies on the root formation of trees have a long history. Even in fully developed mature plant parts, many cells have the ability to turn into a meristem and produce the roots and shoots. Numerous techniques are available to examine the anatomical features of roots. Many of the techniques currently used have been developed in recent years. Additionally, new techniques continue to be developed to improve our understanding of the cellular and histological organization and formation of the root and to provide new insight into cellular and biochemical processes.

Nowadays, new methods are being developed that enable root samples to be examined under a microscope. Considering the thin and fragile structure of root samples, microtome models, sectioning and staining techniques have to allow sections to be taken according to root structures. It is very difficult to take sections from root structures and examine them. Many details, including the thinness of the sections, their preparation, softening technique, cutting angle, staining, drying, cleaning, imaging and photography, need to be taken into consideration.

In this section, methods, some of which were developed by us, for microscopic examination and imaging of grapevine root samples are listed. In this regard, the tools and chemicals required examining grapevine root materials under a microscope, the methods used for softening and fixing the root tissue, cleaning, drying and staining of the sections, photography and image analysis, and solutions to the problems encountered are discussed. The purpose of this chapter is to present introductory approaches and simple methods used in the examination of grapevine root samples. This chapter wishes to provide an overview and a guide, especially to students who plan to experiment to examine tissues for the first time using a morphological and anatomical approach.

In this book chapter, anatomical revelation of the differentiation of adventitious roots by applying staining techniques to thin sections of grapevine cuttings will contribute to a detailed understanding of both the shaping of root outlines on the stem and the effect mechanisms of different applications on grapevine rooting.

Keywords: grapevine, root, microscope, staining, techniques

INTRODUCTION

Propagation of plants is one of the main activities of human beings and studies on the root and stem anatomy of trees have a long history. Even in fully mature plant parts, many cells have the ability to turn into a meristem and produce the necessary roots and shoots. Thanks to this ability, plants can be propagated by cuttings. What is desired in propagation with stem cuttings is the formation of a new root system from the cutting. Because the structure (bud) that will enable the shoot to form on the steel already exists, in many plants, the formation of adventitious roots begins completely after the cutting is prepared. Generally, adventitious roots in stem cuttings consist of groups of cells located just outside and between the conductive tissues (Gökbayrak and Engin 2023). These cell groups divide and create many new cell groups. These groups also become root primordia. Division continues in each cell group and the root tip appears in a short time. A conductive tissue system forms in the new root primordia and connects to the nearest conductive tissue system. The tip of the root grows outwards through the cortex and epidemics, forming a right angle with the stem (Gökbayrak and Engin 2021). Thus, adventitious roots in the cuttings are formed endogenously.

Anatomical observations regarding the formation and shaping of root primordia that occur before the roots emerge from the stem are limited. Filiti et al. (1987) examined *in vitro* rooting of different *Prunus* clones and found that the roots developed directly from the phloem parenchyma cells near the cambium, without forming callus. Naija et al. (2008) reported that *in vitro* adventitious rooting occurred in the cambium region and adjacent to the phloem in MM 106 apple rootstock.

Research on the rooting capacity of grapevine cuttings, a vegetative propagated species, generally focuses on determining the effect of growth regulators (Schumann and Uhl 1975; Keeley et al., 2004; Machado et al., 2005) or different growing environments. Research on the beginning of adventitious root formation in grapevine cuttings and in which parts of the tissues forming the stem these root primordia are formed are not sufficient.

Today, new micro technical methods have been developed that enable samples to be examined under a microscope. Especially in hardy and woody samples, methods (microtome) and staining techniques that enable thin sectioning can enable the observation of differences between cells that are not obvious in the sections. Considering the thin and fragile structure of root samples, new microtome models and staining techniques are being developed with the help of advances in technology. It is very difficult to take thin sections from root structures and examine the sections taken. Many details such as thinness of the sections, preparation, softening technique, cutting angle,

staining, drying, cleaning, imaging and photography need to be taken into account.

In this chapter, revealing the differentiation of adventitious roots anatomically by applying staining techniques to thin sections of grapevine cuttings will contribute to a detailed understanding of both the shaping of root outlines on the stem and the effect mechanisms of different applications on grapevine rooting.

1. Root Formation and Microscopic Examination

Many cells in different parts of the stem structures have the ability to transform into meristems and produce roots. Roots develop from different tissues and different cell types. Roots often develop from cells adjacent to vascular tissues. Phloem and xylem parenchyma may consist of young secondary phloem or cambium cells close to phloem cells (Bellini et al., 2014). It contains information on methods that are very effective in microscopic examination and imaging of grapevine root samples, some of which were developed by us.

1. 2. Root Formation in Grapevine Cuttings

In young stems, root initiations occur close to the outer side of the conductive tissue system, and in old stems, they occur deeper and often close to the conductive tissue cambium. Roots of cuttings made from perennial woody plants, which contain secondary xylem and phloem, often consist of secondary phloem tissue. Moreover, these roots may also consist of various tissues such as pith rays, parenchyma, and pith. In some plants, root points are formed during the development of the stem. These are also present in the cuttings when it is prepared. These are called "pre-formed root areas". These remain in a resting or dormant state until the stems are cut into steel and placed in a suitable environment for the roots to develop. The places where these occur are no different from the places where other adventitious roots form on the stem. It has been observed that some willow and apple varieties are born with branch and leaf cavities outside the cambium in their core rays. On some older apple and quince varieties, these pre-formed dormant eyes cause swellings often referred to as "prickly knots." For rooting to occur in a short time, it is not necessary to have previously formed rootlets. Many vine cuttings root easily even though they do not have such primordia (Gökbayrak and Engin 2023). Likewise, green and wood cuttings of many ornamental plants produce roots quickly, even though they do not have such primordia (Akçal and Kahraman, 2016; Koyuncu et al., 2021).

In some stems, when placed in suitable conditions for rooting, a callus layer forms at the bottom of the cutting. This layer is formed by the accumulation of parenchyma cells in an irregular order. Callus tissue arises mainly from the conductive tissue cambium and the adjacent phloem region. In addition, various cells in the cortex and core also participate in the formation of callus tissue. Many times, the first roots emerge from this callus. Therefore, it is believed that callus formation is necessary for rooting. Usually callus and root form at the same time because the internal and external conditions necessary for the development of both are similar. However, callus and root formation are two separate events that are not interconnected. Callus formation is useful for slow-rooting plants since the protective layer formed by the callus prevents the decay of the cuts coming from the bottom part from rotting. In some cases, the callus layer helps the cuttings absorb water.

Hormones undoubtedly influence the formation of adventitious roots in cuttings (Koyuncu et al., 2021). It has been determined that strong buds in grapevine, blackberry, poplar, and willow cuttings encourage root development. However, the presence of buds is not always mandatory for root formation. Rooting of cuttings with blunted buds, and hence there are no root primordia, is a common occurrence in grapevines. However, cuttings whose buds are blunted are more difficult to root than those whose buds are not blunted. Removing buds from stem cuttings accelerates rooting in some plants and prevents it in others. In some species, such as quince, currants and apple, pre-formed root primordia are found in the nodes. In these species, the problem is root elongation rather than root formation. Many plants, whose cuttings root easily like grapevines, do not have pre-formed root primordia. However, they form roots easily under suitable conditions (Figure 1).

In addition to physiological and biochemical factors, the anatomical structure of the cuttings is also effective in producing adventitious roots. For example, some plants have pre-formed root primordia from their stems. In some parts, root formation occurs in certain ways depending on the anatomical structure of the stem. The stem structures of some plants or the condition of the tissues in their stems seem to be more favourable for the formation of root primordia. For instance, the bark tissue of an easy-to-root plant is placed in the peeled-off bark area of a difficult-to-root plant and rooting is occurred. This shows that root formation is related to anatomical structure. However, adventitious root formation in plants seems to be more closely related to factors within the cells themselves, rather than nutrients or rooting-stimulating hormones that are readily available within the plant.

Figure 1. Root formation in grapevine cuttings

1. 3. Microscopic Examination of Rooting in Grapevine Cuttings

Developments in new root formation can generally be divided into 4 stages (Hartman et al., 1990). The first stage is the differentiation of specific cells. The second stage is the formation of root precursors from certain cells next to the vascular bundles or from vascular tissues that become meristematic because of redifferentiation. The third stage is the development of organized root primordia

from root precursors. The fourth stage is the growth and emergence of root cavities from the shoot tissue, as well as the formation of root conduction tissue between the root primordia and the conduction tissues of the cutting.

In this part, obtaining and preparing material for microscope examination and chemicals, methods used for sample preparation and softening, fixation and storage, sectioning and staining techniques including dehydration and cleaning, microscope and image analysis are reviewed.

1.3.1. Materials, Chemicals and Preparation for Microscope Examination

The list of materials and chemicals required for anatomical studies of the sections is given in Table 1. Staining solutions and bottle sizes vary depending on the structure of the material to be examined. An orderly work layout should be prepared where all chemicals and solutions are labelled and can be easily used after preparation (Figure 2).

Table 1. Some laboratory chemicals and materials to examine root formation under a microscope.

Chemicals	**Equipment**
Ethyl alcohol	Stereoscopic and light microscopes
Distilled water	Microtomes, knifes, disposable blades
Glycerine, Corn starch	Equipment's for boiling samples
Sodium hypochlorite	Electronic scale and stopwatch
Clearing solvents	Erlenmeyer and Beakers
Epoxy glue, spray bandage	Brown glass bottles for alcohol and staining solutions.
Stains (Astra Blue, Aniline Blue, Safranin O, Fast Green, Acetic Acid, Tartaric Acid, Fuchsin, Bromophenol Blue, Giemsa, Toluidine Blue, Methyl Green, Carmin	Fine camel hairbrushes and pipettes
	Tweezers and needles
	Razor blades or scalpel
	Coverslips and slides
	Handsaw, hammer, chisel, gloves

Figure. 2. Overview of chemicals and equipment that can be used to make thin sections and staining of material

1. 3. 2. Sample Preparation and Softening

The samples taken may be in a shape of round or pizza slice. This may vary depending on the diameter of the sample. Samples should be stored in ethyl alcohol before cleaning, washing, and sectioning. It is not easy to obtain thin sections from samples with their pith tissue. Gums, crystals, and tannins in the sections make this situation even more difficult. Micro-sections can generally be stored in 60-70% ethyl alcohol solution. Sometimes this solution may also contain acetic acid. Samples should be stored in brown bottles with low light transmission. Epoxy adhesives and double-sided tapes should be used to attach the samples. To prevent the outer part of the sample from being crushed and broken during cutting, the microtome should be clamped, and sections should be taken by sliding the cutting blade towards the pith.

Boiling is generally used in the softening process. This process should be done in a more controlled manner to allow cutting off the parts that are excessively soft and have damaged outer surfaces. Samples usually stored in alcohol, distilled water and glycerine need to be softened appropriately to obtain good sections. It is difficult to do in the samples that are too soft or not softened enough. In some cases, keeping it in pure water for 10-15 minutes before sectioning is sufficient for softening. In addition to the use of water, more corrosive chemicals such as acids can also be used.

1. 3. 3. Fixing and Storage

It is important to properly clean the samples before proceeding with fixation and storage. The cleaning process is sometimes a simple wash. After the grapevine samples are washed with tap water, the cleaning process can be carried out in pine containers containing pure water. It is important to determine the chemical mixture that will best protect the tissues and cells from deterioration during the storage process. Two different fixing and storage methods are generally used for this purpose. The first is a mixture of formaldehyde, alcohol and acetic acid called FAA. The second is the Copenhagen mixture (ethanol, distilled water, and glycerol)

1. 3. 3. Sectioning

For successful microscopic examinations, it is of great importance to take as thin sections as possible. For this purpose, classical sliding, semi-automatic and automatic microtomes can be used. However, in addition to sectioning with a microtome, manual sectioning is also a very effective technique.

One of the basic processes in preparing thin sections from samples is the use of cutting fluid. A cutting fluid is applied with a fine watercolor brush to keep both the sample and the edge of the blade constantly wet during the process. Cutting fluid prevents the branch sections from softening or hardening and helps the blade slide over while sectioning. They usually contain distilled water, alcohol, and glycerol. Pure water should be used with all ingredients to increase the flexibility of their tissues and prevent them from breaking during cutting. On the contrary, mixtures containing alcohol should be preferred for a hardening effect. Alcohol also prevents very soft and thin sections from tearing. Alcohol and glycerol mixtures should be used to prevent curling during cutting. Very sharp knives must be used to obtain thin sections. Additionally, the blades used should be changed frequently. After adjusting the microtome blade, a drop of 90% ethanol should be put on the surface of the samples and the excess should be removed with the help of a wet brush and the blade should be moved. This process prevents the contact point of the blade from getting wet and the cut part from bending, resulting in much higher quality images.

1. 3. 4. Staining Techniques

There are different methods for staining cross-sections (Bond et al., 2008; Hacle, 2015; Hacle et al. 2015). The purpose of staining thin sections is to reveal the differentiation between different tissue components. The stained sections can be easily examined and photographed under a microscope. Two different staining methods stand out when examining the grapevine samples. The first method is double staining safranin and bromophenol blue. The second

method is double staining bromophenol blue and fast green. Available stains include astra blue, aniline blue, safranin *O*, fast green, fuchsin, bromophenol blue, giemsa, toluidine blue, methyl green, and carmin. Staining can be done directly on the section or by transferring sections from one solution to another.

1. 3. 5. Microscope Examination and Image Analysis

For a detailed examination of thin sections, a careful study should be made using a stereomicroscope. The easy zoom feature of the stereomicroscope allows magnifications to be easily changed. The image can be easily captured using a digital camera connected directly to the stereomicroscope.

Photographs of samples can be taken directly from the petri dishes. Filling the petri dish with pure water just before taking photos reduces light reflection, resulting in better quality images. However, for better close-up observations, especially for small parts and small samples, the petri dish create obstacles. Lighting is important as it provides appropriate light intensity as well as creating shading effects by highlighting structures. For more detailed studies of very thin sections, a compound light microscope should be preferred as it has better resolution power than a stereomicroscope.

2. Rooting Anatomy in Grapevine

A basic study was carried out by Gökbayrak and Engin (2023) to determine the differentiation of roots from stem tissues in grapevine (*Vitis vinifera* L.) at the microscopic level. They stated that development of root primordia and the anatomical differentiation of the cell groups were similar in Cabernet Sauvignon (CS) and 5BB and observed that many cells in the canes of CS and 5BB had the ability to go back to meristematic status and form roots. Statistical analysis showed that genotype played a major role in the characteristics of primordia formation in the stem tissues. It was observed that both cultivars had quite a high number of dense cell groups that might be considered as potential primordia. In terms of the sites of these primordia, CS had considerably more root primordia, most of which originated near the vascular elements. On the other hand, 5 BB produced almost twice the number of root initials in its deeper region compared to its vascular system. Root diameters in CS were comparably thinner than those in 5BB.

The formation of roots and the anatomical differentiation of the formation areas of cell groups in the 'Cabernet Sauvignon' (*Vitis vinifera* L.) variety are given in Figures 3 and 4. It has been determined that the roots of grapevine cuttings are generally formed from two different regions of the tissues that form the stem section. Firstly, it differs from the cell groups located just outside and between the conductive tissues (Figure 3), and secondly, from the cell groups

extending to the inner pith (Figure 4). Cell groups in both regions of the stem section divide to form many new cell groups, and these groups turn into root primordia. New root primordia that continue to develop connect to the nearest conductive tissue system, forming the conductive tissue system. The tip of the root grows outward through the cortex and epidermis and emerges from the trunk section, forming a right angle with the stem. In addition, although rarely, grapevine roots primordia are composed of cell groups consisting of various tissues such as pith rays, parenchyma, and pith. The formation of roots in vine cuttings takes shape in a short time.

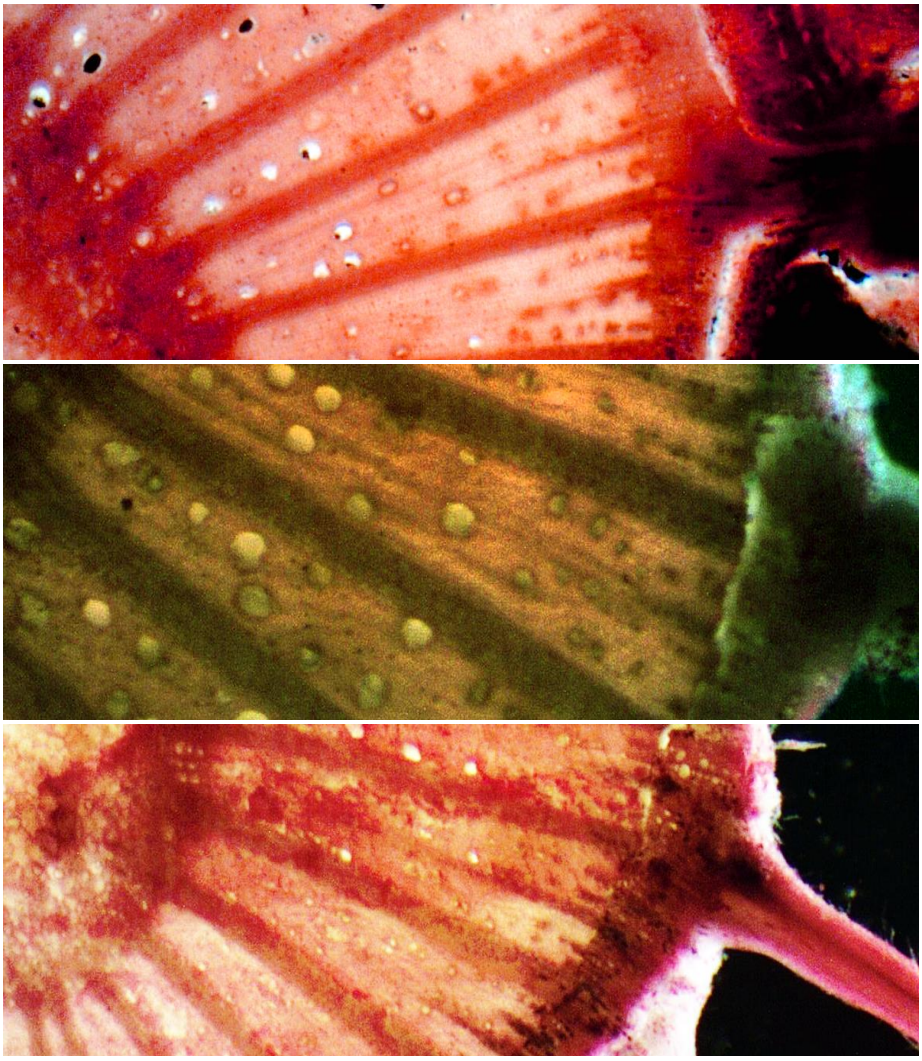


Figure 3. Roots that differ from the cell groups located just outside and between the conductive tissues in grapevine cross-section with different methods for staining.

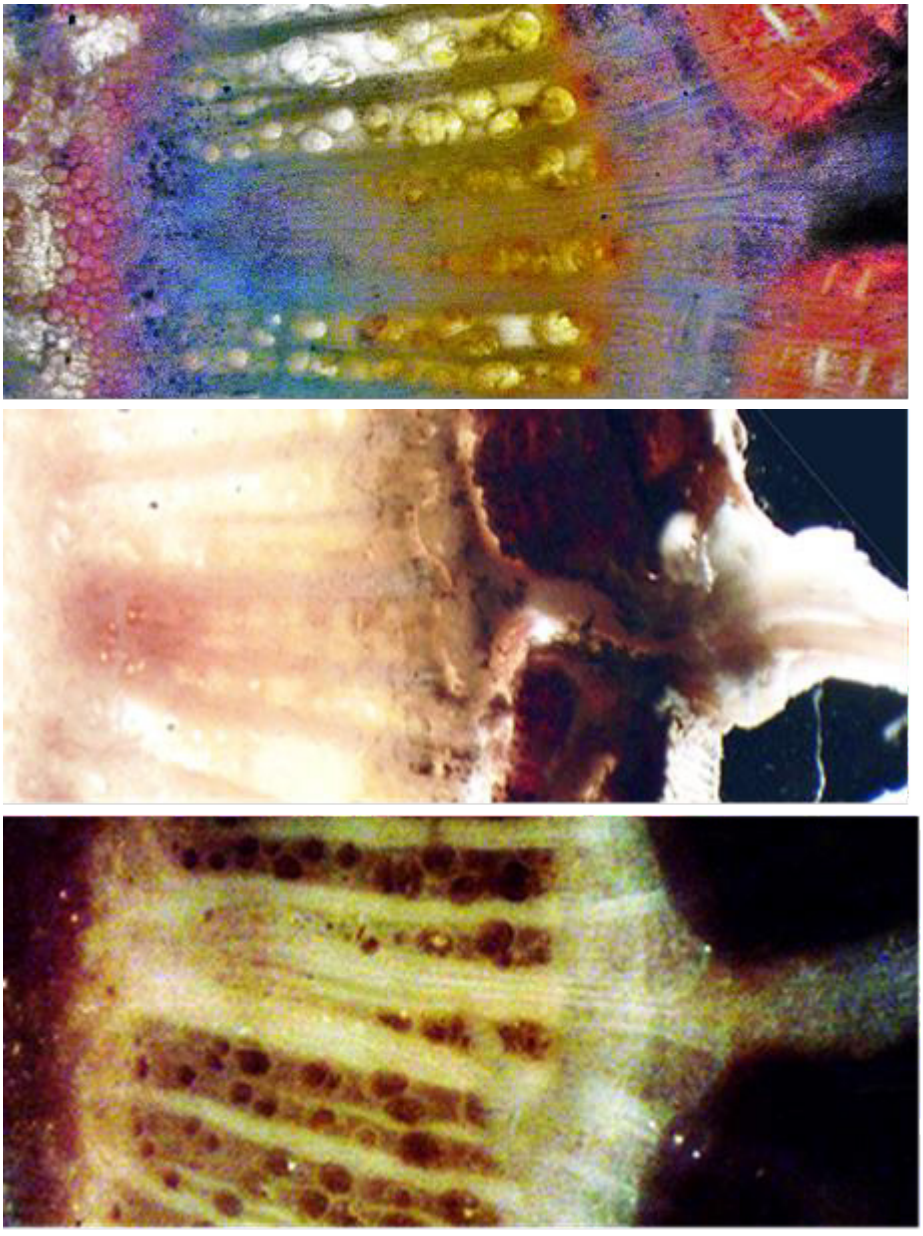


Figure 4. Roots initiated from the cell groups deep and the pith, and roots passing through the cortex and epidermis in grapevine cross-section with different methods for staining.

RESULTS and DISCUSSION

Research has shown that even in fully developed parts of plants, many cells could transform into meristems and form roots. The roots in stem cuttings consist of cells located just outside and between the conductive tissues. These cells divide and form many new cell groups. These groups become root primordia and division continues in each cell group and after a short time the root tip emerges. Conductive tissue system forms in the new root primordia and connects to the nearest conductive tissue system.

Rooting of different fruit species has been studied and it has been found that roots develop directly from the phloem parenchyma cells near the cambium, without forming callus (Filiti et al., 1987). Once started, grapevine root primordia grow and expand until they reach the outer bark surface. Grapevine root primordia could be formed in the stem at specific sites namely traces, parenchyma, primary or secondary rays and cambium tissue (Roy et al., 1987). The results obtained by Gökbayrak and Engin (2023) show that rooting is not restricted to the cambium zone and may develop at pith and cortex or any point along the vascular tissues and through xylem if there is retention of meristematic capacity in certain cells. In grapevine cultivars, initiation of cell division for root formation take place in parenchyma cells of the phloem, cortex, cambial region, xylem, and pith. In studies of propagated other species, cells leading to root formation could be those within or just external to the vascular cambium (Samartin et al., 1986; Hicks, 1987; Ranjit et al., 1988; Isfendiyaroğlu and Ozeker, 2008). Development of root primordia formed in the same way in different cultivars. Grapevine cuttings have been accepted as easy to root compared to other hybrids and higher number of potential root primordia and their location near epidermis in conjunction with vasculature would support this notion.

Newly developed methods enable root samples to be examined in detail under a microscope. Considering the unique thin and fragile structures of root samples, sectioning and staining techniques are being developed. It might be very difficult to obtain thin sections from stem structures. If the sections taken from these structures are not thin enough, it is not possible to examine them under a microscope. Preparation of the sections is as important as their need for thinness. Many details such as softening technique, cutting angle, dyeing, drying, cleaning, imaging, and photographing need to be taken into account.

Rooting in woody trees depends largely on the developmental ability of a group of cells to differentiate into the meristematic form and then develop into root primordia. It has been revealed that sequential events that lead to root formation in the stems of grapevines, where taking thin slices and staining them is not easy and successful, are followed. Anatomical observations are limited

regarding the formation and shaping of root primordia that occur before the roots emerge from the stem. Today, new methods have been developed that enable different root and branch samples to be examined under a microscope. This chapter indicated that further anatomical studies in which time-course changes from planting a cutting to uprooting are observed would allow, especially in hard-to-root species, to sequence root initiation and development inside stems.

REFERENCE

Akçal, A., Kahraman, Ö. 2016. The response of *Leucojum aestivum* L. to different methods of vegetative propagation on bulblet formation and growth characteristics . III. International Symposium on Horticulture in Europe

Akçal, A., Kahraman, Ö. 2016. The usage of different substrates in propagation of snowdrop. Bahçe, 45, 865-868.

Bellini, C., D.I. Pacurar and I. Perrone. 2014. Adventitious roots and lateral roots: similarities and differences. *Annual Reviews of Plant Biology,* 65*:* 639-666. https:// doi.org/10.1146/annurev-arplant-050213-035645.

Bond, J., Donaldson, L., Hill, S. and Hitchcock, K. 2008. Safranine fluorescent staining of wood cell walls. Biotech. Histochem. 83, 161-171.

Filiti, N., N. Montuschi and P. Rosati. 1987. *In vitro* rhizogenesis: histo-anatomical aspects on *Prunus* rootstock. *Advances in Horticultural Science*, 1: 34-38.

Gökbayrak, Z., Engin, H. 2021. Asmada *(Vitis Vinifera L.)* Adventif kök taslaklarının farklılaşmasının incelenmesi. Ziraat Mühendisliği (373), 35-41. DOI: 10.33724/zm.897985

Gokbayrak, Z., Engin, H. 2023. Anatomical observations on formation and development of adventitious root primordium in canes of Vitis sp. International Journal of Agriculture, Environment and Food Sciences, 7 (3), 573-580

Hacke UG, Venturas MD, MacKinnon ED, Jacobsen AL, Sperry JS, Pratt RB 2015. The standard centrifuge method accurately measures vulnerability curves of long-vesselled olive stems. New Phytol 205:116–127. doi:10.1111/nph.13017

Hacke, U. 2015. Functional and Ecological Xylem Anatomy. Springer International Publishing Switzerland. 133. DOI 10.1007/978-3-319-15783-2-5.

Hartmann, H.T., D.E. Kester and J.T. Davies, Jr. 1990. Plant propagation: principles and practices. 5th ed. Prentice Hall, Englewood Cliffs, N.J.

Hicks, G. S. 1987. Adventitious rooting of apple microcuttings in vitro: An anatomical study. Can. J. Bot. 65, 1913-1920. https://doi.org/10.1139/b87-262

Isfendiyaroğlu, M., Ozeker, E. 2008. Rooting of *Olea europaea* 'Domat' cuttings by auxin and salicylic acid treatments. Pakistan Journal of Botany, vol. 40, no. 3, pp. 1135–1141.

Keeley, K., J.E. Preece, B.H. Taylor and I.E. Dami. 2004. Effects of high auxin concentrations, cold storage, and cane position on improved rooting of

Vitis aestivalis Michx. Norton Cuttings. American Journal of Enology and Viticulture 55(3): 265-268.

Koyuncu, D., Akçal, A., Sarıyer, T., 2021. The effects of different auxin applications on some cutting, shoot and rooting characteristics in ruelia. Lapseki Meslek Yüksekokulu Uygulamalı Araştırmalar Dergisi. 4, 128-134.

Machado, M.P, J.L.S. Mayer, M. Ritter and L.A. Biasi. 2005. Effects of indole-butyric-acid on the rooting ability of semihardwood cuttings of grapevine rootstock 'VR 043-43' (*Vitis vinifera* x *Vitis rotundifolia*). Revista Brasileira de Fruticultura, 27(3): 476-479. https://doi.org/10.1590/S0100-29452005000300032.

Naija, S., N. Elloumi, N. Jbir, S. Ammar and C. Kevers. 2008. Anatomical and biochemical changes during adventitous rooting of apple rootstock MM 106 cultured *in vitro*. Comptes Rendus Biologies, 331: 518- 525. https://doi.org/10.1016/j.crvi.2008.04.002.

Ranjit, M., Kester, D.E., Polito, V.S. 1988. Micropropagation of cherry rootstocks: III. Correlations between anatomical and physiological parameters and root initiation. J. Amer. Soc. Hort. Sci. 113(1), 155-159.

Roy, C.R., Carlson, R.F., Audergon, J.M. 1987. Rootstocks for fruit crops. A willey interscience publication. New York.

Samartin, A., Vieitez, A.M. and Vieitez, E. 1986. Rooting of tissue cultured camellias. J. Hort. Sci. 61, 113-120. https://doi.org/10.1080/14620316.1986.11515680

Schumann, F. and F. Uhl. 1975. On the use of auxins favouring root formation. Mitteilungen Klosterneuburg, 25:339-346.

Chapter 9

Distribution and Essential Oil Composition of *Teucrium* Taxon in The Flora of Türkiye

Belgin COŞGE ŞENKAL[1]

[1] *Prof. Dr.; Yozgat Bozok University Agricultural Faculty Field Crops Depaermant. belgin.senkal@yobu.edu.tr ORCID No: 0000-0001-7330-8098*

1- INTRODUCTION

Turkiye is geographically located at the intersection of two important gene centers (Mediterranean and Near East). It has a rich plant diversity. This situation is also reflected in medicinal-aromatic plants (Tan, 2010; Mut et al., 2017; Dogrusoz and Tamkoc, 2019).

The Lamiaceae (=Labiatae) family is distributed in places where the Mediterranean climate prevails, and it is reported to include approximately 400 genera and 3200 species worldwide (Sadeghia et al., 2014; Ozcan et al., 2015; Donmez, 2022; Cakir et al., 2023). This family is represented by 41 genera and 866 taxa in Türkiye. The first three taxon-rich genera of the Lamiacea family are *Stachys* (132 taxa), *Salvia* (114 taxa) and *Sideritis* (61 taxa), followed by *Pholomis* with 56 taxa and *Teucrium* with 54 taxa (Guner et al., 2012).

The plants belonging to the genus *Teucrium* are herbaceous or bushy and perennial. They are aromatic plants. However, although rare, there are also annual or biennial species (Radulović et al., 2012). The leaves may be opposite, stemless, or stalked, simple, with smooth-toothed or lobed edges. Flower structures are variable and have simple or compound shapes. Petals are of different colors (Suvari, 2019). *T.spinosum*, an annual distributed in our country, is also the only species with a thorny stem in our country. The flowering time of taxa belonging to the *Teucrium* genus begins in February and continues until September (Ozcan, 2015).

Figure 1: *T. chamaedrys* subsp. *chamaedrys*
[Yozgat/TÜRKİYE- July 13, 2023]

Species, due to contain the various secondary metabolites, belonging to the genus *Teucrium* have been used since ancient times in the treatment of various diseases and disorders (diarrhea, shortness of breath, bronchitis, cough, eczema,

stomach wounds, antipyretics, diabetes, carminative, anti-rheitis, etc.) are used (Radulović et al., 2012; Tuncturk et al., 2019). Regionally, the stem, leaf and flower parts of the species are used as infusion or decoction (Donmez, 2022). Since many taxa within the *Teucrium* genus exhibit antimicrobial, antioxidant, and antifungal activities, they are important because they have the potential to be used as preservatives in the food industry (Rangahau, 2001, Gulsoy Toplan et al., 2022). On the other hand, research has identified taxa with anti-inflammatory, antimalarial, antipyretic, antiulcer, antinociceptive, antidiabetic, antihypertensive and hypolipidemic activities (Abdollahi and Simaiee, 2003; Bagci et al., 2010; Cakir et al., 2023).

As a result of research conducted on the secondary metabolites contained by taxa belonging to the genus, a wide variety of phytochemicals, such as terpenes, tannins, flavonoids, phenolic acids, glycosides, iridoids and essential oils, etc. have been identified (Kazemizadeh et al., 2008; Sharififar et al., 2009; Bahramikia and Yazdanparast, 2012; Kaska et al., 2019). Essential oils are secondary metabolites that are obtained from aromatic plants by different methods, have their own color, appearance, smell, and taste, and have volatile compounds at room temperature (Donmez, 2022). Essential oils are also used by the public to make primitive medicines and medicines. In recent years, with the increasing interest in aromatherapy and phytotherapy, which are branches of alternative medicine, the use of essential oils has also increased (Rangahau, 2001). The essential oil composition of *Teucrium* has been characterized primarily by compounds such as α-pinene, β-pinene, linalool, caryophyllene oxide, β-caryophyllene, germacrene D, δ-cadinene and bicyclogermacrene (Baser et al., 1997; Cozzani et al., 2005; Ozek et al., 2012; Elabbara et al., 2014; Baser and Kirimer, 2018).

TEUCRIUM TAXA AND DISTRIBUTION IN THE FLORA OF TÜRKİYE

There are 54 *Teucrium* taxon, including 34 species, 17 subspecies and 3 varieties, distributed in the Flora of Turkey. Within the genus *Teucrium*, 14 taxa (13 species and 1 subspecies) are endemic. The endemism rate is approximately 26%. One species in the flora (*T. leucophyllum* MONTBRET ET AUCHER EX. BENTHAM) has become extinct, and according to threat categories; two species are in the EN, two species are in the VU, 3 species are in the CD, and one species is in the LC category (Guner et al., 2012) (Table 1).

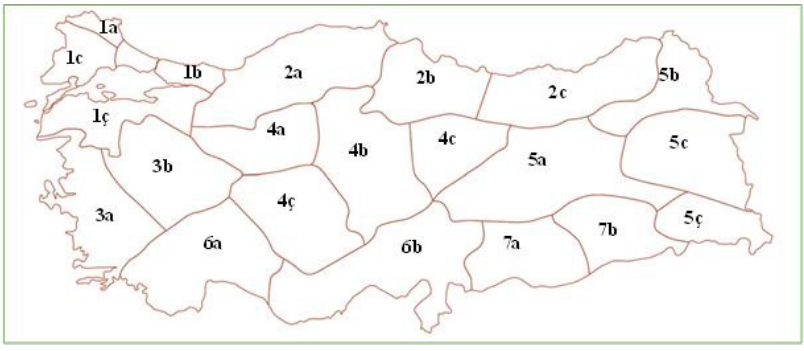
Table 1: Threat categories of *Teucrium* taxa in the Flora of Türkiye

Threat Category	Taxon
EX[1]	*T. leucophyllum* MONTBRET ET AUCHER EX. BENTHAM
EN	*T. odontites* BOISS. ET BAL.
	T. paederotoides BOISS. ET HAUSSKN.
VU	*T. antitauricum* T. EKİM
	T. cavernarum P. H. DAVIS
CD	*T. alyssifolium* STAPF
	T. pestalozzae BOISS.
	T. sandrasicum O. SCHWARZ
LC	*T. chamaedrys* L. subsp. *tauricolum*

1 EX: Extinct, EN: Endangered, VU: Vulnerable, CD: Conservation Dependent: LC: Least Concern (**Reference:** Guner et al., 2012)

Türkiye is divided into 7 geographical regions and 21 sections (Figure 2). These regions and sections are taken into consideration when giving the distribution of plant species.

Figure 2: Map of Türkiye sections



(1a) Istranca Section, (1b) Çatalca-Kocaeli Section, (1c) Ergene Section, (1ç) Southern Marmara Section, (2a) Western Black Sea Section, (2b) Central Black Sea Section, (2c) Eastern Black Sea Section, (3a)) Main Aegean Section, (3b) Inner West Anatolia Section, (4a) Upwards Sakarya Section, (4b) Middle Kızılırmak Section, (4c) Upwards Kızılırmak Section, (4ç) Konya Section, (5a) Upwards Fırat Section, (5b) Erzurum-Kars Section, (5c) Upwards Murat-Van Section, (5ç) Hakkari Section, (6a) Antalya Section, (6b) Adana Section, (7a) Middle Euphrates Section, (7b) Dicle Section (**Reference:** Guner et al., 2012)

The richest sections in terms of the number of *Teucrium* taxa are 3a (27 taxa), 6b (21 taxa) and 6a (20 taxa), followed by 1ç, 2b and 4ç with 13 taxa; 2c and 5b with 12 taxa; 1a, 2a, 3b, 4b and 5a with 11 taxa; 1b, 4a, 5c, 5ç, 7a and 7b with 10 taxa; It is followed by 4c with 8 taxa and 1c with 6 taxa. Antalya (5 endemic) and Adana (4 endemic) are the sections with the most endemic taxa. There are 2 endemic taxa in the Main Aegean and Erzurum-Kars Sections, and 1 endemic taxa each in the Western Black Sea, Upwards Sakarya and Dicle Sections (Guner et al., 2012) (Figure 3).

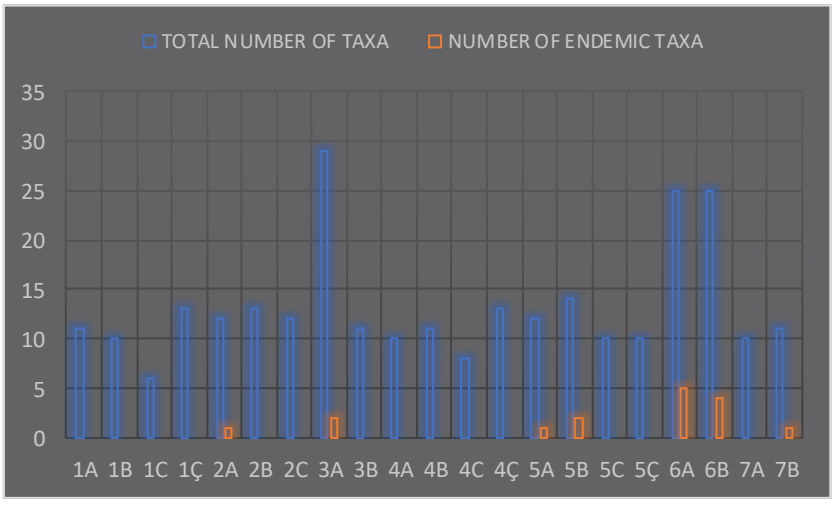


Figure 3: Distribution of *Teucrium* taxa in the Flora of Türkiye numerical (total and endemic) according to sections

The habitats of *Teucrium* taxa growing in Turkey vary, including limestone rocks, serpentine, steppe, edges of wetlands, under forests, and volcanic tuff areas. While 85% of the *Teucrium* taxa in Turkey grow either directly on calcareous rocks or in limestone-based soils, 15% are distributed in serpentine rocks and wetlands. Taxa belonging to the *Teucrium* genus found in our country's flora range from sea level to 3700 m. There are 6 taxa (*T. chamaedrys*, *T. chamaedrys* subsp. *syspirense*, *T. polium*, *T. polium* subsp. *polium*, *T. scordium*, *T. scordium* subsp. *scordioides*) distributed throughout Turkey. On the other hand, the distribution area of 27 taxa is limited to a single section (Guner et al., 2012) (Table 2).

Table 2: *Teucrium* Taxa and Distribution in the Flora of Türkiye

No	Taxa	Turkish Name	Türkiye Distribution Area
1	*T. alyssifolium* Stapf	gülmahmut*	3a
2	*T. andrusi* Post	çölilacı*	7b
3	*T. antitauricum* T. Ekim	yaylayavşanı*	6b
4	*T. brevifolium* Schreber	ververik	3a
5	*T. cavernarum* P.H.Davis	biberyavşanı*	6b
6	*T. chamaedrys* L.	kısamahmut	All over Türkiye
7	*T. chamaedrys* subsp. *chamaedrys*	kısamahmut	1a-1b-2a-2b-3a-4ç-6a-6b
8	*T. chamaedrys* subsp. *lydium* O. Schwarz	bodurmahmut	1b-3a-6a
9	*T. chamaedrys* subsp. *sinuatum* (Celak.) Rech.f.	sancıotu	2c-5a-5b-5ç-7b
10	*T. chamaedrys* subsp. *syspirense* (K.Koch) Rech.f.	sıcakotu	All over Türkiye
11	*T. chamaedrys* subsp. *tauricola* Rech.f.	çobansargısı	3b-6a-6b-7a
12	*T. chamaedrys* subsp. *trapezunticum* Rech.f.	dalakotu	2c
13	*T. chasmophyticum* Rech.f.	gürpüntüotu	7b
14	*T. creticum* L.	akpüren	6b
15	*T. divaricatum* Sieber	mürcüotu	1ç-3a-6a-6b
16	*T. divaricatum* subsp. *divaricatum*	mürcüotu	3a
17	*T. divaricatum* subsp. *graecum* (Celak.) Bornm.	böceotu	1ç-3a-6a-6b
18	*T. ekimii* H.Duman	erkurtaran*	6a
19	*T. flavum* L.	sarıyavşan	3a
20	*T. flavum* subsp. *hellenicum* Rech.f.	arıyavşan	3a
21	*T. haradjanii* Briq. ex Rech.f.	kelmahmut*	6b
22	*T. hircanicum* L.	yağmurotu	2c
23	*T. kotschyanum* Poech	zırnıkotu	3a-6a-6b
24	*T. krymense* Juz.	kininotu	5b
25	*T. lamiifolium* d'Urv.	kumacıotu	1a-1b-1ç-2a-3a-4ç-6a
26	*T. lamiifolium* subsp. *lamiifolium*	kumacıotu	1a-1b-1ç-2a-3a-4ç-6a
27	*T. lamiifolium* subsp. *stachyophyllum* (P.H.Davis) Hedge & Ekim	dermanotu	6b
28	*T. leucophyllum* Montbret & Aucher ex Benth.	buldumcuk*	5a
29	*T. melissoides* Boiss. & Hausskn. ex Boiss.	tetre	5ç
30	*T. microphyllum* Desf.	adayavşanı	3a
31	*T. montanum* L.	dağdalak	1a-1ç-2b-3a-6a-6b

32	*T. montanum* subsp. *montanum*	dağdalak	1a-1ç-2b-6a-6b
33	*T. montbretii* Benth.	fatmacıkotu	6a-6b
34	*T. montbretii* subsp. *montbretii*	fatmacıkotu	6b
35	*T. montbretii* subsp. *pamphylicum* P.H.Davis	sürmelifatmacıkotu*	6a
36	*T. multicaule* Montbret & Aucher ex Benth.	haptutan	4b-4c-7a
37	*T. odontites* Boiss. & Balansa	hamesi*	3a-6a-6b
38	*T. orientale* L.	kirveotu	2a-2b-2c-3a-3b-4a-4b-4ç-5a-5b-5c-5ç-6a-6b
39	*T. orientale* var. *glabrescens* Hausskn. ex Bornm.		2b-2c-3a-3b-4a-4ç-5a-5b-5c-5ç
40	*T. orientale* var. *orientale*	kirveotu	2b-3a-4a-4b-4ç-5b-6a-6b
41	*T. orientale* var. *puberulens* Ekim		2a-2b-2c-3a-5a-5c-6b
42	*T. ozturkii* A.P.Khokhr.	mevlen*	5b
43	*T. paederotoides* Boiss. & Hausskn	yermeşesi*	5b
44	*T. parviflorum* Schreber	koyunotu	3a-3b-4a-4b-4c-4ç-5a-5c-7a
45	*T. pestalozzae* Boiss.	oğlanotu*	6a
46	*T. polium* L.	acıyavşan	All over Türkiye
47	*T. polium* subsp. *polium*	acıyavşan	All over Türkiye
48	*T. pruinosum* Boiss.	puslumahmut	3a-4b-5b-6a-7a-7b
49	*T. pseudaroanium* Parolly, Erdağ & Nordt.	tepeotu*	6a
50	*T. sandrasicum* O. Schwarz	ülper*	3a
51	*T. scordium* L.	susarmısağı	All over Türkiye
52	*T. scordium* subsp. *scordioides* (Schreb.) Arcang.	kurtluca	All over Türkiye
53	*T. scordium* subsp. *scordium*	susarmısağı	3a
54	*T. spinosum* L.	dikenlimahmut	1ç-6b-7b

*Endemic (**Reference:** Guner et al., 2012)

ESSENTIAL OIL COMPOSITION OF *TEUCRIUM* TAXA IN THE FLORA OF TÜRKİYE

The results of the research conducted on the essential oil compositions of taxa belonging to the genus *Teucrium* registered in the Flora of Turkey are summarized in Table 3.

Table 3: Essential Oil Contents and Essential Oil Main Components of Some *Teucrium* Taxa in the Flora of Türkiye

Collection site	Altitude	Collection date	Plant parts	Essential Oil Ratio (%, w/w)	Reference
		T. chamaedrys			
Türkiye (Burdur)	1600 m	-[1]	-	0.20	
Main Compounds	2-Hexen-1-al (12.79%) α-Pinene (7.68%) β-Pinene (4.04%) 1-Octen-3-ol (8.74%) β-Myrcene (6.98%) Limonene (13.49%) Caryophyllene (12.20%) Germacrene-D (11.99%)				Donmez, 2022
Türkiye (Elazığ)	-	2009	Aerial parts	0.3	
Main Compounds	β-Caryophyllene (14.2%) Germacrene-D (32.1%) Bicyclogermacrene (6.7%) δ-Cadinene (13.1%) Neophytadiene (4.1%)				Bagci et al., 2010
		T. chamaedrys* subsp. *lydium			
Türkiye (Mersin)	3000 m	July 2004	Aerial parts	-	Yayli, 2007
Main Compounds	α-Pinene (12.5%) β-Pinene (6.6%) β-Caryophyllene (19.7%) Germacrene-D (9.3%) Caryophyllene oxide (6.1%)				
		T. chamaedrys* subsp. *chamaedrys			
Türkiye (Gümüşhane)	2000 m	July 2004	Aerial parts	-	Yayli, 2007
Main Compounds	α-Pinene (15.8%) β-Pinene (8.9%) β-Myrcen (4.1%) β-Caryophyllene (11.8%) Germacrene-D (16.7%)				
Main	α-Pinene (7.9%)				

Compounds	β-Pinene (5.9%) Limonene (5.1%) β- Caryophyllene (15.0%) α-Muurolene (15.3%)				Kazemizadeh et al., 2008
Türkiye (Mersin)	1600-1800 m	June 19, 2021	-	0.36	
Main Compounds	α-Pinene (11.12%) β-Pinene (4.70%) β-Bourbonene (5.02%) trans-Caryophyllene (22.07%) Humulene (10.47%) Germacrene -D (19.52%) Caryophyllene oxide (4.47%)				Cakir et al., 2023
	T. divaricatum* subsp. *divaricatum				
Türkiye (Antalya)	100-200 m	May 22, 2021	-	0.20	
Main Compounds	α-Pinene (12.71%) β-Pinene (7.01%) trans-Caryophyllene (10.05%) Humulene (4.39%) Germacrene -D (3.22%) Caryophyllene oxide (9.07%) Spathulenol (16.27%)				Cakir et al., 2023
	T. capitatum				
Italy (Sicily)	About 700 m	June 2020	Aerial parts	0.07	
Main Compounds	α-Pinene (19.9%) β-Pinene (27.6%) Myrcene (8.6%) Sylvestrene (16.6%)				Catinella et al., 2021
	T. polium				
Türkiye (Burdur)	1200 m	-	-	0.80	
Main Compounds	2-Hexen-1-al (5.62%) α-Thujene (18.87%) Sabinene (9.89%) β-Myrcene (19.52%) Germacrene-D (4.31%) β-Farnesene (9.23%)				Donmez, 2022
İran (Fars)	1600 m	August 2013	Aerial parts (Full flowering stage)	0.74	
Main Compounds	α-Pinene (6.40%) β-Pinene (10.90%) Carvacrol (8.60%) β- Caryophyllene (28.40%) Farnesene-cis-b (10.70%) Germacrene-D (6.20%)				Asgharipour and Shabankare, 2017
Türkiye (Ağrı)	-	-	Aerial parts (Flowering stage)	0.2	

Main Compounds	α-Pinene (4.7%) β- Caryophyllene (8.8%) Caryophyllene oxide (4.3%) (E)-Nerolidol (5.0%) β-Bisabolol (4.4%) T-Cadinol (6.2%) α-Cadinol (5.4%)				Gulsoy Toplan et al., 2022
Serbia	-	February 2008	Aerial parts (Before Anthesis)	0.01	
Main Compounds	Germacrene-D (31.0%) Bicyclogermacrene (6.7%) Spathulenol (5.0%) γ-Cadinene (4.3%)				Radulović et al., 2012
	T. polium* subsp. *polium				
Türkiye (Elazığ)	-	2011	Aerial parts (Fruiting season)	0.7	Hayta et al., 2017
Main Compounds	α-Pinene (10.2%) Germacrene-D (10.1%)				
	T. scordium				
Iran	-	June 2005	Flowering aerial parts	0.9	Morteza-Semnani et al., 2007
Main Compounds	β- Caryophyllene (22.8%) (E)- β-Farnesene (10.4%) Caryophyllene oxide (8.6%) 1,8-Cineole (6.1%) β-Eudesmol (5.1%)				
	T. scordium* ssp. *scordioides				
Serbia	-	July 2007	Aerial parts (Flowering stage)	0.05	Radulović et al., 2012
Main Compounds	Menthofuran (11.9%) (Z)-Octaddec-9-enoic (oleic) acid (11.5%) Hexadecanoic (palmitic) acid (6.45)				
	T.flavum				
Italy (Sicily)	380 m	June 2020	Aerial parts	0.08	
Main Compounds	α-Pinene (7.0%) β-Pinene (5.4%) Limonene (12.7%) β- Caryophyllene (6.6%) β- Bisabolene (26.8%) γ-Cadinene (5.5%)				Catinella et al., 2021
-	-	Jully 2008	Aerial parts	0.13	
Main Compounds	4-Vinyl guaiacol (6.0%) Caryophyllene (13.5%) α-Humulene (5.0%) Caryophyllene oxide (8.5%)				Formisano et al., 2012

			T. parviflorum		
Türkiye	-	-	Aerial parts	0.3	
Main Compounds	α-Pinene (4.4%) β- Caryophyllene (18.6%) Germacrene-D (9.2%) Bicyclogermacrene (6.0%) δ -Cadinene α-Bisabolene (4.4%) Caryophyllene oxide (8.8%)				Bagci et al., 2011
			T. pestalozzae		
Türkiye (Antalya)	800 m	June 22, 1995	Aerial parts (Flowering stage)	0.09	
Main Compounds	β- Caryophyllene (27.60%) (E)- β-Farnesene (4.37%) α-Humulene (5.59%) Germacrene-D (13.78%)				Baser et al., 1997
			T. orientale* var. *puberulens		
Türkiye (Gümüşhane)	2000 m	August 2004	Aerial parts	-	
Main Compounds	2-Methyl coumarin (20.0%) β-Caryophyllene (21.7%) α-Humulene (4.8%) Germacrene-D (10.6%) δ-Cadinene (4.1%)				Yayli, 2007
			T. sandrasicum		
Türkiye (Muğla)	200 m	June 19, 1995	Aerial parts (Flowering stage)	0.01	
Main Compounds	α-Pinene (6.52%) Sabinene (8.91%) Linalool (5.46%) Terpinen-4-ol (4.50%) β- Caryophyllene (9.06%) Germacrene-D (27.88%) Bicyclogermacrene (5.82%)				Baser et al., 1997
			T. multicaule		
Türkiye (Elazığ)	-	2011	Aerial parts (Fruiting season)	0.5	Hayta et al., 2017
Main Compounds	Caryophyllene oxide (31.11%)				
			T. montanum		
Türkiye (Manisa)	Summit of Sipyl Mountain	May 24, 1995	Aerial parts (Before flowering)	0.02	
Main	α-Pinene (5.16%)				

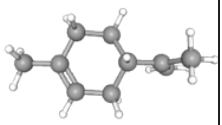
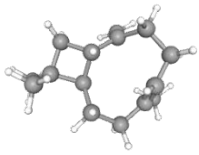
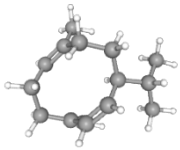
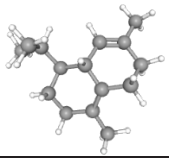
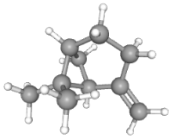
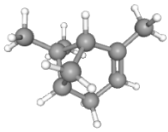
Compounds	Sabinene (11.34%) α-Copaene (5.69%) (E)- β-Farnesene (5.53%) Germacrene-D (5.80%) δ-Cadinene (6.25%) T-Cadinol (5.45%)				Baser et al., 1997
Italy (Sicily)	1450-1550 m	June 2020	Aerial parts	0.15	
Main Compounds	α-Funebrene (4.5) β-Cedrene (8.9%) Globulol (4.5%) Epiglobulol (13.5%) Longifolenaldehyde (14.5%) Ledene oxide (12.1%) 8-Cedren-13-ol (5.7%)				Catinella et al., 2021
	-	-	-	-	
Main Compounds	α-Pinene (4.0%) β- Caryophyllene (5.1%) δ-Cadinene (8.1%) τ-Muurolol (4.2%)				Radulović et al., 2012

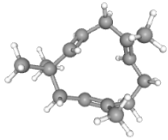
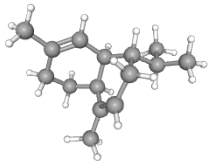
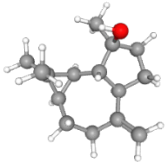
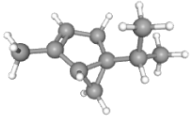
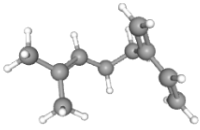
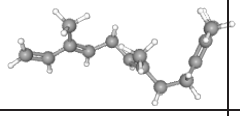
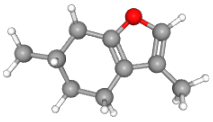
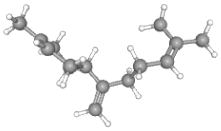
[1] Data not available

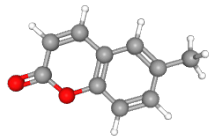
In the literature reviewed, it was determined that studies were carried out on the essential oil composition of 16 from the 54 taxa in the Flora. The essential oil amounts of the *Teucrium* taxa in question varied between 0.01% (*T. polium* and *T. sandrasicum*) and 0.9% (*T. scordium*). "Limonene, Caryophyllene (syn. β-Caryophyllene), Germacrene-D, 2-Hexen-1-al, δ-Cadinene, α-, β-Pinene, α-Muurolene, Humulene, Spathulenol, Sylvestrene, α-Thujene, β-Myrcene, Farnesene-cis-b, Menthofuran, β-Bisabolene, 2-Methyl coumarin, Epiglobulol, Longifolenaldehyde and Ledene oxide" were identified as the main components in essential oils.

It has been observed that both the essential oil contents of taxa and the chemical compositions of essential oils are affected by factors such as genotype, location, development period of the plant, and organ of the plant (Table 3).

Table 4: Chemical structures and uses of main compounds

Compound	Molecular		Classification	Use
Structure	**Formula**	**Weight (g mol^{-1})**		
Limonene 	$C_{10}H_{16}$	136.23	Terpenes-Monoterpenes	fragrances, food additives, flavoring agents, cosmetics (astringent, solvent, tonic), adhesion/cohesion promoter, fuels and fuel additives, odor agents, household products, auto products
Caryophyllene 	$C_{15}H_{24}$	204.35	Terpenes-Sesquiterpenes	food additives, flavoring agents, auto products
Germacrene-D 	$C_{15}H_{24}$	204.35	Terpenes-Sesquiterpenes	agrochemicals and personal care (insecticide-repellent)
δ-Cadinene 	$C_{15}H_{24}$	204.35	Terpenes-Sesquiterpenes	flavors for the beverage industry
β-Pinene 	$C_{10}H_{16}$	136.23	Terpenes-Monoterpenes	
α-Pinene 	$C_{10}H_{16}$	136.23	Terpenes-Monoterpenes	food additives, flavoring agents, flavoring and nutrient, fragrance, intermediates, agrochemicals (pesticides, insecticides)

Humulene 	$C_{15}H_{24}$	204.35	Terpenes-Sesquiterpenes	
α-Muurolene 	$C_{15}H_{24}$	204.35	Parent hydrocarbon-Terpene	
Spathulenol 	$C_{15}H_{24}O$	220.35	Terpenes-Sesquiterpenes	
α-Thujene 	$C_{10}H_{16}$	136.23	Terpenes-Monoterpenes	flavoring agent
Myrcene 	$C_{10}H_{16}$	136.23	Terpenes-Monoterpenes	fragrance, flavoring agent, insect repellent, and detergent additive preparation of perfume chemicals and flavoring
Farnesene 	$C_{15}H_{24}$	204.35	Terpenes-Sesquiterpenes	food additives, flavoring agents
Menthofuran 	$C_{10}H_{14}O$	150.22	Terpenes-Monoterpenes	flavoring agents
β-Bisabolene 	$C_{15}H_{24}$	204.35	Terpenes-Sesquiterpenes	food additives, flavoring agents
Methyl coumarin	$C_{10}H_8O_2$	160.17	Benzopyrans	perfumes, flavoring, food

				additives, flavoring agents, useful in coconut flavors, vanilla, caramel. cosmetics (masking, oral care)

Reference: National Center for Biotechnology Information, 2023.

REFERENCES

Abdollahi, M., and Simaiee, B. (2003). Stimulation by theophylline and sildenafil of rat submandibular secretion of protein, epidermal growth factor and flow rate. Pharmacological Research, 48,445-449.

Asgharipour, M.R., and Shabankare, H. G. (2017). Comparison of chemical composition of *Teucrium polium* L. essential oil affected by phenological stages. Bangladesh J. Bot., 46(2), 583-588.

Bagci, E., Hayta, S., Yazgin, A., and Dogan, G. (2011). Composition of the essential oil of *Teucrium parviflorum* L. (Lamiaceae) from Turkey. Journal of Medicinal Plants Research, 5,3457-3460.

Bagci, E., Yazgın, A., Hayta, S., and Cakılcıoglu, U. (2010). Composition of the essential oil of *Teucrium chamaedrys* L. (Lamiaceae) from Turkey. Journal of Medicinal Plants Research, 4(23), 2588-2590.

Bahramikia, S., and Yazdanparast, R. (2012). Phytochemistry and medicinal properties of *Teucrium polium* L. (Lamiaceae). Phytotherapy Research, 26, 1581-1593.

Baser, K.H.C., Demircakmak, B., and Duman H. (1997). Composition of the essential oils of three *Teucrium* species from Turkey, Journal of Essential Oil Research, 9(5),545-549.

Baser, K.H.C., and Kirimer, N. (2018). Essential oils of Anatolian Lamiaceae-An update. Natural Volatiles and Essential Oils, 5 (4), 1-28.

Cakir, T., Cecen, O., and Maral, H. (2023). Essential oil components of *Teucrium chamaedrys* L. subsp. *chamaedrys* and *Teucrium divaricatum* Sieber subsp. *divaricatum* Sieber growing naturally in Türkiye. *5. Internatıonal Food, Agrıculture and Veterınary Scıences Congress Presented Paper*.

Catinella, G., Badalamenti, N., Ilardi, V., Rosselli, S., De Martino, L., and Bruno, M. (2021). The Essential oil compositions of three *Teucrium* taxa growing wild in Sicily: HCA and PCA Analyses. Molecules, 26, 643.

Cozzani, S., Muselli, A., Desjobert, J.-M., Bernardini, A.-F., Tomi, F. and Casanova, J. (2005), Chemical composition of essential oil of *Teucrium polium* subsp. *capitatum* (L.) from Corsica. Flavour Fragr. J., 20, 436-441.

Dogrusoz, M., Tamkoc, A. (2019). Türkiye florasından toplanmıs *Festuca* L. genotiplerinde morfolojik-agronomik varyasyon. Bilecik Seyh Edebali Üniversitesi Fen Bilimleri Dergisi, 6(2), 261-267.

Donmez, I. E. (2022). Volatile oil composition of *Teucrium* species of natural and cultivated origin in the Lake District of Turkey. Applied Ecology and Environmental Research, 20(3),2235-2245.

Elabbara, F. A., Habel, A. M., Bozkeh, N. M. A., El-Tuonsi, A.T. M., and Awin, T. M. (2014). The essential oil composition of *Teucrium apollinis* (Lamiaceae) from Libya. Der Chemica Sinica, 5(1),26-27.

Formisano C., Rigano D., Senatore F., Bruno M., Maggio A., and Piozzi F. (2012). Chemical composition of the essential oil of *Teucrium flavum* ssp. *flavum* from Zakynthos, Greece. Rec. Nat. Prod., 6,306-310.

Gulsoy Toplan, G., Goger, F., Taskin, T., Ecevit-Genc, G., Civas, A., Iscan, G., Kurkcuoglu, M., Mat, A., and Baser, K. H. C. (2022). Phytochemical composition and pharmacological activities of *Teucrium polium* L. collected from Eastern Turkey. Turkish Journal of Chemistry, 46, 269-282

Guner, A., Aslan, S., Ekim, T., Vural, M. and Babaç, M.T. (edlr.), (2012). Türkiye Bitkileri Listesi (Damarlı Bitkiler). Nezahat Gökyiğit Botanik Bahçesi ve Flora Araştırmaları Derneği Yayını. İstanbul.

Hayta, S., Yazgin A., and Bagci E. (2017). Constituents of the volatile oils of two *Teucrium* species from Turkey. Bitlis Eren University Journal of Science and Technology, 7(2),140–144.

Kaska, A., Çiçek, M., and Mammadov, R. (2019). Biological activities, phenolic constituents, and mineral element analysis of two endemic medicinal plants from Turkey: *Nepeta italica* subsp. cadmea and *Teucrium s*andrasicum. South African Journal of Botany, 124, 63-70.

Kazemizadeh, Z., Basisi, A., and Habibi, Z. (2008). Chemical composition of the essential oil of *Teucrium hyrcanicum* and *T. chamaedrys* L. subsp. *chamaedrys* from Iran. Chemistry of Natural Compounds, 44,651-653.

Morteza-Semnani, K., Saeedi, M., and Akbarzadeh, M. (2007). Essential oil composition of *Teucrium s*cordium L. Acta Pharm., 57, 499–504.

Mut H., Basaran U., Dogrusoz, M., Gulumser E., Ayan I. (2017). Evaluation and characterization of perennial ryegrass (*Lolium perenne* L.) genotypes collected from natural flora. Romanian Agricultural Research, 34, 3-7.

National Center for Biotechnology Information (2023). PubChem Compound. Retrieved September 20, 2023 from https://pubchem.ncbi.nlm.nih.gov/compound

Ozcan, T. (2015). *Teucrium* L. (Lamiaceae) cinsinin revizyonu. Balıkesir Üniversitesi, Fen Bilimleri Enstitüsü, Doktora Tezi, Balıkesir.

Ozcan, T., Dirmenci, T., Martin, E., and Altinordu, F. (2015). Cytotaxonomical study in five taxa of the genus *Teucrium* L. (Lamiaceae). Caryologia, 68(1), 1-8

Ozek, G., Özek, T., Dinç, M., Doğu, S., and Baser, K.H.C. (2012). Chemical diversity of volatiles of *Teucrium orientale* L. var. *orientale*, var.

puberulens, and var. *glabrescens* determined by simultaneous GC-FID and GC/MS techniques. Chemistry & Biodiversity, 9 (6), 1144-1154.

Radulović, N., Dekić, M., Joksović, M., and Vukićević, R. (2012). Chemotaxonomy of Serbian *Teucrium* species inferred from essential oil chemical composition: the case of *Teucrium scordium* L. ssp. *scordioides*. Chemistry & Biodiversity, 9,106-122.

Rangahau, M. K. (2001): Essential oils and their production. Crop and Food Research, 1,1-39.

Sadeghia, H., Jamalpoorb, S., and Shirzadib, M.H. (2014). Variability in essential oil of *Teucrium polium* L. of different latitudinal populations. Ind. Crop Prod., 54, 130-134.

Sharififar, F., Dehghn-Nudeh, G., and Mirtajaldini, M. (2009). Major flavonoids with antioxidant activity from *Teucrium polium* L. Food Chemistry, 112 (4), 885-888.

Suvari, G. (2019). *Teucrium parviflorum* ve *Teucrium p*olium bitkilerinin kimyasal ve biyolojik aktivite yönünden incelenmesi. Dicle Üniversitesi, Sağlık Bilimleri Enstitüsü, Y. Lisans Tezi, 2019, Diyarbakır.

Tan, A. (2010). Türkiye bitki genetik kaynakları ve muhafazası. Anadolu J of AARI, 20(1), 9-37.

Tuncturk, R., Tuncturk, M., and Eryigit, T. (2019). Van florasında yayılış gösteren *Teucrium* cinsine ait bazı türlerin kimyasal içerikleri. KSÜ Tar Doğa Derg., 22(1),138-142.

Yayli, N. 2007. Bazı *Teucrium* L. taksonlarında uçucu yağların kimyasal bileşimleri ve antimikrobiyal aktiviteleri. Karadeniz Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, Trabzon.

Chapter 10

The Devastating Impact of Forest Fires on the Southwest Mediterranean Region of Turkey: Addressing the Root Causes

Ufuk COŞGUN[1], Damla YILDIZ[2]

[1] Karabuk University, Forest Faculty, Forestry Policy and Management Division, Karabuk, TÜRKİYE
ufukcosgun@karabuk.edu.tr. https://orcid.org/0000-0003-4738-6636,
[1] Karabuk University, Forest Faculty, Forestry Policy and Management Division, Karabuk, TÜRKİYE
damlayildiz@karabuk.edu.tr. https://orcid.org/0000-0002-6809-0538,

ABSTRACT

Turkey has approximately 23.1 million hectares of forest area, covering one-third of the country's surface area. About 20 thousand villages and 7 million forest villagers live in these areas. Mediterranean-type ecosystems characterise the forest areas in the southern region of Turkey. The annual average number of forest fires from 1937 to 2021 is 1,385. 1.8 million hectares of forest land have been burned within the same period. The annual burned area is 22,041 hectares, and the average area per unit fire is 15.73 hectares. Moreover, approximately 90% or more of forest fires are caused by human activity. Therefore, it is necessary to understand the socioeconomic reasons behind human-caused forest fires.

Identifying the socioeconomic factors that cause human-caused forest fires is crucial for effectively implementing prevention measures, which constitute the first stage of the fight against forest fires.

Antalya Forest Regional Directorate has been selected as the research area due to its ranking in terms of the annual average site burned according to forest fire statistics in Turkey between 2012 and 2021. In addition, it was chosen as the study area because it is in first place in terms of the area damaged most in the forest fires that occurred in 2021.

This study aims to identify the socioeconomic problems that cause human-caused forest fires and propose potential solutions to these issues. To achieve this aim, the views of a total of 362 individuals were obtained, including 177 forest village mukhtar who are legal representatives of forest villagers who live near forest areas and suffer severe damage from forest fires, as well as 199 technical personnel from the General Directorate of Forestry who are involved in fighting forest fires. The opinions of the groups selected for the study were obtained using focus group meetings, semi-structured interview forms, and limitation cards. The data obtained from these methods have been content analysis performed using the qualitative research method analysed, and the results were presented as means and percentages.

It has been observed that forest village Mukhtar and forest engineer technical personnel focus on different issues regarding the socioeconomic problems that cause forest fires and potential solutions.

Keywords: Forest fire, socioeconomic problems, forest villages, the root cause of forest fire

1-INTRODUCTION

The emergence of terrestrial ecosystems began approximately 550 million years ago. The first fires are predicted to have occurred in the Silurian period, about 440 million years ago (Keeley et al., 2012). Terrestrial ecosystems, especially forests, have evolved with the ability to adapt to natural forest fires. In addition to climate and vegetation, introducing human factors into the system has increased the number of forest fires in all ecosystems (Naveh, 1975; Gill et al., 1981; Keeley and Keeley, 1988; Richardson and Wilgen, 1992).

Fire is an essential component of the ecological and biological cycle in Mediterranean-type ecosystems that occur in five different regions of the world (Mediterranean Basin, Cape Region of South Africa, California State of the United States, central regions of Chile, and southern Australia) (Moreno and Oechel, 1994).

Forest fires spread over large areas, become more difficult to extinguish, and severely impact forest ecosystems (Tedim et al., 2013). As forest fires occur with increasing intensity and spread over large areas due to their unique meteorological conditions, the damage to ecosystems becomes more significant. Therefore, this issue is being discussed in countries within the fire belt (Abram et al., 2021). Ecological, biological, technical, and socioeconomic factors cause forest fires. Climate change, on the other hand, is considered a significant human-induced factor that increases the area, number, and severity of forest fires due to its extreme effects on factors such as temperature, relative humidity, and wind (Camia et al., 2017; Krikken et al., 2019).

Forest area management in Turkey is executed by the General Directorate of Forestry (GDoF) under the jurisdiction of the Ministry of Agriculture and Forestry. The GDoF operates through 30 Forest Regional Directorates (FRD) across the country, aiming to safeguard, enhance, and expand the 23.1 million hectares of Turkish forest areas (GDoF, 2021). Each FRD is structured into Forest Enterprise Directorates (FED) and Forest Enterprise Chefs (FEC). This organizational framework is also responsible for intervening in forest fires.

To prevent forest fires from occurring, various activities must be carried out within this context. This stage includes a wide range of communication and interaction activities to be carried out within the framework of forest public relations. As their effects cannot be seen immediately, these activities must be carried out patiently and sustainably. An essential condition for success is including scientific research in identifying and analyzing the problems that cause forest fires.

The GDoF has classified the causes of forest fires into four main categories: lightning, intentional, negligent, and unknown. Data covering approximately 43

years, from 1960 to 2003, reveal that natural fires accounted for only 3.31% of all forest fires in Turkey. According to these data, the rate of human-caused forest fires between 1960 and 2003 was 96.69%. Between 2004 and 2021, the rate of natural forest fires in Turkey was 12.60% (GDoF, 1988a; GDoF, 1988b; GDoF, 2022). According to this data, the rate of human-caused forest fires during these 19 years is 87.40%.

During 2006-2010, the rate of human-caused forest fires in different regions of Europe was relatively high. For instance, natural forest fire rates were examined in other parts of Europe from 2006-2010. The rates were 7.3% in Northern Europe, 0.5% in Central Europe, and 4.7% in Southern Europe (Ganteaume et al., 2013).

Forest fires in Turkey are primarily caused by "humans." These data require a more detailed analysis of forest-human relationships. Studies have been conducted and are being undertaken on human-induced forest fires with various socioeconomic characteristics. In these studies, the effects of humans on forest fires have been analyzed using different variables. (Almeida and Moura, 1992; Kallidromitou1 et al., 1999; Öktik, 2001; Coşgun, et al, 2010, Coşgun et al., 2012; Kavgacı, et al., 2012; Martinho, 2019; Nyamadzawo, 2013; Kim et al., 2019; Kwak, et al., 2012; Romero-Calcerrada et al., 2010; Vilar et al., 2014; Vilar et al., 2016a; Vilar et al., 2016b; Chinamatira, et al., 2016; Sebastia´n-Lo´pez, et al., 2008; Bar Massada et al. 2009; Martínez et al. 2009; Thompson et al. 2011).

The total number of forest fires in Turkey between 1937 and 2021 was 117,734, with a burned forest area of 1,851,476 hectares (GDoF, 2021). During this period, an average of 1.385,11 forest fires and 21.782,07 hectares of forest area were burned annually. Therefore, it is essential to analyze the reasons for human-caused forest fires. Socioeconomic problems are the leading causes of human-caused forest fires (GDoF, 2021)

In this study, the aim was to determine the socioeconomic problems causing human-caused forest fires and what the possible solutions could be. For this purpose, the views of forest village heads (177 village heads) who are legal representatives of forest villagers who have been seriously affected by forest fires and live close to forest areas and technical personnel working in forest fires. It has been evaluated with a total of 376 people views. The Antalya Regional Directorate of Forestry, which ranked first in terms of burned area and third in the number of forest fires between 1997 and 2021 in Turkey, was selected as the study area. Descriptive statistics were used to present the obtained data.

2. MATERIAL and METHOD

According to data from 1997 to 2021, the Antalya Regional Directorate of Forestry (ARDoF) has the highest average burned area among the 30 FRD in Turkey. Regarding the presence of burned forest areas in Turkey between 2012 and 2021, ARDoF has ranked first among other Forest Regional Directorates with an annual average of 6,900 hectares of burned forest area.

According to forest fire statistics history, Turkey has experienced the highest number of forest fires and burned areas in 2021. During this period, ARDoF again ranked first in the area burned, over 60 thousand hectares, and the highest damage caused by forest fires. The ARDoF has been chosen as the study area due to its ranking in the top position for essential factors such as the number of forest fires and the size of the burned area in recent years (Figure 1 Human factors cause most forest fires in Turkey. Therefore, it is vital to determine the socioeconomic factors that cause forest fires. Forest villages are the most affected by forest fires and suffer severe damage.

This study aims to determine the views on socioeconomic problems and solution proposals that cause forest fires; i) the elected representatives of forest villagers, forest village mukhtars; ii) technical personnel working in forest fires of the Antalya Forestry Regional Directorate; and iii) Forest Enterprises Chiefs working in Forestry Enterprises Directorate's opinions have been assessed.

To this end, the Forest Enterprises of Directorates in the ARDoF were divided into two groups in the eastern and western regions. This is because the socioeconomic structures of the forest villages within the scope of the Eastern and Western Forest Enterprises of Directorates contain differences. The primary sources of livelihood for forest villages affiliated with the FED in the eastern region include agriculture, animal husbandry, and tourism, which also have a significant share. Serious employment opportunities are provided for a considerable population in tourism establishments in these regions.

The primary source of livelihood for forest villages affiliated with the Forest Enterprises Directorates in the western region is agriculture, especially greenhouse cultivation, which is a significant source of production and income. In addition, the distribution of forest fire occurrences between 1979 and 2021 for Forest Enterprises Directorates in the Eastern and Western regions also varies (Table 1).

Table 1: Distribution of Average Number of Forest Fires in Antalya FED Between 1979-2021

Forest Enterprises Directorate	Forest Enterprises	Number of Total Fires
Eastern Region Forest Enterprises of Directorate	Manavgat	1.346
	Serik	1.117
	Alanya	994
	Taşağıl	558
	Gazipaşa	495
	Akseki	480
	Gündoğmuş	399
Western Region Forest Enterprises of Directorates	Kaş	774
	Kumluca	505
	Finike	279
	Korkuteli	104
	Elmalı	49
Total Forest Fire Number		7.100

Forest enterprise units sampled from both groups can represent their groups for forest fire numbers. The ratio of the forest fire numbers that occurred in the sampled forest enterprise units in the east and west groups to the forest fire numbers that occurred in all forest management units in the region is 53.59%. Therefore, it is considered sufficient to represent the entire region. On the other hand, the forest fire numbers for both groups being over 50% of the total forest enterprises units makes the study more specific (Table 1).

The study sampled Manavgat, Serik, and Taşağıl Forest Enterprise Units in the East group and Finike and Kumluca Forest Enterprise Units in the West group and their affiliated forest villages. Forest village Mukhtar, the villagers' elected representatives in these two forest village groups, were sampled through complete area sampling (Table 2).

First sample group: There are 177 forest villages within the scope of the determined FED. 36% of all forest villages affiliated with the Antalya Regional Directorate of Forestry are located in the sampled area for the study.

Second sample group: Technical staff from the Forest Fire Fighting Department Directorate in the ARDoF and technical staff from other Departments who worked in forest fires were sampled using the complete area sampling method, resulting in a sample of 47 people (Table 2).

Third sample group: Another group of participants in the study are Forest Enterprises Directorates and other technical staff working in Forest Enterprises Directorates affiliated with the ARDoF. A sample of 138 people was obtained from this group using the complete area sampling method (Table 2). Three

hundred seventy-six opinions were obtained on this study's "Socioeconomic Problems Leading to Forest Fires and Solution Proposals" topic (Table 2).

Table 2: Distribution of Groups Providing Opinions on the Socioeconomic Problems Leading to Forest Fires and Solution Proposals

Interviewed Groups	Number of People Interviewed
Forest Village Mukhtar	177
Antalya Regional Directorate of Forestry Technical Personnel	61
Forest Enterprise Chiefs in Antalya Regional Directorate of Forestry	138
Total	376

The opinions of the groups selected for the study were obtained using focus group meetings, semi-structured interview forms, and limitation cards. The data obtained from these methods have been content analysis performed using the qualitative research method analysis, and the results were presented as means and percentages.

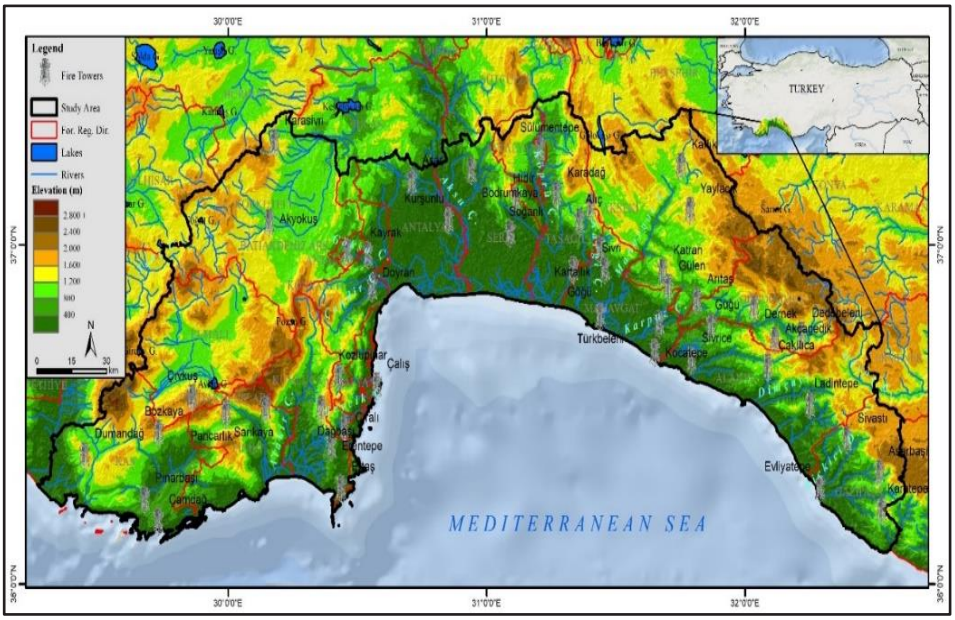


Figure 1: Study area

3- DISCUSSION

3.1. Opinion of Forest Village Mukhtar

The opinions of village Mukhtar on the "socioeconomic problems causing forest fires" were classified into nine main categories (Table 3).

Table 3: Forest Village Mukhtar Opinions on Socioeconomic Problems Causing Forest Fires

Opinions	Opinion Numbers	Opinion Rate (%)
1-Technic Problems	48	27.12
2-Public Awareness, Community Outreach	31	17.51
3-Unemployment	21	11.86
4-Self-Interest	18	10.17
5-Energies Transmission Lines	15	8.47
6-Picnic	14	7.91
7- Inspections/Audit	12	6.78
8-Tourism	12	6.78
9-Carelessness/Negligence-Intention	6	3.39
Total	177	100.00

It can be observed that a significant portion of the opinions expressed by village Mukhtar are categorized under the "technical (27.12%)" reasons for forest fires (Table 3). The technical reasons for forest fires can be further classified into several subcategories, as identified by the village Mukhtar. These subcategories include as follows: i) shepherds and grazing, ii) inadequacy and insufficiency of forest roads, iii) lack of coordination and delay in responding to fires, iv) neglect of forest areas (including periodic maintenance and leftover debris after timber harvesting), v) limited job opportunities due to outsiders coming in for production work, and vi) insufficient water sources (such as lakes and reservoirs) to be used during fire suppression efforts.

According to the opinions of village mukhtars, the second largest group of causes of forest fires is "education-awareness and forest-public relations (17.51%)". Some of the opinions within the scope of "education-awareness and forest-community relations" are as follows: i) the Inability to establish social relations between the Forest Conservation Officers working in the Forestry Management Directorates and the forest villagers, ii) the harsh attitude and behavior of Forest Conservation Officers and their lack of tolerance, iii) controversies between forest villagers and forest management offices due to problems encountered in the implementation of Article 2/B of the Forest Law No. 6831, which involves the removal of some forest areas outside the

boundaries of forest areas, and iv) inadequate education and awareness due to approaches such as the lack of harmony between the Forest Organization and the villagers.

The third issue discussed by village heads is grouped under the title of "Unemployment (11.86%)." Within the scope of employment problems of forest villagers, the following issues are emphasized: i) unemployment of the young population, ii) inadequate seasonal work in hotels in the tourism sector, and iii) insufficient income from agriculture and livestock, the primary sources of livelihood.

The fourth group of opinions gathered under the "Self Interest" heading represents 11.86% of the responses. This group includes behaviors and actions taken by individuals for their benefit. Within this group, the following opinions were mentioned: i) Some people intentionally start fires in the forest in reaction to the strict forest laws that affect forest villagers, ii) Unequal treatment of seasonal fire workers regarding job security, iii) Intentions to obtain profits by taking 2/B land, etc.

Electric power transmission lines can pass through forest areas to provide electricity to towns and villages. For this reason, the forest village Mukhtar has identified the fifth factor that causes forest fires as "Power Transmission Lines" (8.47%). This approach includes i) the maintenance of transmission lines not being carried out by technical standards and ii) sparks from electric currents in the lines during very windy weather conditions, which can reach the vegetation below and cause fires.

The sixth group of opinions is related to the cause of forest fires resulting from "Picnics" in forest areas by rural or urban people, as stated by the forest village mukhtar, with a percentage of 7.91%. It is suggested that the insufficient or lack of picnic areas in forested lands leads to people having picnics inside the forest, which causes the emergence of forest fires.

The seventh factor the forest village Mukhtar identified for the emergence of forest fires is "Inspection (6.78%)". In this context, the lack of inspection practices has been emphasized as a contributing factor. Specifically, the following issues have been raised: i) the lack of control over the entry and exit to the forest areas, ii) the need for forest conservation officers to increase their inspections, iii) Forestry workers putting too much pressure on the Shepherds have been evaluated within this scope.

The eighth factor identified by the forest village Mukhtar is related to the importance of tourism in the region, which contributes to the economy of the country and the region but is also associated with forest fires. Some village Mukhtar included the "Tourism (6.78%)" sector among the factors that cause

forest fires. In this context, some of the issues highlighted include: i) organizing safari tours for foreign tourists in the forest, ii) uncontrolled tourism tours organized in the forest, and iii) tourism areas being located within the forest boundaries.

The ninth factor in the causes of forest fires identified by the forest village Mukhtar is "Carelessness-Intention" (3.39%) and ranks last. Two subheadings were identified within this context: i) glass fragments in the forest causing fires in dangerous weather conditions, and ii) From a silvicultural perspective, it is necessary to conduct quick restoration works in forest areas after fires. Therefore, the second sub-problem has been stated as the auctioning of wood raw material production in the burned areas to contractors or various companies through the application of "Standing timber sales."

Disagreements arise between the contractor firms that purchase products through stumpage sales and the forest villagers and forest village cooperatives who want to be involved in the production process.

According to the disagreements between contractor companies that purchase products through "Stumpage sales" and forest villagers and cooperatives who want to participate in production, some individuals are said to cause forest fires. The socioeconomic problems that cause the fires mentioned by the village leaders overlap with human-caused fire reasons in European and Mediterranean countries. Forest fires caused by humans, such as accidents, neglect, or intent, are considered important in fire risk assessments for Mediterranean countries (Henderson et al., 2005). Especially Unemployment, utilization of recreational areas, agricultural production, and intersecting areas between recreate to agriculture (Ganteaume et al., 2013).

The opinions of forest village Mukhtar as the legal representatives of forest villagers have also been identified for solutions to the socioeconomic problems that cause forest fires (Table 4). The first proposed solution is grouped under the "Technical" category with the highest percentage of opinions (46.33%). These opinions include: i) urgently opening roads in block forests within the forest, ii) sustaining the maintenance of the opened roads, iii) Ensuring that forest areas that lost their forest status with the amendment made in Law No. 6831 are offered free of charge to forest villagers, who are their traditional users, iv) conducting necessary silvicultural maintenance (monitoring, thinning, strip cleaning) works within the forest, and v) granting grazing permission to villagers who engage in small-scale livestock breeding in certain forest areas.

Table 4: Solution Proposals for Socioeconomic Problems Causing Forest Fires According to Forest Village Mukhtar Opinions

OPINIONS	Opinion Numbers	Opinion Rate (%)
1- Solutions to Technical Problems	82	46.33
2- Public Awareness, Community Outreach	27	15.25
3- Unemployment	22	12.43
4- Energy Transmission Lines	19	10.73
5- Carelessness/Negligence-Intention	15	8.47
6- Tourism	8	4.52
7- Inspections/Audit	4	2.26
Total	177	100.00

The second group of solution proposals is "Education-awareness and Public Relations (15.25%)". Within this context, the following approaches are mentioned: i) Increasing Forest fines, ii) Sufficient training of Forest Fire Workers, iii) Forest Enterprises Chiefs affiliated with Forest Enterprises Directorates establishing a healthy dialogue with Village Mukhtar, iv) Forest Enterprises Directorate staff being more sensitive to forest fires, v) Forest fire workers need to be educated and young.

The third group of solution proposals consists of "Unemployment (12.43%)." Within this context, the proposed solutions include: i) employing forest protectors from forest villages, ii) ensuring that the workers working in forest fires are selected from forest villagers, and iii) providing continuous employment opportunities for forest villagers in forestry jobs and operations.

The fourth group solution proposals are "Energy Transmission Lines (10.73%)". In this context, suggested solutions include i) Energy companies inspecting power transmission lines frequently, ii) employing forest villagers to control and clear the vegetation under the lines' routes, and iii) employing forest villagers to inspect against forest fire hazards in sensitive forests.

Fifth on the list is the topic of "Negligence-intent (8.47%)." Within this context, it is stated that timber production in burned areas should not be awarded to contractors or various companies in the form of "Standing-cutting sales" to enable the restoration of forest areas after the fire.

The sixth solution proposal focuses on "Tourism (4.52%)." The proposed solutions for this issue are as follows: i) organizing safari tours in forest areas during the summer season under the control of local guides, ii) avoiding the use

of the "Stumpage sales method" for marketing purposes for the production of timber after the fire of Forest, iii) supporting to be the employment of forest villagers who work in local hotels in the tourism sector because of continuous and standard working hours.

The seventh solution proposal group is related to the "Control (2.26%)" issue. The views suggest: i) increase the frequency of controls in the forest and ii) the supervisors who monitor the forest workers be audited by their managers. The statement highlights the lack of input from village heads on specific socioeconomic issues regarding the solutions to forest fires. The mukhtars have not provided any recommendations on personal interests and picnic-related matters.

3.2. Opinions of Forest Engineers in ARDoF and Views of FECs in ARDoF

The technical staff and Forest Enterprise Chiefs, who are forest engineers at the Antalya Regional Directorate of Forestry, have been provided with their opinions on the main problems contributing to forest fires. These opinions have been grouped into nine main categories, as presented in Table 5.

According to socioeconomic issues leading to forest fires, " Public Awareness, Community Outreach (45.23%)" has been identified as the most crucial topic by Forest Enterprise Chiefs and forest engineers in Antalya Regional Directorate of Forestry. The opinions under this heading include: i) inadequacy of forest community relations, ii) negative attitudes towards citizens by the government, iii) forest management officials not listening enough to forest villagers, iv) individuals who have been caught and processed legally for forest crimes but have not received the expected results, burning forests out of anger towards forest management, v) burning forests to punish forest management for their practices, vi) conducting forest management activities despite the opposition of the villagers, vii) neglect, viii) carelessness, ix) ignorance, x) lack of education and awareness, and xi) the carelessness of hunters and shepherds in starting fires, xii) deficiencies and inadequacies in forestry policies and legislation, xiii) failure to form effective firefighting teams, xiv) inexperienced support forces unable to fully participate in the organization, xv) the transition of firefighting personnel to permanent positions, which has reduced their effective participation in firefighting, xvi) irregular monitoring of the forest boundaries of forested areas with a cadastre, xvii) stubble burning, xviii) land clearance, and xiv) the coexistence of state forests and settlements (Table 5).

Tablo 5: The Views of Technical Personnel in ARDoF and FECs in ARDoF on Socioeconomic Issues Causing Forest Fires

OPINIONS	Opinion Numbers	Opinion Rate (%)
1- Public Awareness, Community	90	45.23
2- Technical Problems	43	21.61
3-Poverty of Forest Villages	17	8.54
4- Energy Transmission Lines	13	6.53
5-Self-Interest	10	5.03
6- Dispute Between Villages and Peasants	7	3.52
7- Picnic	7	3.52
8- Carelessness/Negligence-Intention	6	3.02
9- Stubble-Burning	6	3.02
Total	199	100.00

The second proposed problems group was identified as the "Technical Problems" topic (21.61%). Within this category, the opinions include: i) the unresolved issue of forest cadastre, ii) Before the restoration process in burned forest areas, the production of wood raw materials by the local people where the fires broke out, iii) inadequate forest firebreaks, which are areas cleared to stop or slow the spread of fires, iv) inadequate road networks within the forest, v) forest management chiefs not giving enough attention to fire prevention measures due to work overload, vi) Density of agricultural-forest cross-sectional areas, vii) unresolved legal issues, viii) the implementation of the Stumpage Sales method, xi) Deterioration of forest-public relations, x) Forestry studies are not sufficiently covered in the press, xi) deficiencies in media and public relations, and xi) Socioeconomic problems of people living in or near the forest, etc. approaches are included

The third problem group constitutes the "poverty of forest villagers" (8.54%) as its subject. These views include i) setting fires for employment opportunities due to poverty, ii) inadequacy of agricultural production, iii) unproductive agricultural and livestock incomes, iv) poverty, v) setting forest fires for clearing land to become a landowner, vi) It includes approaches such as utilizing forest areas for profit.

The fourth proposed solution has emerged on the subject of "Energy Transmission Lines" (6.53%). In this context, it has been pointed out that the periodic maintenance of energy transmission lines is not being carried out regularly. In this category, it is expressed that i) the company related to energy

transmission lines does not invest enough in necessary maintenance, ii) the maintenance activities are not carried out in accordance with the necessary technical qualifications, and iii) the interruption of electricity transmission in the lines during extremely windy weather conditions in the region.

The fifth opinion group is formed under "Self-Interests (5.03%)". Under this heading, opinions such as i) village conflicts (especially between the former and new village Mukhtar) and ii) burning forest areas to open up areas for cultivation were expressed.

The sixth problem proposal has emerged as "Disputes between Villages and Villagers" (3.52%). The view included in this topic is that i) there are border disputes between villages and villagers, and ii) there are disagreements between villages or forest administrations due to land use in rural areas.

The seventh problem proposal addresses the issue of "Picnic" (3.52%). In this group, the following issues were stated: i) the concentration of picnic activities in forest areas during the summer season and ii) the lack of sufficient picnic/recreation areas that rural and urban people can easily benefit from at the regional level. Recreational forest activities, particularly during the spring, summer, and fall, often involve picnics. However, inadequate attention to fire safety during and after these activities can lead to forest fires.

The eighth heading is "Negligence-Intention (3.02%)". "Carelessness, Irresponsibility, Neglect" and "the low deterrent effect of politics and government policies" have been expressed in this context.

The ninth solution proposal addresses the issue of "Crop Residue Burning" (3.02%). It has been observed that forest villagers, whose primary sources of livelihood are agriculture and livestock and who primarily engage in dry farming, burn the crop residues (straw) left in their fields after completing their agricultural production. Although this practice has been banned by law, its continuation has been identified as a problem.

In the context of socioeconomic problems leading to forest fires, the sixth issue identified by Forest Enterprise chiefs is conflicts between villages and villagers. Similar conflicts have contributed to forest fires in rural areas in Northern Portugal and Greece (Moreira et al., 2001; Tabara et al., 2003; Lekakis, 1995). This study confirms the alignment between the opinions of Forest Enterprise chiefs and these previous findings.

The views of technical staff, who are forest engineers at the Antalya Regional Directorate of Forestry and Forest engineers who serve as Forest Enterprise Chiefs in the Antalya Regional Directorate of Forest, solution of problems on forest fires have been expressed in eight main categories (Table 6).

"Public Awareness, Community Outreach" ranks first with a rate of 35.18%. In this context, the following solutions have been proposed: i) applying education and awareness-raising activities to all relevant groups (children in schools, shepherds, hunters, village mukhtar, local people in mosques, forest rangers, women etc.), ii) supporting education and awareness-raising activities through national and local written, verbal, and visual media, iii) intensifying media support during the fire season, iv) encouraging the rural community to form fire protection teams, v) increasing awareness-raising activities by using warning signs and banners, i) Ensuring the promotion of technical staff with the merit system and having well-equipped managers, ii) ensuring complete and effective organization during fires, iii) regular monitoring of forest boundaries in areas where cadastral surveys have been conducted, iv) urgently opening and maintaining roads in block forests within the forest, v) employing trained and young workers as forest firefighters, vi) employing forest guards from forest villages to protect the forest, vii) Carrying out the necessary maintenance studies in the forest (dilution, density maintenance, lane cleaning), viii) strictly prohibiting unauthorized grazing of goats in the forest and not allowing it under any circumstances, and ix) allowing small-scale livestock farmers to graze their animals in certain forest areas (Table 6).

Tablo 6: Solutions Proposal about Socioeconomic Problems Causing Forest Fires: Views of Technical Personnel in ARDoF and FECs in ARDoF

OPINIONS	Opinion Numbers	Opinion Rate (%)
1- Public Awareness, Community Outreach	70	35.18
2- Solutions to Technical Problems	69	34.67
3- Income-Generating Activities, Development and Employment	19	9.55
4- Energy Transmission Lines	17	8.54
5-Picnic	12	6.03
6- Straw Burning or Controlled Burning	7	3.52
7-Carelessness/Negligence-Intention	3	1.51
8-Inspections/Audit¤	2	1.01
TOTAL	199	100.00

Secondly, "Solutions to Technical Problems" issues (34.67%) related to solutions are included. Solutions with technical aspects can be categorized into twelve groups. These opinions include: i) resolving cadastre problems in forest villages, ii) improving forest fire monitoring systems, iii) having adequate and standardized roads that allow for quick intervention in forest fires, iv) clean

forestry management (such as reducing combustible materials like logging waste in forests), v) trained and equipped forest firefighting teams, vi) supporting forestry operation managers with trained assistant personnel to reduce their workload, vii) not implementing the Stumpage Sales system, viii) increasing sanctions, ix) not employing villagers in production activities in villages affected by forest fires, x) changing forestry laws and not neglecting the rights of forest villagers, xi) the issue of forest villagers is not only a forestry problem but also a state problem. The state needs to produce decisive and permanent policies, xii) scientifically separating areas for agriculture and forestry, evacuating villages from areas that should be forests by moving them to specific regions, and increasing service and investment efficiency by providing services to larger consolidated settlements: i) Ensuring continuous awareness of the public about forest fires, ii) Creating informative and awareness-raising campaigns about forest fires and their damages in local and national media throughout the year, iii) Information activities should be created through advertisements in the visual media for the fight against forest fires. iv) Holding educational meetings regularly among the public (in villages and municipalities), v) Increasing Forest fines, vi) Ensuring that forest firefighters receive adequate training, vii) Establishing a healthy dialogue with the village Mukhtar of the Forestry Enterprise Chiefs affiliated to the Forestry Enterprises Directorates viii) Raising the sensitivity of forest personnel to fires, and ix) Providing support from NGOs to create fire sensitivity

The third group of solution proposals includes "Income-Generating Activities and Development with Employment (9.55%)". It emerged as a solution to the problem of forest fires caused by poverty among the people in forest villages. In this context, the views consist of i) providing income to forest villagers through rural development projects, ii) paying attention to increasing employment in forest villages, iii) giving priority to forest villagers in employment opportunities, and iv) diversifying the product pattern for economic income by expanding non-timber forest products that can be produced using new and economically profitable production techniques suitable for local conditions and cultivating them in agricultural areas. The study evaluated the effects of forestry policies on forest fires in European Union countries; rural development was examined as a variable, and its importance was emphasized (Galiana et al., 2013).

The fourth solution proposal consists of the views on "Energy Transmission Lines" (8.54%). In this context, the opinions of i) bringing the energy transmission lines up to the standards of the European Union and ii) ensuring regular maintenance and inspections of the lines have been expressed, i)

Changing the fire poles made of trees in the forest, ii) Ensuring complete maintenance and repair of energy transmission lines, iii) Renewal of equipment used in the transmission mechanism of energy transmission lines, iv) Increasing legal sanctions against companies operating energy transmission lines, v) Suggestions such as removing high voltage lines in forest areas are included.

The fifth solution proposal is about "Picnics (6.03%)". For this view, it has been suggested to i) increase the number of accessible picnic areas, ii) create standard areas where picnics can be carried out in a controlled manner, i) determine the picnic area needs of rural and urban communities, ii) creating areas that will meet the picnic and recreation needs of the community while taking sufficient measures against forest fires, iii) The third sub-suggestion is to be allowed the use of forest areas for picnics and recreational purposes during summer.

The sixth solution proposal concerns the "Control or Controlled Burning of Stubble Burning (3.52%)". Within this framework, it is suggested that i) the stubble-burning activities in agricultural fields should be controlled, and ii) stubble-burning should be conducted in a controlled manner.

The seventh-ranked solution proposals have been identified as "Carelessness/Negligence-Intention (1.51%)." Within this scope, i) Burned Forest areas should not be given as sales of "The Stumpage Sale, " ii) Forest enterprises need to abandon their commercial mindset, iii) The political pressure on forestry must be wholly eliminated, iv) Equal pay for equal work have to implement.

The eighth solution proposal was on the subject of "Inspection/Audit (1.01%)". These opinions are i) Increasing the controls in the forest, ii) Supervising the officials in direct contact with the villagers in the forest by their managers in terms of relations and behavior patterns.

For the socioeconomic problems that cause forest fires, the approach of increasing the employment of forest villagers, which is stated by the forest management chiefs and included in the solution proposals, was evaluated as pressure on forest fires in a study conducted in Italy. However, despite the absence of such an assessment in Turkey, it is an issue that needs to be discussed. In the study of socioeconomic and environmental factors modeling in determining the long-term fire hazard, which includes Southern European countries (Portugal, Spain, France, Italy, and Greece); Economic variables (Agricultural Production -9- variables, Livestock -4- variables and Sectoral Production Statistics -3- variables) and social variable (Population-2- variables, Unemployment -3- variables) were used. The criteria that this study includes as socioeconomic variables coincide with the sub-headings emphasized within the

scope of income-generating activities and development and employment (9,55%), which is in the third place in the solution proposals stated of the Chiefs (Sebastián-López et al., 2008).

4- CONCLUSIONS

The GDoF has been increasing its investments in firefighting operations to enable effective intervention during and after forest fires. Over time, establishing fire-resistant forests has become an approach that has been emphasized and gradually adopted by forestry organizations. This approach has been reflected in the Concrete Plan for Establishing Fire-Resistant Forests published by the Forest Fire Management Directorate (GDoF) with the regulation numbered 6665. (Neyisci et al., 1990; GDoF, 2010).

Controlled burning is gaining acceptance to reduce the risk of forest fires (Neyisci et al., 2002). Such practices represent direct, ecological approaches to fire prevention in forest ecosystems. However, these studies do not consider the social dimension of forest fires before they occur. In contrast, fire simulation studies based on vegetation and fuel load data are focused on the forest fire regime and the firing process. Regrettably, socioeconomic investments, which are cheaper and more sustainable and can prevent forest fires from occurring, have been overlooked. Thus, a comprehensive and sustainable approach to forest fire prevention must address the ecological and socioeconomic dimensions of forest ecosystems.

The allocation of resources for education and awareness-raising to prevent forest fires is smaller than that for firefighting and post-fire rehabilitation. Hence, investments in education, awareness-raising, and the creation of employment opportunities based on forestry in the region can lead to more sustainable outcomes with a smaller investment of resources.

When the total investments made for forest fires are evaluated, it is evident that new policies are required to ensure that pre-fire prevention measures receive adequate attention. Socioeconomic problems and proposed solutions that cause forest fires are discussed in the opinions of Muhtar, Technical Personnel of ARDoF and FEC, where 'Public Relations, Education and Awareness-raising' take priority. This result indicates that more emphasis should be given to fire prevention efforts.

Over the years, the increase in the number of fires indicates the need to evaluate the relationship between fire and climate regime and other socioeconomic factors that could cause fires (Vilar et al., 2016/a; Kim et al., 2019).

A "master plan for the solution of socioeconomic problems causing fires" should be prepared, which includes the socioeconomic factors causing the fires in the region and the targets and strategies for the solution of these factors. In this context, various authorities and responsibilities should be given to local public and civil society organizations and the local community (Górriz-Mifsuda et al., 2019).

In the initial rankings of opinions on the socioeconomic problems causing forest fires and their solutions, forest community relations, education and awareness, and technical reasons are the most significant factors. It is a standard view that written, verbal, and visual media are highly effective regarding forest community relations, education, and awareness. Additionally, FEC needs to conduct widespread education through face-to-face meetings at all levels of villages. On the other hand, technical problems and solution proposals also show some differences in approaches between village Mukhtar and forest engineers.

The opinions of FEC are also highly noteworthy among forest engineers. Their opinions are even more crucial because they are the unit facing the problems directly and dealing with the public at the end of the implementation. The unresolved issue of forest cadastre is a significant problem that persists today and has far-reaching effects, even causing forest fires.

FEC faces significant workload challenges in dealing with the problems that cause forest fires and finding solutions. This situation raises concerns regarding the country's effectiveness and efficiency of the forest fire management system.

Various interest groups have expressed their views on the issue of forest fires, the socioeconomic factors underlying them, and potential solutions. These perspectives are crucial in shaping forestry policy approaches. Measures to ensure that forest fires do not occur can be realized by adopting a large part of the approaches stated in the views of the interest groups as a forestry policy. The General Directorate of Forestry should expand the work in this direction in areas that stand out regarding forest fires.

Conflicts of Interest

The author declares no conflicts of interest.

REFERENCES

Abram, N.J., Henley, B.J., Sen Gupta, A., 2021. Connections of climate change and variability to large and extreme forest fires in southeast Australia. Communications Earth & Environment, 2,8 (17 pages).

Almeida A.M.F., Moura, P.V., 1992. The Relationship of Forest Fires to Agro-Forestry and Socioeconomic Parameters in Portugal, Journal of. Wildland Fire 2(1), 3740, USA.

Bar Massada A, Radeloff V.C, Stewart S.I., Hawbaker T.J., 2009. Wildfire risk in the wildland–urban interface: A simulation study in northwestern Wisconsin. Forest Ecology and Management 258, 1990–1999.

Camia, A., Liberta, G., San-Miguel-Ayanz, J., 2017. Modeling the impacts of climate change on forest fire danger in Europe. doi:10.2760/768481.

Chinamatira, L., Mtetwa, S., Nyamadzawo, G. 2016. Causes of wildland fires, associated socioeconomic impacts and challenges with policing, in Chakari resettlement area, Kadoma, Zimbabwe, Chinamatira et al. Fire Science Reviews (2016) 5:1, DOI 10.1186/s40038-016-0010-5.

Coşgun, U., Yolcu, H., İ., Tolunay, A., Orhan, K., H., 2010. Identification of Socioeconomic Factors Causing Forest Fires in Antalya Regional Directorate of Forestry, Southwest Anatolia Forest Research Institute, Technical Bulletin No: 40, Antalya.

Coşgun, U., Kavgacı, A., Güngöroğlu, C., 2012. Evaluation of Forest Fire Regime Data in Turkey: The Case of Antalya Regional Directorate of Forestry, The Journal of Southwest Anatolia Forest Research Institute, II/15, pages: 53-80, Antalya.

Galiana, L., Aguilar, S., Lázaro, A., 2013. An assessment of the effects of forest-related policies upon wildland fires in the European Union. Forest Policy and Economics 29, 36–44. http://dx.doi.org/10.1016/j.forpol.2012.10.010.

Ganteaume, A., Camia, A., Jappiot, M., San-Miguel-Ayanz, J., Long-Fournel, M., Lampin, C., 2013. A review of the main driving factors of forest fire ignition over Europe. Environ. Manage. 51, 651–662. http://dx.doi.org/10.1007/s00267-012- 9961-z.

GDoF, 1988a. Evaluation of Forest Protection and Fire-Related Statistics, Ministry of Agriculture and Forestry, General Directorate of Forestry, Department of Forest Protection and Firefighting, Ankara.

GDoF, 1988b. Turkey Forest Fire Prevention Seminar, Ministry of Agriculture and Forestry, General Directorate of Forestry, Department of Forest Protection and Firefighting, Publication No: 29, Serial Number: 672, Ankara.

GDoF, 2010. Rehabilitation of Burned Forest Areas and Establishment of Fire-Resistant Forests Project, Regulation Number 6665, Ministry of Environment and Forestry, General Directorate of Forestry, Directorate of Silviculture, Ankara.

GDoF, 2021. Forestry Statistics, General Directorate of Forestry. Ankara.

GDoF, 2022. Fire Statistics, General Directorate of Forestry, Department of Forest Protection and Firefighting Ankara.

Gill A.M, Groves R.H, Noble I.R., 1981. Fire and the Australian Biota. Australian Academy of Science, Canberra, Australia.

Górriz-Mifsud, E., Burns, M., Govigli, V.M., 2013. Civil society engaged in wildfires: Mediterranean forest fire volunteer groupings. Forest Policy and Economics 102 (2019) 119–129. https://doi.org/10.1016/j.forpol.2019.03.007

Henderson M, Kalabokidis K, Marmaras E, Konstantinidis P, Marangudakis M., 2005. Fire and society: A comparative analysis of wildfire in Greece and the United States. Hum Ecol Rev 12(2), 169–182.

Kwak, H., Woo-Kyun Lee, Joachim Saborowski, Si-Young Lee, Myoung- Soo Won, Kyo-Sang Koo, Myung-Bo Lee, Su-Na Kim. 2012. Estimating the spatial pattern of human-caused forest fires using a generalized linear mixed model with spatial autocorrelation in South Korea. International Journal of Geographical Information Science Vol. 26, No. 9, September 2012, 1589–1602. https://doi.org/10.1080/13658816.2011.642799

Kallidromitou, D., Bonazountas, M., Petros P., Caballero, D., 1999. Forest Fire Management & Fire Prevention System, 14th.ESRI European Users Conference Germany, 15-17th November.

Kavgacı, A., Salıs, M., Arca, B., Cosgun, U., Gungoroglu, C., Spano, D. 2012. Historical relationship between climate and fire regime in Asagı Köprüçay Basin (Antalya, Turkey). In: Modeling Fire Behaviour and Risk (eds) D. Spano, V. Bacciu, Michele Salis, C. Sirca. PROTERINA - C Project - Universita di Sassari, p. 70-79.

Keeley, J.E., Bond, W.J., Bradstock, R.A., Pausas, J.G., Rundel, P.W., 2012. Fire in Mediterranean ecosystems: ecology, evolution, and management. Cambridge University Press.

Kim, S.J., Lim C.H., Kim, G.S., Lee, J., Geiger, T., Rahmati, O., Son, Y., Lee, W.K., 2019. Multi-Temporal Analysis of Forest Fire Probability Using Socioeconomic and Environmental Variables,

Remote Sens. 2019, 11, 86. doi:10.3390/rs11010086.

Krikken, F., Lehner, F., Haustein, K., Drobyshev, I., van Oldenborgh, G.J., 2019. Attribution of the role of climate change in the forest fires in

Sweden 2018. Natural Hazard and Earth System Sciences. Doi. org/10.5194/nhess-2019-206.

Keeley J.E., Keeley S.C., 1988. Chaparral. In: Barbour MG and Billings WD (eds) North American Terrestrial Vegetation. Cambridge University Press, New York, pp 165-207.

Lekakis J.N, 1995. Social and Ecological Correlates of Rural Fires in Greece. Journal of Environmental Management 43, 41-47.

Lovreglio R, Leone V, Giaquinto P, Notarnicola A., 2010. Wildfire cause analysis: four case studies in southern Italy. iForest 3, 8-15.

Martinho, V.J.P.D. 2019. Socioeconomic Impacts of Forest Fires upon Portugal: An Analysis for the Agricultural and Forestry Sectors. Sustainability 2019, 11, 374. doi:10.3390/su11020374.

Martínez J, Vega-García C, Chuvieco E., 2009. Human-caused wildfire risk rating for prevention planning in Spain. Journal of Environmental Management 90: 1241–1252.

Moreno, J.M., Oechel, W.C., 1994 (eds.). The role of fire in the Mediterranean-Type Ecosystems. Springer-Verlag, 203 p.

Moreira F, Rego F.C., Ferreira P.G., 2001. Temporal (1958-1995) pattern of change in a cultural landscape of northwestern Portugal: implications for fire occurrence. Landscape Ecology 16: 557-567.

Naveh Z., 1975. The evolutionary significance of fire in the Mediterranean region. Vegetation 9: 199-206.

Neyisci, T., Ayaşlıgil, Y., Ayaşlıgil, T., Sönmezışık, S., 1999. Fire Resistant Forest Establishment Principles, TÜBİTAK TOGTAG–1342, TMMOB OMO Publication Number. 21, Ankara.

Neyisci, T., Şirin, G., Sarıbaşak, H., 2002. Opportunities for Applying Controlled Burning Technique to Reduce Forest Fire Hazards in the Western Mediterranean Region, Antalya.

Nyamadzawo. G., Gwenzi. W., Kanda, A., Kundhlande, A., Masona, C., 2013. Understanding the causes, social and environmental impacts, and management of wildland fires in tropical Zimbabwe. Fire Science Reviews 2, 9–13.

Oktik, N., 2001. Socioeconomic and Cultural Causes of Forest Fires, Muğla University Publication No: 25, Rectorate Publication No: 16, Muğla.

Richardson D.M., van Wilgen B.W., 1992. Ecosystem, community and species response to fire in mountain Fynbos: Conclusions from Swartboskloof experiment. In:

R. Romero-Calcerradaa, F., Barrio-Parraa, J.D.A., Millingtonb, C.J. Novillo., 2010. Spatial modeling of socioeconomic data to understand patterns of

human-caused wildfire ignition risk in the SW of Madrid (central Spain). doi: 10.1016/j.ecolmodel.2009.08.008.

Sebastián-López, A., Salvador-Civil, R., Gonzalo-Jimenez, J., San-Miguel-Ayanz, J., 2008. Integration of socioeconomic and environmental variables for modeling long-term fire danger in Southern Europe. Eur. J. Forest Res. 127, 149–163. http://dx.doi.org/10.1007/s10342-007-0191-5.

Tabara, D., Sauri, D., Cerdan, R., 2003. Forest fire risk management and public participation in changing socio-environmental conditions: A case study in a Mediterranean region. Risk Analysis 23, 249-260.

Tedim, F., Remelgado, R., Borges, C., Carvalho, S., Martins, J., 2013. Exploring the occurrence of mega-fires in Portugal. Forest Ecology and Management, 294, 86-96.

Thompson, M.P., Calkin, D.E., Finney, M.A., Ager, A.A., Gilbertson-Day, J.W., 2011. Integrated national-scale assessment of wildfire risk to human and ecological values. Stochastic Environmental Research and Risk Assessment. DOI 10.1007/s00477-011-0461-0.

Vilar, L., Camia, A., San-Miguel-Ayanz, J., 2014. Modeling socioeconomic drivers of forest fires in Mediterranean Europe. In: Viegas, D.X. (Ed.), Advances in Forest Fire Research. Imprensa da Universidade de Coimbra, Coimbra, pp. 1874– 1882. DOİ: 10.14195/978-989-26-0884-6_209. ISBN: 978-989-26-0884-6 (PDF).

Vilar L, Camia A., San-Miguel-Ayanz J., Martín PM., .2016a. Modeling temporal changes in human-caused wildfires in Mediterranean Europe based on Land Use-Land Cover interfaces. Forest Ecology and Management 378, (2016), 68–78.

Vilar, L., Gómez, I., Martínez-Vega, J., Echavarría, P., Riaño, D., Martín, P.M., 2016b. Multitemporal Modelling of Socioeconomic Wildfire Drivers in Central Spain between the 1980s and the 2000s: Comparing Generalized Linear Models to Machine Learning Algorithms. PLoS ONE 11(8), e0161344. Doi 10.1371/journal.pone.0161344.